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The Final Report of ICCAP

The Research Project on the Impact of Climate Changes on Agricultural Production System in Arid Areas (ICCAP)

March, 2007

Research Institute for Humanity and Nature
The Scientific and Technological Research Council of Turkey

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At the ICCAP Workshop, on January 30, 2007 at RIHN, Kyoto, Japan

At the ICCAP Symposium, on February 12, 2007, at Çukurova University, Adana, Turkey

Preface

The Research Project ICCAP - Impact of Climate Changes on Agricultural Production System in Arid Areas - of The Research Institute for Humanity and Nature (RIHN) was launched as a five-year research project in April, 2002. The ICCAP selected the Seyhan River Basin in Turkey as a main case study area, and then it has been implemented in cooperation with TÜBİTAK (The Scientific and Technological Research Council of Turkey). At the end of the project period, March 2007, we have summarized the research outcomes and publish them as the Final Report pf ICCAP.

In January 2007, at the final stage of the project, the ICCAP held the workshop at RIHN in Kyoto, Japan and there we shared the final results of the sub-groups and the individual collaborators and discussed the way to finalize the integrated assessment of climate change impacts on agricultural production. And then in February 2007, we held the final Symposium in Çukurova University in Adana, Turkey to discuss the final results and their implication inviting some from out of the project, including Lecture Dr. Mostafa Jafari of Islamic Republic of Iran Meteorological Organization, and Dr. Waltina Scheumann of TU Berlin, who gave us keynote lectures. This Final Report contains the joint final reports from all sub-groups of the Japanese and Turkish Teams with the final general outcomes of the whole project and the reports in individual research topics of some Japanese and Israeli members. Almost all these final reports were presented and discussed at the Kyoto Workshop and/or the Adana Symposium. The paper of the keynote by Dr. Mostafa Jafari, who is one of the lead authors for IPCC-AR4, is also included in this volume.

Now, when we are going to close the project, we remember that we held the Kick-off Meeting of the project in Çukurova University in July 2002. Now, we are in the last minutes of the game. No extra time we can expect. Since the beginning of the project ICCAP in 2002, we have worked together toward the one same objective that is to assess the climate change impacts and to improve the agriculture in the Seyhan River Basin. We realize, our outcomes expected at the beginning are not quite realized yet. I believe, however, we should be proud of our outcomes and put them in the public and academic society to be discussed, reviewed and improved.

It is a fact that, now, we have experiences of international cooperation among Japan, Turkey, Israeli and other countries and of cross-disciplinary approach to the research topic. Then, we would like to ask all collaborators of ICCAP to utilize these experiences and knowledge for the future works. This evolution of the research network is one on the role of RIHN. We will appreciate their further challenges.

The methodology for assessment of climate change impacts on agriculture developed in our project, and outcomes should be disseminated to the international academic societies and the public, especially those who live in the study area. We hope our trial and findings will contribute to improvement of global environment and this report itself is very useful for it. IPCC has just released its latest report on climate changes, IPCC-AR4. Our results should be refined, published and finally included in the next report of IPCC.

For ICCAP, we, both of the coordinators, have tried to provide better research environment for the project and the participants, to result in the better results for the public. We believe, at least, we have prepared the platform or arena that the collaborators can work together. We have been enjoying coordination of a quite interesting and challenging project on urgent issue. We are lucky to be educated and grown up through the research of ICCAP. We thank again all project collaborators and the related organizations.

Finally, we also express our special thanks to our colleagues of RIHN and Çukurova University, who have devoted themselves to work as the secretariats for the project including editing this volume. Our special gratitude should be extended to Ms. Noriko Sasaki and Ms. Atsuko Iwata, our project secretaries of RIHN ICCAP Team.

March 1, 2007

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Table of contents

Impacts of Climate Change on Subsurface Water Environment in the Lower Seyhan River Basin －Final Results of Calibration and Projection－

Katsuyuki FUJINAWA, Takahiro IBA (Shinshu University) and Yoichi FUJIHARA (RIHN)

Projection of the Impact of Climate Change on the Surface Energy and Water Balance in the Seyhan River Basin Turkey

Kenji TANAKA (Kyoto University), Yoichi FUJIHARA (RIHN) and Toshiharu KOJIRI (Kyoto University)

Assessing the Impact of Climate Change on the Water Resources of the Seyhan River Basin, Turkey

Yoichi FUJIHARA (RIHN), Kenji TANAKA(Kyoto University), Tsugihiro WATANABE (RHIN) and Toshiharu KOJIRI (Kyoto University)

An Inverse Modeling Approach to Assess the Impacts of Climate Change on Water Resources Management at the Watershed Scale

Yoichi FUJIHARA (RINH), Slobodan P. SIMONOVIC (University of Western Ontario), Fatih TOPALOGLU (Çukurova University) , Tsugihiro WATANABE (RIHN) and Kenji TANAKA (Kyoto University)

【Vegetation】

Effect of climate changes on the species composition and productivity of plant communities in the eastern Mediterranean region of Turkey

Shigenobu TAMAI, Keisuke KATO (Tottori University), Yuki Kishibe (Tottori University), Makoto ANDO (Kyoto University) and Junji SANO (Tottori University)

Possible scenario for the vegetation change in seyhan river basin and role of land uses “anthropozoic pressures”

Atik, M. (University of Akdeniz), Tamai, S.(Tottori University Arid Land Research Center), Altan, T. (University of Çukurova), Ando, M. (Kyoto University Field Research Center), Sano, J. (Tottori University Agriculture Fac. Forest Ecology and Ecosystem Management Lab.), Atmaca, M. (University of Mustafa Kemal), Aktoklu, E. (University of Mustafa Kemal), Kaplan, K. (University of Mustafa Kemal), Artar, M. (University of Karaelmas Bartın Forestry), Güzelmansur, A. (University of Mustafa Kemal), Çinçinoğlu, A. (University of Çukurova) and Büyükaşik, Y. (University of Mustafa Kemal)

Field Research of Dominant Vegetation and Environmental factors on the Basis of Projection on the Vegetation Change after Global Warming in the Eastern Mediterranean Region of Turkey

Junji SANO (Forest Ecology and Ecosystem Management Laboratory, Field Science Center, Faculty of Agriculture, Tottori University), Makoto ANDO (Kyoto University Field Research Center) and Shigenobu TAMAI (Tottori University)

The Vertical Distribution of the Vegetation on Cukurova Plain in the Eastern Mediterranean Region of Turkey

Makoto ANDO (Kyoto University), Junji SANO (Tottori University) and Shigenobu TAMAI (Tottori University)

Past, present and future perspectives of indigenous livestock production systems in the seyhan basin, southern turkey

Okan Güney(University of Çukurova), Aykut Gül (University of Çukurova), Nazan Darcan (University of

Çukurova), Nafiz Çeliktaş (University of Mustafa Kemal), İnanç Güney (University of Çukurova), Hilal Işık (University of Çukurova) and Masahiro HIRAT(Obihiro University of Agriculture and Veterinary Medicine)

【Crop Productivity】

Estimation of Crop Production by the Future Climate Changes in Surrounding Areas of the Seynan River in Turkey
Tohru KOBATA (Shimane University)

The effect of desiccated soils on transpiration in spring wheat subject to elevated temperature and CO2 concentration
Tohru KOBATA (Shimane University)

Predicting the Impact of Global Warming on Wheat Production in Adana
Hiroshi NAKAGAWA (Ishikawa Prefectural University), Tohru KOBATA (Shimane University), Tomihisa YANO (Kyushu Kyoritsu University), Ceraleddin BARUTÇULAR (Çukurova University), Müjde KOÇKenji TANAKA (Kyoto University), Takanori NAGANO, Yoichi FUJIWARA, Keisuke HOSHIKAWA, Takashi KUME and Tsugihiro WATANABE (RINH)

Actual Evapotranspiration and Potential Evapotranspiration of Maize Crop in Adana Region, Turkey
Hiromichi ODANI (University of Shiga Prefecture), Shinichi TAKEUCHI (Kyushu Kyouritsu University), Mustafa UNLU (Çukurova University), Kanako SASAKI (University of Shiga Prefecture) and Tomohisa YANO (Kyushu Kyouritsu University)

Separate estimation of transpiration and evaporation from a maize field
Shinichi TAKEUCHI (Kyushu Kyouritsu University), Hiromichi ODANI (University of Shiga Prefecture), Mustafa UNLU (Çukurova Univerisy) and Tomohisa YANO (Kyushu Kyouritsu University and Tottori University Arid Land Research Center, Emeritus)

Simulation of Crop Productivity for Evaluating Climate Change Effects
Tomohisa YANO (Kyushu kyouritu University), Masumi KORIYAMA, Tomokazu HARAGUCHI (Saga University) and Mehmet AYDIN (Mustafa Kemal University)

Prediction of Future Change of Water Demand Following Global Warming in the Cukurova Region, Turkey
Tomohisa YANO (Kyouritsu University), Tomokazu HARAGUCHI, Masumi KORIYAMA (Saga University) and Mehmet AYDIN (Mustafa Kemal University)

Combined Effects of Elevated Temperature and Carbon Dioxide Concentration on Growth and Water Use of Maize
Tomokazu HARAGUCHI (Saga University), Yoshisuke NAKANO (Kyusu University) , Tomohisa YANO (Kyushu Kyouritsu University) and Masumi KORIYAMA (Saga University)

【Irrigation and Draiange】

The Integrated Assessment of the Impact of Climate Change on Lower Seyhan Irrigation Project
Takanori NAGANO (RIHN), Sevgi DONMA (6th regional directorate of State Hydraulic Works), Keisuke

HOSHIKAWA, Takashi KUME, Chieko UMETSU (RIHN), Erhan AKÇA (Çukurova University), Sermet ÖNDER (Mustafa Kemal University), Suha BERBEROĞLU (Çukurova University), Bülent OZEKICI (Çukurova University), Tsugihiro WATANABE (RIHN) , Selim KAPUR (Çukurova University) and Rıza KANBER (Çukurova University)

Impact of the Irrigation Water Use on the Groundwater Environment and the Soil Salinity
Takashi KUME, Takanori NAGANO (RIHN), Erhan AKÇA (Çukurova University), Sevgi DONMA (6th Regional Directorate of State Hydraulic Works), Keisuke HOSHIKAWA (RIHN), Suha BERBEROĞLU, Musa SERDEM, Selim KAPUR (Çukurova University), and Tsugihiro WATANABE (RIHN)

Long-term Changes of Level and Salinity of Shallow Water Table in the Lower Seyhan Plain, Turkey
Takanori NAGANO (RIHN), Sevgi DONMA (6th regional directorate of State Hydraulic Works), Takashi KUME (RIHN), Suha BERBEROĞLU (Çukurova University),Keisuke HOSHIKAWA (RIHN), Erhan AKÇA (Çukurova University), Selim KAPUR (Çukurova University) and Tsugihiro WATANABE (RIHN)

Evaluation of Impact of Climate Changes on the Lower Seyhan Irrigation Project, Turkey
Keisuke HOSHIKAWA, Takanori NAGANO, Takashi KUME (RIHN), Sevgi DONMA (6th Regional Directorate of State Hydraulic Works) and Tsugihiro WATANABE (RIHN)

Climate Change and Alternative Cropping Patterns in Lower Seyhan Irrigation Project: A Regional Simulation Analysis with MRI-GCM and CSSR-GCM(Tottori University)
Chieko Umetsu (RIHN), K. PALANISAMI (Tamilnadu Agricultural University), Ziya COŞKUN, Sevgi DONMA (6th Regional Directorate of State Hydraulic Works), Takanori NAGANO, Yoichi FUJIHARA (RIHN), Kenji TANAKA (Kyoto University)

【Socio-Economics】

The Final Report of the Socio-economic Sub-group of the ICCAP Project
Hiroshi TSUJII (Ishikawa Prefectural University) and Onur ERKAN (Çukurova University)

The Features of Agriculture in Adana Prefecture -From the Result of Farm Survey-
Motoi KUSADOKORO and Takeshi MARU (Kyoto University)

An Econometric and Agro-climatological Study of the Impact of Global Warming and Prices to Production of Rain-fed Wheat and Barley in Konya and Adana.
Hiroshi TSUJII (Ishikawa Prefectural University) and Ufuk GULTEKIN (Çukurova University)

The Change of the Weather Risk by Global Warming and the Impact on the Yield of Wheat in Adana, Turkey
Motoi KUSADOKORO (Kyoto University)

The Effect of Irrigation on the Adoption of Crop-Livestock Multiple-Farming and the Livestock Keeping
Takeshi MARU (Kyoto University)

Impacts of Climate Change and the EU Accession on Turkish Rural Industries by the Input-Output model and Markov-Transition Matrix
Masaru KAGATSUME (Kyoto University)

Acronyms used in this report

AGCM	Atmospheric General Circulation Model
AR4	Assessment Report No.4 of IPCC
CCSR	Center for Climate Science Research, the University of Tokyo, Japan
CGCM	Coupled General Circulation Model
CMAP	CPC (Climate Prediction Center) Merged Analysis of Precipitation
DSİ	Devlet Su İşleri Genel Müdürlüğlü (General Directorate of State Hydraulic Works)
EC	Electric Conductivity
ECMWF	European Centre for Medium-range Weather Forecasts
ERA15, ERA40	ECMWF Reanalysis for 15 years/40 years
ESSP	Earth System Science Partnership
ET	Evapotranspiration
FAO	Food and Agriculture Organization of the United Nations
GCM	General Circulation Model
GIS	Geographic Information System
IHDP	International Human Dimensions Programme on Global Environmental Change
ICARDA	International Center for Agricultural Research in the Dry Areas
ICCAP	Impact of Climate Changes on Agricultural Production System in Arid Areas
ICID	International Commission on Irrigation and Drainage
IMPAM	Irrigation Management Performance Assessment Model
IPCC	Inter-governmental Panel on Climate Change
IWMI	International Water Management Institute
LSIP	Lower Seyhan Irrigation Project
MRI	Meteorological Research Institute/Japan Meteorological Agency, Tsukuba, Japan
NCAR	National Center for Atmospheric Research (USA)
NCEP	National Centers for Environmental Prediction (USA)
RAMS	Regional Atmospheric Modeling System
RCM	Regional Climate Model
RIHN	Research Institute for Humanity and Nature, Kyoto, Japan
SAR	Sodium Adsorption Ratio
SiBUC	Simple Biosphere including Urban Canopy (Land Surface Model)
SRES	Special Report on Emission Scenarios
SWAP	Soil, Water, Atmosphere and Plant (Model)
TERC	The Terrestrial Environmental Research Center, University of Tsukuba, Japan
TRMM	Tropical Rainfall Measuring Mission
TÜBİTAK	Türkiye Bilimsel ve Teknolojik Araştırma Kurumu (The Scientific and Technological Research Council of Turkey)
WUA	Water Users Association

Summary of ICCAP

- Framework, Outcomes and Implication of the Project -

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1. Background and Outline

The research project ICCAP - Impact of Climate Changes on Agricultural Production System in Arid Areas - is the project of RIHN (Research institute for Humanity and Nature) launched in 2002 as five year project, to analyze the relationship between climate and agricultural system. It has been being implemented as an international joint project in cooperation with TÜBİTAK (The Scientific and Technological Research Council of Turkey). The interests and aims of ICCAP can be summarized as follows:

What impacts will the global warming or climate change have on the agricultural production system in arid areas? How can the system adapt to the changes and what measures should be applied to sustain productivity? This research project aims at identifying the direction and dimension of potential impacts and adaptations in the agricultural production system, based on the projection of future regional climate changes in the east coast of the Mediterranean Sea as the case study region. The basic structure and problems of the agricultural production system are to be elucidated through analyzing cropping patterns and land/water management.

In this summary, the project framework is outlined and the outcomes are summarized, focusing on its challenging aspect on developing the methodology for integrated assessment, which is to be applicable to not only the case study area but also other agricultural regions in arid and semi-arid area.

2. Objectives and Framework

2.1 Scope of the project

As the world population grows and the demand for food increases, agriculture in arid areas is required to improve its productivity, while its development is severely restricted by water availability. In many arid regions of the world, the development of agriculture and irrigation has resulted in land degradation and desertification, and has also caused serious problems in the hydrological regime. The changes in agricultural land and water management practices pose serious threats to the sustainability of agriculture itself.

Moreover, future global climate change can provide climatological and hydrological conditions in arid region with substantial changes in temperature, rainfall and evapotranspiration, thus present another challenge or constraint to the agricultural production system.

Agricultural is basically a human activity. To cope with climate and other subsequent changes in natural conditions, humans have adapted to the new environment, or taken appropriate measures accordingly. Then now, is the conventional ‘wisdom’ of region or agriculture adequate enough to overcome the future global climate change?

Transcending the traditional framework of studies, this project attempts to comprehend ‘the agriculture as a system of relationship between human and nature’, with a view to identifying current and future challenges, and effective countermeasures against possible climate changes. The scope of the research is schematically depicted in **Fig. 1**.

Agriculture is based on the interaction of human activities with the natural system including climate changes. This relationship is complex and causes various problems if they malfunction. This project aims at considering this interaction through the investigation of fundamental structure of land and water management as well as through the projections of abrupt climate changes and the assessment of their impacts.

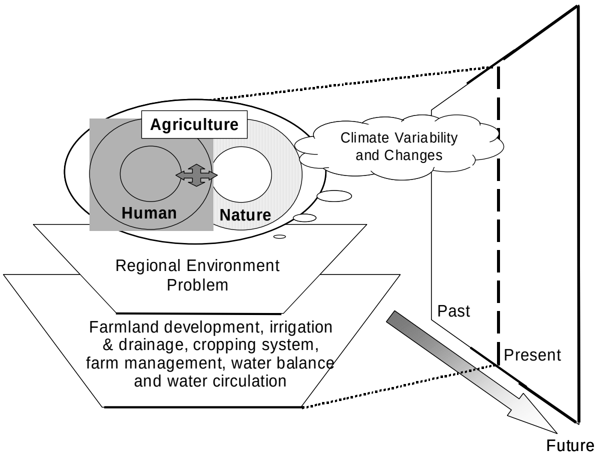

Fig. 1 Scope and framework of the research

2.2 Main objectives of ICCAP

The original research objectives include the following four points:

(1) To examine and diagnose the structure of land and water management in agricultural production systems in arid areas, especially to evaluate quantitatively the relationship between cropping systems and hydrological cycle and water balance in farmland and its environs.

(2) To develop the methodology or model for integrated assessment on impacts of climate change and adaptations for it on agricultural production systems, mainly on the aspect of the land and water management.

(3) To assist the development and improvement of the Regional Climate Model (RCM) for more accurate prediction with higher resolution of future changes in regional climate.

(4) To assess the vulnerability of agricultural production systems from natural change and to suggest possible and effective measures for enhancing sustainability of agriculture, through integrated impact and adaptive assessment of climate changes.

3. Methodology and Case Study Area

3.1 Methodology

The research of this project has been implemented in the east coast of the Mediterranean Sea, mainly in the Seyhan River Basin of Turkey as a main case study area. Firstly, a comprehensive assessment of the basic structure of agricultural production system was carried out with special reference to regional climate, land and water use, cropping pattern and irrigation system. Then, it has been attempting to predict and evaluate the impacts of future climate change and the regional adaptability, and finally through these analyses, the correlations between changes in nature and human activities are to be examined in an integrated manner.

In this process, regional climate change projection with higher resolution is critical to precise impact assessment. Furthermore, impacts on the regional water resources, irrigation and drainage system, natural vegetation, crop production, farm management and cropping patterns as well as the effect on the food production and marketing are to be taken into account. Also feedbacks of agricultural production systems on regional climate are to be considered. The project aims at providing suggestions for regional policies and monitoring systems as well as accumulating information that will assist to analyze relationship between climate/natural systems and human activities. The research procedures in the original research plan are shown in **Fig. 2**.

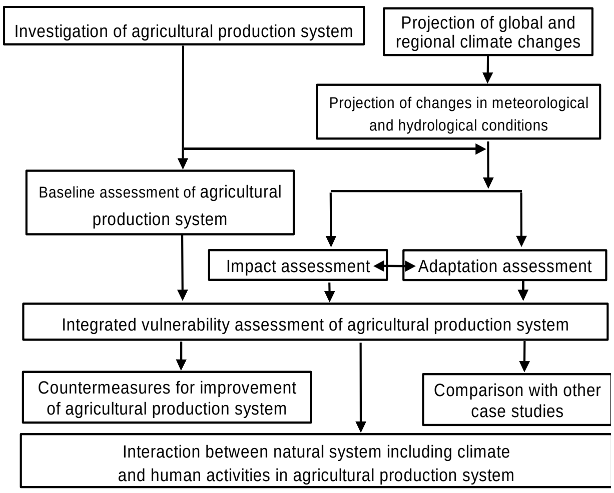

Fig. 2. Flow of research in the original plan

3.2 Case Study Area

The Seyhan River Basin (**Fig. 3**), which area is about 25,000km^2, was selected as the case study basin. In the basin, rain-fed wheat production area spreads over the hilly area in mid and upstream area, while irrigated agriculture, cultivating maize, wheat, fruits and other economic crops, has been developed in the lower flat region of the basin. The almost whole basin is located in the region of the

Mediterranean climate zone, with winter precipitation of about 700mm annually. Runoff of precipitation and snow-melt in winter and spring is stored in the large reservoirs and released in summer time for power generation and irrigation use.

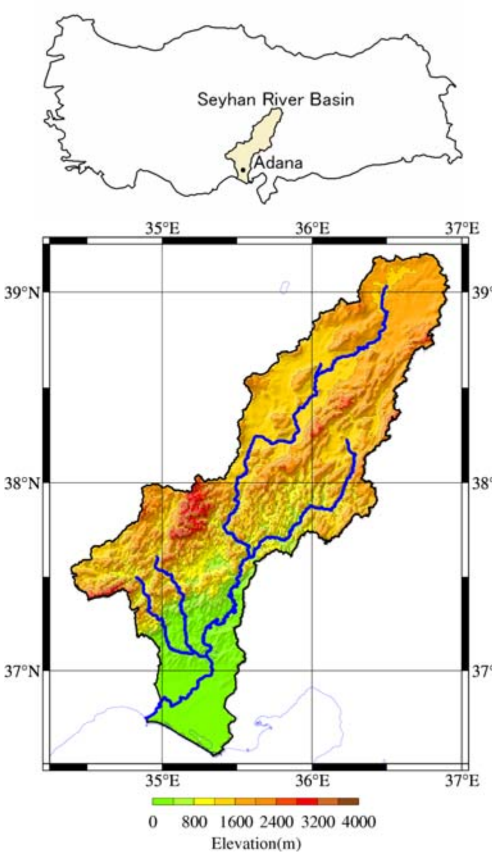

Fig. 3 The Seyhan River Basin of Turkey

The reasons why the project had selected the Seyhan River Basin as the case study area include the following points:

(1) The Mediterranean region, where the basin is located, is recognized as the place sensitive to global warming.

(2) Turkey is an important food production area in and for the Europe or European Union.

(3) Wheat is one of most important crop in the world. Turkey has a long history of wheat production, and in the upper basin it is cultivated widely.

(4) In the Seyhan River Basin, there are different types of agriculture including rain-fed agriculture in the upper basin, irrigated agriculture in the lower delta, and livestock farming or pasturage in the whole basin. We could assess the different types or features of the climate change impacts in agricultural production.

(5) The size of the basin is suitable in terms of area for basin wide case study, and it is not a trans-boundary basin with some international political issues.

The research works in Turkey are carried out in cooperation with TÜBİTAK, as the international joint project. In the project, case study area could be expanded to other regions in arid and semi-arid areas, and in the earlier stage, the Nile Delta was selected as a candidate area. Unfortunately, however, for this project period of five years, the exact research activities could not be launched there.

3.3 Research Organization

According to the structure of the problems, six sub-groups are established in the project, including a. Climate, b. Hydrology and Water Resources, c. Vegetation, d. Crop Production, e. Irrigation and Drainage, and f. Socio-Economic sub-groups. The Vegetation Sub-group includes livestock farming sub-module, and the Crop Production Sub-group consists of sub-modules for soil and water, wheat, and salinity.

In the project, total 103 persons are involved at the final stage, including 41 Japanese, 58 Turkish, three Israeli and one Canadian. Their names and affiliations are listed in the Appendix I in this volume.

4. Approach in Integrated Assessment

In the project, based on the preliminary diagnostic studies on the natural condition of the basin including climate, hydrology, water resources, and on human activities like land use, cropping system, and irrigation and drainage management, present basic structure of the agricultural production system is analyzed. Simultaneously, the future climate change scenarios of the basin in the 2070s were generated by the most advanced GCMs and RCM with downscaling methods based on the SRES scenarios of A2 and A1B. With generated climate scenarios, impacts of climate changes on regional hydrological regime, natural vegetation, crop productivity, irrigation management, cropping cultivation system, and national economy have been assessed by some particular models developed in this project. The results of these scenario generation and assessment are summarized in the following sections and reports of sub-groups in this volume.

These assessments verify some points about the method for generating future climate scenarios and its certainties, and prove the basic structure of the present agricultural system and the path of climate change impacts on the system, as summarized below:

(1) The climate change scenarios for the 2070s of the basin have been generated, with which impacts of climate changes on basin hydrology and agriculture were assessed and discussed.

(2) The projection of future climate by the GCMs and RCM has still much uncertainty, while measures for improvement were developed and applied during the model development stage.

(3) Basic framework of paths of climate change impacts on the agricultural production system of the basin was depicted as **Fig. 4**, with concerning components, critical factors and relations.

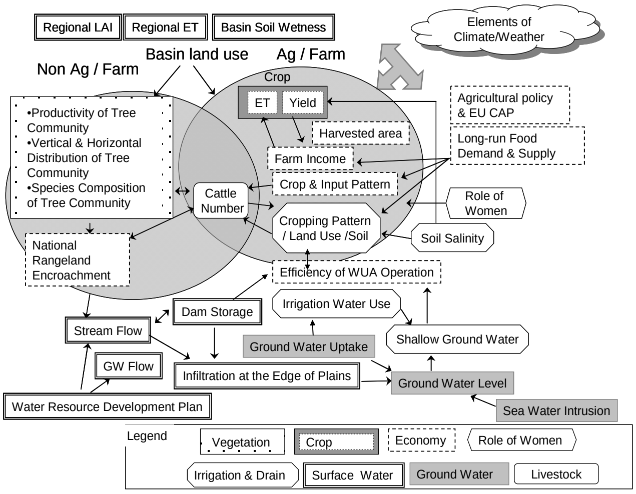

Fig. 4 Major components and course of climate change impacts on agricultural production system in the Seyhan River Basin

In the project, we had not taken the strategy to develop the combined agricultural production model consisting of some sub-models including basin hydrology, vegetation transition, crop production, water dynamics and economics, which covers our topics or aspects to be analyzed, since in this moment, the basic policy, structure and elements, temporal and spatial resolution of parameters of the sub-models are quite different and difficult to be linked each other. Then, we had given up to establish the implicit linkage of the sub-models and then tried to connect each other explicitly in repeated feedbacks, like iterations, where actually the models share the common input parameters and some model provide another with its output and another model received the output as its input. Actually, in the project, due to the time and resources constraints, these feedbacks with parameter exchanges have been done only in beginning cycle.

In the project, the following strategy for integrating the sub-group activities for assessing the climate change impacts and identifying the adaptation and mitigation measures (See **Fig. 5**). At first, it was recognized that it is very difficult to predict the exact features of future agricultural production, even with future climate prediction, since the future socio-economic conditions can not be predicted with a certain reliable accuracy. We narrowed down the research filed into land and water management aspects in climate change impacts on agriculture.

Secondly, with current basin conditions and future climate scenarios, basic trend of future changes are estimated in various aspects, including crop yield and production, natural vegetation, water resources, irrigation water supply, and others. And then, to bring future possible problem to light, we set up some future basin conditions assuming some human reactions to climate changes.

At last, three social scenarios or assumptions of basin condition are generated and future changes are projected in water resources availability, water supply security, cropping pattern and water balance. These predictions led to identifying the current problem in land and water management. The social scenarios are explained in detail in the following chapter.

The process for setting up the social scenarios or basin condition assumptions needs dialog among the sub-groups and collaborators from different disciplines, and the predictions requires the exchange of the information among sub-groups. In the project, we term those processes a “context base integration”.

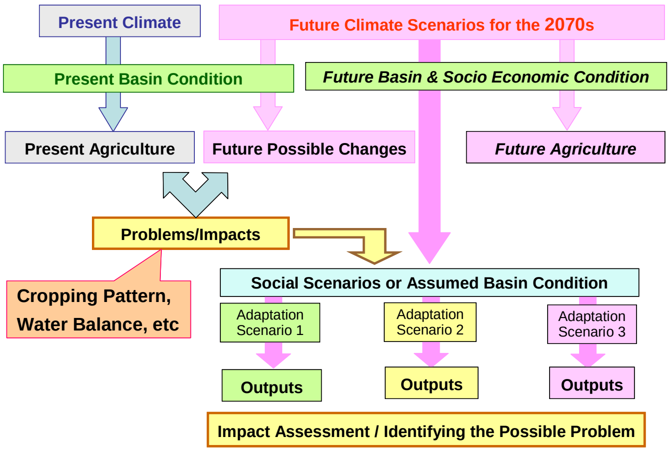

Fig. 5 Approach in integrated impact assessment
It is very difficult to predict the exact features of future agricultural production, even with future climate prediction, since the future socio-economic conditions can not be predicted with a certain reliable accuracy.

5. Summary of Sub-group Outcomes

In this section, results of research activities of the sub-groups are briefly summarized mainly in the integrated assessment mentioned above in the global context of the project. Here, the outcomes provided by sub-groups are edited. The detailed outcomes of the sub-groups appear in the following sections. The sub-group reports of the Turkish members are published in separate volumes.

5.1 Climate Sub-group

The Climate Sub-Group provides scenarios of the likely climate change in Turkey by greenhouse gases, in which precipitation, temperature and insolation are estimated for ten years in the 2070s. The sub-group completed downscaling for ten years climate during the 2070s in whole Turkey with 25 km and that in Seyhan with 8.3 km grid interval. The provided climate dataset contains interpolated precipitation, temperature, moisture and insolation at every observation stations in Turkey.

Two independent GCM projections were downscaled by only one RCM. The group made a comparison with a very high horizontal resolution GCM in order to assess the reliability of the downscale done in this project.

Three figures in **Fig. 6** indicate change in winter precipitation until 2070s. In the figure, brown colored areas are projected to be decreasing precipitation. The top panel indicates the precipitation change in the winter season of December, January and February projected by MRI-CGCM. The bottom-left and bottom-right indicate the precipitation change in January downscaled from the MRI-CGCM and CCSR/NIES-CGCM, respectively. Both downscaling show that the precipitation will prominently decrease in the slopes along the Mediterranean.

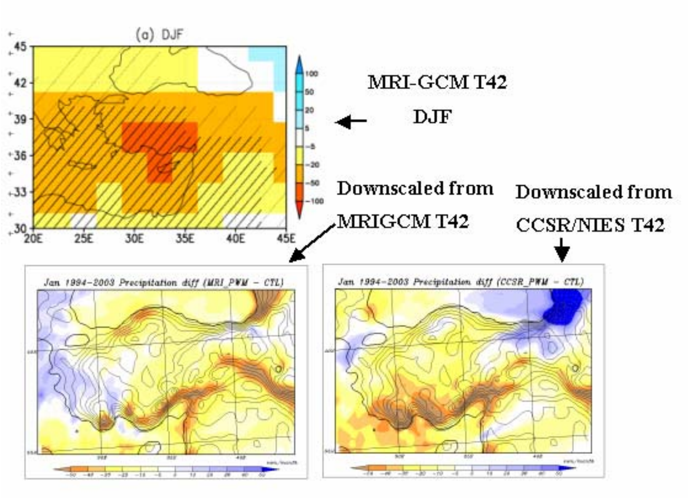

Fig. 6 Projected changes in the winter precipitation until 2070s of Turkey

According to the generated scenarios, surface temperature in Turkey may increase by 2.0 ^{O}C MRI-GCM) and 3.5 ^{O}C (CCSR/NIES-GCM). Total precipitation in Turkey may decrease about 20 % except summer and deference with GCMS is relatively small. The projected trend of changes in temperature and precipitation in the Seyhan River Basin is almost similar to the changes in the whole Turkey, while there precipitation my decrease about 25% (**Fig. 7**).

Climate projection and downscaling are still very difficult subjects. More comprehensive discussion between climate modelers and scientists who intend to assess the impacts of climate change are needed.

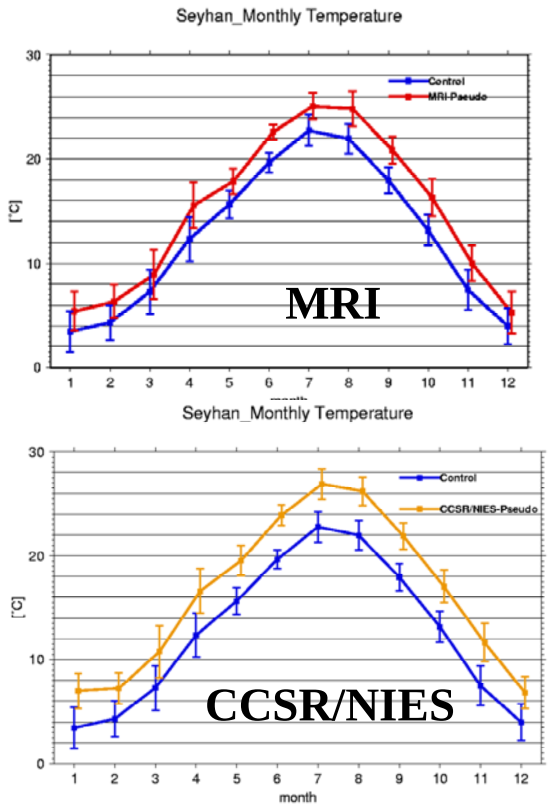

Fig. 7 Changes in monthly temperature in the Seyhan River Basin

5.2 Hydrology and Water Resources Sub-Group

The research topics of the Hydrology and Water Resources Sub-Group are the followings:

a. Assessment of climate changes impacts on subsurface water environment in the Lower Seyhan River Basin.

b. Projection of the climate change impacts on the surface energy and water balance in the Seyhan River Basin.

c. Assessment of climate changes impacts on the water resources of the Seyhan River Basin.

The direct impacts of future sea-level rise on groundwater salinity will not be serious, while increased evaporation and decreased precipitation with sea-level rise could cause significant increase in salinity of the lagoon (**Fig. 8**). Therefore, further groundwater withdraw may result in salt water intrusion. Buildup of a higher saline zone in the aquifer beneath the lagoon could cause water-logging on the land surface. Water logging and increased salinity in shallow groundwater may cause salt accumulation on land surface. To minimize the damage with salt accumulation on the land surface, improvement of local drainage system is strongly recommended in the future.

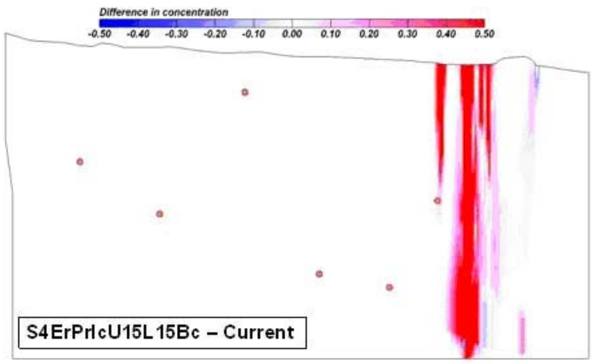

Fig. 8 Difference in groundwater salinity between the future with increased groundwater use and sea-level rise and the present. (unit: g/cm^3)

Precipitation in the basin is projected to decrease by about 170 mm, while evapotranspiration and runoff will decrease by about 40 mm and 110 mm, respectively. Because of snow fall decrease and temperature rise, snow amount will considerably decrease (**Fig. 9**).

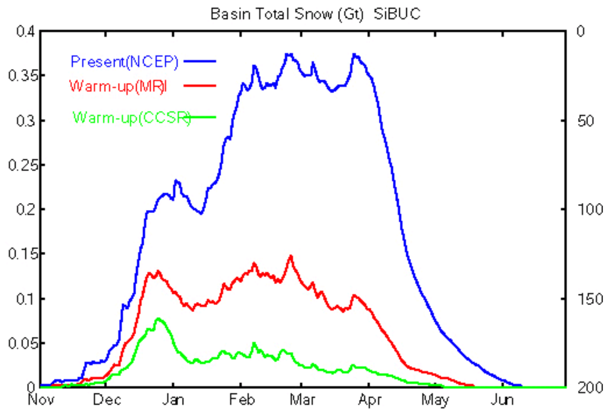

Fig. 9 Changes in total snow fall in volume equivalent to water (unit: 10^9 m^3)

Compared with the present condition, decreased precipitation may result in considerably decrease of the inflow to the Seyhan Reservoir, in which the peak of monthly inflow may occur earlier than in the present. Less flood events will occur with under the warmed condition. The expansion of irrigated land in the middle basin with increased water demand there decreased river flow may lead to the water scarcity for the LSIP (**Fig. 10**). Here, the "Reliability" is defined as "Water Supply / Water Demand", that is an indicator to show how much the demand if satisfied with the supply of the reservoir. The figure shows that irrigation in the delta region may face to water shortage when water use in upstream increases in the case of Social Scenario 2, called as Adaptation 2 previously.

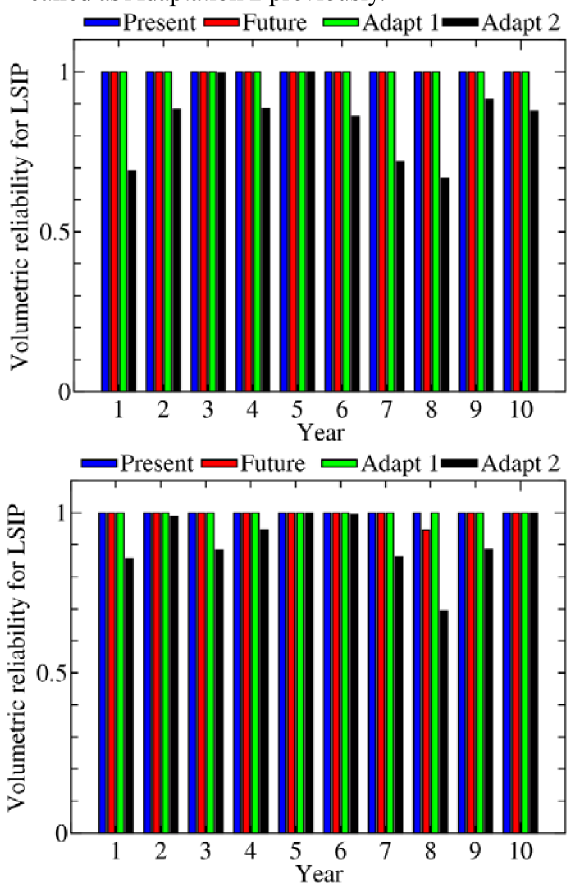

Fig. 10 Reliability changes
(Top: by MRI, Bottom: by CCSR/NIES).

5.3 Vegetation Sub-Group

In the Vegetation Sub-Group, the practical and potential present vegetations were estimated using satellite images and field data. Areas of Maquis and woodland with broadleaved evergreen trees in potential present vegetation were practically occupied by crop field and P.bruitai as secondary forest, respectively. Areas of steppe and Maquis will be increased in the 2070s while those of coniferous evergreen forest will be decreased. Biomass of Maquis and deciduous broadleaved woodland in future were increased and coniferous evergreen forest will be markedly decreased, and total biomass in the area will be only 45% of the present one.

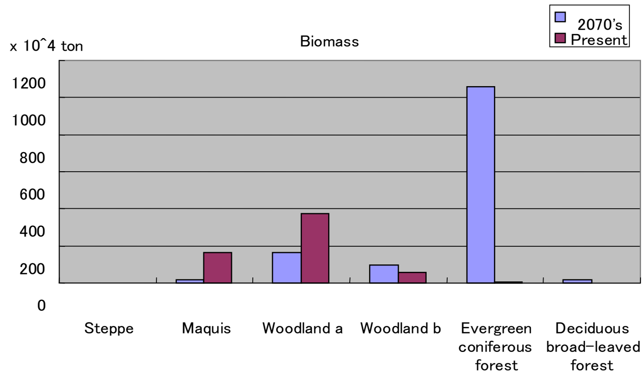

Fig. 11 Biomass of each vegetation types in present and future (in the 2070s)

In the project, difference of area occupied by each vegetation type was made clear, and its difference in biomass between the practical and potential present was clarified. The future changes in these items are predicted. These outcomes suggest the method to assess the climate change impacts on vegetation.

There are rare biomass data in such a semi-arid of the world like the Seyhan River Basin, while in the project, unfortunately, the sub-group could not estimate biomass from data supplied in the field investigation. This unfortunate lack is regrettable for ecological aspect and for the project objectives.

5.4 Crop Production Sub-Group

The research objectives of the Crop Production Sub-Group are to assess the impact of climate changes on crop production in the Seynan River Basin.

In the project, two crop growth simulation models were developed. The models project that wheat and maize yields in Adana areas may increase at most by 15% of the current yield in the 2070s with the changed climate conditions in the generated scenarios, although wheat yields in one model decrease by 10% if CO_2 concentration is not incorporated for the estimation (**Fig. 12** and **Fig. 13)**.

The yield estimated by two models suggests that the effect of elevated CO_2 almost offsets the impact of elevated temperature and reduced rainfall on wheat and maize grain yield.

In the future, the models should include accurate estimation for the effects of elevated temperature and water deficit on harvest index (yield/biomass yield). Furthermore, the sub-model evaluating the effects also should be developed.

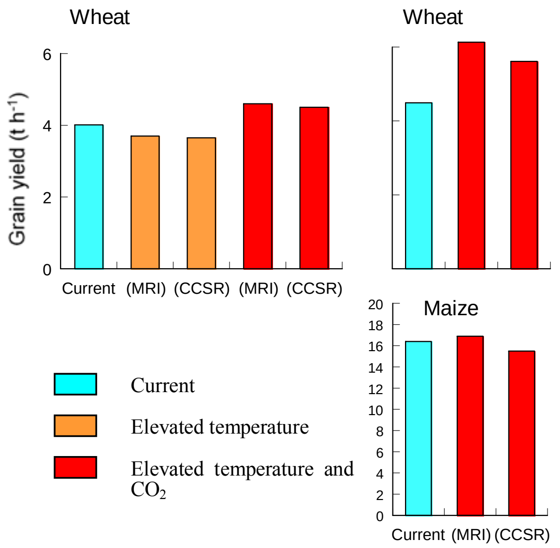

Fig. 12 Estimated grain yield in wheat and maize in the 2070's. (Left is from the simplified process model (SimWinc) and the right is from SWAP model.)

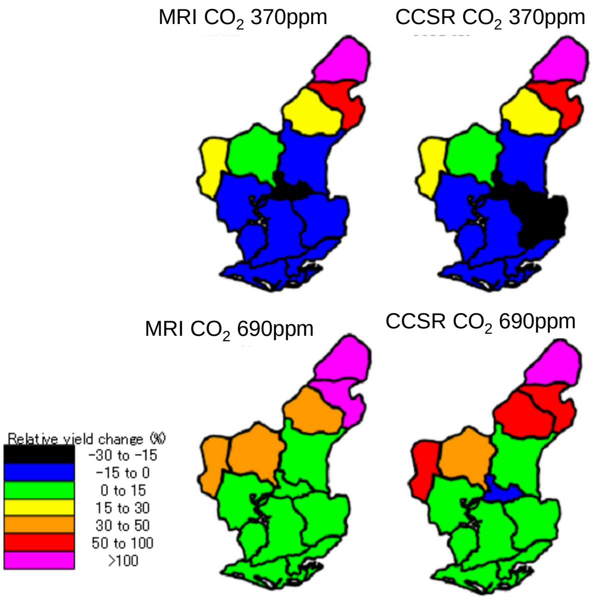

Fig. 13 Differences in changes of wheat grain yield in the 2070s among the counties in the Adana Province

The wheat growth and yield is one of the main interests that attract the public attention in the context of climate change impacts on agriculture in Turkey. Then, here, the findings on this issue are summarized below.

(1) The projected decrease in precipitation will give negative effects on wheat yield, especially in the plain area of Adana, where total precipitation during the growth period of wheat will decrease to below 500 mm. The amount and intensity of rain at the beginning of the rainy season also may affect the production of wheat through their effects on the establishment of seedlings.

(2) Negative effects of elevated temperature would be expected on wheat yield due to the shortening of the growth duration and some adverse effects on reproductive growth in the plain area. On the other hand, increase of temperature will enhance canopy development, resulting in the better yield in the mountainous regions with sever winter.

(3) Those negative effects of climate changes will be at least partly compensated by increased CO_2 in the 2070s.

(4) The global warming effects on wheat yield in Adana projected both by the wheat growth model and the economic model, which will be explained in the following section, are around +13%, and another wheat growth model projects them to range between + 25% and +37%.

(5) Wide spatial variability will be expected in the climate change impacts on wheat yield within the Adana Province. Climate changes will increase and stabilize the wheat yield in the mountainous area, while it will destabilize the yield in the plain.

5.5 Irrigation and Drainage Sub-Group

The Irrigation and Drainage Sub-Group has executed the research activities, including a. preliminary questioning to Water Users Associations, b. collection and archive data related to irrigation, c. land use classification using remote sensing images, d. monitoring actual water budget of the tertiary canals in the LSIP, d. development of Irrigation Management Performance Assessment Model and its validation for the small monitored area, e. field monitoring of salinity of soil and shallow water table in the coastal area, f. generation of social scenario of the LSIP in the 2070s, and g. simulation of land-use changes in the 2070s using pseudo-warming outputs and expected value-variance (E-V) model.

As the results, the sub-group identified typical problems of the present system by visiting and questioning all water users associations (WUAs) in the LSIP. Farmers and WUAs had more concern on recent conflicts over allocation of water at the peak irrigation season.

The sub-group collected archive data and created homogenous data-sets for the delta. Through remote sensing, spatial distribution of the land use in present and in the past are detected and the wheat cultivated area is identified. With field observations, reference water budget was obtained and the characteristics of the actual irrigation method are examined.

In the project, Irrigation Management Performance Assessment Model (IMPAM) was developed in cooperation with other similar projects being implemented in the Yellow River Basin of China. It was validated being applied the small monitored area in the LSIP. Field monitoring of salinity of soil and shallow water table in the coastal area proves that EC of shallow water table in the irrigated area has continuously decreased over the past 20 years, yet in the coastal area, soil salinity still reflects distribution of shallow water table back in 1977, suggesting poor drainage.

With simulation of land-use changes in the 2070s using pseudo-warming outputs and expected value-variance (E-V) model, it is projected that in the 2070s, land use would shift to more cash generating crops than present, even under decreased water resources availability (**Table 1**). Using the IMPAM, crop growth and water budget of the whole delta was simulated, and as the results it is revealed that irrigation demand for the future increases due to extended irrigation period. However, the change seems to be within the range of its adaptive capacity.

Water table was more sensitive to the degree of management than to climate change. In general, the risk of higher water table seems less possible due to projected decrease in precipitation and due to decrease in water supply. Water logging only partially occurred in along the coast (**Fig. 14**).

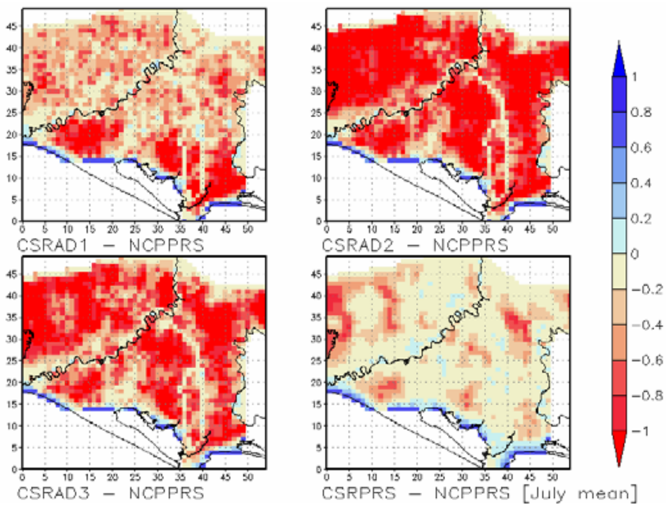

Fig. 14 Comparison of water table level between present and different adaptation scenarios (The case of CCSR runs for July average, Scenario 1: Top left, Scenario 2: Top right, Scenario 3: Bottom left, Present landuse: Bottom right)

Table 1 Simulated cropping pattern with climate and social scenarios

Scenario	Base case	MRI-S1	MRI-S2	MRI-S3	CCSR-S1	CCSR-S2	CCSR-S3
Available water (mm)	585	469	429	579	398	330	480
Citrus	22.0	22.1	22.1	21.9	21.9	18.3	21.8
Cotton	59.3	24.0	15.1	48.3	4.3		26.0
Vegetables	7.0	4.4	3.6	6.4	3.0	3.2	4.7
Watermelon & Maize		41.3	51.7	12.9	64.0	78.5	38.8
Fruit	11.6	8.3	7.5	10.4	6.8		8.6
Gross revenue (YTL/da)	717.9	706.9	702.6	715.6	696.4	670.0	707.9
Shadow price of water		0.1	0.1	0.1	0.2	0.1	0.1
Idle water (mm)	23.5						

*The case of risk aversion parameter set as 0.01

In the 2070s citrus would remain constant around 20% and in the case of scarce water supply, water melon would emerge. Watermelon is usually cultivated only once in five years to avoid replant failure. In order to take the crop rotation of watermelon into account, weighted average of watermelon (1 year) and maize (4 years) was used for simulation.

5.6 Socio-economics Sub-Group

The Socio-economics Sub-Group has carried out econometric analysis of climate change impacts on the production of wheat and barley and the farmers' economy and behavior in Adana and Konya region.

Changes in crop yield were predicted with price effect, drought effect, high temperature effect, and CO_2 concentration effect. Changes of the area sown were predicted with price effect and soil moisture effect. According to the predictions, with climate change the wheat and barley yield in Adana will increase by 13% and 6% respectively in the 2070s, while in Konya they will decrease by 18% and 17% respectively. The larger temperature increase in Konya than Adana may cause this difference. The area sown for wheat and barley in Adana and Konya will decrease slightly. Consequently, the total production of wheat in Adana will increase by 10% and the production of barley decrease by 2%, as shown in **Fig. 15**. On the other hand, in Konya, the production of both wheat and barley will decrease by 18%. The results imply that in Turkey they may face to possible food security problem or food shortage with global warming, since Konya is a representative wheat producing area in Turkey.

In the farm surveys, farm economy situation, rural credit market, rural land tenure problems and their relation with cropping patterns, livestock economy, and other farmers' behavior were studied. The results were used to understand the actual farm situation.

6. Major Project Outcomes

6.1 Attained research goals

The research goals attained in the original research plan mentioned previously are outlined below with the reasons for those portions not addressed:

(1) By developing the models on water movement, the water dynamics in the field and basin were evaluated quantitatively, while the factors that decide land use and soil condition were not analyzed due to limited basin survey and lack of basic basin information and data.

(2) Two General Circulation Models (GCMs) were used as planned, but only one RCM was used for downscaling their outputs. The mechanism, degree and extent of impacts were made clear to the expected extent. On the other hand, adaptation was not projected in relation with basic policy of agriculture and environmental conservation.

(3) Analysis of the basic relation among agriculture, natural condition including climate, and socio-economic condition history in the case study area were not studied satisfactorily due to insufficient availability of research organization and resources.

(4) The present and future possible problem on land and water management were identified and methodology for quantitative analysis of climate change impacts was developed with primary outputs, while the actual requests or feedbacks from personnel or organizations tackling these problem and making decision for them did not materialize.

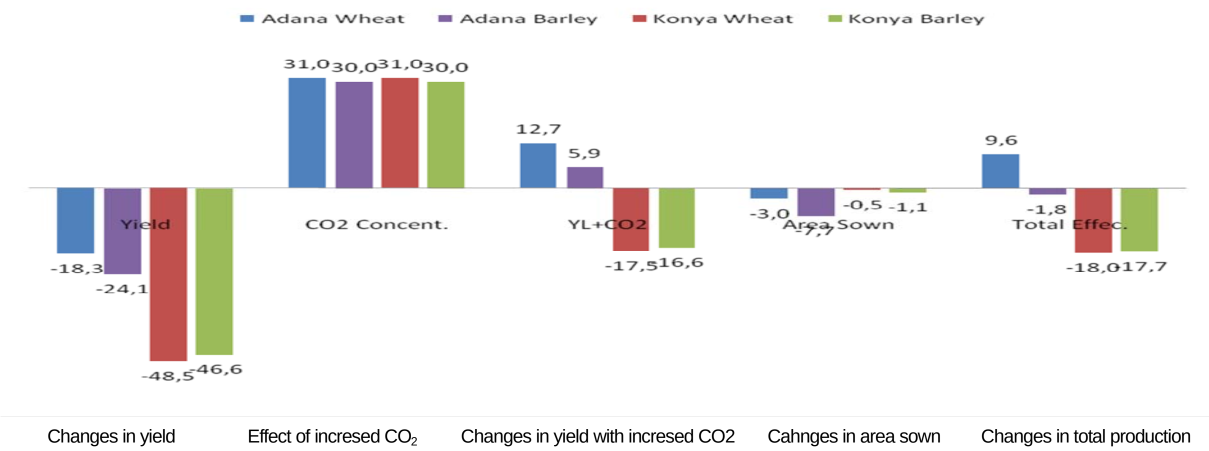

Fig. 15 Changes in yiled, area sown, and production of wheat and barley in Adana and Konya (the futures in the 2070s – the present)

6.2 Specific research findings

This project was implemented in Turkey selecting the Seyhan River Basin as the case study area. Since the study area was changed from Israel to Turkey in the final stage of the Feasible Study in 2001, this project had to be initiated without any past research experiences or foundations of RIHN in Turkey, and consequently it took time and cost to organize the research team there and to acquire basic information. Against these constraints, the efforts of collaborative researchers and their organizations developed a process to realize the project objectives through trial and error, and finally produced the expected results.

The major findings and outcomes are outlined as follows.

(1) Future climate changes

a. Pseudo-warming experiment technique was developed to generate future regional climate for assessing the impacts of climate change, which utilizes reanalysis climate data to raise accuracy when downscaling outputs of GCMs.

b. According to the output of the pseudo warming experiment under A2 scenario of SRES, Turkey in the 2070s is likely to face increase of 2 to 3.5 degree C in surface air temperature in all seasons, and decrease of 25% in precipitation.

c. Inter-annual variability is larger than climate change in the 2030.

(2) Water resource availability

d. In the Seyhan River Basin, precipitation is projected to decreased as it is in the whole Turkey.

e. In the 2070s, with less precipitation, runoff in Seyhan river will decrease.

f. Future sea level rise might trigger drainage problems in the coastal region of the delta. The degree of sea water intrusion would be dependent on the degree of deep ground water exploitation.

(3) Future vegetation

g. The higher part of mountain needs most attention for conservation of flora and fauna. Projected extinction of conifers is very critical.

h. Combination of low precipitation and high temperature will raise vegetation limit to 2000m.

(4) Crop production

i. The newly developed crop model predicts increases of wheat yields in Adana in the 2070s because the positive effect of elevated CO_2 exceeds the negative impact of elevated temperature and decreased precipitation. In economic analysis it is predicted that decreases of the sowing area of wheat will result in reduction in wheat production.

j. The amount and intensity of rain in the beginning of the rainy season also may affect the production of wheat through their effects on the establishment of seedlings.

(5) Agriculture and water use in the irrigated region of the delta

k. With current level of water resource exploitation in the upper basin, reservoirs can secure enough water for the irrigated agriculture in the delta.

l. However, if there would be additional 30,000ha of irrigation development in the upper basin, the delta is likely to suffer water shortage.

m. Fruits and vegetables would require irrigation in the early spring. Irrigation scheme must be modified to adapt to longer water release period.

(6) Irrigation management

n. Seepage loss from irrigation canals account for significant amount of irrigation intake in the LSIP. This occurs mainly due to aging of the canals and loose gate operation.

o. The canal water management has large influence on water regime. If irrigation efficiency is improved, there seems to be enough adaptive capacity of the system towards climate change.

p. Restructuring of water user associations and improvement of their operation are necessary for better water management in terms of water use efficiency and economy.

q. When the irrigation facilities would be rehabilitated, potential changes in cropping pattern in future should be taken into account for their design.

(7) Under climate changing

r. For realizing inter-disciplinary and context based approach to prepare for the possible climate change, it is important to involve stake holders in all fields, including farmers, experts of agriculture, water resource, climate etc.

s. To sustain reasonable land and water management to adapt to climate change, projection of possible changes with the state-of-art models is indispensable. Management is not possible without good monitoring.

(8) Agriculture and environment through climate change impacts assessment

t. Wheat is suited to environment of Turkey and it is the important staple food of the nation. Its yield and quality needs more detailed and continuous monitoring.

u. In Seyhan River Basin, water resource development has reached to considerable extent with construction of huge reservoirs. These reservoirs are providing the agricultural production system, larger adaptive capacity to climate change.

6.3 Research findings outside of original expectations

(1) A new downscaling method of the GCM outputs called "pseudo-warming technique" was developed. In this method, reanalysis data is used as the boundary condition for the RCM and climate change bias of the GCM is added to reanalysis data for downscaling. The output has much better agreement with observed data compared to the ones of conventional downscaling so that end user can use it without further elaborate corrections.

(2) For precise hydrological analysis, grid daily precipitation is indispensable. This project contributed to the establishment of a new project for generating grid daily precipitation record for the middle-east region, by means of data collection and human resources.

(3) It was found out that climate change would affect growth and mating season of small ruminants. Consequently agro-ecological relation between the farmland and cattle (fodder production, pasturage, cattle-dung use as organic manure, etc.) was projected to change considerably. But unfortunately, the project could not carry out elaborate research to quantify this issue within project period.

6.4 Relevance of research findings to RIHN's philosophy

The main focus of this project was to study how humans have utilized and managed regional resources and environment including climate, and how deeply human society depends on these conditions. This means implication of agriculture as the interface between natural system and human society.

Though agriculture has been long-lasting and local activity, in these decades, it has become controlled by the global market with rapid world-wide expansion of production and trade of food. In this process, agriculture has been loosing its specific features matching local conditions, and water and material cycle has shifted from their original natural situation. These changes are inducing world-wide issues to a large extent in terms of spatial scale and number of people and human elements, and consisting of the global environmental problems. Especially in arid areas, where water and other natural resource are limited, agriculture and its land and water use intensely controls life and production, and there is a need to identify the problem structure and to prepare better solutions for them.

Climate change due to global warming will affect natural condition for agriculture like land and water resources and consequently impacts agricultural production. With these impacts, humans may act to adapt to the changes or to mitigate the damages caused by climate change. These human reactions may result in other changes in the environmental problems mentioned above. Therefore, for better solution of the problems, it is essential to understand and project the impacts of climate change on agricultural production, and to let local knowledge and system react to the changes. In other words, it is important to recognize the local events in local points of view in a region and to prepare and select the best ways to treat the anticipated problems.

In this project, a method to diagnose the problems on land and water use and identify the crucial points was developed. In Turkey, where the case study area is located, the project provided the opportunity to establish new research organizations and cross-disciplinary approach to the problem, and promoted to enhance the consciousness on importance of impact assessment of global warming on basin hydrology and agriculture.

In this project, "better human life in the future" is defined as the life or society with the system and its performance to realize, maintain and improve the life and production with a certain quality and level, taking historical and regional aspects into account. According to this definition or context, in agricultural production, especially in land and water management that was mainly studied in this project, the foundation of the regional system was identified that could sustain agricultural land and water management under the local conditions and constraints essential to the "better human life in the future".

In this viewpoint, the project succeeded in identifying the elements that should be included into the condition of agriculture, land and water for "better human life in the future". On the other hand, studies on water and material dynamics and mechanism of problem occurrence in agriculture were not completed including the dynamics of soil salt, fertilizers and agrochemicals. Thus, in the future, studies on these dynamic and the way to establish sustainable land and water management for sound and safe life based on these process studies are necessary.

In addition, regarding impacts of global warming of main aspect of the project, the next research subject is to be prediction of impacts on agriculture, land and water management, evaluation of the extent of these impacts, and prepare the way to control the impacts to an acceptable level.

6.5 Accumulated knowledge for improving global environmental problems

In the project, a methodology was established to assess impact of climate change on agricultural production system at a regional (basin) scale, combining climatic and social scenarios. It was proved that integration of social scenario (obtained through dialogue of experts) with quantitative physical models for generation of quantitative projections is the only way to assess possible changes more than 50 years in the future.

A pseudo-warming technique developed in the course of this project would contribute significantly to raising the accuracy of projection of regional climate changes.

This project contributed to establishment of a new project for generating grid daily precipitation record for the middle-eastern region, by means of data collection and human resources.

7. Publications and Disseminations of the Outcomes

7.1 Communication to general society

(1) The project leader and collaborative researchers of the project have introduced the outcomes on local environment land and water management in the books published for the general public. Books based on the project findings are in preparation in Japan and Turkey.

(2) The project leader and collaborative researchers of the project have given lectures and talks in symposium or other events for ordinary people, NPO, university and high school students, and engineers.

(3) In the case study area in Turkey, the research outcomes are reported to the farmers and governmental organizations related to agriculture and water management and to be reflected to identifying the future tasks and measures.

(4) In Japan, project findings supported the TV Program on water in agriculture in the world of NHK in 2005, and in Turkey, the documentary program "Global Warming" is going to be broadcasted by TRT (Turkish Radio Television) in three series, which are to be "Climate" "Water" and "Land" under the scientific consultancy of some Turkish collaborators of the project with project findings.

(5) Some project outcomes were presented at international conferences and initiatives related to environmental issue including IHDP and ESSP.

(6) The project leader provided the Cabinet Office and the Science Council of Japan with the outcomes and suggestions of the project as the references of their master plans and tasks

7.2 Communication to academic societies

The project has disseminated and the collaborators are going to publish the results to the academic society in the following ways.

(1) Many scientific papers were published and presented in the international and national journals and conferences, and more are ready to be submitted. At the end of February 2007, 33 books and book chapters, 91 peer reviewed papers,

71 non-reviewed or conference papers, and 68 other articles were published by the collaborators. In these numbers, publications that has very limited relation to the project were included, while twenty-two papers acknowledge the ICCAP and the paper with acknowledgement to ICCAP will be increased since the collaborators has just prepared their material and results for their paper.

(2) Books on impacts of climate change for researchers, engineers and students are under planning in Japan and Turkey.

(3) In April 2006, the project and RIHN co-organized the International Symposium in Adana in the case study area on land and water management and discussed the methodology and research results of the project in the international context.

(4) Based on the outputs and experiences of this project, the project leader supported to establish the Working Group on Global Climate Change and Irrigation of ICID (International Commission of Irrigation and Drainage) in 2006, and is disseminating the project outcomes to the international organizations and institutions including FAO, IWMI, ICARDA, and IPCC.

8. Future Necessary Works

Important issues that remain to be addressed and plans to deal with them in the future include the following points.

(1) Land use and water use have large influence on regional climate system. Therefore, before evaluating the impacts of climate change there is a need to assess the response of the regional climate to change in land and water use, too.

(2) A systematic model for projecting possible adaptations of farmers or the region towards climate change should be developed.

(3) Geologist, hydrologist and soil scientist should work inter-disciplinary to quantify the impact of climate change on environmental quality dynamics of the basin and agricultural region.

(4) Consciousness, value and behavior of farmers towards land and water management have large influence to their capacity for adaptation. This human aspect should receive more research attention.

9. Conclusions – at the end of the project -

Although the project ICCAP has made the above preliminary conclusions, predicting the future changes caused by global warming is still a difficult undertaking, and in some quarters, prediction of future agricultural production in a specific place and year, like in the Seyhan River Basin in the 2070s, is considered “impossible”. At the moment, future climate change projection is still uncertain and a challenging topic, and the response of crops to climate change is also still in the basic study stages, even for a major staple crop like wheat.

If the phenomena or factors associated with climate change and its attendant impacts are difficult to appraise, how can we humans respond or react? We have a problem of natural events that are difficult to simulate or examine quantitatively in the laboratory or computer. Likewise, the impacts of human activity in a natural system, such as land reclamation or irrigation development, also can not be evaluated precisely in advance even though we may have a substantial knowledge base.

One of more effective and feasible measures for such a dilemma are to take actions incrementally , as in trial-and-error manner, utilizing the best available current knowledge and past experiences, and collecting additional information as needed. In pursuing such an adaptive approach, stakeholders should participate in the decisions and actions taken incrementally. For adaptation and mitigation in agriculture against global warming, farmers and their associations or cooperatives, and other organizations interested in climate, water resources, and agriculture need to be involved jointly.

Acknowledgments

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Generated Social Scenarios and Basin Conditions for the Final Integration

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1. Introduction

The ultimate goal of the project ICCAP is not to provide accurate forecast of the impact of climate change but rather to assess vulnerability of the agricultural production system through simulating its response towards climate change. Since agricultural system is an interface between nature and human activity, we needed some assumptions on socio-economic condition and its reflection on land use in the 2070s, especially to calculate water resource availability and its consequences.

Presently there is no sound scientific methodology for projecting socio-economic settings of a region or a country in the 2070s. Also, according to the methodology that we chose, there were additional limitations as shown below.

1) We used pseudo warming climate data for obtaining better agreement between projection data and observation data. We did not downscale data for the years between the 1990s and 2070s.
2) We did not have international trade condition of Turkey in the research frame.
3) Adaptive capacity of future crop variety was unpredictable.
4) The 2070s was more than 60 years away and assuming any economic equilibrium in the basin was not realistic.

Therefore we decided to generate social scenario qualitatively through discussion among the participants, based on impact assessment of climate change carried out individually by each subgroups assuming present land use.

2. Assumptions and basic frames for scenario generation

2.1 Assumptions

Our scenarios were created with assumptions below.

1) Although A2 scenario was assumed for climate data, we did not reflect the social setting of A2 scenario to Seyhan River Basin.
2) The scenarios were basically created based on the results of impact assessment with the present land use and the present social setting.
3) We tried to create extreme scenarios rather than optimal adaptation scenarios for testing the adaptive capacity of the system.
4) We did not consider farmers' adaptation by change of crop variety and assumed that that physiological response of crops would be same.
5) The effect of pest and disease were not considered.
6) The effects of domestic and international trades were not considered.
7) We did not consider demographic change and its potential consequences.

2.2 Basic frames of scenarios

To develop scenarios, the order of chain reaction was determined from upstream to downstream and from natural response to human response.

1) Climate condition.
2) Natural vegetation condition.
3) Cropping pattern and productivity of rain-fed crop land.
4) Degree of water resource development.
5) Available water for the irrigated agriculture.

6) Cropping pattern of the irrigated area.
7) Groundwater use in the irrigated area.
8) Water budget and salt water intrusion in the irrigated area.

2.3 Basic direction of change

At the time of scenario generation in the summer of 2006, we were aware of the following impacts of climate change.

1) Seyhan Basin would receive approximately 25% less precipitation in winter time and temperature would rise 2-3.5 ºC in the 2070s.
2) Natural vegetation would be subject to change but transition would occur very slowly. The effect of forest policy may have more significant impact on vegetation coverage until the 2070s.
3) The productivity of wheat was likely to decrease (in the final report, it is reported to increase).
4) Crops would have shorter growing periods due to increased photosynthetic productivity with elevated CO_2 and they would have increased evapotranspiration per day because of higher temperature.
5) Accession to EU would have large impact on land use in the basin.
6) Degree of sea water intrusion would be limited to a few kilometers from the coast.

3. Generated scenarios

3.1 Main setting of the scenarios

We developed three different scenarios as shown below.

1) Scenario 1: a passive and low investment scenario for agricultural production. Rather than making additional investment, farmers choose the crops that they can grow with available resource. The maintenance level of infrastructure declines from present. Phase IV area is not irrigated.
2) Scenario 2: a pro-active and high investment scenario for increasing productivity. For counter-acting the decrease of water resource, additional reservoir construction is carried out. The maintenance level of canal improves from present. Phase IV area would be irrigated.
3) Scenario 3: the same setting as the scenario 2. Additionally, groundwater uptake occurs in the low lying area. On the average of whole LSIP, 150mm of new groundwater use occurs.

The scenarios 1 and 2 were set as contrary to each other. The scenario 3 was basically same as scenario 2 except for the great increase of groundwater use in the delta plain. Table 1 shows the brief summary of scenarios.

3.2 Detailed setting of the scenarios

Here are some additional explanations for the details of scenarios.

1) Natural vegetation: in the scenario 1, vegetation cover was assumed to remain same as present with conservation efforts. Projected decrease of evergreen conifer forest was reflected on the scenario 2 and 3. The decrease was assumed to be 20% of present (although quantified as 45% of total at final report). The effect of elevated CO_2 was not incorporated. The impact of grazing on vegetation cover was not incorporated.
2) Winter wheat: scenario 1 assumed relatively lower productivity and lower market competitiveness in the middle reach of the basin and therefore projected 100% of cultivated area being converted to pasture. The scenario 2 and 3 assumed 25% of wheat cultivated area being converted to irrigated field (see below for details). The rest would again turn into pasture.
3) Water resource development: different degrees of upstream development were tested. Out of all wheat cultivated area in the middle reach, we tested 50%, 25% and 12.5% of it being converted to irrigated field and compared reliability for the water demand of the LSIP as shown in Fig.1. We obtained severe but not absolutely water deficit condition with the case of 25% (30,000ha).The reliability for that case is shown in Fig.2. For this area, assumed crops were maize (75%) and citrus (25%).
4) For irrigated agricultural area in the LSIP, Umetsu et al. used the calculated available water and projected land use change in the 2070s using expected value-variance (E-V) model. In the scenario 1, the coastal area called “phase IV” would not be irrigated and water use efficiency would be lower than present because of less

Table 1 Summary of scenarios

	Changing factors	Pesent	Scenario 1: Less resource deriving, low water stress scenario	Scenario 2: Pursuing productivity, high water resource development scenario	Scenario 3: Pursuing productivity, high water resource development scenario
Natural vegetation (non agric. Land)	Vegetation cover	No change	No change	20% decrease in evergreen conifer forest	20% decrease in evergreen conifer forest
Agricultural land (rain-fed)	Wheat cultivated area in the middle reach	100% cultivated	100% converted to pasture (abandoned)	25% converted to irrigated agricultual land. 75% converted to pasture	25% converted to irrigated agricultual land. 75% converted to pasture
	Construction of additional dam		No	Yes	Yes
Agricultural land (LSIP)	Available water (MRI)	585	469	429	579
	Available water (CCSR)	585	398	330	480
	Crops	See Umetsu et al.	See Umetsu et al.	See Umetsu et al.	See Umetsu et al.
	Groundwater use	No	No	No	150mm (area average)
	Phase IV area	Partially irrigated	Not irrigated	Irrigated	Irrigated

intensive management. In the scenario 2, phase IV would be irrigated with less water supply and water use efficiency would be higher than present because of more investment on water saving techniques. In the scenario 3, water stress is eased by use of groundwater from the deep aquifer. However this scenario has high risk potential for salinity hazard.

5) With assumed land use in the LSIP, Irrigation Management Performance Assessment Model (Hoshikawa et al.) and SIFEC (Fujinawa et al.) were run to assess the risks.

3.3 Reflection of scenarios on basin condition

Figure 3, 4 and 5 show reflections of scenarios on the land use in the basin. For the evergreen conifer forest, which decreases 20% in area (scenario 2 and 3) and for the newly irrigated area that appears in the middle reach (scenario 2 and 3), their spatial distribution was given randomly. Table 2 show the area of each land use in the present condition and in the scenarios.

References

For the reference of the authors below, please refer to individual report of this final report.

Fujinawa et al.
Hoshikawa et al.
Umetsu et al.

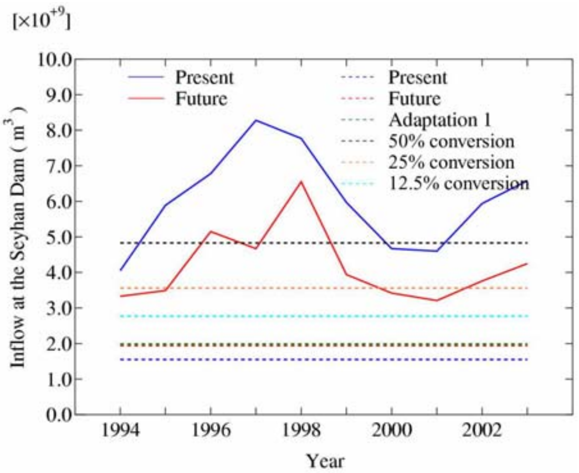

Fig. 1 Comparison of annual total inflow to the Seyhan dam and water demand of different cases

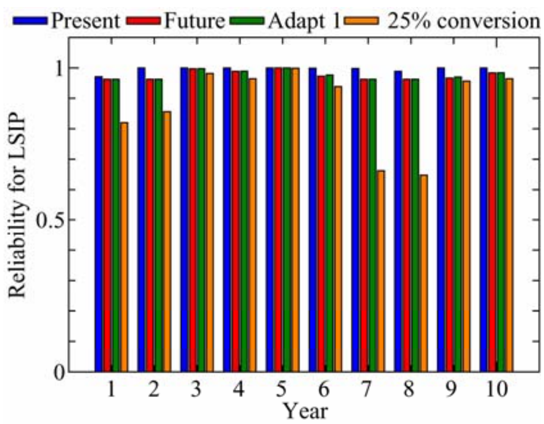

Fig. 2 Reliability of the LSIP with assumed 30,000ha of newly irrigated land in the upstream

Table 2 Area of each land use of the basin condition according to scenarios.

Land use	Present		Scenario 1		Scenario 2/3	
	Km^2	%	Km^2	%	Km^2	%
Water body	191.5	0.87	191.5	0.87	191.5	0.87
Evergreen coniferous fore	4226.4	19.38	4226.4	19.38	3584.2	16.45
Mixed forest	86.8	0.40	86.8	0.40	86.8	0.4
Grassland	6865.9	31.75	11682.2	53.98	7508.1	34.68
Maize	3137.1	14.34	2748.1	12.58	3137.1	14.34
Dry crop land	4816.3	22.23	0.0	0.00	4530.6	20.93
Urban area	45.1	0.21	45.1	0.21	45.1	0.21
Crop/ natural vegetation	0.7	0.00	0.7	0.00	0.7	0
Barren	2171.5	9.98	2560.6	11.74	2171.5	9.98
Citrus	192.3	0.87	192.3	0.87	478.0	2.17

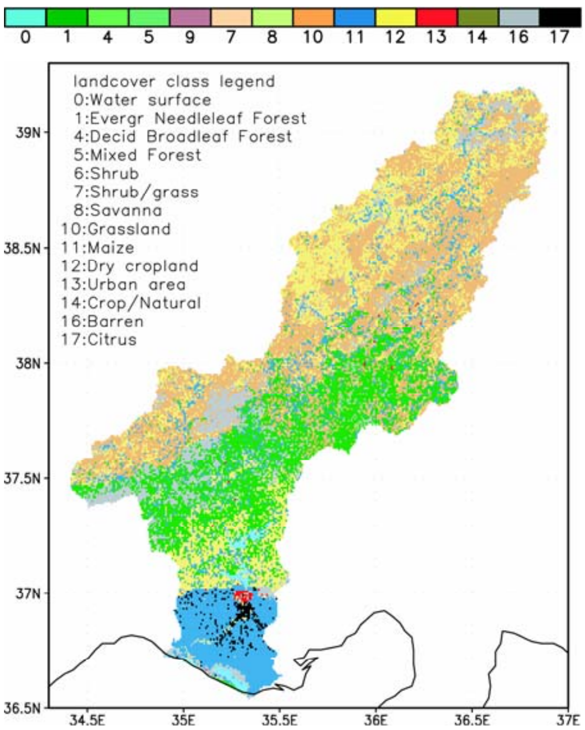

Fig. 3 Present land use.

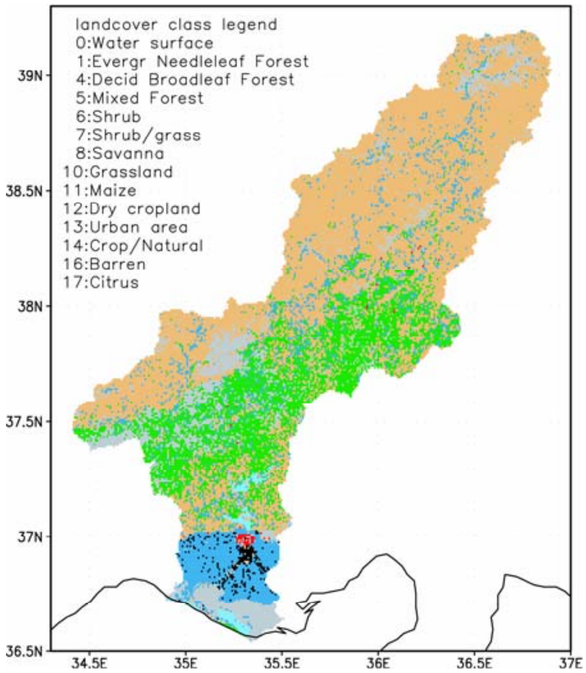

Fig 4 Land use for the scenario 1

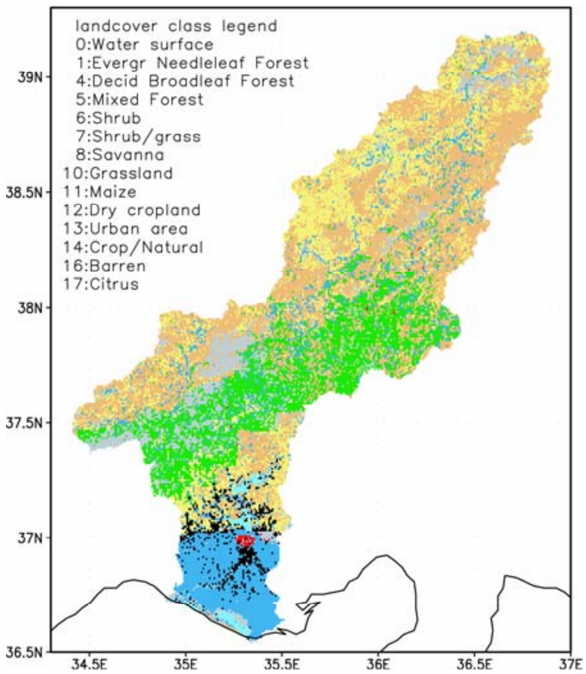

Fig. 5 Land use for the scenario 2 and 3.

Downscaling of the global warming projections to Turkey

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1. Introduction

Around the Mediterranean including Turkey is the one of the most prominent area in which precipitation is projected to decrease by GCMs, while total amount of precipitation in the world will increase. In the most part of Turkey, present precipitation is not so large, further decreasing in precipitation may seriously damage agriculture and ecosystem. Climate change in a limited area such as Turkey is quite difficult to be projected. Climate change by increasing of greenhouse gas is usually estimated by General Circulation Model (GCM). However, horizontal resolution of the ordinary GCM is quite low, i.e., grid interval is about 100-300km, although these are being improved day by day associated with the increase of computer power. The resolution is still not enough to estimate the climate change in a basin, such as Seyhan river basin in Turkey. Downscaling of GCM using Regional Climate Model (RCM) may arrow to estimate the regional climate change, although GCMs and the downscaling methods still have many problems for reliable projection. In this report, we try to project the climate change in Turkey and even in Seyhan basin in order to provide scenarios of the likely climate change in this basin. The reliability of the projection methods is also discussed by the comparison of several methods.

2. Method

In generally, one of the largest difficulty in the downscale process using a nested regional climate model is the bias of GCMs, especially shift of a regional scale climate system in GCMs may gives serious error in the nested model (Wang et al., 2004). To avoid this difficulty, we apply PGWM (Pseudo Global Warming Method) reported by Kimura and Kitoh (2007) in the ICCAP final report. PGWM reduces some components of model bias, whose horizontal scale is larger than the synoptic scale. Another advantage of PGWM is to allow to estimate the global warming effects on the specific past year. The assumed boundary conditions after global warming will keep their characteristics of short time variation in the specific past year although they are modified by the differential climatology between before and after global warming. This advantage makes easy to estimate the difference between present and future climate without ensemble of numerous number of members.

Figure 1 shows the nested regions in RCM for the downscaling. The coarse grid covers Europe and the Mediterranean with the interval of 100 km (Top) and is driven by the boundary conditions by reanalysis data or GCMs. The second grid covers the entire Turkey with the interval of 25 km (Bottom) and the finest grid covers Seyhan basin with 8.3km.

Figure 2 indicates a flowchart of the downscaling. The flow can be separated into two parts: the left side flow is the downscaling from MRI-CGCM2, while right side flow is that from CCSR/NIES-CGCM. Downscale method is the PGWM using regional climate model, i.e., TERC-RAMS. The reanalysis data for the PGWM are 2.5 degree resolution provided by NCEP/NCAR. The hindcast and downscaled projection in 2070s are interpolated at each observation stations and made further correction to reduce the model bias. The

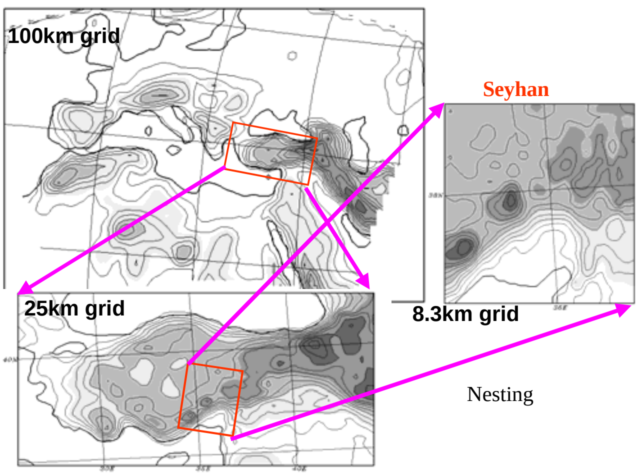

Fig. 1. Nested regions in RCM. Coarse grid covers Europe and Mediterranean with the interval of 100km (Top), the second grid covers entire Turkey (Bottom) and the finest grid covers Seyhan basin with 8.3km.

interpolated data are distributed to the members of the project.

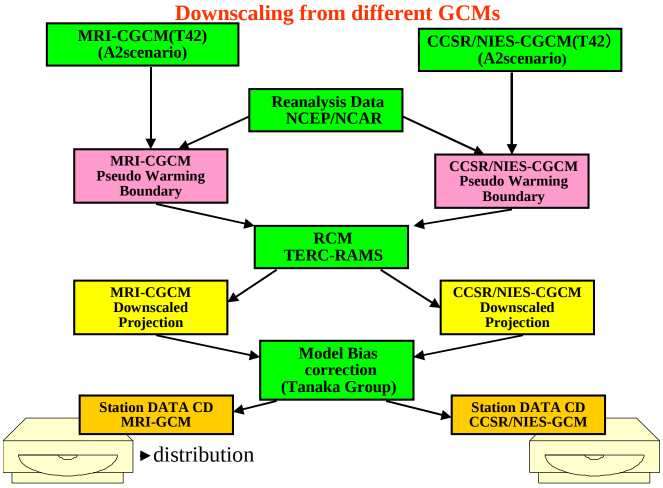

Fig. 2. Flowchart of the downscaling.

3. Simulation of the past climate (hindcast)

Top panel of Figure 3 is nine-year mean monthly observed precipitation in January, during 1994 to 2002. Since precipitation strongly depends on orography, horizontal interpolation is difficult. The bottom of the figure is ten-year mean monthly reproduced (hindcasted) precipitation in January during 1994 to 2003, which is almost corresponding observation shown by the top panel. Horizontal distribution of the hindcasted precipitation agree well to the observation, particularly heavy precipitation along the Black Sea and some areas along the Mediterranean, although precipitation is slightly overestimated. Figure 4 is same as Fig.3 but in April. Observed precipitation distribute quite uniformly although a few stations observing heavy precipitation are scattering along the coastal regions and mountainous areas. The hindcast somewhat overestimate precipitation and shows stronger tendency of stronger precipitation in the coastal and mountainous areas. In July (Fig.5), precipitation becomes minimum in the seasonal cycle. The hindcast agrees well to the observation except for underestimation along the coast line of the Black Sea. The simulated distribution of precipitation also agrees to the observation in October (Fig.6).

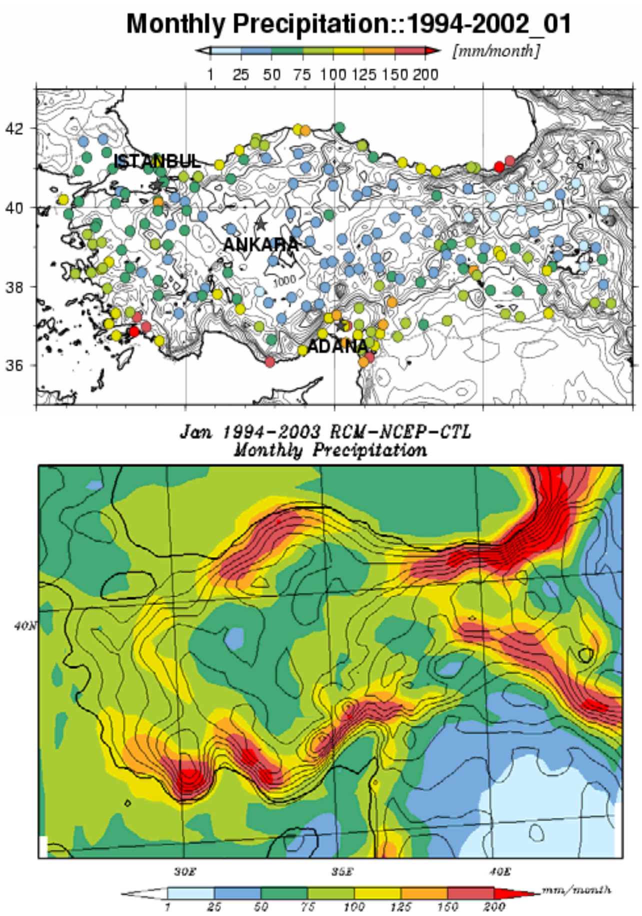

Fig. 3. Ten year mean monthly observed (Top) and hindcast (Bottom) precipitation in January, during 1994-2003, but nine years during 1994-2002 for observation.

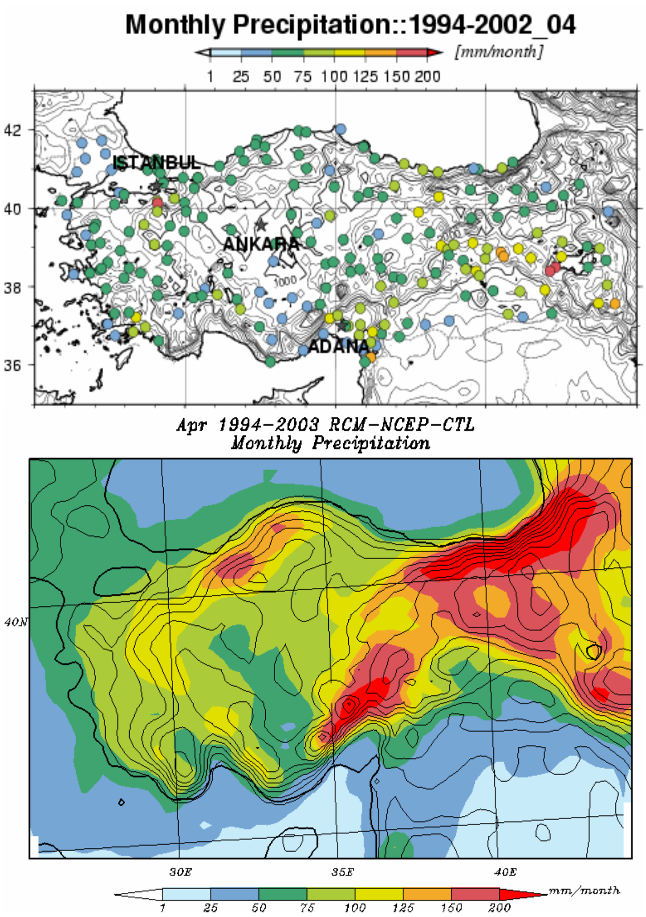

Fig. 4. Same as Fig.3 but in April

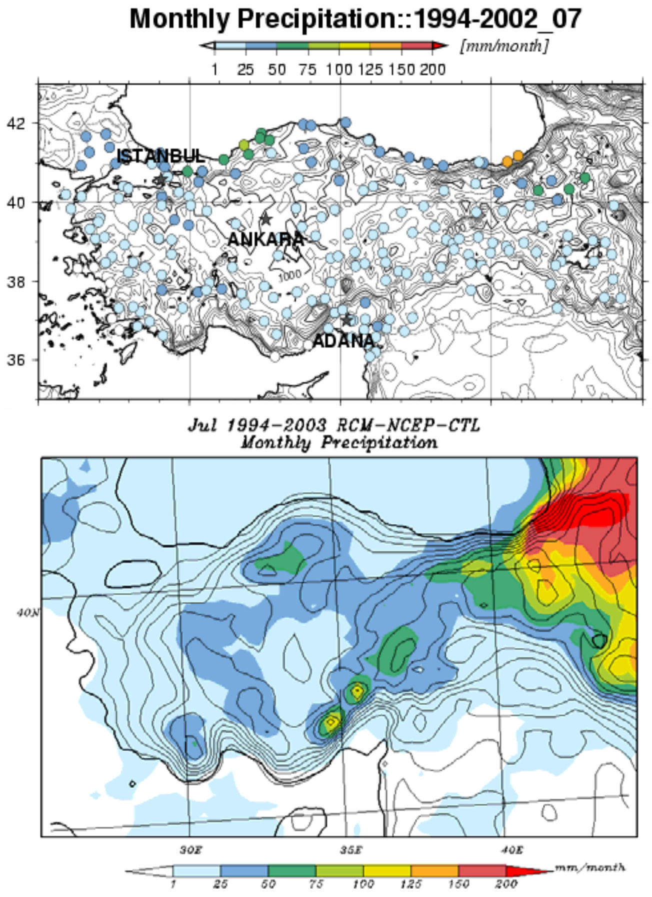

Fig. 5. Same as Fig.3 but in July

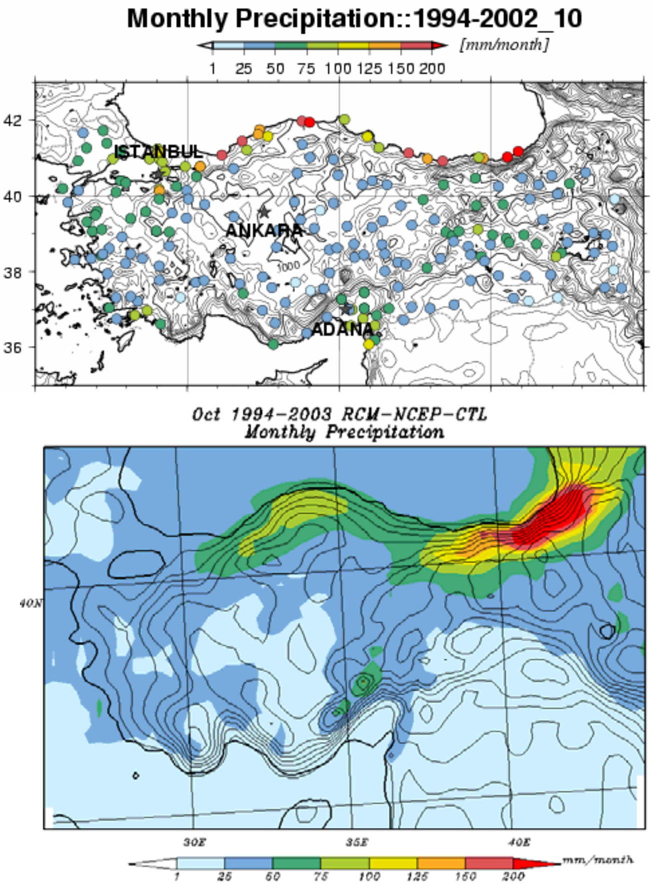

Fig. 6. Same as Fig.3 but in October

Figure 7 shows seasonal cycles of observed and hindcasted precipitation. Observed precipitation is smaller than 20 mm in July, but it exceeds 100 mm in December and keeps about 70 mm during January to April. This is a quite typical seasonal cycle of the Mediterranean climate. The hindcast almost agree well to the observation during May to December. From February to April, in particular in February and March, hindcast overestimated the amount of precipitation.

Error bars indicate the standard deviation of inter-annual variation of precipitation. The amplitude of inter-annual variation is quite large, especially in November and December. The standard deviations of the control run, namely; hindcast, agree well to the observed ones, but it is overestimated in February to April, when amount of precipitation is overestimated. When the amplitude of inter-annual variation is larger, the estimation of difference in precipitation between the present climate and the future climate becomes difficult because of smaller Signal (climate change) to Noise (inter-annual variation) ratio, i.e., S/N ratio.

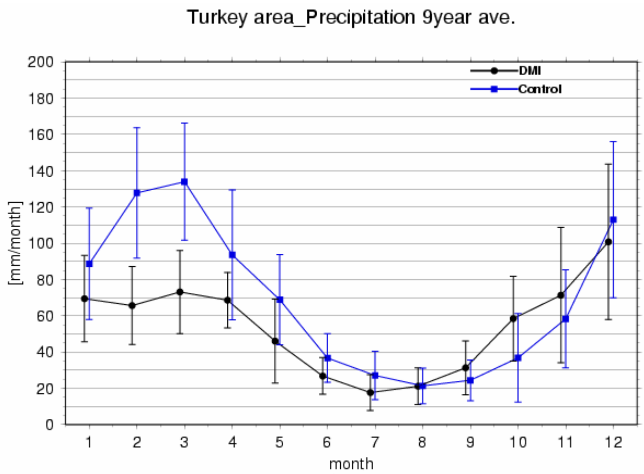

Fig. 7. Seasonal cycles of observed (black, provided by DMI) and hindcasted (blue, by the control run) precipitation. Observed one is the average of 206 in situ stations in the entire Turkey, while the hindcast is average of 206 grid points nearest to the stations in the second grid system. Error bars indicate the standard deviation of inter-annual variation.

4. Projected Precipitation

Figure 8 shows seasonal cycle of the mean monthly precipitation with the downscaled projections by MRI-GCM (red) and by CCSR/ NIES (orange). The downscaled precipitation is almost always smaller than that of the control run except for February estimated by downscaling from MRI-GCM. The model predicts that precipitation of Turkey will decrease almost through year. Ratio of the decreasing is prominent during cold season, while decreasing rate is small during summer. Total decreasing rates through year are not so different between those downscaled from MRI and CCSR/NIES, the former is about 27% and the letter is 25%. Note that these differences by the climate change is not always larger than the inter-annual variations, which also are indicated in Fig.9.

Figure 10 shows seasonal cycles of observed and hindcasted precipitation as well as downscaled precipitation from MRI-CGCM and those from CCSR/NIES-CGCM. Disagreement between observation and estimation by the control run is slightly larger than that of the entire Turkey. The tendency of precipitation change is almost same as that of the entire Turkey, while decreasing in winter is more prominent, especially the downscaling from CCSR/NIES.

Since horizontal distribution of precipitation change in the entire Turkey will be discussed latter, only change around Seyhan basin are discussed here. Figure 11 shows horizontal distribution of difference in precipitation between present and future climate in the finest grid in April. Horizontal pattern of precipitation change between in 1990s and 2070s projected from MRI-CGCM are quite similar to that from CCSR/NIES-CGCM.

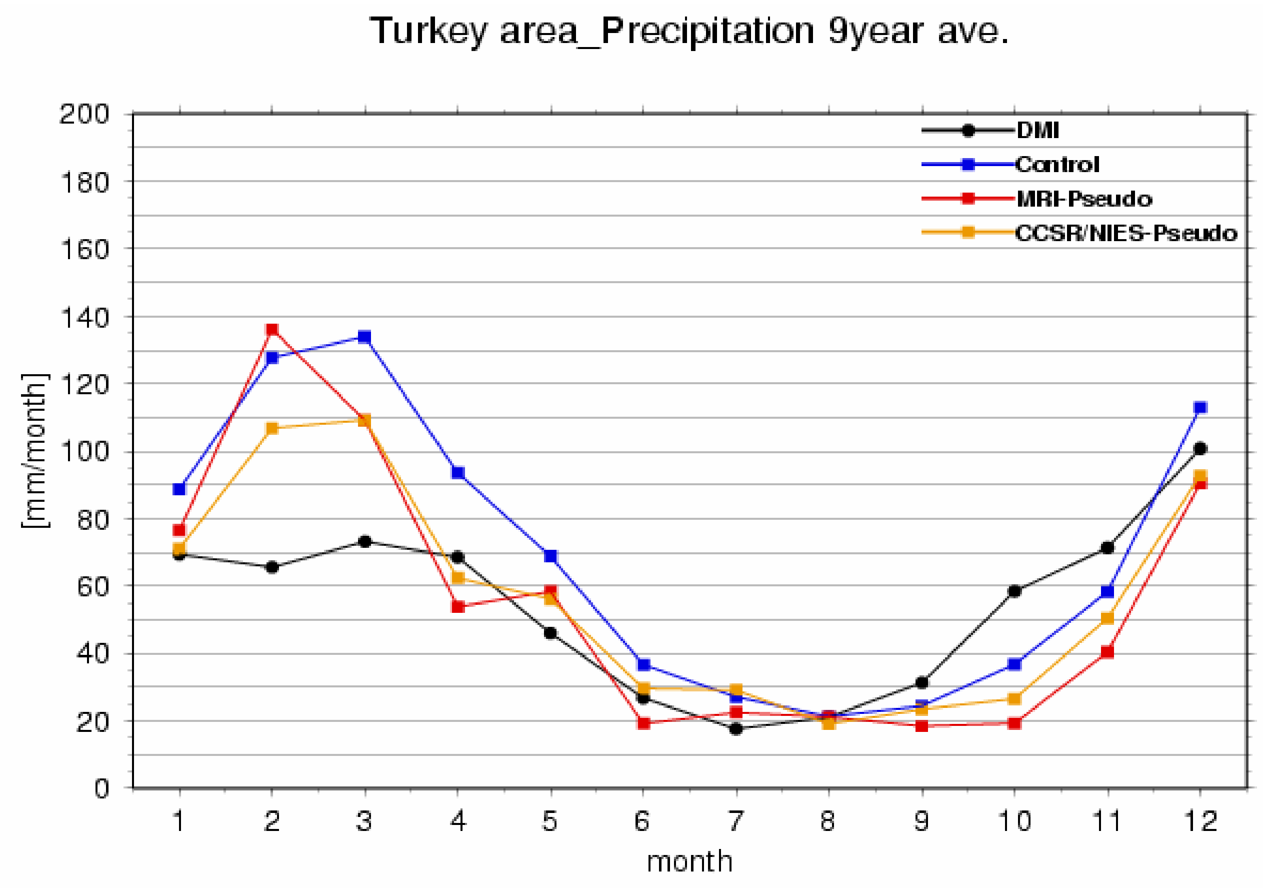

Fig. 8. Same as Fig.7, but for with the downscaled predictions by MRI-CGCM (red) and by CCSR/NIES-CGCM (orange).

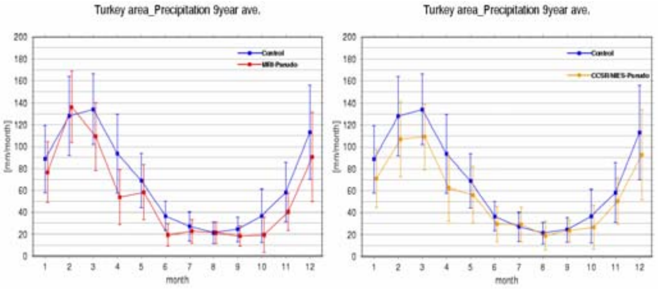

Fig. 9. Standard deviations of precipitation each month (error bars) in the control run (blue) versus downscaling from MRI-CGCM (red, in left panel) and that from CCSR/NIES-CGCM (orange, in the right panel)

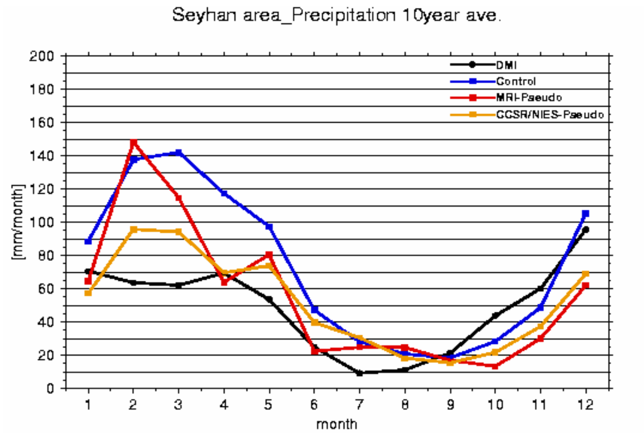

Fig. 10. Same as Fig.8, but mean precipitation in the finest grid (8.3km grid interval)

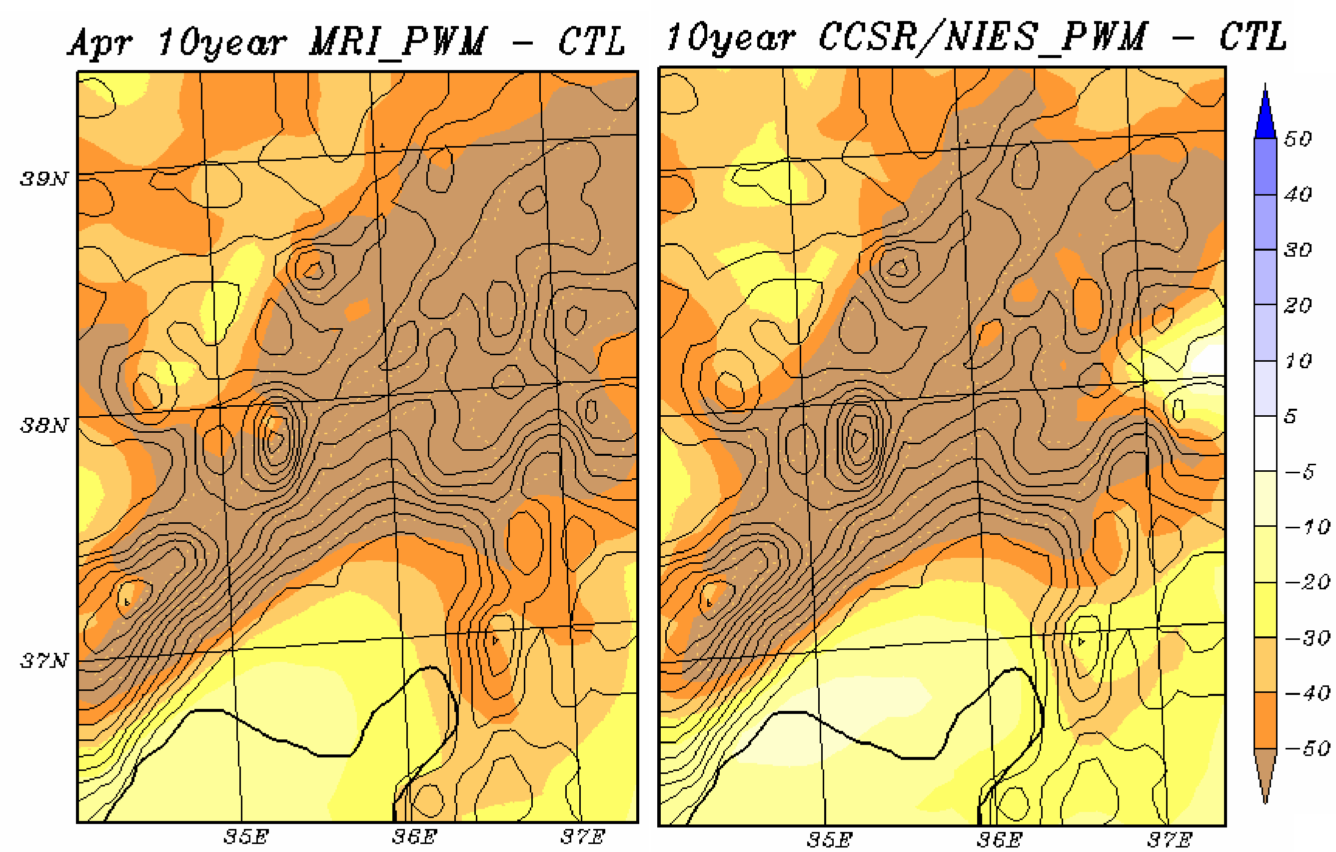

Fig. 11. Horizontal distribution of difference in precipitation between present and future climate in the finest grid downscaled form MRI-CGCM (left) and CCSR/NIES-CGCM (right)

5. Projected extreme events of rainfall

Disasters caused by weather may increase by the effects of climate change. Flood and drought are often the most concernments not only for the farmers but others. Extreme events of daily precipitation and period of no precipitation are good indexes for the potential of these disasters. Figure 12 shows probability density function (PDF) of daily amount of precipitation in four in situ stations. These are statistics of ten years data given by observation (black), control run (blue), downscaling of projection (2070s) by MRI-CGCM (red) and by CCSR/NIES-CGCM (orange). Although accuracy of the control run for the PDF, particularly for the extreme events, depends on the stations, probability up to 32 mm/day are reproduced well. The downscaling from both GCM project that the probability of extreme precipitation will not much change. PDF of the period of no precipitation is shown in Figure 13, in which the vertical axis is number of days of no precipitation periods while horizontal axis indicate the rank of no precipitation period.

No precipitation periods given by the control run and observation at Adana has large discrepancy in the long duration. Others are mostly agree well. The change in PDF of long no-precipitation periods are not so different between present climate and future climate. We are not sure that these results are reliable or not. The meaning of the extreme events estimated by PGWM should be studied in the future.

6. Projected Temperature

Figure 14 shows seasonal cycles of observed and hindcasted surface level air temperature. Temperature estimated in the control run has cold bias, particularly in the warm season. Inter-annual variability is larger in the cold season and spring. Projected seasonal cycles are shown in Figure 15. Both downscaling indicate increase of surface temperature in all months. Seasonal variation of the difference is quite small as well as the inter-annual variation which is indicated in Figure 16. The range of differences projected by the downscale from CCSR/NIES- CGCM is much larger than that of MRI-CGCM. The former projects to increase by about 2.0K, while latter by about 3.5K. The large difference between two downscaling is a faithful reflection of the difference of GCMs. The change in temperature is quite similar to the projection in the finest grid as shown in Figure 17.

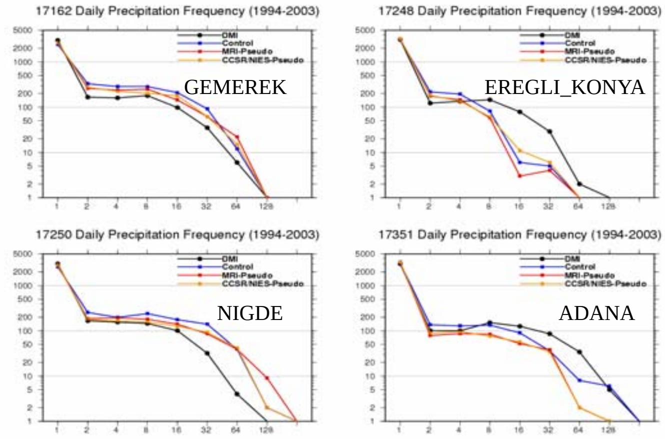

Fig. 12. Probability density function of daily amount of precipitation in four in situ stations. The vertical axis is number of days during 10 years and the horizontal axis is daily precipitation. Black line indicate observed PDF other three colors are the same as Fig.8.

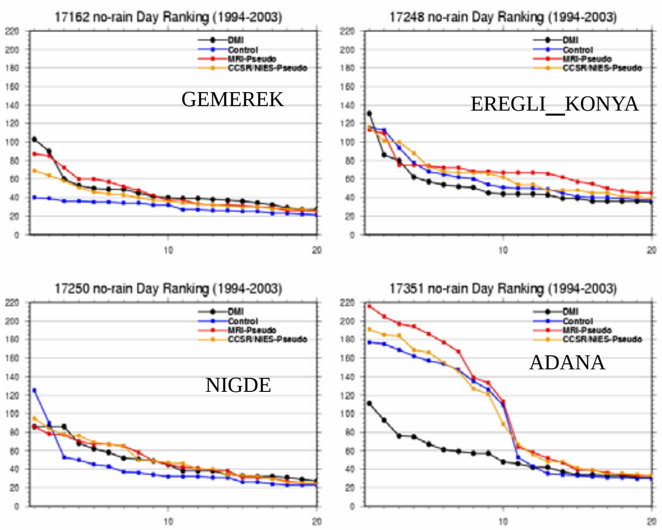

Fig. 13. The longest period of no precipitation. Vertical axis: number of days of the period of no precipitation. Horizontal axis: the rank of the longest period

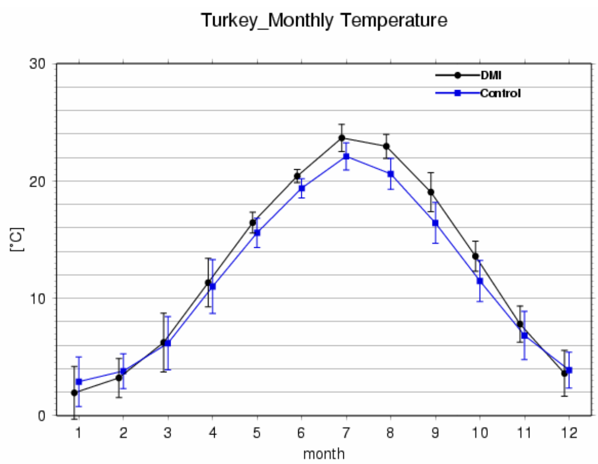

Fig. 14. Same as Fig.7, but for Temperature

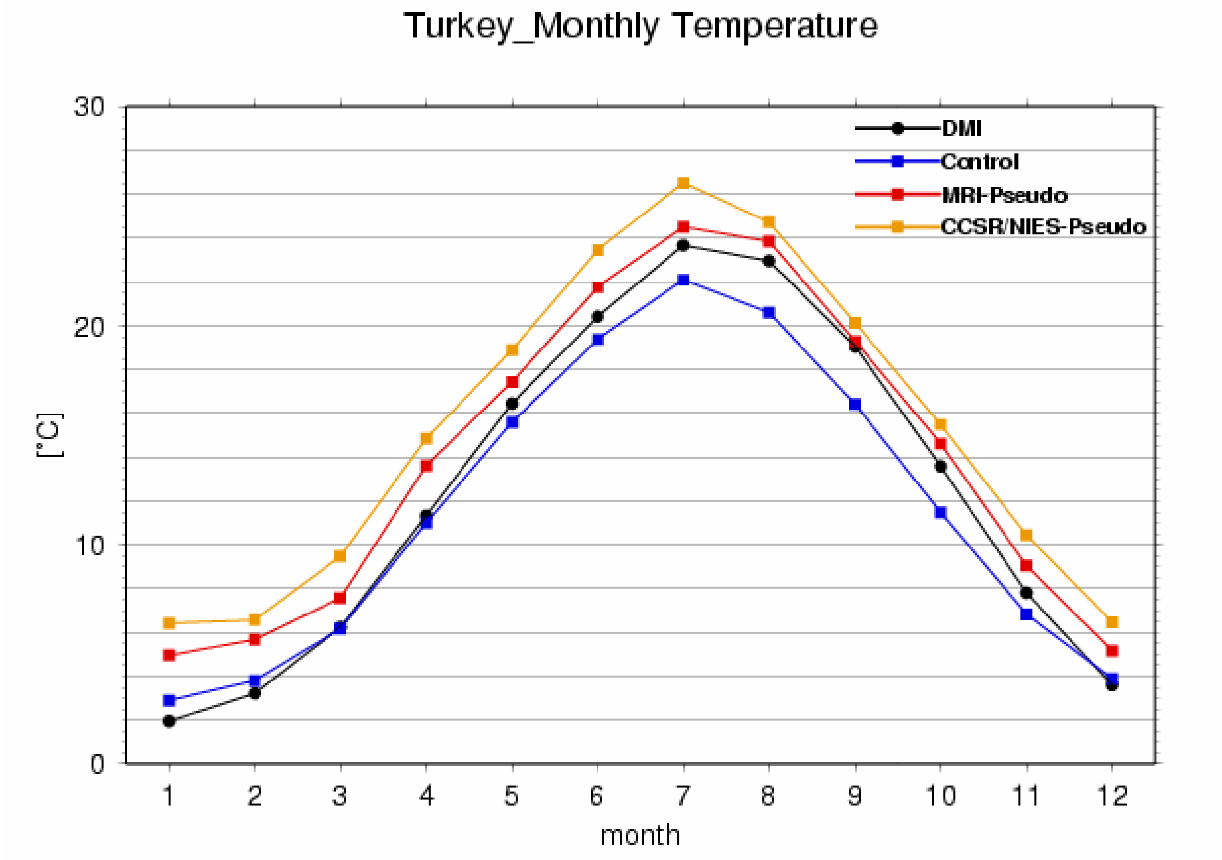

Fig. 15. Same as Fig.8, but for Temperature

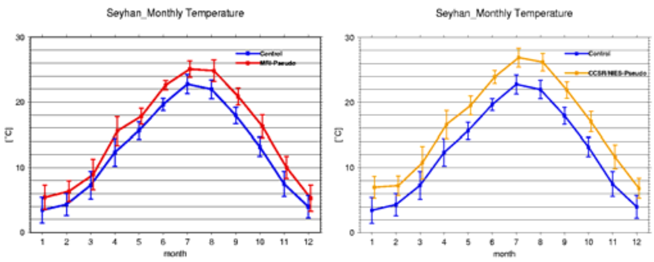

Fig. 16. Same as Fig.9, but standard deviations of temperature

Figure 18 shows horizontal distribution of difference in surface temperature between present and future climate in the second grid and the finest grid of downscaling form MRI-CGCM in the top and bottom panels, respectively. Temperature change is larger in the southern part of Turkey, particularly in the mountainous area along the Mediterranean. The change is large also in the south western part of Turkey. The bottom panel indicates that the change is relatively small along the coast in Adana plain, while it is larger in the surrounding mountains, showing a tendency of stronger warming in the southern slopes. Projection based on CCSR/NIES-CGCM shows much stronger increase of surface temperature. Figure 19 indicates that the difference will excess 3.0K in the most part of Turkey.

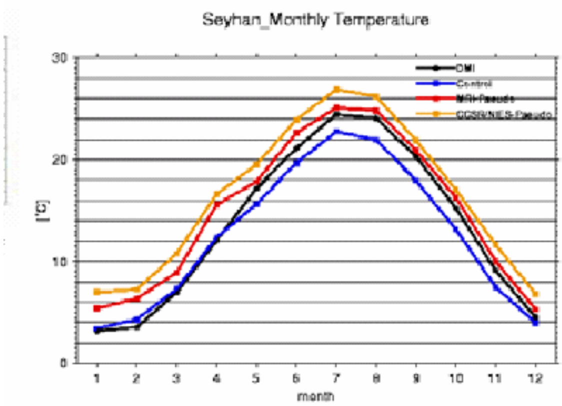

Fig.17: Same as Fig.10, but for mean surface temperature in the finest grid

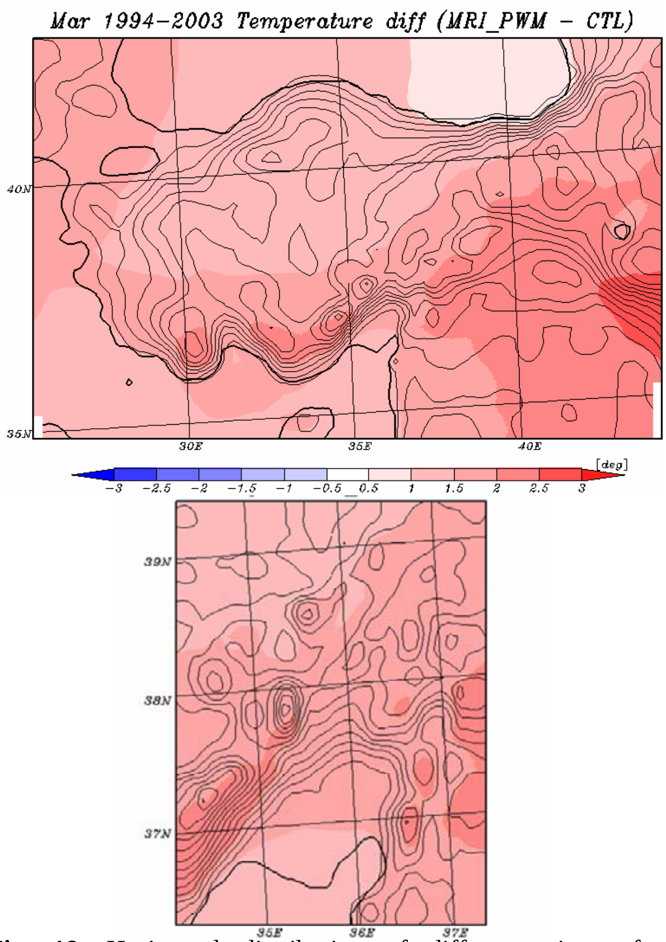

Fig. 18. Horizontal distribution of difference in surface temperature between present and future climate in the second grid (top) and the finest grid of downscaling form MRI-CGCM

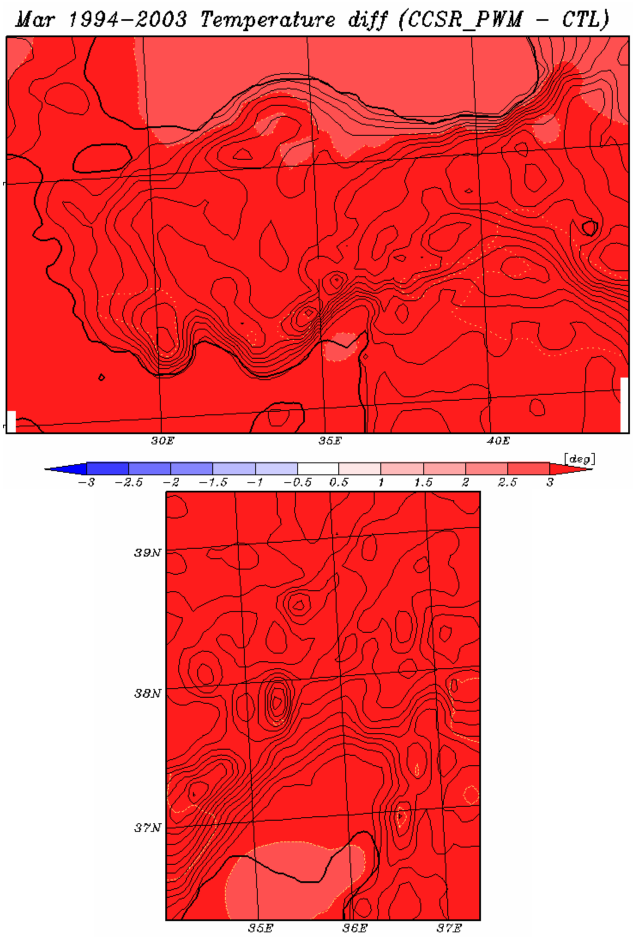

Fig. 19. Same as Fig.18,but for CCSR/NIES-CGCM

7. Projected Insolation

Figure 20 shows monthly mean daily total insolation (MJ/m^2) at Adana during the period of January 1994 to December 1996. Although the control run overestimate in the warm season, it agrees to observation in cold seasons. The change between 1990s and 2070s are very small. Only some difference can be seen in the cold season, in which it frequently becomes cloudy and rainy. Figure 21 shows horizontal distribution of monthly mean daily total insolation in March. Insolation change is also affected by orography. Insolation change is larger in mountainous area in April but weaker in August. This fact is related to distribution of precipitation.

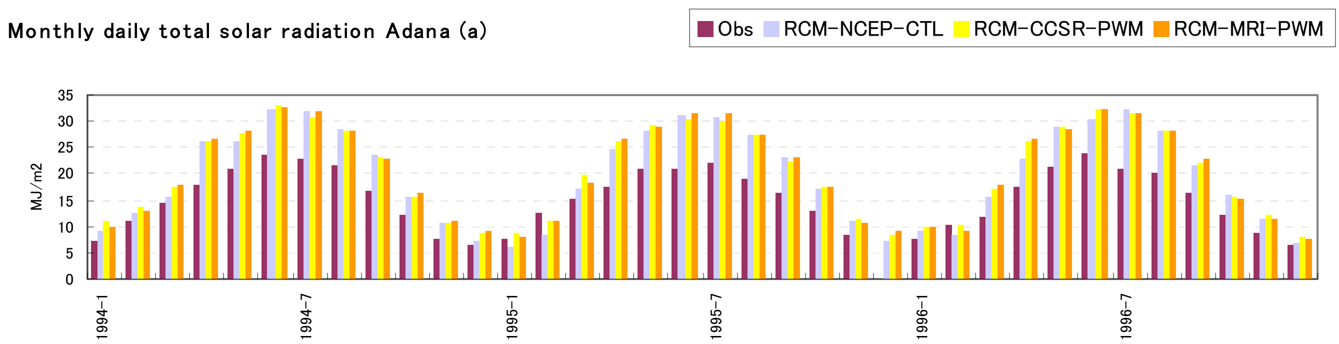

Fig. 20. Monthly mean daily total insolation (MJ/m2) at Adana. Brown bars: observation, gray: control run, yellow: downscaled from CCSR/NIES, orange: MRI

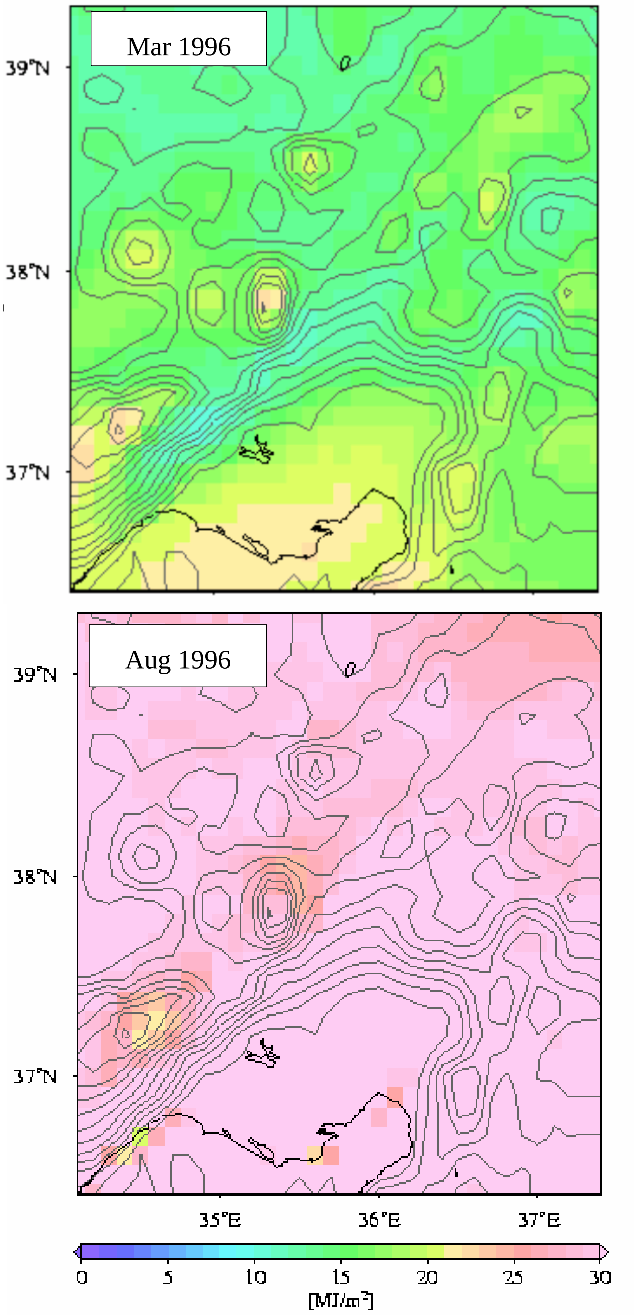

Fig. 21. Horizontal distribution of monthly mean daily total insolation in March (top) and August(bottom) in 1996.

8. Comparison to the projections by GCMs.

To assess the reliability of the downscaling, comparison between different models is useful. Kitoh (2007) presented some climate projection in Turkey by Global Climate Models. Since precipitation reflects generally quite well the characteristic of the model, projected change in precipitation is compared here. Figures 22 to 24 are comparison to some other projections presented by Kitoh (2007) as an individual report of the Climate Group of ICCAP. Top left panel of Fig.22 is the projection by AOGCM (resolution is about 200km) and top right panel is that of CGCM (TL959) with 20km horizontal resolution shown in his report. These are precipitation difference during December, January and February between the present period (1981-2000) and future period (2081-2100) assuming the SRES A1B scenario. Although the comparing periods and scenario is different from the downscaling, the results are expected to have high similarity to those under same conditions as the scenario we assumed. AOGCM indicates decreasing of precipitation especially in the southern part of Turkey. CGCM (TL959) shows increasing in precipitation along the coast of the Black Sea but decreasing along the coast of Mediterranean. The two downscaled projection, lower left panel (MRI-CGCM) and lower right panel (CCSR/NIES-CGCM), are quite similar to those of CGCM (TL959). The downscaled projection also have some similarity to the results of AOGCM, although resolution is quite different.

On the other hand, during spring, March, April and May (Fig. 23), we can not see any similarity between two downscaling and CGCM (TL959). Two downscaling are quite similar each other and AOCGM has also some similarity. During summer (Fig. 24) and autumn (Fig. 25), no similarity can be seen between two downscaling and CGCM (TL959). Particularly downscaling from CCSR/NIES-CGCM has an opposite pattern against the projection by CGCM (TL959) in October and November. On the other hand, two downscaling keep some similarity to AOGCM in spring and winter. Similarity between AOGCM and downscaling form MRI-CGCM has been previously expected because this GCM is basically same as the source of the downscale, i.e., MRI-CGCM. On the other hand AOGCM and the downscaling from CCSR/NIES-CGCM are completely independent each other. These two seem to agree well each other.

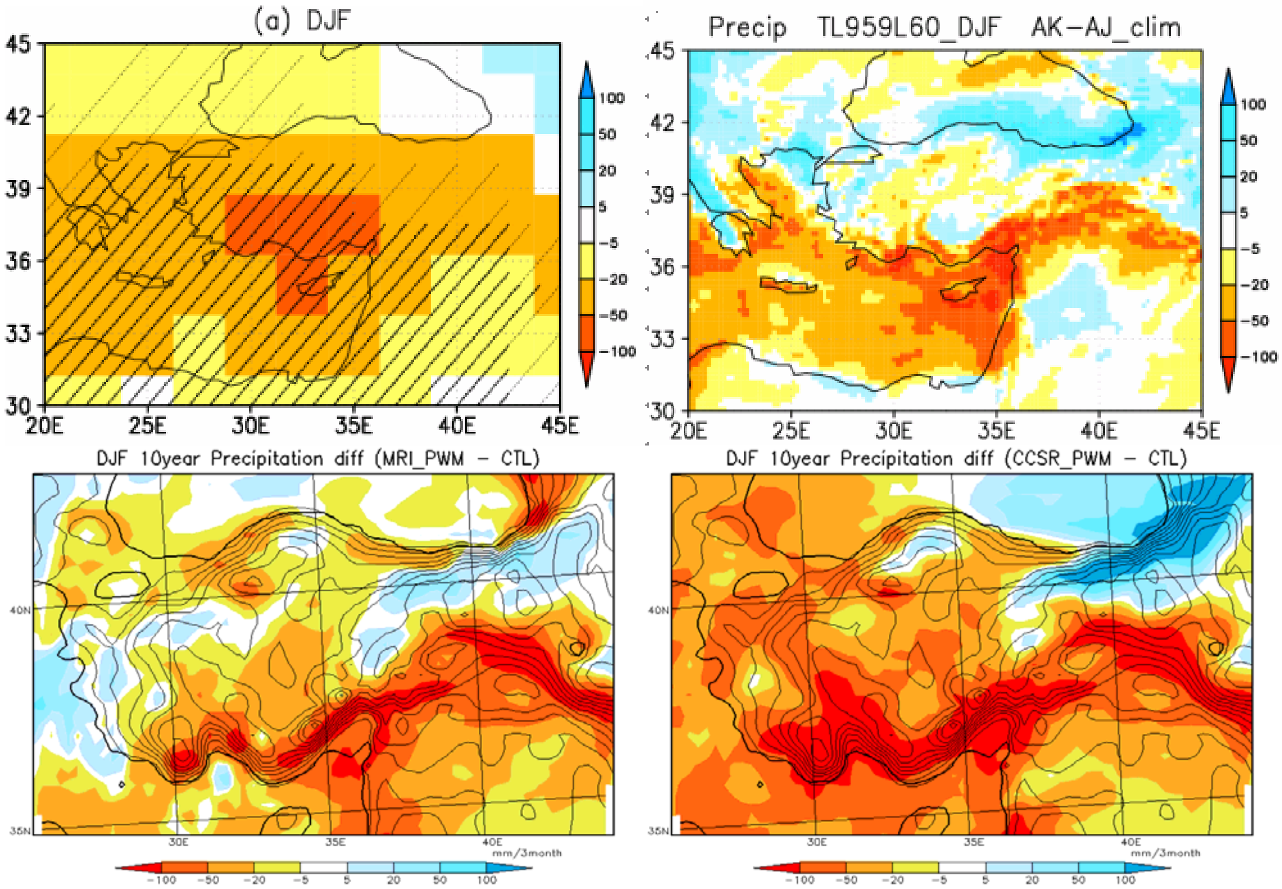

Fig. 22. Projected precipitation change in December, January and February. Top left: AOGCM, top right: CGCM(TL959), the lower left panel: downscaling from MRI-CGCM, lower right panel: downscaling from CCSR/NIES-CGCM.

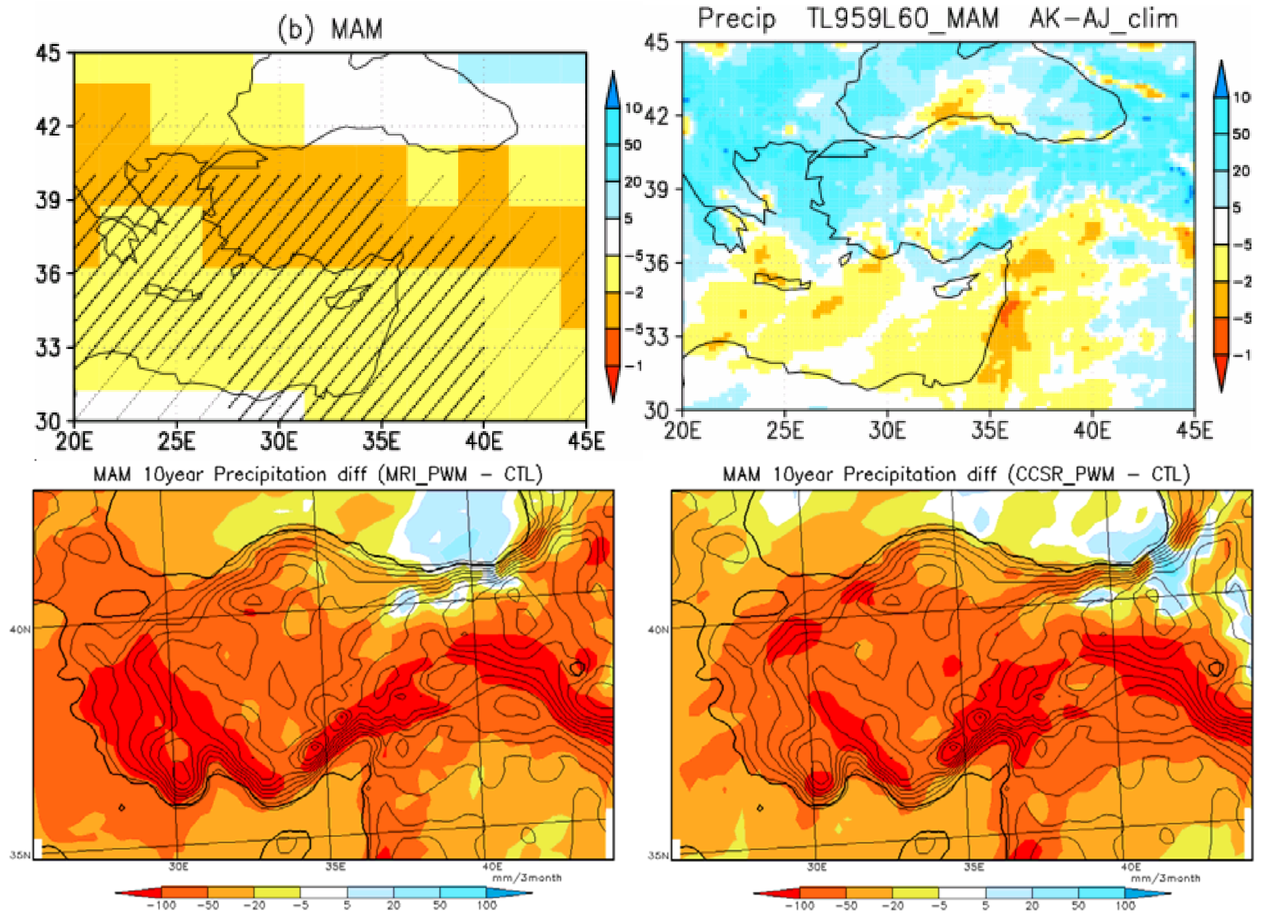

Fig. 23. Same as Fig.22, but for March, April and May

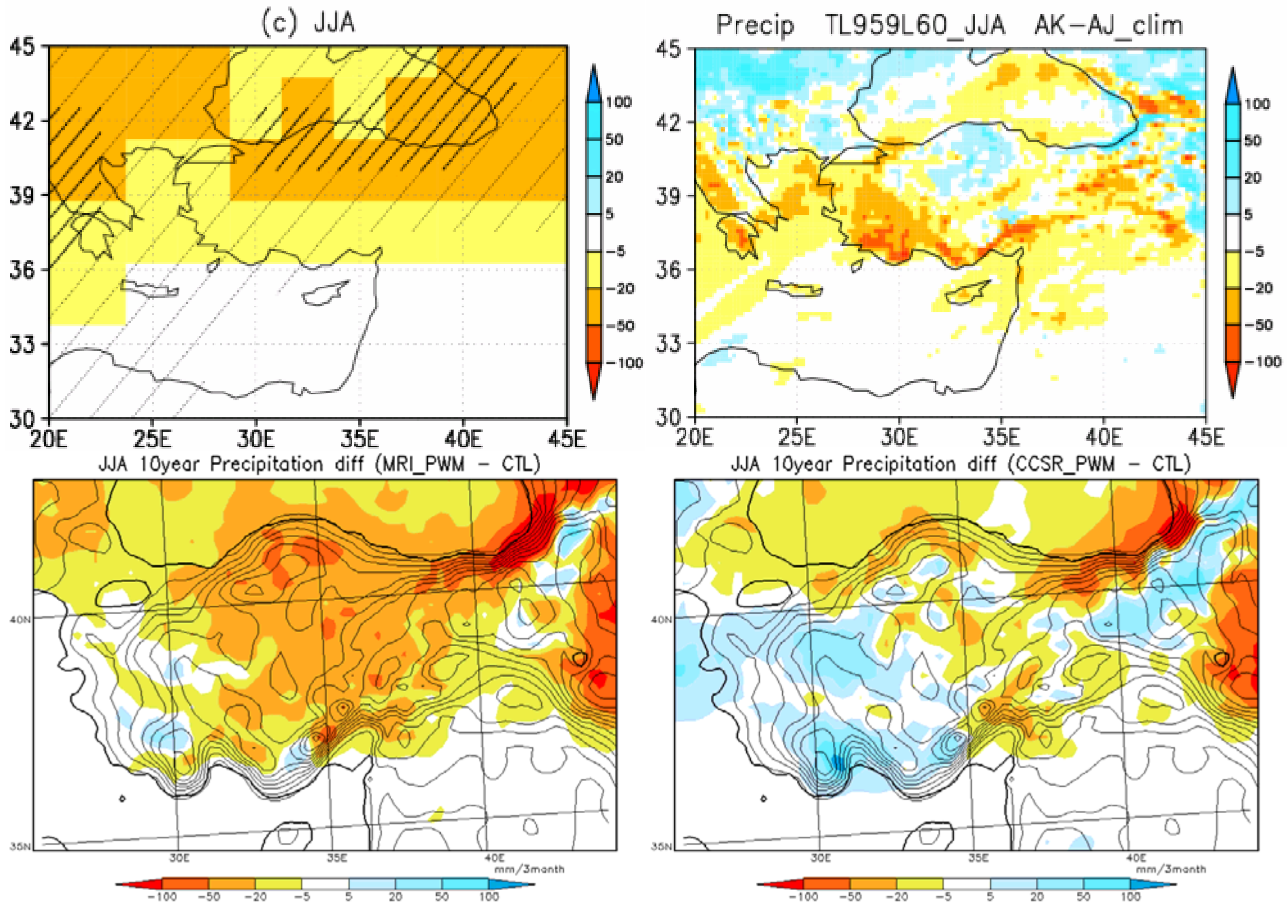

Fig. 24. Same as Fig.22, but for June, July and August

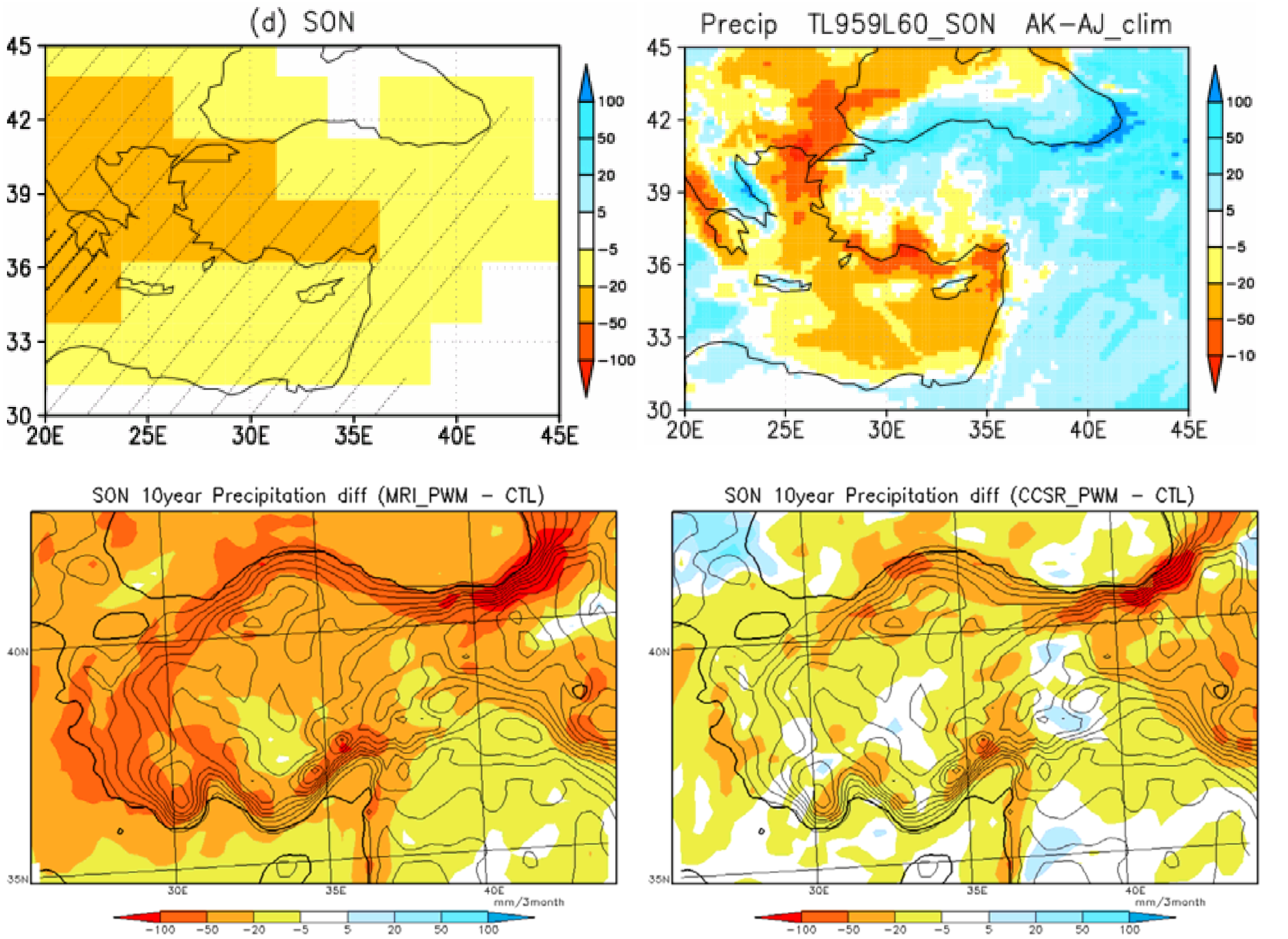

Fig. 25. Same as Fig.22, but for September, October and November

9. Conclusions

Control run of RCM tends to overestimate precipitation during winter. RCM has cold bias in surface temperature because of the numerical scheme for the dynamics over steep slopes, while this effects are limited in the lowest atmosphere and only when wind is strong and the lower atmosphere is strong stable condition.

The downscaling suggests that precipitation will decrease 10-40 mm/month during cold season in 2070s. Precipitation change has good similarity between two downscaling projections using MRI and CCSR/NIES GCMs. Amount of precipitation is strongly affected by the orography, as the result, the change in precipitation is also affected by the orography. Decreasing of precipitation is more prominent in the slopes along the Mediterranean. Temperature change strongly depends on GCMs. Surface temperature increase by 2.0K (MRI-GCM) to 3.5K (CCSR/NIES-GCM). Temperature change is also clearly affected by the topography. The change is larger in the southern part of Turkey, particularly in the mountainous area along the Mediterranean. Independent two projections of precipitation, using MRI-AOGCM and CCSR/NIES have some similarity in horizontal distribution, but they are quite different from the projection by the high-resolution CGCM (TL959), which must be currently one of the most advanced projection method in the world for the regional climate change. We have to say that the reliability of the small scale projection is still not very high.

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Development of a daily grid precipitation data in the East Mediterranean and its application for the ICCAP studies

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1. Introduction

Precipitation is a definitely important element to assess the impact of global warming on agricultural production in arid/semi-arid regions. However, it is not easy to obtain reliable simulation results of precipitation comparing to that of temperature by the following two reasons. 1) Precipitation has a localized structure in distribution, and 2) simulated precipitation by climate models depends on a cumulus parameterization scheme that is used in the model. In other words, climate modelers are tuning their precipitation pattern and amounts against the observations.

Therefore, quantified high resolution precipitation dataset based on direct observation is necessary for validation of the simulated value. Recently, it is one of the important topics to simulate the change of extreme events due to global warming. Satellite-estimates have a good special coverage and frequent time intervals, however they are not suitable for validating extreme events. Hence daily grid precipitation dataset based on rain-gauge observation is warranted.

There have been many papers to show gridding algorithms, and recently those for showing daily grid precipitation dataset are indicated (Rajeevan et al., 2005; Xie et al., 2004; 2007). A method that I adapted to the ICCAP project is shown in Yatagai (2006).

Here, additional explanation of our gridding algorithm that was used for the ICCAP studies is displayed in section 2. Validation of model precipitation results those were used for the ICCAP project is shown in section 3. Application studies of using the grid precipitation products, trend analysis and hydrological budget studies are given in section 4 and 5, respectively.

2. Grid Analysis

As written in Yatagai (2005), we created daily grid precipitation dataset over the East Mediterranean by taking a similar method with Xie et al. (2004, 2007) that developed an analysis over East Asia. The differences in method with Xie et al. (2004, 2007) are 1) we did not use PRISM (Daly et al., 1994) because it was not available in this region, and 2) we used Shepard (1968) for interpolation instead of optimum interpolation.

I collected more rain-gauge data over Israel as well as Iran, and the analysis was improved after Yatagai (2005). Here I briefly write about our method and used data to develop the latest version of our precipitation analysis over the Middle East.

2.1 Gauge data

It is undoubtedly very important to collect rain gauge data from as many stations as possible to create a gauge-based analysis data set. To create the monthly climate normal precipitation analysis and the daily climate normal precipitation analysis, we collected monthly and daily precipitation data in the domain 15°E–70°E, 15°N–55°N using the following data sources.

2.1.1 Monthly precipitation

We obtained monthly precipitation data from a total of 1222 stations.

1) Turkey
   Monthly precipitation data from 225 stations for 1975–2004 compiled by the Turkish State Meteorological Service were used to compute the monthly precipitation climatology.
2) Israel
   Monthly precipitation from 19 stations for the 1960s to the present from the Israel Meteorological Service were used to compute the monthly precipitation climatology.
3) Iran
   We obtained two kinds of monthly precipitation data

from the home page of the Islamic Republic of Iran Meteorological Organization. We used data from 154 World Meteorological Organization (WMO) stations and from 183 non-WMO stations. The data coverage period differed among stations, with the longest period from the 1960s to the present. In this version, we used data from stations with more than 5 years of data to compute the monthly climatology.

4) Global Historical Climatological Network

We used the Global Historical Climatological Network ver. 2b data set for countries other than the above three. We used data from stations with more than 5 years of observation records to compute the normal climate.

2.1.1 Daily precipitation

We used daily precipitation data from a total of 2194 stations.

1) Turkey

We used daily precipitation data from 338 stations with observation records covering at least 20 years, compiled by the Turkish State Meteorological Service.

2) Global Telecommunication System (GTS)

We used GTS data from stations with 5 years or more of records during 1978–2004 in the data domain (15°E–70°E; 15°N–55°N), excepting Turkey.

2.2 Analysis

As indicated in Yatagai (2005, 2006), we first defined the monthly climate normal by using the data from 1222 stations. Then, we analyzed the climate normal using the algorithm of Shepard (1968) to interpolate the values into 0.05° grid boxes.

Yatagai (2006) shows January precipitation climatology for a 0.5° grid, and mountain precipitation over the western Zagros Mountains is clearly seen as a result of the addition of the Iranian data compared with the first version (Yatagai, 2005). Also, a precipitation zone south of the Caspian Sea can be clearly observed.

As the next step, we defined daily climate normal for each station by averaging daily precipitation and then truncating the averaged time series after the first six harmonics. Then, we adjusted the daily precipitation climatology by the monthly precipitation climatology. An example of the adjusted daily precipitation climatology is shown in Fig. 1. Patterns of orographically induced precipitation over eastern Anatolia and the coastal areas of Turkey and Israel are shown. October is the most important month for rain-fed agriculture in Turkey and Israel because it is the beginning of the rainy season. A crescent-shaped precipitation zone is observed along the Jordan Valley northward through northwestern Syria into southeastern Turkey (Anatolia), then eastward through northern Iraq, and finally southeastward along the western slope of the Zagros Mountains in western Iran. The pattern is shifted a little northward into Anatolia and eastward into Iran compared with the ancient region known as the "Fertile Crescent" (Bellwood, 2004). In particular, the modern high-precipitation zone is at a higher elevation than the ancient Fertile Crescent was. Observations as well as models clearly show that orographically induced precipitation in Anatolia and the Zagros Mountains is a very important water resource in the Fertile Crescent region.

After defining the daily climatology, we calculated the ratio of the daily observed precipitation at each station to the corresponding daily grid climatology for the target day. Figure 2 shows an analysis of the precipitation on 5 January 2000. Since the analysis used a 0.05° grid, a detailed pattern is seen where rain gauge data are available. Figure 3 shows an enlarged view of the Chukurova basin in south central Turkey. Although the monthly climatology aided the interpolation, in this analysis we could not reproduce an orographic effect where no daily rain gauge data or climatological data were available. Only a few stations are situated in the upper reaches of the Ceyhan and Seyhan rivers, which flow into this basin. Efforts to develop a PRISM-type monthly climatology data set by using Geographic Information System (GIS) data and satellite products are under way and results are expected in the near future.

3. Model Validation

Using the above mentioned monthly and daily climatology dataset, simulated precipitation by both TEAC-RAMS RCM and the MRI 20km mesh GCM, those are used for the ICCAP studies were validated (Yatagai et al., 2006).

The TEAC-RAMS RCM and the MRI 20km mesh GCM successfully simulate precipitation patterns over Turkey presented in our grid precipitation data. The both two models project decrease of precipitation in 2070s (based on SRES A2 or A1B scenario) over the southern part of Turkey including Chukurova basin. According to the MRI 20km AGCM, which simulates precipitation amount and its seasonal change around Adana better, average annual precipitation change for Adana -123 mm/year, which corresponds to around 18% of the present total precipitation. It is inevitably important for projecting the future change of the water resources over a basin to estimate daily precipitation accurately. Representation of precipitation around mountaineous region is one of the challenging subjects for climate system modeling. It is warranted to further development of daily grid precipitation for the past several decades by taking into account of orographic enhancements.

4. Trend Analysis

A trend analysis is done over Turkey based on daily/monthly precipitation data from Turkish State Meteorological Service (Yatagai, 2005). After quality check, a linear trend of monthly precipitation from 1975 – 2004 was computed for each month over Turkey. Result is shown in Fig.1 of Yatagai, 2005. In Yatagai (2004a), trend from 1977 to 2000 using GTS gauges are reported for January, April, July and October over the East Mediterranean. Here we could use much more qualified and consistent data to analyze trend.

Clear decreasing trend in January is observed in Fig.1 of Yatagai (2005) and it is consistent with that is shown Yatagai (2004a). Interestingly, the strong decreasing trend is not observed in other winter months (December and February). In March and April, a decreasing trend is observed around central part of Turkey including Cukurova basin, while other area show increasing trend. The April trend pattern is very different from that shown in Yatagai (2004a). Both May and June show similar decreasing trend overall Turkey, although the value is small due to small amount of precipitation in this season. We will analyze statistical significance of the trend as the next step.

It is stimulus to see increasing trend around Cukurova basin for August and September. It may relate to irrigation system development. We need further investigation on this point.

October shows clear dipole pattern of trend. Increasing trend is observed in the northern part of Turkey, while decreasing trend is observed in the southern part. Further analysis related to regionality of climate change should be done because October rainfall is one of the most important meteorological elements for agricultural activity in Turkey.

Further analysis is necessary to reveal trend in precipitation character such as extreme events.

5. Hydrological Budget Analysis

Yatagai (2003) compared seasonal variation of hydrological budget of Turkey with the same latitude band of Central Asia and China by using a 15-year reanalysis dataset of European Centre for Medium-Range Weather Forecasts (ECMWF, Gibson et al., 1997). The reanalysis datasets made it possible to analyze inter-annual variations.

As described in Yatagai (2004b, 2005), the moisture flux vector (Q_λ, Q_φ) facilitates a computation of atmospheric moisture convergence $-\nabla_H \cdot \mathbf{Q}$. If the time rate of change of liquid and solid water and their horizontal transports are neglected (Peixoto and Oort 1983), then $-\nabla_H \cdot \mathbf{Q} \fallingdotseq$ (Precipitation) – (Evapotranspiration) for spatial and temporal averages over a large area at monthly to seasonal time scales. This equation yields an estimate of evapotranspiration if regional mean precipitation data is available.

We used the CPC Merged Analysis of Precipitation (Xie and Arkin, 1997) and ECMWF 15-year reanalysis (ERA15; Gibson et al., 1997) to assess interannual variability in the hydrologic budget over Turkey for 1979-1993, although more precise estimation is underway by using the new daily precipitation analysis shown in the previous section over Turkey and ERA40 (Simmons et al., 2000) for a longer period. The vapor convergence (C) was computed as described by Yatagai (2003).

Figure 3 of Yatagai (2005) showed preliminary estimates of interannual variability in the hydrologic budget in July over the central part of Turkey. Since July is dry season for Turkey, it is interesting that E is mostly explained by convergence because P is almost zero for summer. Arid regions in China show completely different character in the atmospheric hydrological balance (Yatagai, 2003).

The figure also shows ERA15 evapotranspiration (Ef) computed with a fixed land surface model in the ERA15 assimilation scheme. During the forecast, atmospheric conditions were used at each time step to compute Ef. The magnitude of Ef was almost equal to that of Ea for the first several years; however, Ef did not show a linear trend. Because it was derived from large-scale changes in the atmospheric moisture balance, Ea represents observational values that include changes in surface land/water use. In contrast, Ef includes no surface changes. The ERA15 assimilation scheme and models yielded a Pf that was very close to Pa even though the two values are independent. Even though the land surface model used to compute Ef in ERA15 does not always represent real land use (e.g., irrigation are not represented in the model), the surface parameters were constant over the 15 years. Therefore, the increase in Ea could represent increasing anthropogenic (mostly agricultural) water use that causes increasing evapotranspiration during the summer.

Similar graphs for other part of Turkey, and also those for January are shown Yatagai (2004b). Further analysis is currently in progress to assess the hydrologic budget for all months and over a longer period using ERA40 (Simmons and Gibson, 2000) high-resolution analysis. A grid precipitation with dense precipitation network of Turkey shown above and incorporating mountain effect will give a better estimation of the hydrological budget, especially for the evapotranspiration over the complicated terrain.

6. Concluding Remarks

In order to contribute to the project ICCAP, I did the following things.

1) Development of a daily grid precipitation dataset over the East Mediterranean,
2) Validation of simulated precipitation by the models used for the ICCAP by utilizing 1),
3) Assessment of the precipitation trend over Turkey as well as the East Mediterranean, and
4) Assessment of hydrological budgets and its inter-annual variation over Turkey.

ICCAP project clarified the needs of daily grid precipitation dataset in order to validate the simulated precipitation as well as to investigate the impact of climate changes on the local water resources. The author's proposal to make a grid precipitation dataset for evaluation of the impact of global warming to local water resources over the arid region was funded by the Ministry of Environment for the fiscal year 2005. After one-year feasibility study of the global environmental research fund, we (RIHN and Meteorological Research Institute, Japan Meteorological Agency) got a 3-year's project for development of a daily grid precipitation dataset over Asia from the Ministry of Environment.

Further development of the algorithm shown in this report are underway, especially we are expressing orographic rainfall over the mountaineous regions because it is a very important water resources for the arid/semi-arid regions.

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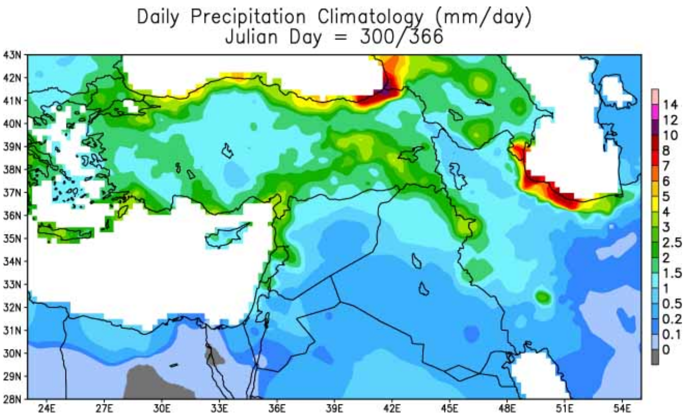

Fig. 1. A sample of daily precipitation climatology from late October (300 Julian day).

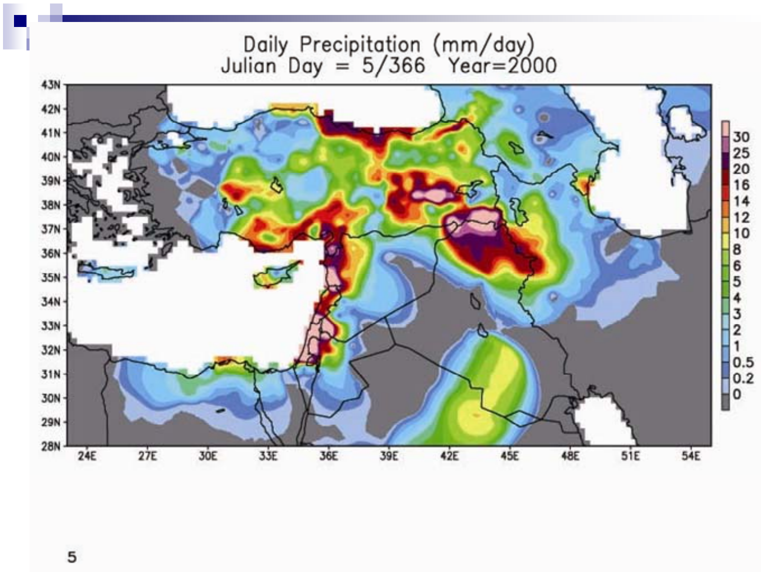

Fig.2. A sample daily gauge-based analysis for 5 January 2000.

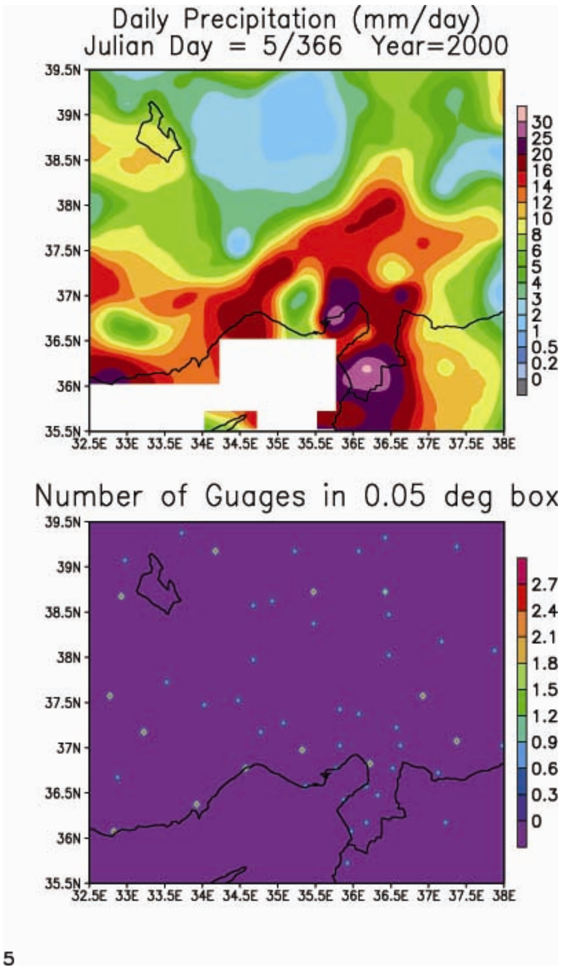

Fig. 3. A sample daily analysis for 5 January 2000 for the Chukurova basin, Turkey. The lower panel shows the number of gauges in each 0.05° grid box.

Future Climate Projections around Turkey by Global Climate Models

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1. Introduction

In this report, we compare the future precipitation change obtained by 19 coupled atmosphere-ocean general circulation models (AOGCMs) under the SRES A1B scenario, whose horizontal resolution is about 200 km, and that obtained by a time-slice experiment with an atmospheric general circulation model (AGCM) with a horizontal resolution of about 20 km (TL959 linear Gaussian grid) (Mizuta et al. 2006).

2. Present-day precipitation validation

We first validate model precipitation with two observations. Figure 1a illustrates observed annual precipitation from East Mediterranean 0.05 degree climatology (Yatagai 2006), while Fig. 1b is from the Climate Research Unit (CRU; New et al. 1999). Two observations show areas of large precipitation such as coastal regions and mountainous areas.

Figure 1c shows the ensemble averaged annual precipitation of 19 AOGCMs corresponding to the 1981-2000 period. Here, data are interpolated to common 2.5 degree grids as the models' horizontal resolution varies between 500 km and 100 km. See Nohara et al. (2006) for details of the models used. Due to coarse resolution, the model ensemble reproduces large-scale characteristics of annual precipitation distributions with a north-south contrast within this region and large precipitation at the northeastern part of Turkey, but orographic rainfall pattern and coastal maximum are not visible.

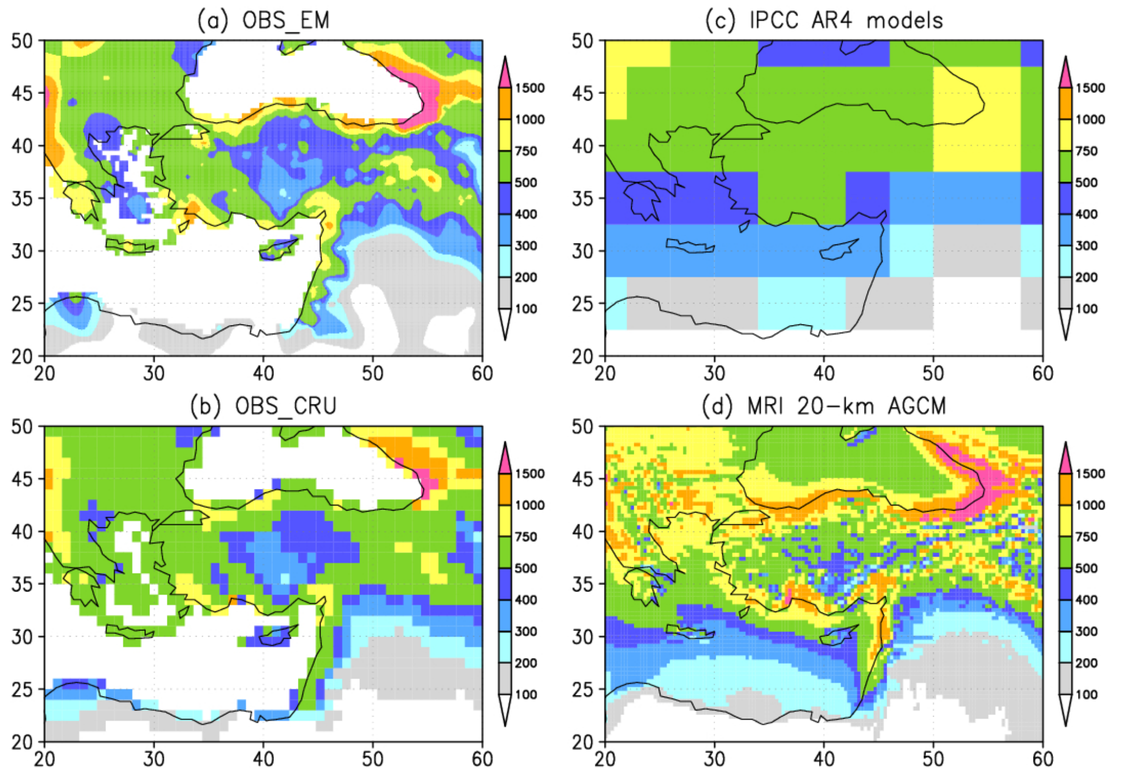

Fig. 1. Annual precipitation. (a) East Mediterranean 0.05 deg climatology (Yatagai 2006). (b) CRU (New et al. 1999). (c) IPCC AR4 model ensemble means. (d) MRI 20-km AGCM.

Figure 1d is the annual precipitation obtained with the 20-km mesh AGCM, which clearly depicts orographic rainfall along the Mediterranean and the Black Sea coast, as well as over the Zagros Mountains. Precipitation maximum over the Adana region is also well reproduced. There also is a hint of "Fertile Crescent"-like precipitation belt, which runs from the Jordan Valley northwards through inland Syria, into southeastern Turkey (Anatolia), eastwards through northern Iraq, and finally southeastward along the Zagros foothills of western Iran. It is apparent that the high-resolution model depicts orographic rainfall very well, and is suitable for regional climate projections.

3. Future projections by AOGCMs

Before discussing future climate projections by the 20-km mesh model, projected precipitation changes by AOGCMs are shown in comparison.

Using daily precipitation data of the MRI AOGCM simulations (Yukimoto et al. 2006), we calculated various statistics of precipitation and their changes (Kitoh et al. 2005). It is found that the Mediterranean region is classified as the region where total precipitation decreases and the precipitation frequency decreases but its intensity increases in the future. Figure 2 shows the monthly mean precipitation averaged for the region 27°–37°E, 36°–41°N. It is shown that the precipitation decreased significantly in the future during early winter season (Nov–Jan). Analysis of frequency of rainy day and intensity (not shown) reveals that the frequency of rainy day events decreased throughout the year, with significant decrease during Nov–Jan and Apr–Jul season, while changes in intensity are smaller and there is even a month (Oct) when intensity has increased. Therefore, a decrease in total precipitation mainly comes from a decrease in rainy day.

Figure 3 shows the changes in seasonally averaged precipitation between the end of the twenty-first century and the end of the twentieth century of IPCC AR4 model ensemble means. Here model uncertainty is estimated by comparing the ensemble mean change and the model scatter (inter-model standard deviation of the changes). In Fig. 3, lightly and heavily hatched region denotes the grid point where the ensemble mean precipitation change is larger than 0.5 times or 1 times of inter-model standard deviation of the changes, i.e., consistency among model projections. As a large-scale feature, future precipitation in this region will decrease throughout the year. It is noted that future precipitation will significantly decrease over the Mediterranean and the surrounding region including Middle East in winter. A positive phase of North Atlantic Oscillation-like pattern dominates in the mean response of sea level pressure anomaly in the future, which favors to suppress cyclone activity and precipitation in this region. A decrease is also significant in this region among models in spring, although its magnitude is less than in winter. The summertime decrease in precipitation shifts northward toward the Black Sea area.

4. Future projections by 20-km mesh AGCM

Using the 20-km mesh AGCM, we have conducted two “time-slice” 20-year simulations. One is a present-day and the other is a global warming simulation that uses the sea surface temperature (SST) corresponding to the 1981-2000 and 2081-2100 period, respectively, by the MRI-AOGCM simulations.

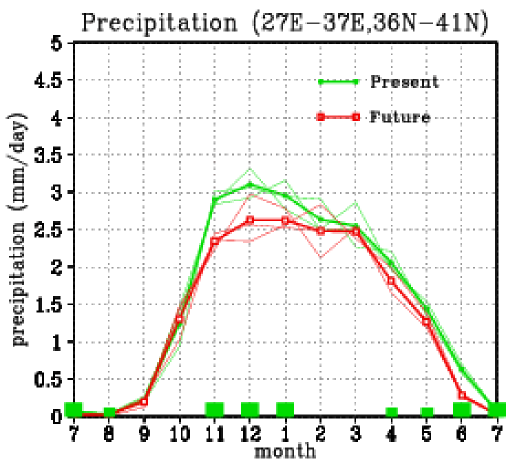

Fig. 2. Monthly mean precipitation averaged over the Turkey (27°–37°E, 36°–41°N) by the MRI-CGCM2 for the present (green line) and the future (red line). Thin lines are for each ensemble member and thick lines are for the ensemble mean. Large (small) boxes are plotted when the difference is significant at 90 (70)% level.

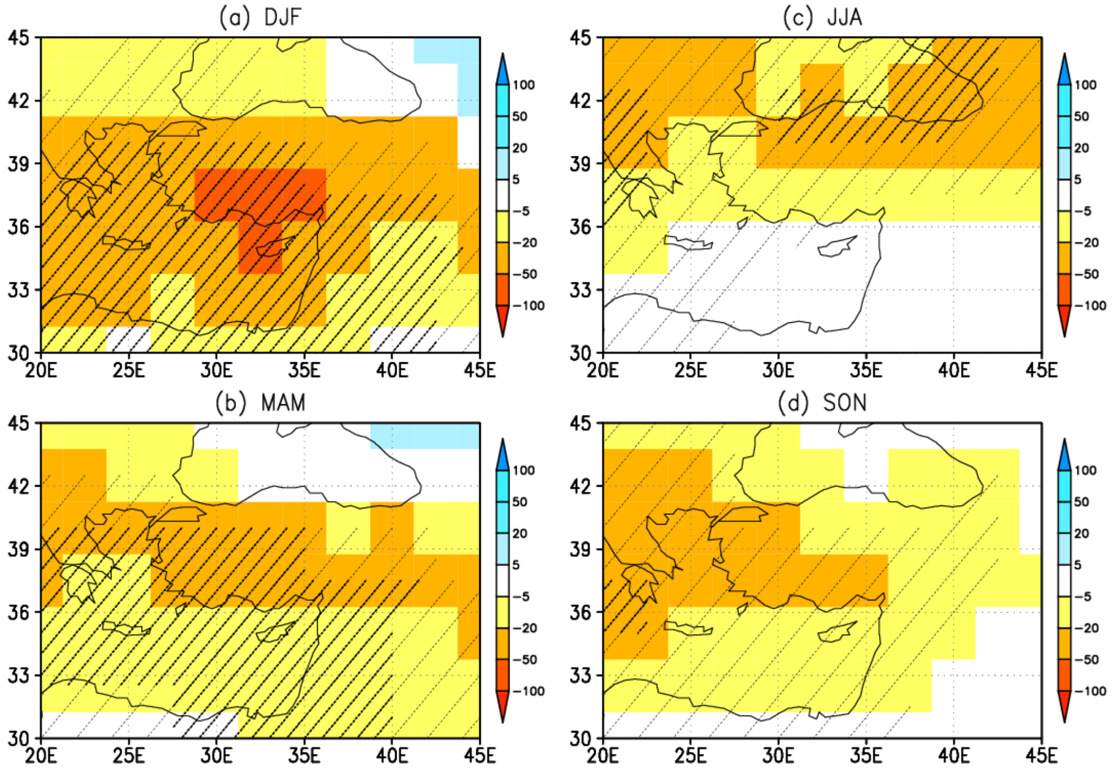

Fig. 3. Seasonal precipitation changes from the present to the future (2081-2100) by the IPCC AR4 model ensemble means. Light and heavy slant lines denote areas where the change is larger than 0.5 and 1.0 times of intermodel standard deviation, respectively.

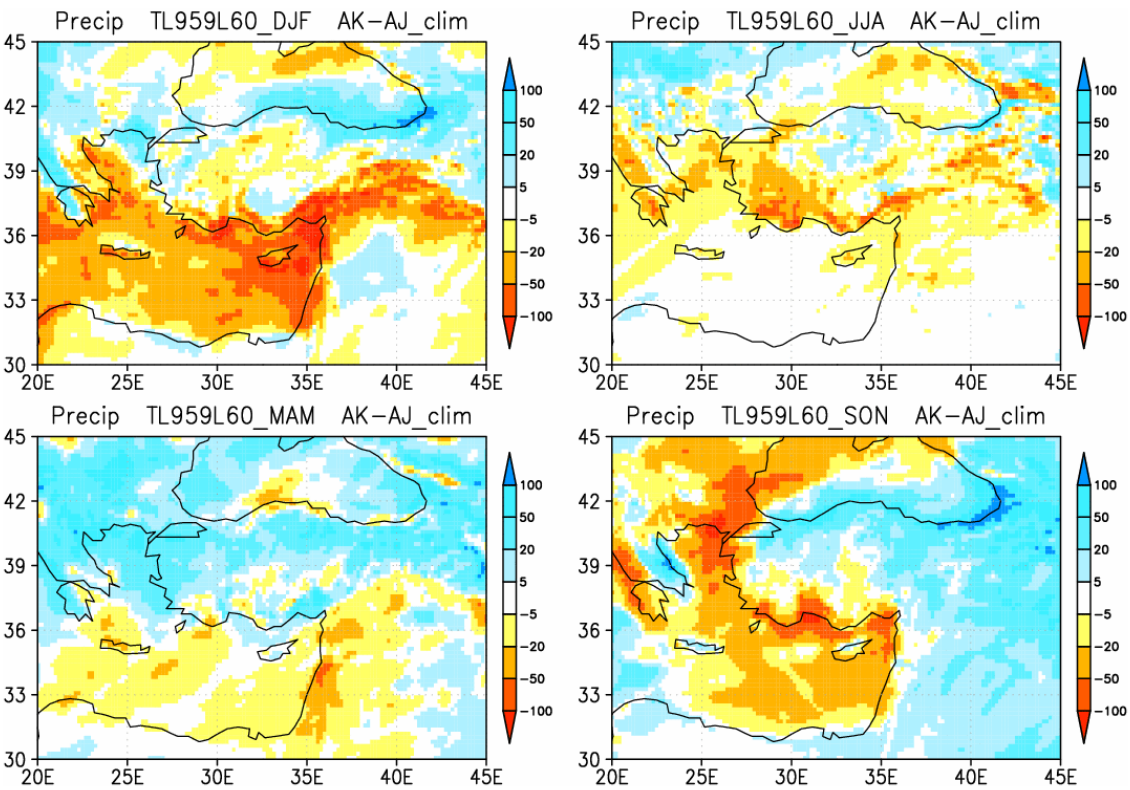

Fig. 4. Seasonal precipitation changes from the present to the future by the 20-km mesh AGCM.

Figure 4 shows the changes in seasonal mean precipitation at the end of the 21st century simulated by the 20-km mesh AGCM. Large decrease in precipitation is found in winter (DJF) around the southern coastal region of Turkey, particularly over the eastern Mediterranean Sea. It is noted that an area of large precipitation decrease is extended into the lower Seyhan River Basin, blocked by the Toros Mountains to the north. There is an increase in precipitation over the northern coastal region in Turkey facing the Black Sea. The pattern is different in spring (MAM), when magnitude in precipitation changes over the Mediterranean Sea becomes smaller, and even a sign of precipitation changes becomes opposite from that in winter in some areas, in particular over the ICCAP region of the lower Seyhan River Basin. The Central Turkey region is projected to have more precipitation in this season. There is a small belt of precipitation decrease over the upper Seyhan River region, where a decrease becomes more evident in summer. In summer (JJA) most of Turkey experiences decreased rainfall in this model projection. In fall (SON), decreased precipitation over the Mediterranean region becomes dominant again with a northern wet and southern dry contrast.

Evaporation generally increases in all seasons, but this field is distinct in a clear contrast between land and the oceans (not shown). There are large evaporation increases over the Mediterranean and the Black Sea in summer, fall and winter seasons, while in spring evaporation increase over land is larger. Large evaporation decreases are only projected over southern part of Turkey in summer and over eastern Mediterranean countries in spring and summer. Decreased evaporation in these regions may be related to soil moisture changes, but further investigation is needed.

Even in areas of increased precipitation, evaporation excess overcompensates and surface runoff has decreased. This is particularly true over the central Anatolia in spring, where precipitation increased but runoff decreased. Over the lower Seyhan River Basin, decrease in runoff is projected in winter but changes its sign in spring. On the other hand, opposite runoff changes are seen over the upper Seyhan River area. In summer, there is little change in surface runoff, although precipitation decreases over the southern Anatolia region. Cancellation between precipitation changes and evaporation changes resulted in little changes in runoff in this season.

5. Concluding remarks

The 20-km mesh global AGCM simulations are performed for the present and future conditions, respectively. Due to increased resolution, synoptic scale atmospheric circulations are very well simulated together with orographic precipitation features. There is a discrepancy between low-resolution AOGCM results and high-resolution AGCM results on the sign in future precipitation change in some areas. Whether this discrepancy comes from different resolution, i.e. how orographic rainfall is resolved in the model, or stems from other reason should be investigated in the future.

These very high resolution model's results would be very useful for regional climate change assessment because the global model has no artificial boundaries that regional models must use. A limitation of time integration due to huge computational resource and non-existence of air-sea interaction are trade-offs.

Acknowledgment

MRI 20-km model results are from the research project "Development of Super High Resolution Global and Regional Climate Models" funded by the Ministry of Education, Culture, Sports, Science and Technology (MEXT).

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Downscaling by Pseudo Global Warning Method

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1. Objectives

Climate change by increasing of greenhouse gas is usually estimated by General Circulation Model (GCM). However, horizontal resolution of the ordinary GCM is quite low, i.e., grid interval is about 100-300km, although these are being improving much with the computer power day by day. However, the resolution is still not enough to estimate the climate change in a basin, such as Seyhan river basin in Turkey. Downscaling of GCM using Regional Climate Model (RCM) may arrow to estimate climate and provides scenarios of the likely climate change in a basin, although GCMs and the methods of downscaling still have many problems for the reliable projection.

In generally, one of the largest difficulty in the downscale process using a nested regional climate model, is the bias of GCMs, especially shift of a regional scale climate system may gives serious error in the nested model (Wang et al, 2004). To avoid this difficulty, we present a new downscaling method called PGWM (Pseudo Global Warming Method) in which the boundary conditions are assumed to be a linear coupling of the reanalysis data (observation) and the difference component of the global warming estimated by GCMs. This assumption may valid when the change of the global warming is small enough and allows to neglect the nonlinear interaction between the climate change and the inter-annual variation of the regional climate systems.

2. Method

Figure 1 shows a flow chart of downscaling by PGWM. Reanalysis data are provided every 6 hours and are assumed as a boundary condition of the RCM. In the RCM, the reanalysis data are further interpolated for every time step when RCM simulates the current climate. This process reproduces the past climate using reanalysis data, which is called 'hindcast'. The hindcasted data are compared to in situ observation data and the results give feedback to the RCM in order to tune some parameters in the RCM. Two data sets of monthly climate are obtained by ten-years average of GCM produces. One is for the current climate during 1990s (period A) and another is for 2070s (period B). The difference of them is the climate change by the increase of greenhouse gases. Some of the 6 hourly reanalysis data and the different components, which are provided at each grid point and each month, are assumed to be as the boundary condition for the RCM in the future (PGWM run). The downscaled climate will be compare to the hindcast data.

A similar nesting method named 'anomaly nesting' has been presented by Vasubandhu and Kanamitsu 2004. Object of their method is to improve seasonal forecasts by regional climate models. They tested this method for a simulation of regional climate affected by some large scale climate systems such as ENSO or inter-annual variability around South America. A big difference from PGWM is that the boundary data are assumed to be the GCM products whose climate values have been replaced by the climate values estimated from the reanalysis data. Short term components, such as daily variation, are almost retain in GCM produces, while they will be replaced by these of reanalysis data in PGWM.

One of the advantage of PGWM is to allow to

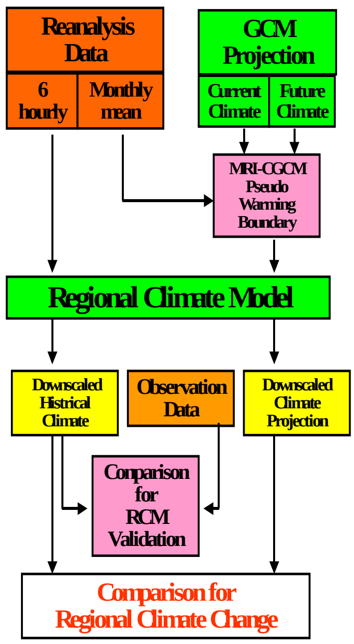

Fig.1. Flow chart of downscaling by pseudo global warming method (PGWM).

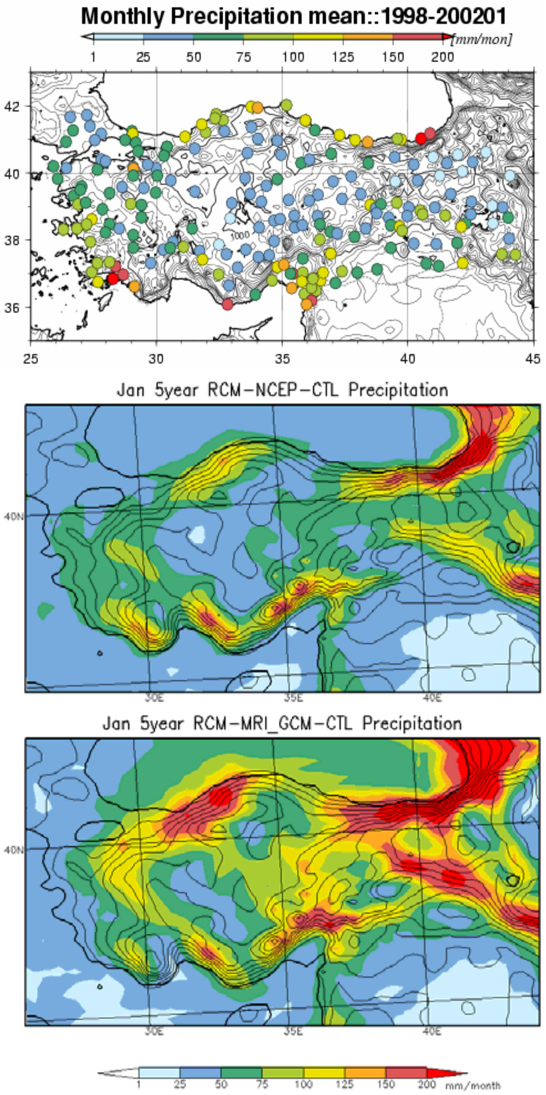

Fig. 2. Top panel:Monthly mean precipitation of in situ observation, January 1998-2002. Middle panel: Hindcasted precipitation in the same area and the same period as the top panel. Bottom: Simulated precipitation by the direct downscaling form the products of MRI-CGCM in the same period. Color bar is common for three panels.

estimate the global warming effects on the specific past year. This advantage makes easy to estimate climate difference between current and future climate without ensemble of numerous number of simulations. Usually the effects is only possible to estimate by the difference between the climatic mean of many years before and after global warming. Any GCM can not estimate the difference between each single year without large effects of natural inter-annual variation. When the difference of the global warming is smaller, detection of the global warming effect becomes more difficult because of inter-annual variation. This method have been already applied to Mongolia (Sato et al, 2006).

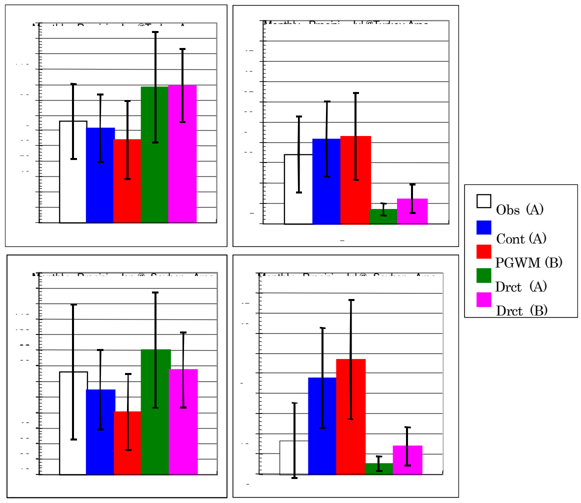

Fig. 3. .Projected monthly precipitation in January (left) and July (right) during the period A (1998-2002) and the period B (Five years in 2070s). Top panels indicate mean values in the entire Turkey and the bottom panels indicate those in the Seyhan basin. White bar indicates observed data in the period A, blue indicates the control run (hindcast in the period A), red indicates projection by PGWM (period B), green indicates the direct downscale from GCM (period A) and pink indicates the direct downscale in period B.

Comparison with direct down scaling

Downscaling by PGWM and ordinary direct downscaling are compared in order to discuss the accuracy and reliability of the method. Beside five years hindcast (control run) using NCEP/NCAR reanalysis data and five years projection during 2070s by PGWM, directly nesting runs driven by daily GCM products are also carried out for the periods A and B. Test periods are restricted to January and July. Global-scale projection data were provided by MRI-CGCM-2 (Yukimoto et al, 2001) assuming A2 scenario in Special Report on Emission Scenarios (SRES) (IPCC, 2000).

Figure 2 indicates monthly mean precipitation of in situ observation, January 1998-2002 (top panel), hindcasted precipitation in the same area and the same period (middle panel) and simulated precipitation during five years in 1990s by the direct downscaling form the products of MRI-CGCM (bottom). Color bar is common for three panels. We chose January and July for the test of PGWM, since amount of precipitation becomes large in winter and small in summer in this region. The hindcasted precipitation agree well to the observation, particularly heavy precipitation along the Black Sea and some areas along the Mediterranean. Horizontal distribution of the direct downscale also agree to the observation, but the amount is overestimated.

Projected total amount of precipitation in

January and July are shown in Figure 3 for the entire Turkey (top) and for the finest grid system around Seyhan basin (bottom). White bar indicates observed data in the period A, blue indicates the control run, namely; hindcast in the period A. Hindcast slightly overestimated in July but slightly underestimated in January. The red bars indicate projected precipitation during 2070s by PGWM (period B). The model projects that amount of precipitation will decrease in January but it slightly increase in July. Green bars and pink ones are five years mean precipitation by the direct downscaling from GCM in the period A and that in the period B, respectively. The direct downscaling overestimates and seriously underestimates during July.

Figure 4 indicate horizontal distribution of the difference in monthly precipitation between period A (1998-2002) and B (five years in 2070s) in January projected by PGWM (top) and by the direct downscaling (bottom). Dark blue indicate increasing in precipitation, while brown indicate decreasing. Precipitation change is depend on place in Turkey. The patterns of horizontal distribution have good similarity except for the Southeast corner of the Black Sea. Figure 5 is the same as Fig.4, but the finest grid system. The tendency is the same as Fig.4. These projections agree well each other, since the amplitude is somewhat larger in the direct simulation.

Figure 6 indicates the inter-annual variation of precipitation (top) and temperature (bottom). Inter-annual variation of the direct downscaling for the past year does not need to agree to observation, since only statistics of the variation has meaning. Temperature given by the direct downscaling from GCM-2 has strong cold bias. The hindcast (CTL) follows the inter-annual variation very well. Differences between the current years and the corresponding pseudo global warming year depend on years, but the amplitude of inter-annual variation of the difference is much smaller than those between a single year of period A and that of period B

3. Conclusions

PGWM not only reduces large scale model bias, it allows to estimate climate difference between current and future climate without ensemble of numerous number of simulations. This method has the certain advantages, but it needs further study to make sure the reliability for the extreme events.

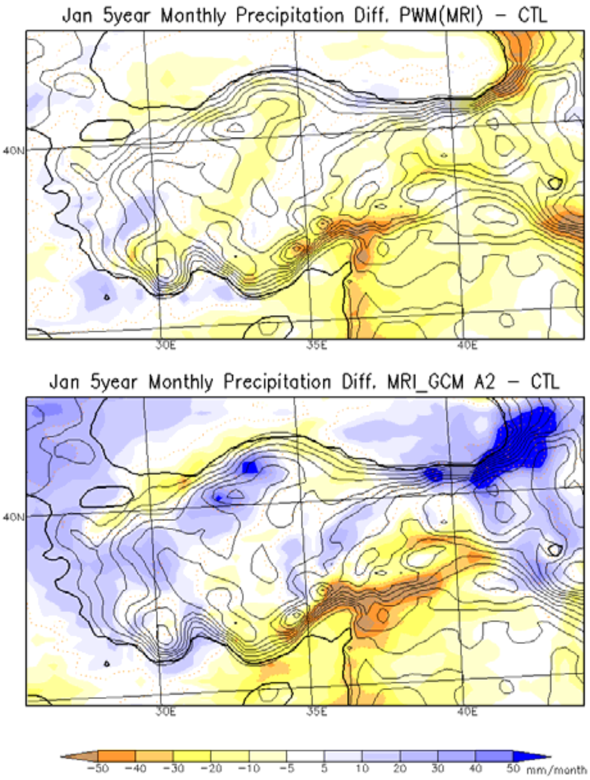

Fig.4. Difference in monthly precipitation between period A (1998-2002) and B (Five years in 2070s) in January. Top: projected by PGWM, Bottom: by the direct downscaling from GCM. Dark blue indicate increasing in precipitation, while brown indicate decreasing.

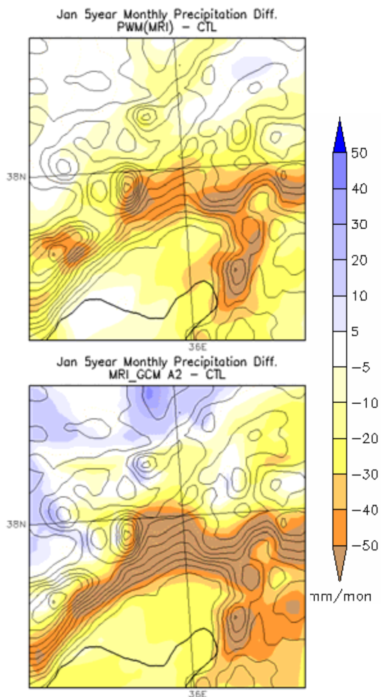

Fig. 5. Same as Fig.4, but for the finest grid system around Seyhan basin.

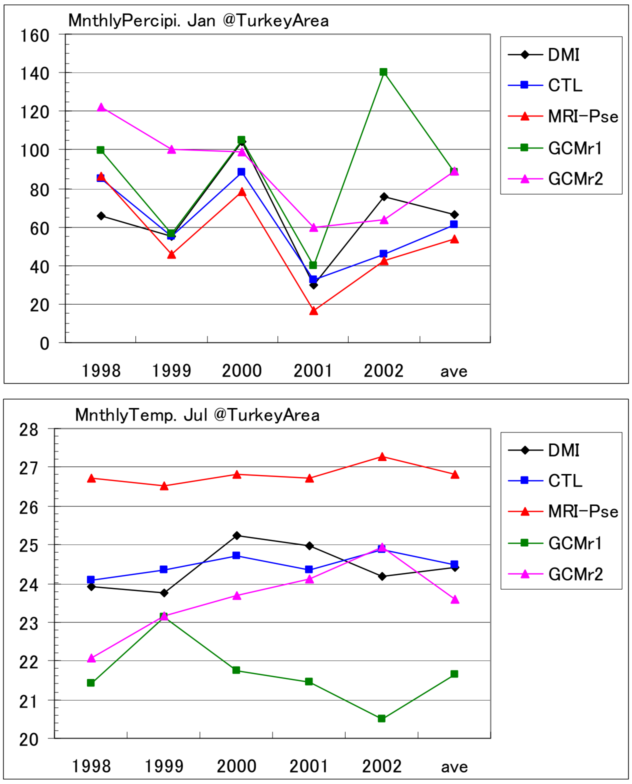

Fig. 6. Year to year variation of precipitation (top) and temperature (bottom). Meaning of color is same as Fig.3.

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Effect of Irrigated Agriculture on Low-level Cloud in the Chukurova Plain, Turkey

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1. Introduction

Southern Turkey is dominated by the Mediterranean climate. Precipitation in summer is less 50 mm/month (Turkes, 1996). However, Chukurova Plain, which locates lower Seyhan River Basin, is often covered by low-level clouds even in dry summer season (Fig. 1).

The observed clouds are expected to be shallow cumulus clouds, and these clouds are sensitive to land surface condition in comparison with high-level clouds. In Chukurova Plain, current water consumption for agricultural irrigation reaches to 440 million m^3 during August (Nagano and Donma, 2004). Since total irrigated croplands is 90 thousands ha (Kameysma, 2004), the irrigation water fed to a unit square cropland can be estimated to 489.8 mm/month (= 15.8 mm/day). This amount of irrigated water is comparable to 70% of the annual precipitation in this area. Considering such background, the clouds may be affected by the large-scaled and intensive irrigation. Thus, this study aims to reveal the effect of irrigated agriculture on the clouds by using a Regional Climate Model (RCM).

2. Data and methods

2.1. Satellite image data

The satellite images are used to validate the reproductivity of the RCM as an observational data. The Moderate Resolution Imaging spectrometer (MODIS) data were obtained from the MODIS Rapid Response System (NASA/GSFC, 2006). Adapted data is the near-real-time true-color products in the archive of the "AERONET_IMS-METU_ERDEMLI" Subset. The subset covers southern Turkey with a 250m spatial resolution. The satellites of Terra and Aqua observed Chukurova Plain once a day; the Terra observes in a morning, mostly at 1000 Local Standard Time (LST) to 1200 LST; the Aqua observes in an early afternoon, mostly at 1200 LST to 1430 LST.

2.2. Numerical experiments

A RCM (TERC-RAMS) was adapted to reproduce the clouds and to simulate the effect of irrigated agriculture. The TERC-RAMS is a version of the Regional Atmospheric Modeling System modified by the Terrestrial Environmental Research Center, University of Tsukuba (Sato and Kimura, 2005). The RCM has a two-way nested grid system; the outer domain covers Turkey with a grid interval of 16 km; the middle one covers entire Chukurova Plain with a grid interval of 4 km; the innermost one covers western part of the plain with a grid interval of 1 km (Fig. 2). Every domain includes 46 layers in the terrain following vertical coordinate system. The lowest layer is located 90 m up from the screen height. The RCM used no convective parameterization in the innermost domain, thus the model works as a cloud resolution model.

Two sensitivity analysis was conducted; (1) the actual land-use ("CTL-run"), the land-use data was given by the 30 second grid land cover and land use data of the U.S. Geological Survey (USGS); (2) the spatially-uniform short grass ("UNI-run"). The soil types are silt roam in both runs.

The initial boundary conditions for the outer domain were fed by the global reanalysis data provided by the National Center for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) and monthly mean sea surface temperature (Reynolds et al., 2002). The integration period is 23 hours from 2100 LST in 6 August to 2000 LST in 7 August, 2004.

3. Results

3.1. Validation of the reproductivity in the RCM

The model simulates the spatial pattern of clouds comparatively well. At the snap shot of 1100 LST in the model, the simulated clouds along the east coast of the plain agree with those observed by the satellite (Fig. 3). The model also simulates the clouds in western plain fairly well; however, the simulated clouds are less than those in the satellite image. In addition, the model fails to simulate the haze, which distributed the entire plain. At 1200 LST in the model, the model simulates well the clouds distributed along the western coast.

The model also simulates the diurnal change of the clouds (no figure); the diurnal change is derived from the sea breeze, and the simulated change agrees well with the results of continuous photographic observation from the ground surface (Iizumi et al., 2005).

3.2. Effects of irrigation agriculture on low-level clouds

At 0900 LST in the model, the amount of simulated clouds in the CTL-run is significantly greater than that in the UNI-run (Fig. 4). The result in the CTL-run shows much clouds in western and eastern part of plain, and the area around the lake created by the dam. The spatial pattern of the clouds in the CTL-run agrees with that of irrigated cropland (no figure). Such tendency is consistently observed in before noon in the model; however, the difference between two runs becomes unclear in afternoon.

4. Discussion

As the mechanism of the low-level clouds enhancement, following factors are assumed to play important roles i.e., (1) the supply of water vapor from the irrigated croplands to the atmosphere through evapotranspiration; (2) the strong sensible heat flux from the ground surface derived from sufficient radiation. Since, the factors enhance the depth of the mixed layer and height of thermals, then, the clouds are formed at the top of the thermals. However, the result in UNI-run shows that the clouds in southern plain appear even in drier land surface condition. It suggests that the clouds in Chukurova Plain are formed by multiple mechanisms depending on the area.

5. Conclusion

The RCM simulates well the characteristics of the low-level clouds in spatial pattern and diurnal change. The spatial pattern of the clouds in before noon agrees with that of irrigated cropland. Thus, large-scaled and intensive irrigated agriculture is certainly one of factors to form the clouds. However, simulation results suggest that the clouds are formed by other mechanisms as well the irrigation depending on the area in the plain.

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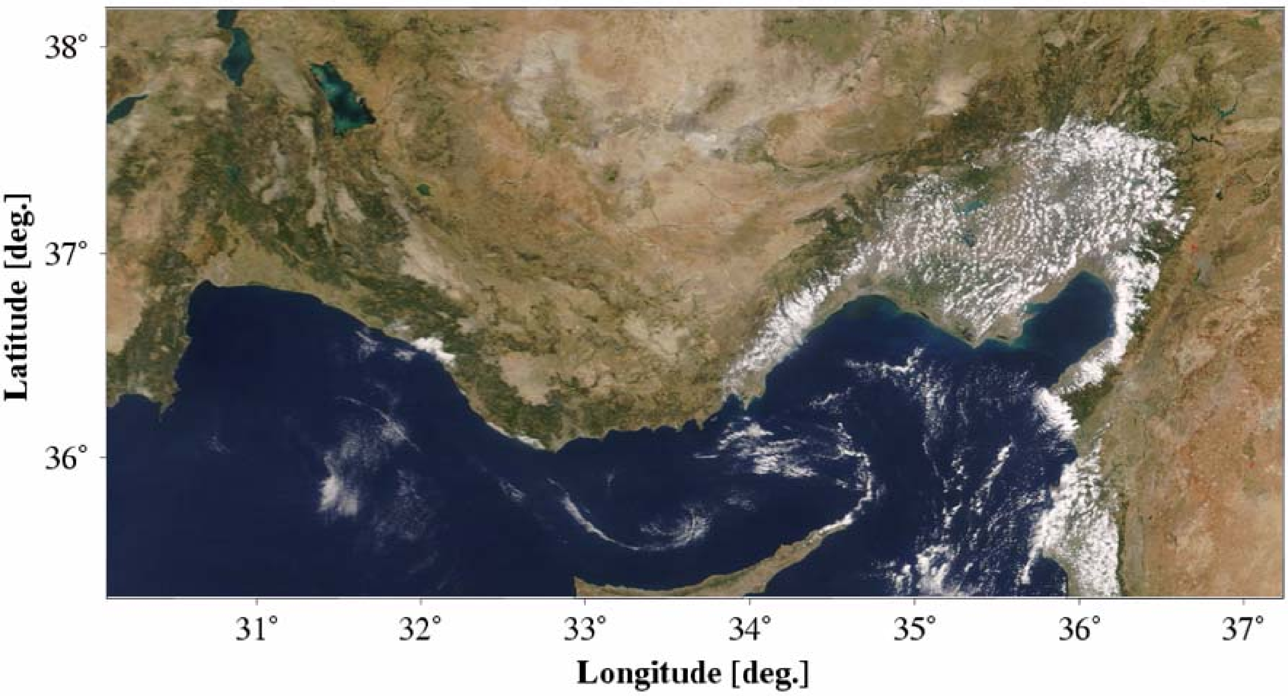

Fig. 1. Typical low-level clouds observed by the MODIS/Terra at 1008 LST (0808 UTC) on 01 July, 2005.

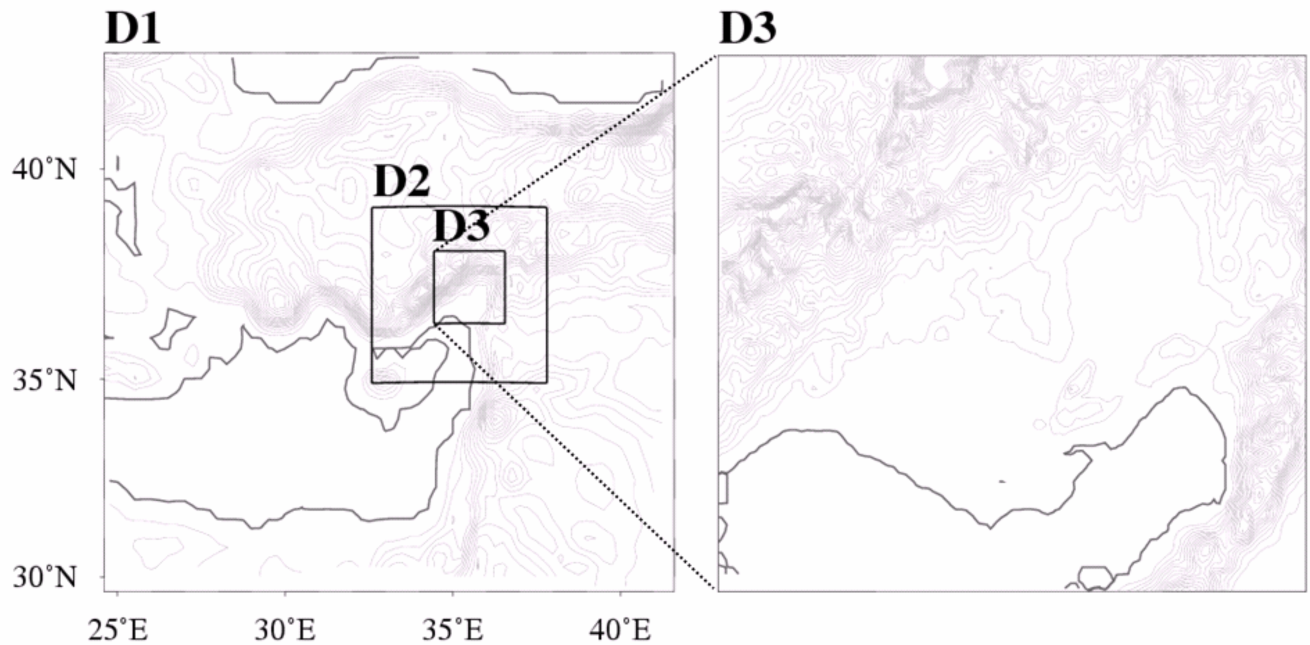

Fig. 2. RCM domains; the bold lines show elevation of 0 m in the RCM, while the thin lines show that of 100 m.

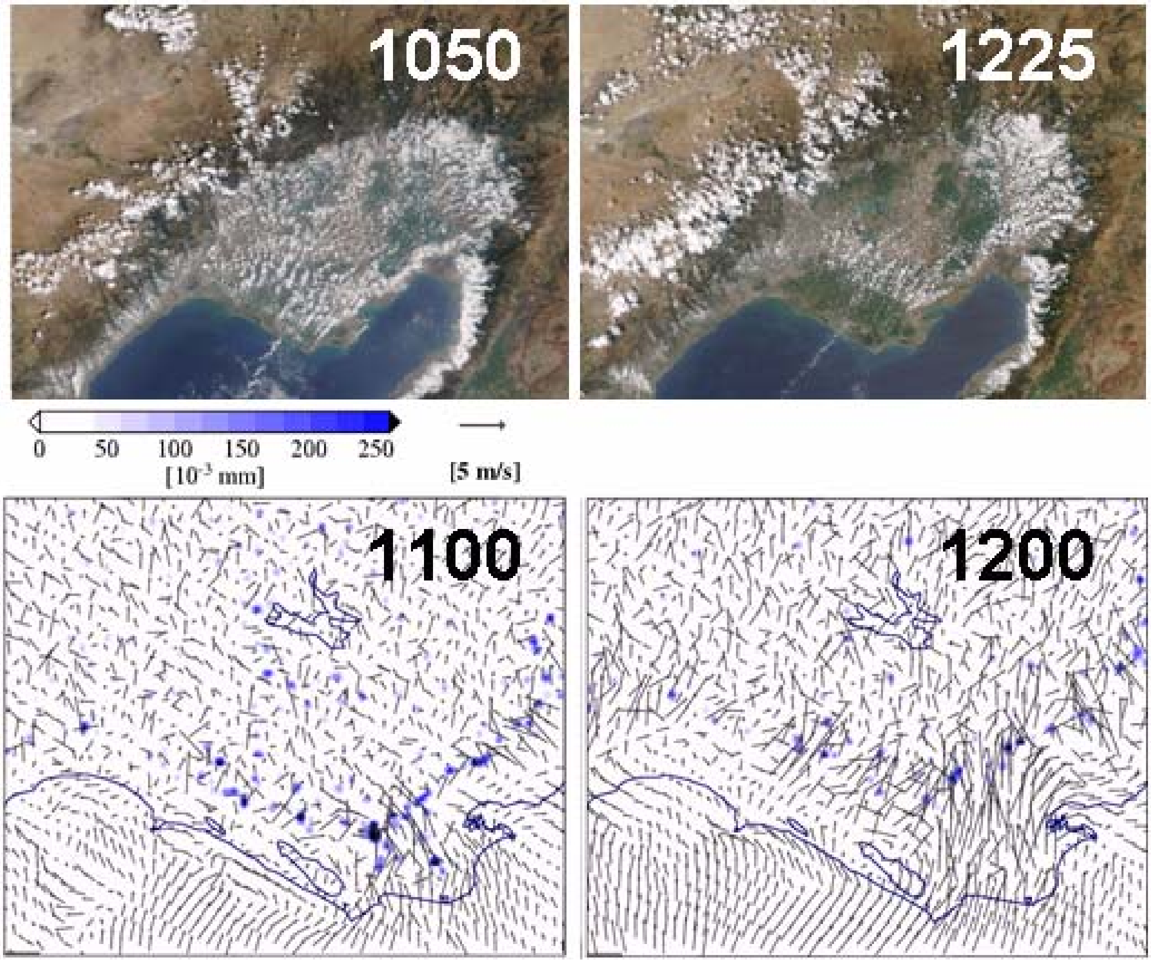

Fig. 3. Snap shots of clouds observed by the MODIS/Terra and Aqua at 1050 LST and 1225 LST on 07 August, 2004 (Top), and those of simulated clouds and wind systems at a height of 1100 m (bottom); The blue shades show the integrated cloud water amount (10^{-3} mm).

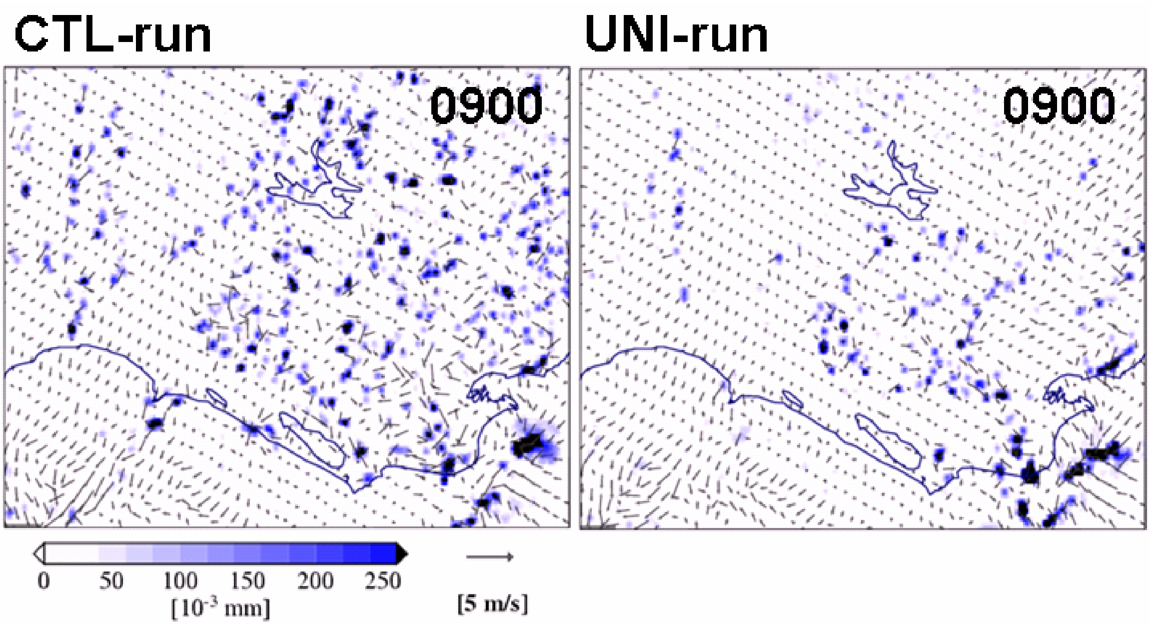

Fig. 4. Snap shots of simulated clouds and wind systems at height of 1100 m on 0900 LST in the CTL-run and UNI-run. The blue shades show the integrated cloud water amount (10^{-3} mm).

The Impacts of Climate Change on the Hydrology and Water Resources of the Seyhan River Basin, Turkey

Hydrology and Water Resources Sub-Group
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1. Introduction

This report assesses the impacts of global warming on the hydrology and water resources of the Seyhan River Basin, Turkey. The ICCAP Hydrology and Water Resources sub-group consists of three groups focusing on (a) groundwater (Dr. Fujinawa, Shinshu University), (b) surface energy and the water balance (Dr. Tanaka, Kyoto University), and (c) water resources (Dr. Fujihara, RIHN). Although these groups act individually, they exchange data to integrate the hydrology sub-group (**Figure 1**).

Section 2 of this paper summarizes the methods used and results found by these groups. Conclusions and suggestions based on the results are described in Section 3. Detailed descriptions of each group follow this paper, as separate reports.

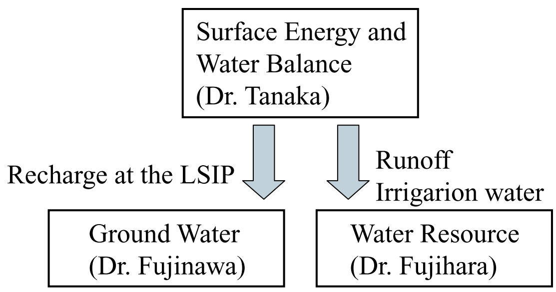


Fig.1 The ICCAP hydrology sub-group.

2. Methods and Results

2.1 Groundwater

A two-dimensional groundwater flow/mass transport model, referred to as the Saltwater Intrusion by Finite Elements and Characteristics (SIFEC) model, was developed and applied under various scenarios to assess the impacts of climate change on the subsurface water environment of the lower Seyhan River Basin (LSRB), Turkey.

Following calibration processes (**Figure 2** shows the current salinity distribution in the aquifer), projections for assessing the impacts of climate change on the subsurface water environment of the LSRB were performed for various scenarios based on adopted sea-level rise and climatic elements, irrigation practices, river runoff, and groundwater abstraction (see Fujinawa and Fujihara, 2007). Outputs of the projections are explained in terms of salinity of the Akyatan lagoon and groundwater, the groundwater table and velocity, salt accumulation on land, and water-logging. The results are summarized below.

The combination of sea-level rise by as much as 0.88 m/century, increasing evaporation, and reduced precipitation will cause a significant increase in salinity in the lagoon (**Figure 3**). Increased salinity in the lagoon will in turn deteriorate the groundwater quality. Groundwater salinity may drastically increase first beneath the lagoon (**Figure 4**) and then further inland in the aquifer.

The buildup of a high-saline zone in the aquifer beneath the lagoon could reduce the freshwater lens in the sand dune aquifer and also cause water-logging on the land surface (see sand dune area of **Figure 5**). Water-logging and increased salinity in shallow groundwater may cause severe accumulation of salt on the land surface.

Increasing evaporation, sea-revel rise, and increasing groundwater abstraction may all contribute to salt accumulation. Thus, drainage measures are strongly recommended in the future to minimize the impacts of salt accumulation on the land surface. The groundwater table may decline significantly in accordance with enhanced groundwater abstraction (**Figure 5**).

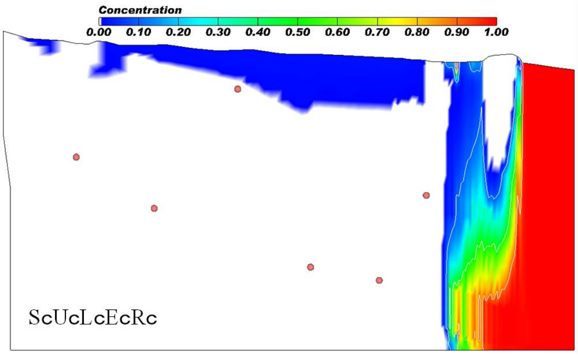


Fig.2 Distribution of salinity relative to Mediterranean.

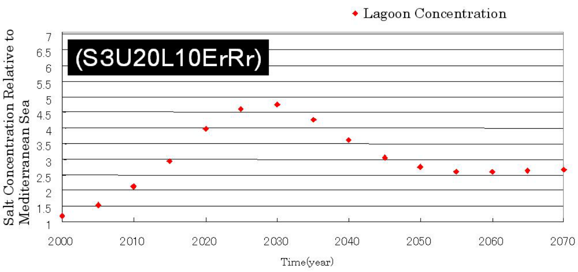


Fig.3 Temporal changes in the salinity of the lagoon water for scenario S3U20L10ErRr.

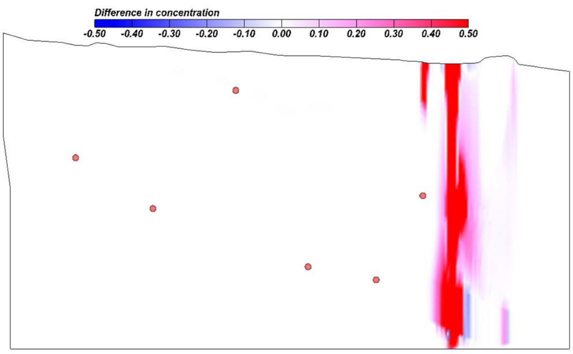


Fig.4 Difference in groundwater salinity between S3U20L10ErRr and control run.

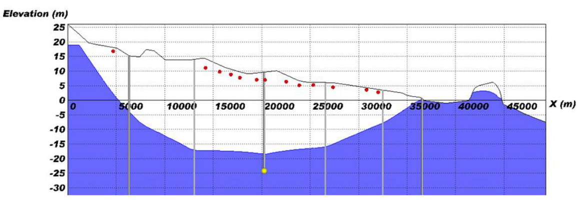


Fig.5 Location of groundwater table for scenario S3U20L10ErRr.

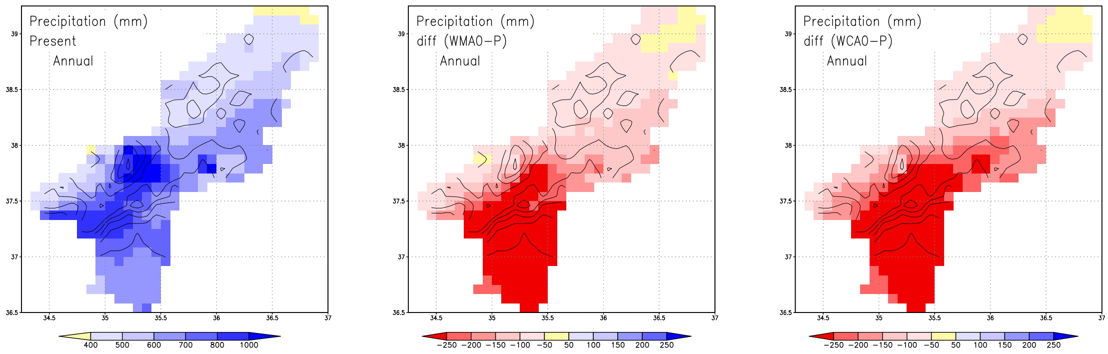
2.2 Surface Energy and Water Balance

Surface energy and water balance components and related hydrological variables of the Seyhan River Basin were estimated using an off-line simulation by the Land Surface Model (LSM) forced by the product of the Regional Climate Model (RCM) for both present and future (warm-up) conditions. The simulation period was from 1994 to 2003 for the present climate condition. For the future climate condition, two products were produced from different general circulation model (GCM) results (Meteorological Research Institute [MRI] and Center for Climate System Research [CCSR]). For the landcover condition, three land use scenarios (A0: no adaptation, A1: adaptation 1, A2: adaptation 2) were used. By combining climate conditions and land-use scenarios, six simulations were conducted for the future.

Maize and citrus were selected to represent irrigated crops. Based on information from the Irrigation and Drainage sub-group, the irrigation periods for maize and citrus were set as 23 May to 6 August and 14 May to 9 October, respectively. For the future climate simulation, the growing period was shortened by 10 days, considering faster plant growth under warmer conditions.

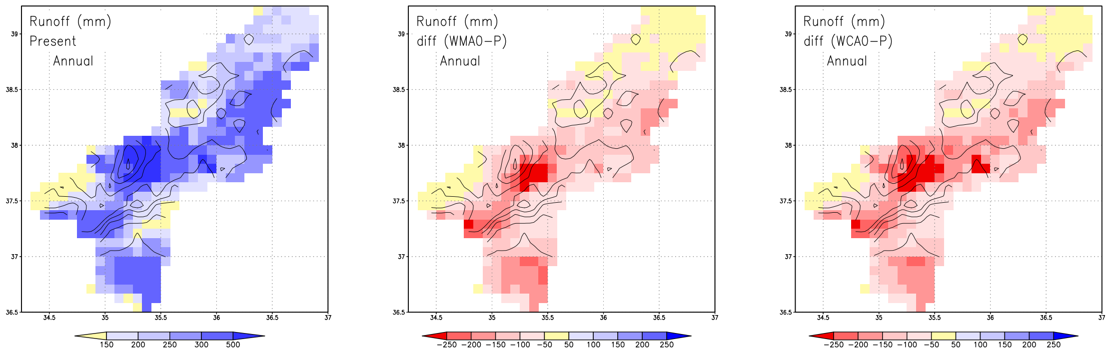
The SPOT VEGETATION Product and ECO-CLIMAP database allow for good descriptions of the spatial distribution and time evolution of vegetation parameters. For consistency with the landcover condition, vegetation parameters were changed accordingly for the future land-use adaptation scenario by applying the average seasonal cycle for each vegetation class.

Figures 6-9 show the annual (10-year average) water balance components (precipitation, runoff, snowfall, maximum snow water equivalent [SWE]) for present and future climates (A0). Precipitation will decrease for the entire Seyhan basin, with particular reductions of more than 250 mm in the middle and delta regions. Maximum SWE is almost 0.4 Gt in the present climate but will decrease to as little as 0.1 Gt under the future climate (**Figure 10**). For the Seyhan delta (irrigated area), annual evaporation is about 800 mm, and about 500 mm of irrigation water must be supplied to maintain soil wetness during the growing



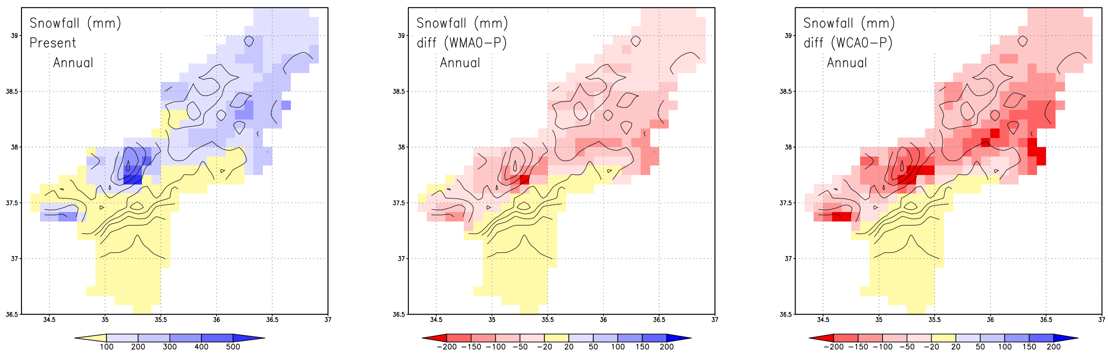
(a) Present (b) Diff(MRI) (c) Diff(CCSR)

Fig.6 Annual precipitation of present climate and its difference in MRI and CCSR run



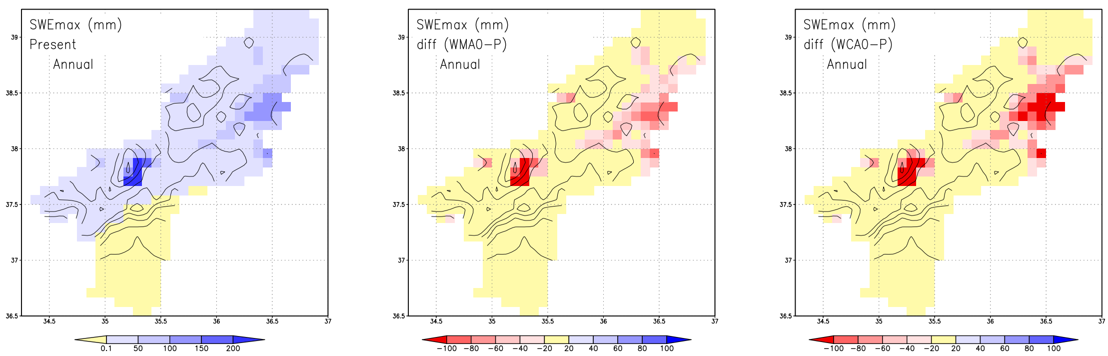
(a) Present (b) Diff(MRI) (c) Diff(CCSR)

Fig.7 Annual runoff of present climate and its difference in MRI and CCSR run



(a) Present (b) Diff(MRI) (c) Diff(CCSR)

Fig.8 Annual snowfall of present climate and its difference in MRI and CCSR run



(a) Present (b) Diff(MRI) (c) Diff(CCSR)

Fig.9 Maximum SWE of present climate and its difference in MRI and CCSR run

Table 1 Basin average annual water balance components

unit:mm	Present	Future(A0)	Future(A1)	Future(A2)	diff(A0)	diff(A1)	diff(A2)
Prec	634.0	464.3	464.3	464.3	-169.7	-169.7	-169.7
Evap	411.3	373.9	365.4	378.9	-37.5	-45.9	-32.4
Runoff	281.6	168.9	168.1	170.4	-112.6	-113.5	-111.2
Irrig	53.8	69.7	60.4	76.4	15.9	6.6	22.5
delS	-5.0	-8.7	-8.8	-8.7	-3.7	-3.7	-3.6

season in the hot, dry summer. While precipitation will decrease over the whole basin, evaporation will increase in some parts. This coincides with the area of large SWE decreases. As a result of the reduced snow cover, those areas will receive more shortwave radiation (albedo effect). This increased energy will contribute to the increased evaporation in spring. Although the period for crop maturation will be shortened, the amount of irrigation water required is projected to increase because of the higher evaporation demand during the growing season and the reduction in soil moisture at the beginning of the growing period.

As a basin average, precipitation is projected to decrease by about 170 mm, while evapotranspiration and runoff will decrease by about 40 mm and 110 mm, respectively (**Table 1**). Considering the amount of the current water balance component, the impact on runoff is significantly large.

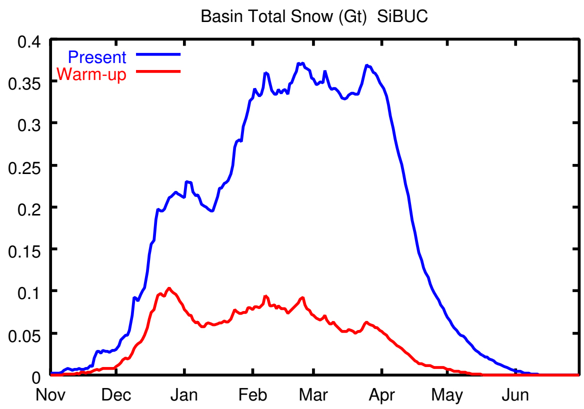


Fig.10 Basin total storage of snow.

2.3 Water Resources

The climate projected using two GCMs under the Special Report on Emissions Scenarios (SRES) A2 emissions scenario was used to drive hydrologic models to assess the impact of climate change on the water resources of the Seyhan River Basin. We used the Simple Biosphere including Urban Canopy (SiBUC) LSM to estimate the surface energy and water balance components. In addition, we employed the stream-flow routing model of Hydro-BEAM to simulate river discharge. We also developed reservoir models to simulate the reservoir operations of the Seyhan and Catalan dams.

The land and water use in the present period are the actual conditions in the Seyhan River Basin. For the future period, the following three scenarios were used: (a) Future: land and water use are the same as at present, (b) Adaptation 1: land and water use under low-investment conditions, and (c) Adaptation 2: land and water use under high-investment conditions. The results show the following.

Future inflow will decrease remarkably compared to that at present (**Figure 11**). In addition, decreases in April, May, and June inflow will be greater than those in other months, and the peak monthly inflow will occur earlier than at present.

The ratio of water withdrawal to discharge, which indicates the degree of water scarcity, is less than 0.4 at present (low water stress), but ranges from 0.4 to 0.7 in the future period and for Adaptation 1 (high water stress), and from 0.5 to 1.0 for Adaptation 2 (extremely high water stress).

The reservoir volume in the future and scenario 1 is less than at present, and in a few cases, the reservoir is empty (**Figure 12**). In contrast, in Adaptation 2, the reservoir is frequently empty. The reliabilities of the dams in the future and in Adaptation 1 range from 1 to 0.95 by the MRI and CCSR models. For Adaptation 2, the reliability ranges from 1 to 0.7 by the MRI and CCSR (**Figure 13**).

Although the ratio of water withdrawal to discharge will increase due to the effects of global warming (decreased discharge), it would be possible to meet water demands using the water resources system in the future case and in Adaptation 1. In contrast, the effects of global warming and the increased demand for water in the upper basin will lead to water scarcity for the Lower Seyhan Irrigation Project (LSIP) area in Adaptation 2.

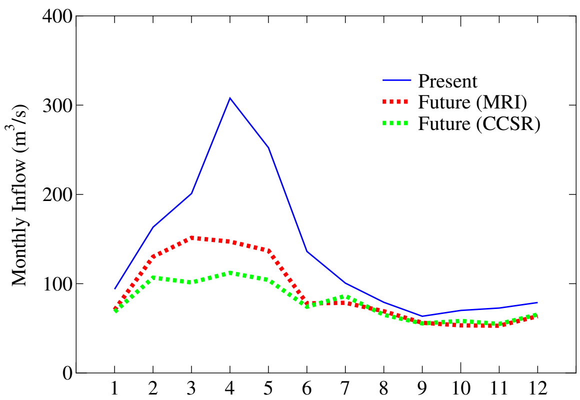


Fig.11 Stream flow changes predicted under different models.

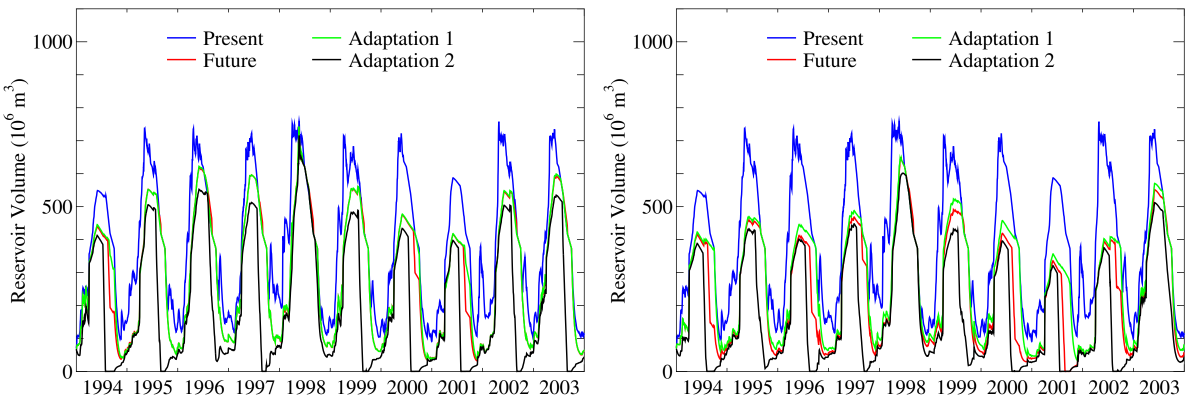
3. Conclusions and Suggestions

The results suggest the following for the Seyhan River Basin:

1. The direct impacts of sea-level rise on salinity will not be serious. Nevertheless, the combination of sea-level rise, increasing evaporation, and reduced precipitation could cause a significant increase in salinity in the lagoon. Therefore, further groundwater abstraction will draw salt water.

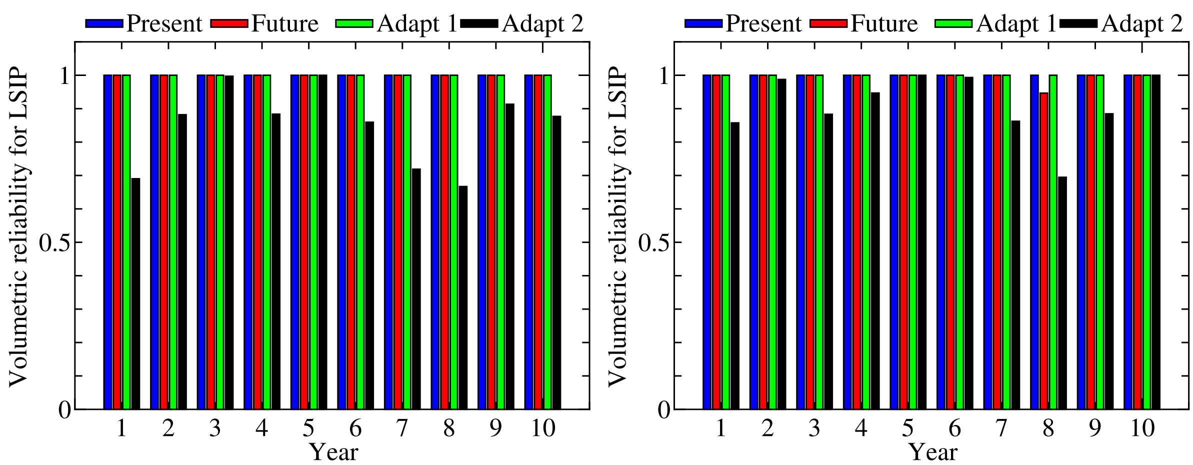
2. The buildup of a high-saline zone in the aquifer beneath the lagoon could cause waterlogging on the land surface. Water logging and increased salinity in shallow groundwater may cause salt accumulation on the land surface. The area planned for LSIP 4 will be unusable as irrigated land.

3. To minimize the impacts of salt accumulation on the land surface, drainage practices are strongly



(a) MRI (b) CCSR

Fig.12 Reservoir changes.



(a) MRI (b) CCSR

Fig.13 Reliability changes.

recommended in the future.

4. As a basin average, precipitation is projected to decrease by about 170 mm, while evapotranspiration and runoff will decrease by about 40 mm and 110 mm, respectively. Flood events will probably occur less frequently under global warming.

5. The expansion of irrigated land in the middle basin (increasing water demand) and the effects of global warming (decreasing river flow) will lead to water scarcity for the LSIP.

6. Quality control should be done to hydrological and meteorological data such as river flow, precipitation, temperature, and solar irradiation, and accurate databases should be created. In addition, attention should be paid to changes in these data to detect global warming and adapt to it.

7. Several observations should be made for mountainous areas. Snow should be observed and monitored on a daily basis. By observing the snow amount in winter, it is possible to forecast inflow, and it is relatively easy to operate reservoirs for flood control and water resource in the spring.

8. Forests will basically reduce river flow (increase transpiration). Therefore, in the case of an afforestation project, this effect should be considered.

References

Fujinawa, K., and Y. Fujihara (2007) Impacts of Climate Change on Subsurface Water Environment in the Lower Seyhan River Basin -Final Results of Calibration and Projection- (in this volume).

Assessment of Climate Change Impacts on Water Resources of Seyhan River Basin

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1. Introduction

This research was conducted within the framework of a multi-disciplinary bi-lateral project supported by the Turkish Scientific and Technological Research Council (TUBITAK) and the Research Institute for Humanity and Nature-Japan (RIHN). A total of 8 subgroups conducted their research independently but in coordination of the "Impact of Climate Change on Agricultural Production in Arid Areas" ICCAP. For several reasons, the Seyhan River Basin was selected as the pilot research area for the project. The water resources of the basin were studied by the International Research Center For Karst Water Resources (UKAM) of the Hacettepe University (Ankara) in cooperation with the DSI, University of Cukurova in Adana and Mustafa Kemal University in Antakya.

The Seyhan River Basin, located at a semi-arid part of Turkey-having significant water and land resources potential- was selected as a pilot study area, to inspect the vulnerable components of water resources (surface water and groundwater) systems, and define and quantify their vulnerability to climate change. The Seyhan River Basin (SRB), one of the major water resources basins in Turkey is located in the Eastern Mediterranean geographical region of Turkey (Figure 1.1). The drainage area of the SRB is more than 21000 km^2 extending between 37°13'-40°12'N and 35°03'-37°56'E. Highland makes large parts of the basin, particularly in the northern areas. The basin is subdivided into two major parts with regard to water resources: the whole Seyhan River Basin (SRB) which was studied for the surface water resources of the basin and the Adana Plain (AP) that comprises the groundwater resources in the alluvial aquifer (see Figure 1.1).

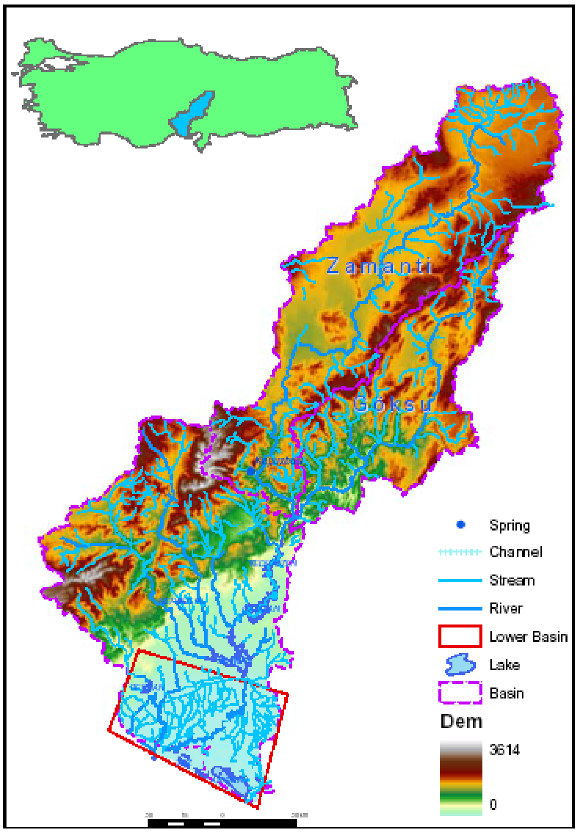


Figure 1.1 Geographical location and division of Seyhan River Basin according to type of water resources

2. Theoretical Conceptualization

Interactions between hydrological and biogeochemical systems, involves climatic conditions represented by meteorological parameters like precipitation and evapotranspiration, infiltration as the excess precipitation from interception and evaporation from surface storage, deep percolation to groundwater system and the factors controlling the biomass including nutrient uptake, decomposition and leaching and weathering. As depicted in Figure 2.1, the soil moisture seems to have not only the more linkages than other components, but also linkages with both surface and subsurface environment, implying that the soil zone plays a key role in the climate-soil-vegetation dynamics. This dynamics can be interrelated within a differential equation that describes the volumetric water change in the soil zone (Rodriguez-Iturbe, 2000).

$$nZ\frac{d\theta}{dt} = I(\theta, t) - E(\theta, t) - D(\theta, t) \qquad (1)$$

where, n: porosity, Z: depth of soil zone, θ: soil moisture content, $I(\theta, t)$: infiltration into soil, $E(\theta, t)$: evapotranspiration, and $D(\theta, t)$: deep percolation to groundwater system.

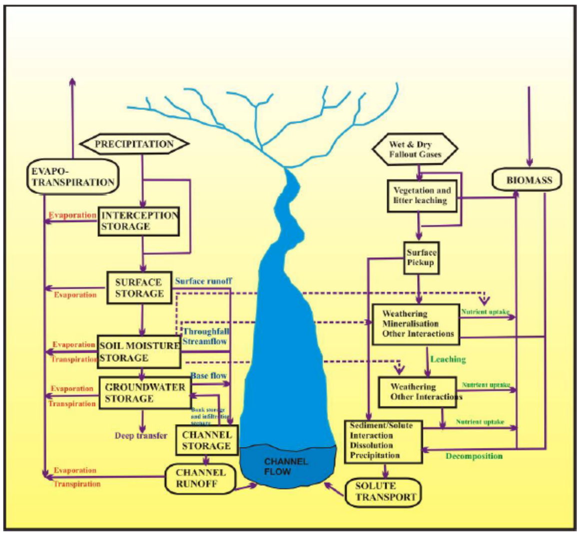


Figure 2.1 Simplified representation of the interaction of hydrological and biochemical processes operating in a drainage basin [from Webb and Walling, 1996: Rodriguez-Iturbe, 2000]

The terms on the right hand side of Equation 1, are all functions of θ, the soil moisture content. Infiltration depends on the saturation degree of the soil. In other words, infiltration does not exceed the available void volume in the soil during a particular storm. Surface runoff is assumed to take place only when the substrate is saturated with water, relating the surface runoff with the availability of water in the subcutaneous zone.

Vegetation and soil characteristics control the evapotranspiration to a large extent. Wilting point and field capacity are known to control the evapotranspiration. However, the rate of evapotranspiration depends on the type of vegetation because of different wilting point and the soil moisture allow maximum evapotranspiration vary among different types of vegetation. Evapotranspiration in forested area is quite different from an area covered by herbaceous vegetation even when climatic conditions and soil environments are similar. The last term, deep percolation is apparently under the control of the saturated hydraulic conductivity, soil water and soil characteristics. This relation is generally given as $K_s\theta_c$, where K_s is the saturated hydraulic conductivity, θ is the soil moisture and the exponent c is a constant dependent on the type of soil. Although the nature of equation (1) may be regarded as stochastic differential equation (e.g. Rodiguez-Iturbe, 2000) because of the fact the precipitation which controls the water content in the subcutaneous zone is a random process, it can be solved by for a certain basin by combining separate solutions for each term.

3. Technical Approach and Methodology

The approach followed in assessing the impacts of climate change on the water resources of the SRB is based on geographical information system (ArcGIS) based modeling studies and comprises three major steps. The overall approach is schematized in Figure 3.1.

Following a comprehensive development of conceptual models, the water systems are simulated by numerically solved mathematical models. Although a holistic approach will be applied in defining the hydrological interactions between surface and subsurface water resources, the conceptual models were developed for interconnected surface and subsurface water systems separately.

The interactions then will be defined within the boundary conditions of each system. The conceptual models were developed based upon all geological, hydrogeological, hydrometeorological data including the spatial distribution of surface cover. The second step was the transfer of the conceptual models to appropriate mathematical models. The selected mathematical models were used for both informative and predictive purposes.

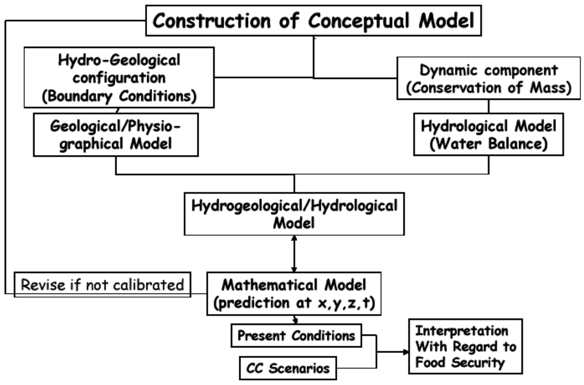


Figure 3.1 Schematic representation of the approach applied in the project studies

The conceptual models were defined on a grid by the initial and boundary conditions. They were calibrated to define the current situation of the systems and then will be run to specify the vulnerable components of the systems to climate changes. Regarding the aim of the project, the models will be run for vulnerability of parameters to climate changes. In this context, not only the input parameters, such as recharge regime but also the changes of boundary conditions as a consequence of climate change were reflected within the models. Therefore, the boundaries of the systems, particularly those of the groundwater system (aquifer) were set on site so as to control the changes rather than estimating the groundwater potential to be managed. That is, the models were run for a purpose of the effects of climate changes on the behavior of the water resources systems rather than providing a base for a management strategy.

After calibrating the models, at the last stage, the models were run to predict the response of water systems to climate changes scenarios. The inputs at this stage were obtained from the downscaled GCM by the model output of the MRI and CCSR at this specific region by Dr. Kimura the head of the Climate sub-group of the ICCAP.

MIKE-SHE (Systeme Hydrologique Europeen), a software combining climate-soil-vegetation and groundwater systems was used to assess the interrelations between these systems in the Seyhan River Basin. The code has six modules for snowmelt, evapotranspiration, surface runoff, flow in the subcutaneous zone, channel flow and groundwater flow. The first two are calculated by analytical methods, while the surface runoff and channel flow are simulated by finite difference solution of the 2-D and 1-D Saint-Venant equation, respectively. The unsaturated flow is simulated by the finite difference solution of the 1-D Richards equation. Groundwater flow is simulated by the finite difference solution of the 3-D Boussinesq equation (Abbott et al, 2000). The MIKE-SHE software was used to simulate the surface hydrology of the mountainous Upper Seyhan Basin.

The Plain section, called the Adana Plain, is rather flat and has no significant surface flow. Therefore, another code that embodies the MODFLOW and MT3DMS in SEAWAT-2000 which also capable of simulating the variable density flow and solute transport, enabling simulation of sea water intrusion.

4. Characterization of the Water Resources Systems

Two major water resources systems exist in the Seyhan River Basin. The Seyhan Dam located at the northern edge of Adana city can be regarded as the approximate divide between the groundwater system and the surface water system. The groundwater system occurs in the alluvial plain extending from the Seyhan Dam site to the Mediterranean in the south (see Fig. 1.1).

4.1 Surface Water Resources in the Upper Seyhan River Basin

The surface water resources of the Upper Seyhan River Basin was conceptualized based on the main factors such as basin characteristics, soil cover and type, vegetation type and cover, geological and hydrogeological structure and hydrometeorological properties. The approach was based on the mass-conservation law which was reflected in the basin scale hydrologic cycle. Precipitation occurs mainly as rain and snow onto the basin. Some portion of the precipitation is evaporated and intercepted by vegetation while the rest reaches the ground surface. Once it is on the surface, a small part of the water is infiltrated into the soil to form the vadose zone storage. The rest forms the surface runoff that reaches the channel flow in the streams and rivers. The groundwater is recharged by deep percolation of some of the infiltrated water within the vadose zone. This approach is schematized in Figure 4.1.

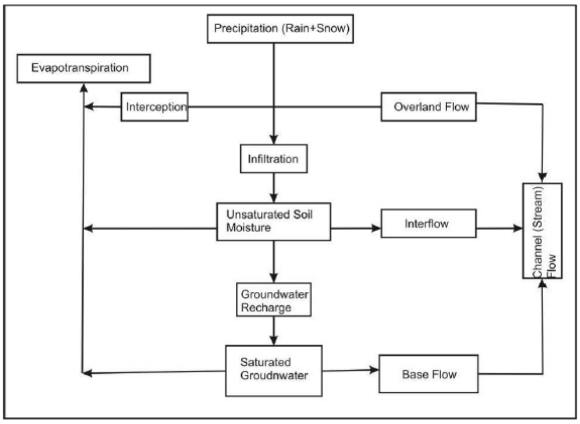


Figure 4.1 Schematic conceptualization of the surface hydrology system in the Upper Seyhan River Basin

The surface water resources in the Seyhan River Basin originate from the runoff of the hydrologic cycle. This potential depends to great extent upon the physiographical and meteorological conditions of the basin. In addition to the type and spatial and temporal distribution of precipitation, vegetation, land-use, soil type, underlying lithology, slope, and basin characteristics such as area, shape, drainage patterns and density etc. controls the occurrence of the runoff and the storage capacity of the basin (Maidment, 1993). Upstream of the Seyhan Dam was considered as the study area where the impact of climate change on surface hydrology was investigated. This part of the basin covers about 21750 km^2. Three main tributaries make the Seyhan River; namely, Cakit, Zamanti and Goksu. The physiography and orohydrography of the basin varies from south to north; the lowlands characterizing the south while the north is represented by harsh topography. The Zamanti subbasin, being the largest, requires a

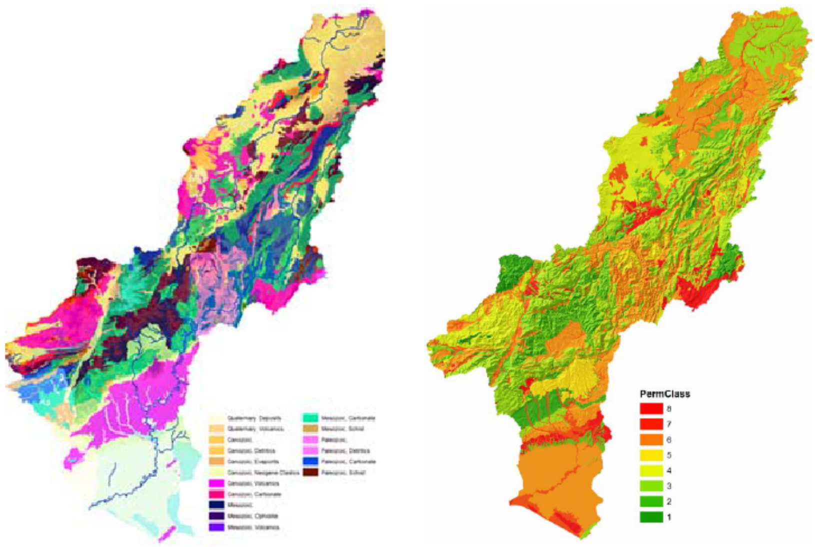
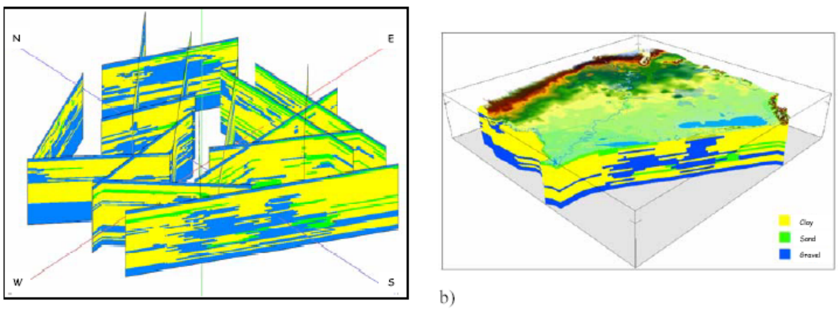


Figure 4.2 Simplified geological and permeability class maps of the Seyhan River Basin



a) b)

Figure 4.3 Simplified geological a) fence and b) block diagrams of the Adana Plain conceptualizing the hydrogeological structure special attention due to its relatively complex hydrological structure. The average elevation of this subbasin is about 1250 m. asl., and karstic discharges supply the main contribution to the river flow.

Geologically the upper basin comprises lithological units representing a time span from Paleozoic to Quaternary (Figure 4.2). The Paleozoic is represented by carbonates and schists. Mesozoic units are made up of mainly carbonates and ophiolitic rocks while the extensive clastics, carbonates and evaporitic lithologies represent the Cenozoic units. Volcanic rocks are of Neogene age. Alluvium, morain and slope wash are of Quaternary age. The pervious lithological units are generally made of carbonate rocks most of which are extensively karstified. The carbonate rocks that form karst aquifers constitute 6758.3 km^2 corresponding to about 30 % of the whole basin. The geological units arre classified into 8 units with respect to their relative permeabilities. In Figure 4.2, these 8 units are presented, where class 1 indicates the most permeable unit, and class 8 represents the less permeable unit.

In the higher elevations of the basin, the precipitation falls in the form of snow. In addition to its contribution to the runoff, the importance of the snowmelt stems from the fact that karst groundwater system contributes in significant amounts to the streamflow through numerous huge karstic springs. The karstic groundwater systems (aquifers) are recharged by the snowmelt as well as rainfall. Therefore, the change in type of precipitation should change the recharge conditions of karst aquifers which in turn will alter the stream flow regime of the Seyhan River.

4.2 Groundwater Resources in the Adana Plain

The Adana Plain geologically is composed of alluvium deposited mainly in deltaic and fluvial environments. Clearly, the tectonic development of the country is reflected in the deposition, because the thickness of the alluvium exceeds 1000 m. in some places. The surface area of the alluvial plain is 2211.9 km^2 corresponding to about 10 % of the total area of the basin. Owing to the heterogeneity that is evident from the boreholes, the groundwater reservoir is constituted by more than one aquifer separated by less permeable layers. On the other hand, because the lithological layer covering the upper aquifer is not homogenous, the aquifer is confined in some areas. That is the groundwater system is a multilayered system partly unconfined in the north and confined in the southern part. The general hydrogeological structure is depicted Figure 4.3.

5. Modeling of the Water Resources in the Seyhan River Basin

5.1 Selected Mathematical Models

The surface hydrology of the Upper Seyhan River Basin was modeled by MIKE- Systeme Hydrologique Europeen (MIKE-SHE) a modular distributed parameter model combining all flow processes at the surface, in the vadose zone and the saturated zone. The model simulates the snow melt (analytical), evapotranspiration (analytical), flow in the vadose zone (1-D Richards equation), overland flow (2-D Saint-Venant equation), channel flow (1-D Saint Venant equation) and groundwater flow (3-D Boussinesq equation). The model uses the finite difference techniques in solving the partial differential equations. Structure of the modular model is depicted in Figure 5.1.

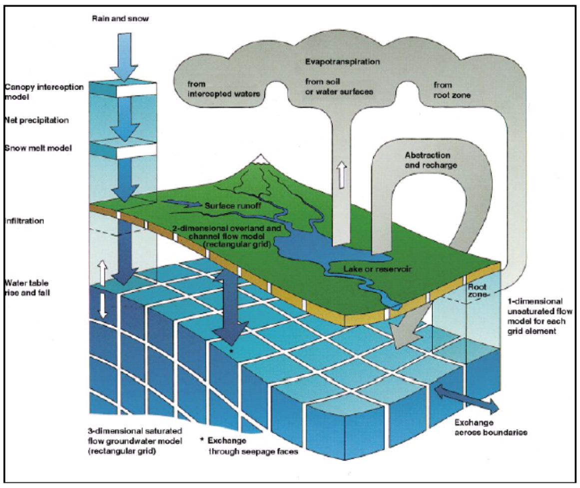


Figure 5.1 Modular structure of the MIKE-SHE model

Following the hydrogeological characterization of the Adana alluvial plain, the conceptual model was transferred to the mathematical models. Sea water intrusion was also considered in the conceptual model. Therefore, in addition to the groundwater flow model, the seawater intrusion was also transferred to a mathematical model and run together with the groundwater flow model. MODFLOW (McDonald & Harbaugh, 1998) was used to simulate the groundwater flow while the sea water intrusion was simulated by SEAWAT-2000 (Langevin, et al., 2003), integrated with MODFLOW.

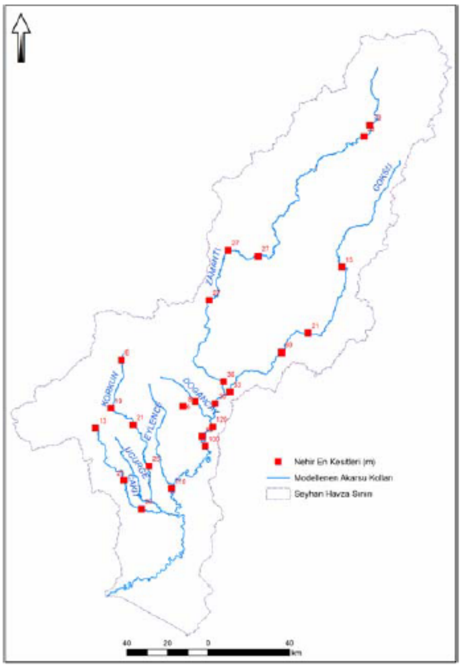


Figure 5.2 Sections where measurements were made for channel flow simulation

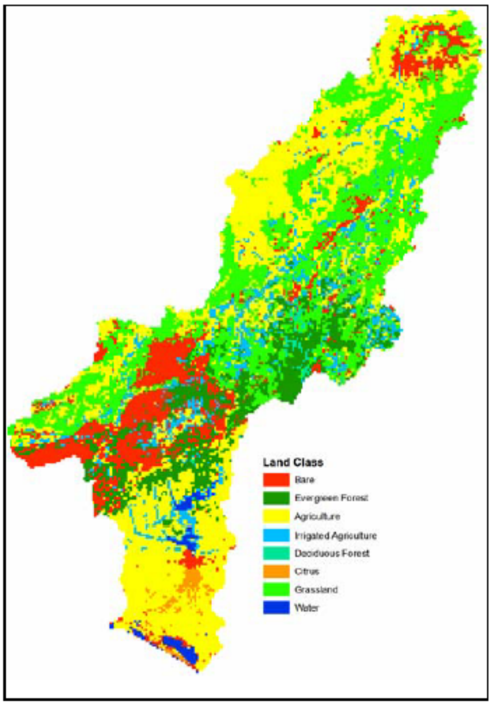


Figure 5.3 The land class units used for evaporation estimations

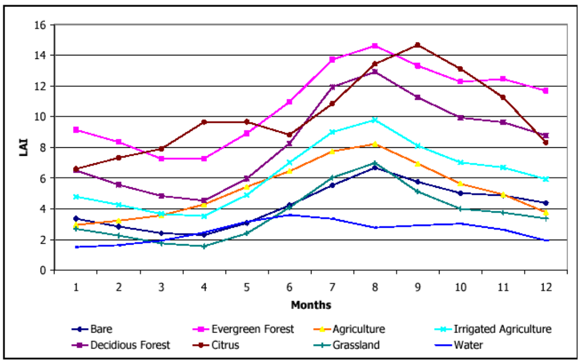


Figure 5.4 The monthly average LAI values depicted from MODIS images

5.2 Preparation and Processing Relevant Data

5.2.1 Seyhan River Basin

The available data were designated, digitized and transferred to a geographical information system. The basin boundaries were defined according to the topographical divide. Topographical, geological and soil maps were digitized and input as separate layers. At the first phase the model was run to simulate the present conditions. Meteorological data estimated for the period between 1994-2003 by the RCM (Kimura, 2007) were used as input to the model in this simulation phase. All simulations were made on daily basis. The model was calibrated using the flow rates recorded at the gauging stations in the basin (Figure 5.2). The evapotranspiration was calculated by using the estimated parameters required for Penman-Monteith equation, and the root depth and the leaf area index (LAI). The LAI values are extracted from monthly MODIS satellite images for the period of 2000 - 2006. The MODIS images are obtained from the Boston University, Department of Geography, Climate and Vegetation research groups ftp site (ftp://primavera.bu.edu/pub/datasets). The monthly values for each year are averaged for each land class units given in Figure 5.3. The interannual change of the LAI is not taken into account. The monthly LAI distribution for each land units is given in Figure 5.4.

The basin was discretized into 216 x 299 finite difference grids of 1 km^2 each. The boundary of the basin was defined in the model by assigning the value indicating impervious unit in cells that fall on the divide. The southern boundary of the basin is Mediterranean Sea, where the boundary is defined by fixed head and attributed with a head value of 0 for present conditions. For the warm-up conditions the fixed head value is taken as 80 cm.

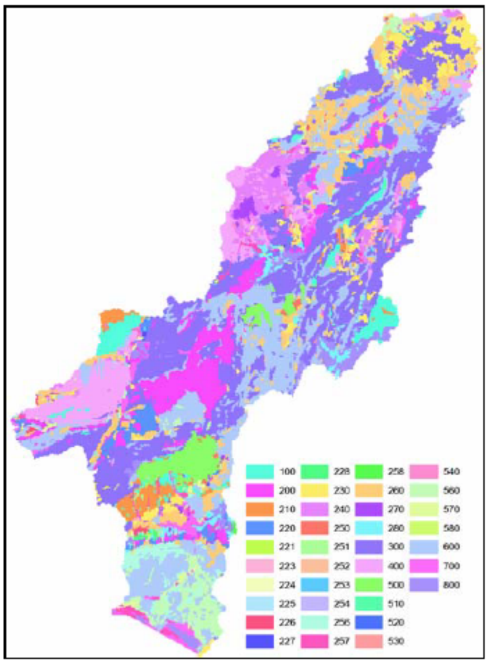


Figure 5.5 The classes of the vadose zone parameters

Because the subsurface water is among the major factors that control evapo-transpiration rate and the infiltration, the vadose zone is taken into account in the model. The soil map was re-arranged so as to define the soil type and some model parameters like effective porosity, specific retention, saturated hydraulic conductivity, and Van Genuchten (1980) parameters that are used in solving the Richards equation were defined for two major types of soil in the basin. The vertical dimension of the vadose zone was taken as maximum 500 m. The depth to the groundwater level is taken as the lower boundary of the vadose zone, and the thickness of the vadose zone is calculated in each model time step according to the groundwater level. The vadose zone divided into 80 finite-difference layers of thickness varying between 0.1 to 10 m. The horizontal distribution of the vadose zone parameters are distributed to the basin by considering the shallow soil and underlying lithologic properties. The vertical zone is divided into three parameter layers. The upper zone is characterized by the soil thickness and structure; the lower layers are based on the lithological structures. A total of 37 distinct classes are defined and the vadose zone parameters are attributed for each class. The distribution of the classes is given in Figure 5.5. The saturated hydraulic conductivities for the vadose zone are within the range of 10-5 to 10-9 m/s. The Van Genuchten parameters for soil moisture - conductivity and retention relations are given from the literature values considering the average grain size for each class.

The groundwater zone is divided into two layers. In the upper layer, the impervious units are defined as confining units for the lower layer. The ophiolite, schist and clay units are defined as impermeable, and groundwater circulation is not allowed within these units (Figure 5.6). The thickness of the upper layer is taken as 200 m, where as it is taken as 1200 m for the lower layer.

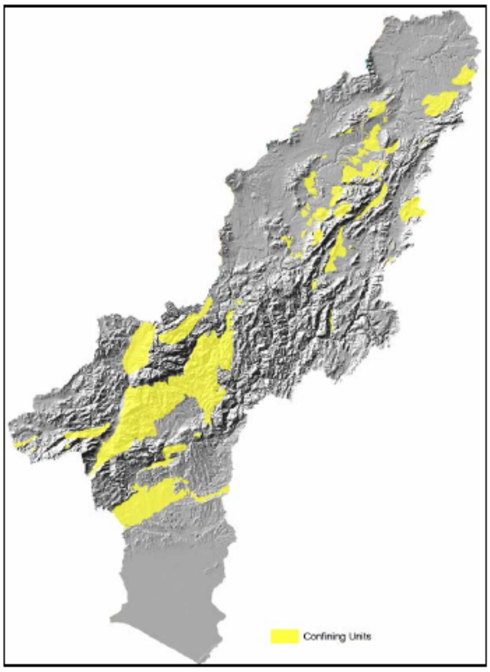


Figure 5.6 The distribution of the upper impervious confining units for groundwater circulation

The surface runoff was simulated by finite difference solution of the Saint Venant equation. Runoff occurs whenever the overland storage exceeds a certain threshold. Overland storage starts to develop when precipitation rate exceeds the infiltration capacity. The model parameters required in this calculation are the detention storage (Figure 5.7) and Manning number (Figure 5.8) which was distributed to the basin by considering the soil and land use classes.

Channel flow component was simulated using the geometry of the river bed defined by finite difference nodes. This required measurement of width and depth of the river at sections where flow rate was observed. The distance between river nodes ranges between 200 and 1500 m depending on the river morphology. More frequent nodes were defined where the river bends in shorter distances.

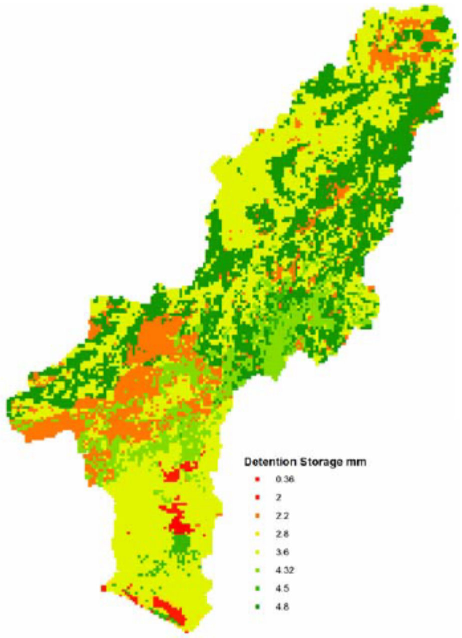


Figure 5.7 The spatial distribution of the detention storage values for overland flow

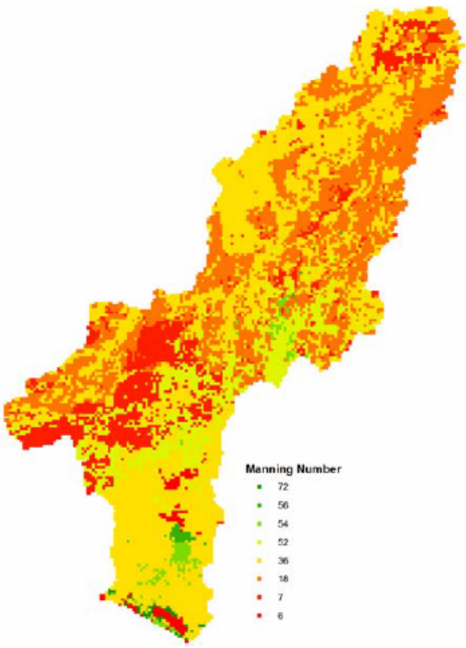


Figure 5.8 The spatial distribution of the Manning Numbers for overland flow

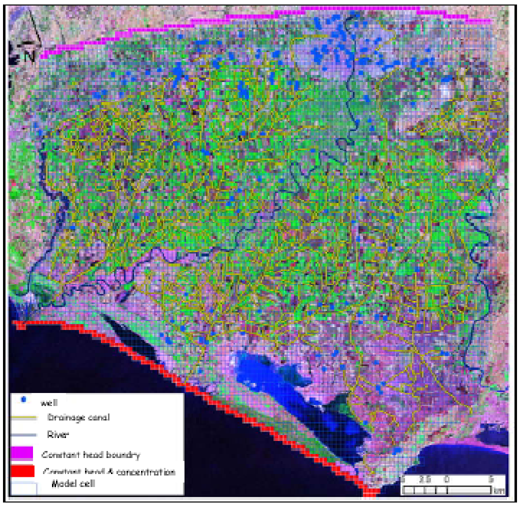


Figure 5.9 Grid mesh and boundary conditions in the Adana Plain

5.2.2 Adana Plain Aquifer

The Berdan-Tarsus river and Ceyhan River borders the study area from the west and east respectively. The plain aquifer covers an area of about 2271 km^2, extending between these borders. Water demand for irrigation in the plain is supplied to a great extent from the Seyhan Dam Lake that borders the study area from the north. Therefore, only a certain number of boreholes were drilled, most of which are located in the northern part of the plain to supply water to the Adana Metropolitan city. However, after drip-irrigation system became attractive to the farmers in the plain, a few boreholes are drilled in the southern part of the plain. The data of these boreholes were used in conceptualizing the groundwater system. The geohydrologic characterization of the plain aquifer system was based upon the 203 well logs. Depth of boreholes drilled at the northern part does not exceed 100 m., whereas the boreholes at the south are deeper; 363 m. the deepest. The Tarsus-Berdan river that borders the area from the west, flows over a thick clay (impervious) layer. Similarly the Ceyhan River flows over a thin sandy layer underlain by another thick clayey layer. The northern part of the plain is covered by a succession of gravel-clay-gravel. Detailed study of the well logs suggests that it is difficult to distinguish more than one aquifer, but instead, it is more realistic to consider one heterogeneous aquifer with vertical and horizontal interfingering layers of pervious and impervious deposits; which is also supported by the type of the depositional environment. The

3-D distribution of the clay, sand and gravel layers (Figure 4.3) was transferred to the mathematical model assigning a distinctive hydraulic coefficient for each. The conceptual model outlined above was transferred to a finite difference grid of 500×500 m composing 250860 cells in total (Figure 5.9). The third dimension was taken between elevations of 20 m. above and 320 m below sea level. 20 model layers of 20 m thickness each were defined to represent the vertical dimension. The model is run continuously from 1993 to 2079.

The aquifer is recharged through direct rainfall onto the areas where coarse deposits are exposed, from seepage from the Seyhan River where the bed is composed of pervious material and through inflow the northern boundary. The recharge from the northern boundary is identified by stable isotope analysis in deep wells in the plain. The isotope content of the groundwater clearly indicates the recharge from higher elevations. Because the amount of the inflow through the northern boundary is difficult to predict and any prediction would associate significant uncertainty, the boundary condition was defined based upon the groundwater level measurements in the boreholes close to this boundary. This provided that recharge through this boundary is computed by the model based on the gradient changes. The head values obtained by MIKE-SHE simulation for present and warm-up conditions are given for the northern boundary for each time step. Discharge of the aquifer occurs as the outflow into the sea, effluent flow to the Seyhan River where hydrogeologic conditions are appropriate, and as groundwater abstraction through wells and drainage canals. The boundary condition at the south where the aquifer is in contact with the sea was taken as ”constant head-concentration boundary” for the first 10 years; whereas this boundary was changed to ”variable head-concentration boundary” during the second and third periods where the system is affected by the climate change. The concentration of the sea water was taken as 19200 mg/l of Cl from chemical analysis of the sea water. The initial head values were obtained by steady state simulations under natural conditions. The head is attributed as 0 for present conditions. Two different rates for the sea level increase are given to the model for warm up conditions. For the first 20 years, the sea level is assumed to reach to 40 cm, whereas it is assumed as 80 cm at the end of 2079. The groundwater utilization is also increased within these stress periods. The increase rate is taken as 20 % for the first 20 years, and 50 % for the rest. The locations of the new wells are attributed randomly.

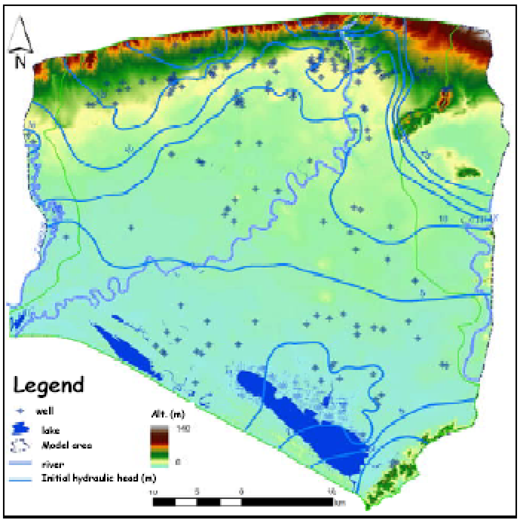


Figure 5.10 The steady state head distribution in the Adana Plain

6. Climate Change Impacts on the Water Resources of the Seyhan River Basin

The impacts of the climate change on the water resources are assessed by comparing the results of the hydrologic model run under present and warm up conditions. The daily values of the temperature, precipitation, and the potential evapotranspiration estimated by the data provided by the Dr. Kimura’s Climate Subgroup for the periods of 1993 to 2004 and 2070 to 2080 are used to reflect the water circulation under present and global warming conditions. The mean values of the climate variables are given in Figure 6.1. The spatial averages of these parameters are given in Table 6.1. The grid size of the climate input given to the hydrologic model is about 8 km, whereas the model cell dimension is 1 km.

The results of the MIKE-SHE simulations for present and warm up conditions are summarized in Table 6.2. The figures in Table 6.2 reflect the percent decrease of the water budget elements with respect to present conditions. The CCSR climate data results more decrease than the MRI data. The decrease in the actual evapotranspiration is limited

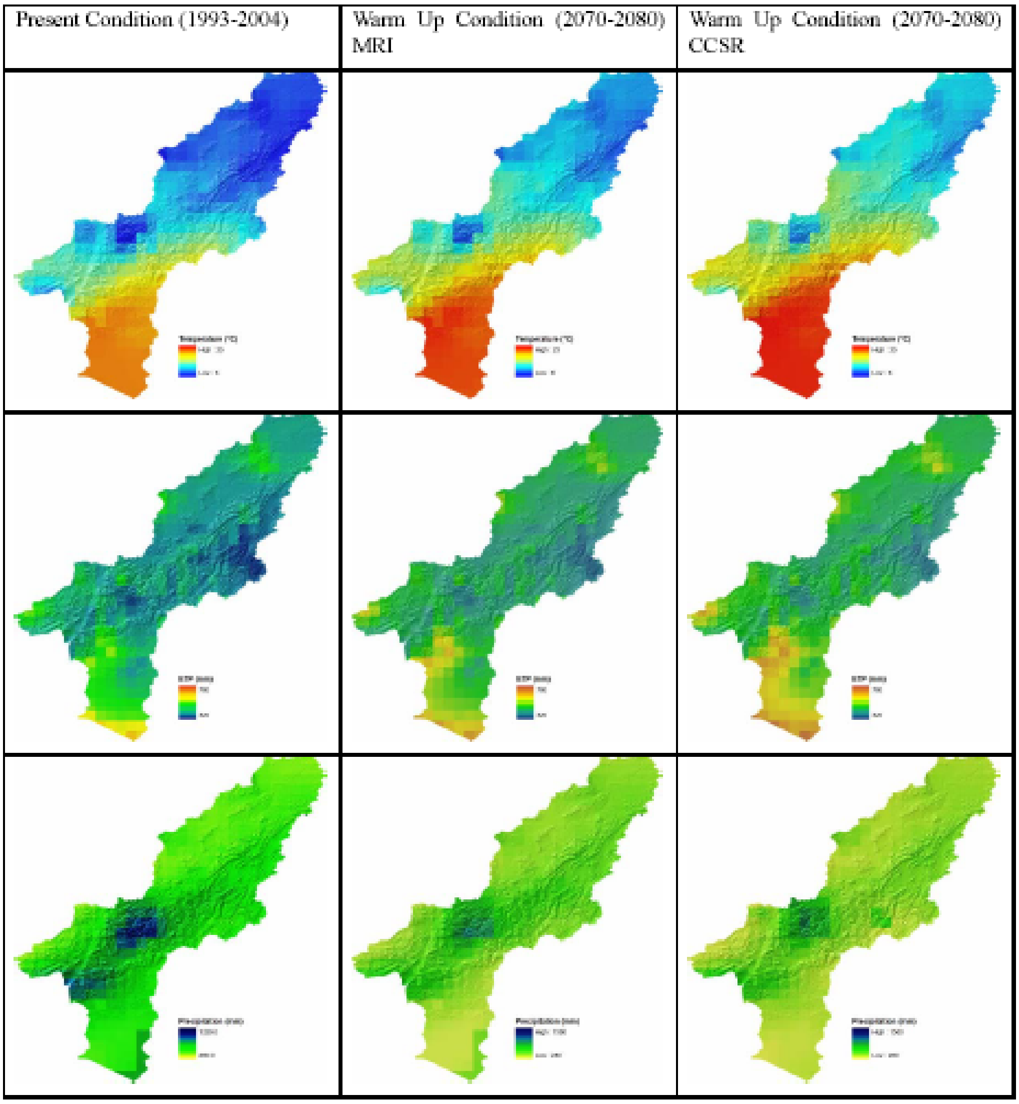


Figure 6.1 The distribution of the mean annual temperature, mean annual total potential evapotranspiration and mean annual total precipitation for present (1993-2004) and for warm up (2070-2080) periods estimated by MRI and CCSR data

because of the decrease in the precipitation. The decrease in the precipitation in warm up period is 29.4 % and 34.7 %, which causes 37.5 % and 46.4 % decrease in the river flow. The groundwater recharge in whole Seyhan Basin decreases 24.7 % - 27.4 %. The majority of the springs in the basin become dry due to decline of the groundwater level below the spring level.

The temporal change of the river flow is depicted on Figure 6.2, at 18-18 gauging site on Seyhan River. The peak discharge decreases in both MRI and CCSR projections. The month for the peak flow is same in present and warm up period, but the volume decreases radically.

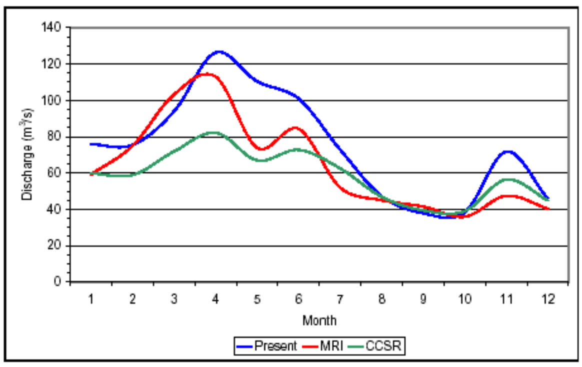


Figure 6.2 Change in mean monthly discharge of the Seyhan River at 18-18 gauging station

The change in evapotranspiration depends on the available water. The decrease in the precipita-

Table 6.1 The Spatial Average Values of the Annual Temperature, Precipitation and Potential Evapotranspiration in Seyhan River Basin

	Present (1993-2004)			MRI (2070-2080)			CCSR (2070-2080)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Temperature (°C)	12.3	6.2	20.3	14.3	8.3	21.8	15.3	9.3	22.7
Precipitation (mm)	681.3	451.6	1313.5	514.9	324.9	1004.9	455.9	303.7	968.9
Pot.Evapotranspiration (mm)	433.1	328.4	669.9	469.8	350.5	697.0	495.8	367.9	750.1

Table 6.2 The Percent Decrease of the Water Budget Elements in Warm up Period with Respect to Present Conditions

	MRI	CCSR
Precipitation	29.4	34.7
Actual Evapotranspiration	16.9	16.9
River Flow	37.5	46.4
Discharge to the Mediterranean Sea	50.0	54.2
Recharge	24.7	27.4
Spring Discharge	50.0	50.0

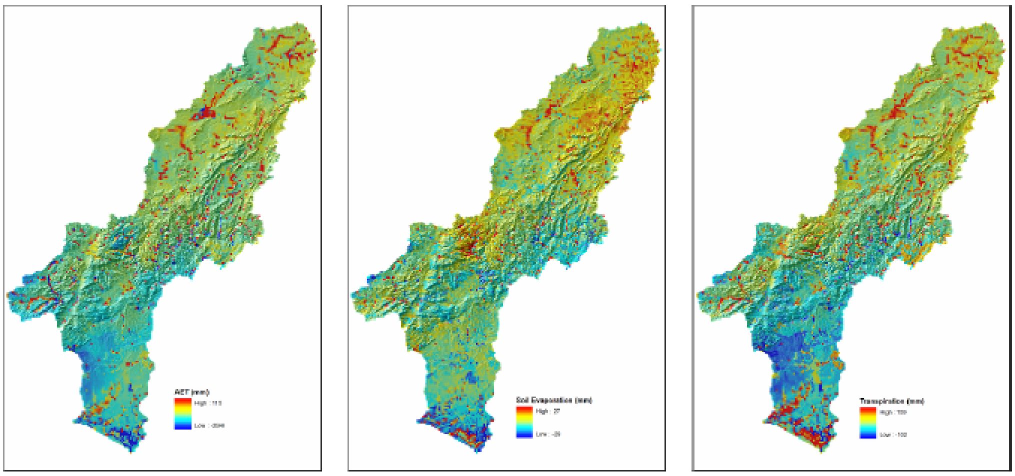


Figure 6.3 Change of the actual evapotranspiration, soil evaporation, and transpiration, positive values indicate increase, negative values indicate decrease with respect to present conditions

tion causes the decrease in the evapotranspiration. In Figure 6.3, the spatial distributions of the differences between the CCSR projection and present conditions of the actual evapotranspiration, soil evaporation, and transpiration are given. In the north of the basin, the evapotranspiration values are increasing in the warm up period, whereas they are decreasing in the south, especially in the areas of crop production, and natural vegetation. The decrease is due to the lack of the available water to evaporate. In these zones, the irrigation water requirement will be greater in the future. Maximum increases occur over the branches of the Seyhan River, and lagoons at the coastal zone. The change of the average water content in root zone is shown in Figure 6.4. The root zone water content decreases in agricultural areas in Lower Seyhan Plain, and in low level zones at the north. The decrease of the snow storage is also significant (Figure 6.5). The decrease in the mean annual snow storage is 14.56 km^3 in warm up period. The major decrease occurs in Aladaglar, southeast slopes of the Erciyes and in the north of Goksu Basin. The decrease in snow storage will influence the discharge of the springs in Zamanti and Goksu basins, feeding the Seyhan River.

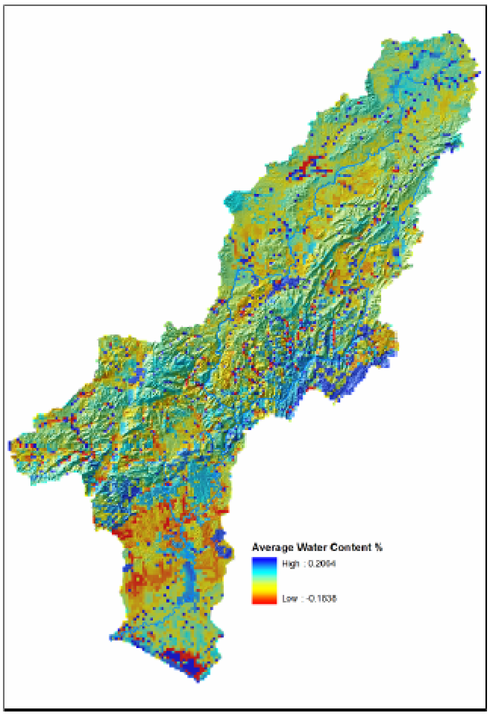


Figure 6.4 The change of the Average Water Content in root zone in warm up conditions

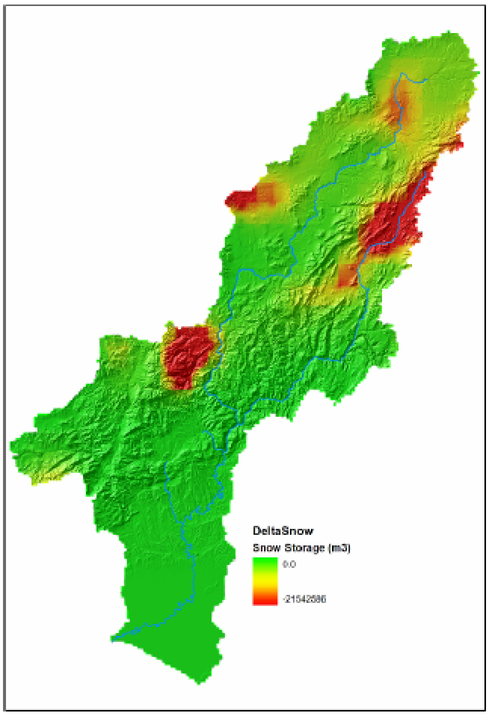


Figure 6.5 The decrease of the snow storage in warm up conditions

The groundwater resources in Adana Plain will be influenced by climate change drastically. The decrease in the recharge in Seyhan Basin will cause the decrease in the subsurface recharge to the Adana Plain from north, and infiltration over the plain. Additional loss will occur due to increase in the abstraction in warm up period to comply the irrigation water requirement. The water budget for the groundwater system in Adana Plain is given in Figure 6.6, whereas the change in the groundwater storage is given in Figure 6.7.

The groundwater resources in the Adana Plain are highly susceptible to the climate change. The most important impacts are the decrease in the recharge in higher elevations, and increase in the abstraction due to the limitations in surface water resources. The decline in the head will also cause saline water intrusion. The simulations indicate that the intrusion length is controlled by the groundwater level in the plain. In case of % 50 increase of the groundwater abstraction in warm up conditions, the length of the sea water intrusion will reach 10 km inland (Figure 6.8) at the end of 2080.

The decline in the storage will be accompanied with the quality degradation in the groundwater resources. In the coastal zone of the Adana Plain, the groundwater salinity will reach 25 % of sea water composition.

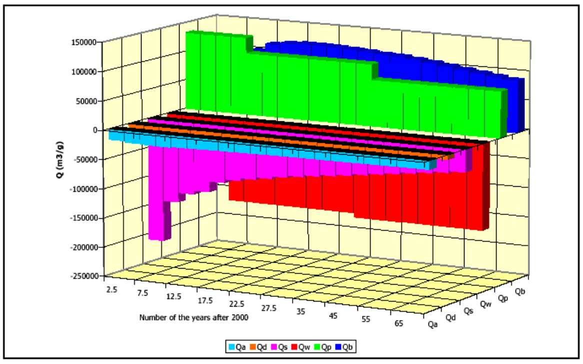


Figure 6.6 Components of the water budget calculated by the model (Qb: inflow from the northern border, Qp: recharge from precipitation, Qw: abstraction by wells, Qs: outflow to the sea, Qd: drainage by drainage canal, Qa:

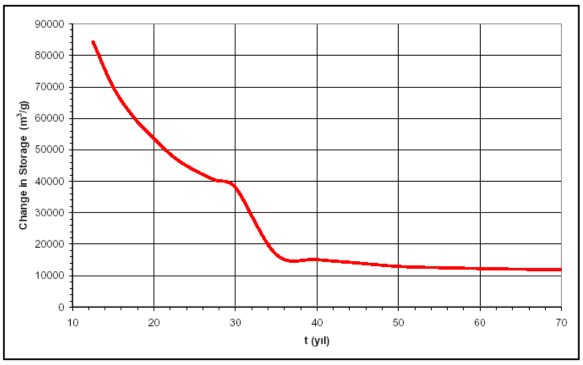


Figure 6.7 The impact of the climate change on the ground water storage in Adana Plain

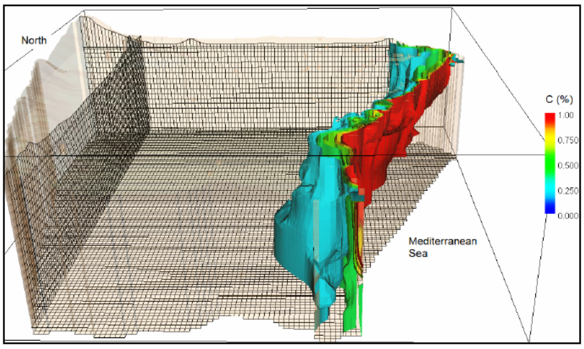


Figure 6.8 The sea water intrusion in the year of 2080

7. Conclusions

The climate change impacts on the water resources of the Seyhan River Basin are evaluated in basin scale by physically based hydrologic models. All the elements of the hydrologic cycle are considered with in a comprehensive hydrology model. The temporal and spatial distribution of the changes in the water resources potential are calculated, by using the climate variable estimations, downscaled from two different GCMs.

It is necessary to emphasize that the values given in this report are based on many assumptions, including the fundamental scenarios of the GCM estimations. The conceptualization and parameterization of the hydrologic model have been based on very limited data and field observations. The temporal and spatial representativity of the available data are very low. Many data and parameter required by the model were derived from secondary sources. Thus, the actual figures may deviate from the values given here. However, the tendency of the change will be similar, if the scenarios of the GCM would occur.

The management of the water resources in the warm up conditions will require more precise and extensive data. The continuous observations of the hydrologic cycle are essential for sustainable utilization of the water resources.

The climate change will result the reduction of the input to the basin, and all types of the water resources will be influenced by these reduction. The surface water resources, the snow storage, and groundwater resources will decrease drastically. The water requirement for the agricultural production and natural vegetation will increase. Therefore efficient utilization of the water resources in all sectors, water saving, control of the water usage, extension of the observation network, enlargement of the artificial storage potential in the basin are high priority management issues to be prepared for warm up conditions.

8. Acknowledgement

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Impacts of Climate Change on Subsurface Water Environment in the Lower Seyhan River Basin

ーFinal Results of Calibration and Projectionー

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1. Introduction

According to IPCC, climate change is expected to cause abnormal weather and sea-level rise, and may accordingly influence water-resources management for agricultural productions. Although groundwater may be considered to be an important water resource as an substitute of reducing surface water resources, subsurface water environment can also be significantly affected by climatic, hydrogeologic and anthropogenic conditions in a very complicated way. The objective of this study is to assess future subsurface water environment of the arid area extending in the Seyhan River Delta, the Cukurova plain, Turkey, in accordance with climate change and agricultural activities.

Major phenomena related to the subject include flow and salinity of groundwater in coastal aquifers, salinity in lagoons, and salt accumulation on land surfaces. Quantitative assessment of impacts on such complicated phenomena can only be performed by using numerical models. To achieve this objective, a coupled, 2-D, groundwater flow and mass transport model, SIFEC (Salt-water Intrusion by Finite Elements and Characteristics), was developed and applied to assess future changes under various scenarios. SIFEC is a numerical model based on a coupling of the Galerkin-finite element method for saturated-unsaturated, density-dependent flow and the method of characteristics for mass transport. Basic methodology, properties, accuracy, etc, have been described elsewhere[1)] and will not be repeated here.

2. Scenarios

Provided with temporal changes in sea level, evapo-transpiration, precipitation, irrigation practice, groundwater use, and base flow from mountainous area into lowland aquifers of the lower Seyhan river basin (LSRB), a specific version of SIFEC was applied to assess impacts of climate change and enhanced abstraction on groundwater table, salinity distribution in groundwater including seawater intrusion, water logging, salt accumulation on land surface, salinity concentration in lagoon water for various scenarios.

Simulation models were run under several scenarios. Each scenario is composed of five elements as shown in **Fig.1**; that is, sea level rise, climate, recharge due to irrigation, abstraction rate, and inland B.C.

Each element has three to four components. The sea-level-rise(S) has three components; that is, 0.0 cm rise by 2100 (denoted by Sc), 0.88 cm rise by 2100 (Maximum rise projected with SRES A1Fl scenario and reported in the IPCC 3rd AR

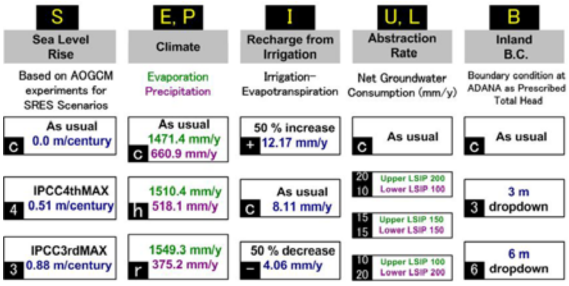


Fig.1 Scenarios for Projecting Subsurface Environment in 2070

Table 1. Rainfall and Evaporation

	Rainfall (mm/y)	Rainfall (m/d)	Evaporation (mm/y)	Evaporation (m/d)
Current	660.9	0.00181	1471.4	0.00403
2070 by MRI	379.2	0.00104	1522.2	0.00417
2070 by CCSR	371.1	0.00104	1576.4	0.00432
2070 Mean of MRI and CCSR	375.2	0.00103	1549.3	0.00424

Table 2 Abstraction Rate of Representative Wells

	Abstraction (m^3/day)					
	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6
Pre-Irrigation	0.00	0.00	0.00	0.00	0.00	0.00
Current	0.03	0.22	0.92	0.44	0.09	0.03
U20L10	5.31	3.82	1.85	1.67	0.81	0.00
U15L15	3.98	2.87	2.78	2.51	1.22	0.00
U10L20	2.65	1.91	3.70	3.35	1.62	0.00

denoted by S3), and 0.51 cm rise by 2100 (Maximum rise projected with SRES A2 scenario and reported in the IPCC 4th AR, denoted by S4).

Evaporation rates from water surfaces in the climate element (E) were evaluated with the aid of the Penman method using the temperature projected by MRI-RCM (Meteorological Research Institute – Regional Climate Model) and CCSR-RCM (Center for Climate System Research, University of Tokyo) and has three components; that is, 1471.4 mm/y (currently observed and denoted by Ec), 1549.3 mm/y in 2070 (mean of MRI and CCSR Projection for SRES (Special Report on Emission Scenario) A2 scenario and denoted by Er), and 1510.4 mm/y in 2070 (mean of the currently observed and the mean of MRI and CCSR Projection, denoted by Eh).

Precipitation rate in the climate element (P) has three components; that is, 660.9 mm/y (currently observed and denoted by Pc), 375.2 mm/y in 2070 (mean of MRI and CCSR projection for SRES A2 scenario and denoted by Pr), and 518.1 mm/y in 2070 (mean of the currently observed and the mean of MRI and CCSR Projection and denoted by Ph). Table 1 shows the adopted values of precipitation and Evaporation.

The recharge-from-irrigation element has three components; that is, 8.11 mm/y (calibrated current estimation and denoted by Ic), 12.17 mm/y in 2070 (50 % increase of the calibrated current estimation and denoted by I+), and 4.06 mm/y in 2070 (50 % decrease of the calibrated current estimation and denoted by I-).

The abstraction-rate element has four components; that is, as usual (calibrated current estimation and denoted by c), upper LSIP 200 and lower LSIP 100 (denoted by U20 and L10), upper LSIP 150 and lower LSIP 150 (denoted by U15 and L15), and upper LSIP 100 and lower LSIP 200 (denoted by U10 and L20). The numbers 200, 150, and 100 denote adapted future water requirements for agriculture in mm/year for the Lower Seyhan Irrigation Project and these data are converted to abstraction rates for six representative wells).

Inland boundary condition (B) in the inland B.C. element is given as a prescribed head boundary and has three components; that is, as usual (currently observed 19m above sea level at Adana city and denoted by Bc), 3 m dropdown (denoted by B3), and 6 m dropdown (denoted by B6)

Hereafter, each scenario is entitled with abbreviations used in Fig.1 such as ScEhPhI-U20L10B6, etc.

3. Calibration of mathematical model

(1) Calibration for pre-irrigation stage

Numerical simulations conducted so far for real fields by many researchers have usually been hampered by the lack of important data needed for calibration processes. This was also the case for this study.

Although there has been no estimation for the amount of annual groundwater recharge due to precipitation in the study area, W.Scheumann[2)] describes in her book as follows;

"In the 1960s, prior to the installation of the irrigation project, rainfed agriculture was practiced on 95 % of the projected land" "The groundwater level is high, reaching a maximum level of 0.5 to 1.0 meter below land surface and a minimum of 2 to 4 meters. Large areas become water logged during the winter."

For this pre-irrigation stage back to 1960s, it can be assumed that there were neither artificial groundwater recharge due to irrigation nor groundwater abstraction.

Thus, natural recharge due to precipitation was applied on the entire land surface and its rate was inversely estimated so that most of the land surface becomes seepage face.

An inversion process of this simulation for the pre-irrigation stage resulted in the annual recharge rate from precipitation of 8.11mm/year. The upper

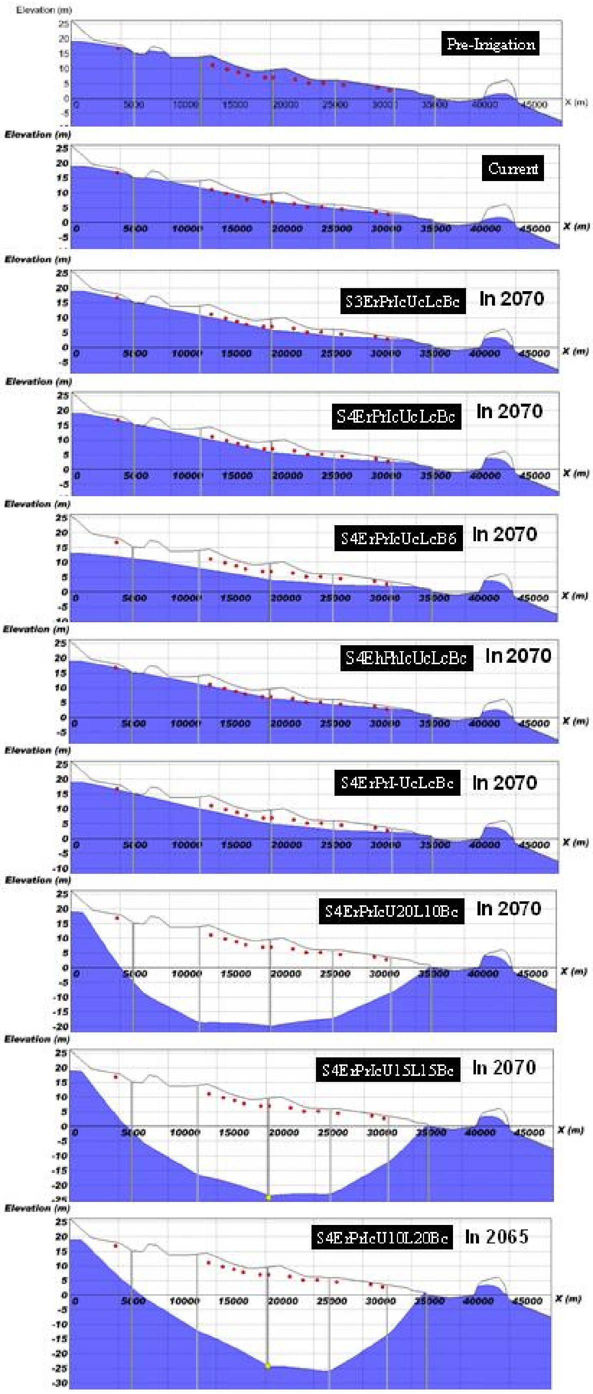


Fig.2 Groundwater tables calibrated for pre-irrigation and current stages and projected for various scenarios

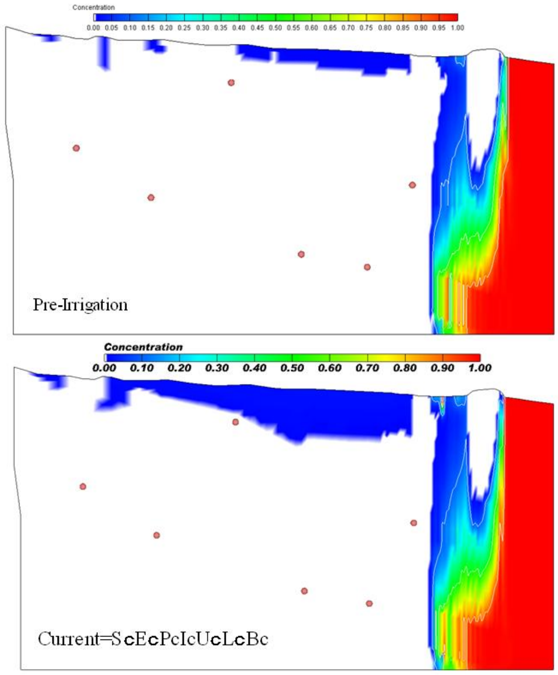


Fig.3 Distribution of groundwater salinity relative to the Mediterranean at the pre-irrigation and the current stage

most figure of **Fig.2** shows the location of the calibrated groundwater table for the pre-irrigation stage, where red dots indicate locations of observed groundwater table heights at the current stage. As Scheumann described, the land surface corresponds to the seepage face over the large area.

Water of Akyatan Lagoon was observed to have salinity of 6.8 S/m, which is higher than 5.8 S/m of the Mediterranean. In shallow zone of LSRB and in the left side of the lagoon, salinity of groundwater was also observed to be more than 0.02 S/m and less than 0.12 S/m. The upper figure of **Fig.3** shows the calculated distribution of salinity relative to the Mediterranean in the groundwater at the pre-irrigation and the current stage.

It should be noted that fresh groundwater is found in sand dune aquifer close to the Mediterranean, forming a fresh water lens above the saline groundwater, while salt water intrudes into the coastal aquifer from the sea, followed by upward flow of groundwater toward the lagoon.

Fig.4 shows calculated distribution of groundwater vectors near the lagoon. It can be seen that in the pre-irrigation stage, groundwater used to flow upward toward land surface and the lagoon.

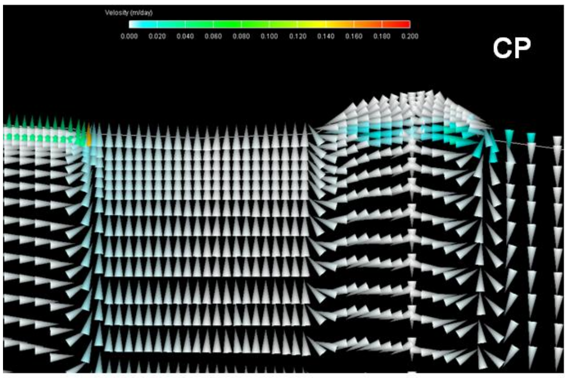


Fig.4 Groundwater Velocity at the pre-irrigation stage

(2) Calibration for the current stage

Groundwater abstraction rates of six wells were identified so that calculated groundwater table heights coincide with those by observation. Groundwater recharge rate due to irrigation in agricultural area was assumed to be the same as natural recharge rate due to precipitation for the current stage since the contribution of irrigation to groundwater-table rise is almost the same as that of precipitation.

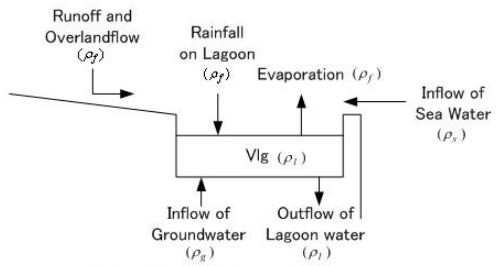
The second figure from the top of **Fig.2** shows that the simulated groundwater table coincides quite well with the observed one. Identified values of current abstraction rate of wells are shown in Table 2.

The lower figure of **Fig.3** shows the calculated distribution of groundwater salinity at the current stage. Due to abstraction from wells, groundwater table declines compared to the pre-irrigation stage shown in Fig.2. Thus, the salinity in shallow groundwater slightly increases in agricultural areas eventually.

4. Influence of Evaporation from the Lagoon

Observed electric conductivity of Akyatan lagoon was 6.8 S/m, which is higher than that of the Mediterranean by 1.0 S/m due to evaporation from the lagoon. **Fig.5** is a schematic diagram illustrating input/output relations for volume and mass balance of the lagoon water. Equations for the volume and the mass balance are also shown in the figure.

Water level of the lagoon has been maintained to be the same as the Mediterranean since both water



Volume Balance of Lagoon Water

$$V^{t+\Delta t} = V^t + \Delta IG - \Delta OL + \Delta RO + \Delta RL - \Delta Ev + \Delta ISW$$

$$\Delta ISW = V^{t+\Delta t} - V^t - \Delta IG + \Delta OL - \Delta RO - \Delta RL + \Delta Ev$$

Mass Balance of Lagoon Water

$$(M^t = 0, \quad \rho_l^{t+\Delta t} < \rho_{\max})$$

$$V^{t+\Delta t} \bullet \rho_l^{t+\Delta t} = V^t \bullet \rho_l^t + \Delta IG \bullet \rho_g^{t+\Delta t/2} - \Delta OL \bullet \rho_l^{t+\Delta t/2} + (\Delta RO + \Delta RL - \Delta Ev) \bullet \rho_f^{t+\Delta t/2} + \Delta ISW \bullet \rho_s^{t+\Delta t/2}$$

$$\overline{\rho_l^{t+\Delta t}} = (V^t \bullet \rho_l^t + \Delta IG \bullet \rho_g^{t+\Delta t/2} - \Delta OL \bullet \rho_l^{t+\Delta t/2} + (\Delta RO + \Delta RL - \Delta Ev) \bullet \rho_f^{t+\Delta t/2} + \Delta ISW \bullet \rho_s^{t+\Delta t/2}) / V^{t+\Delta t}$$

$$\overline{M^{t+\Delta t}} = 0$$

Fig.5 Volume and Mass Balance of Akyatan Lagoon

bodies are connected via a narrow channel. Condensation of salt in the lagoon water is taking place due to seepage of saline groundwater, inflow of sea water, and evaporation.

Unknown volume of sea water inflow to the lagoon during a simulation time span of Δt, ΔISW, can be calculated by the second equation describing the volume balance of the lagoon water. Another unknown factor ΔRO, the amount of runoff and overland flow during Δt, is identified so that salinity of the lagoon water is constant. Unknown variable $\rho_l^{t+\Delta t}$, density of the lagoon water at $t+\Delta t$, can be calculated by the second equation for the mass balance of the lagoon water. ΔIG (inflow of groundwater) and ΔOL (outflow of lagoon water) as well as ρ_g (density of groundwater) and ρ_l (density of lagoon water) can also be evaluated in the calculation process of simulation runs.

Table 1 shows the current and the projected rate of rainfall and evaporation in2070. The current evaporation and the precipitation rate are 1471.1 mm/year and 660.9 mm/year, respectively, while average values of future evaporation and rainfall rate projected for 2070 by using MRI and CCSR are 1549.3 mm/year and 375.2 mm/year, respectively. The difference between the evaporation and the precipitation rate enormously widens from 810.5 mm/year to 1174.1 mm/year during the coming 70 years. Since the current maximum depth of the lagoon is less than 1 meter, condensation process is considered to be extremely significant.

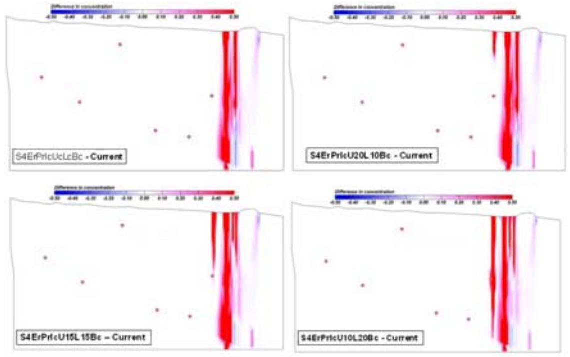


Fig.6 Difference in Groundwater Salinity between Runs of Current and Each Scenario with different Abstraction rates

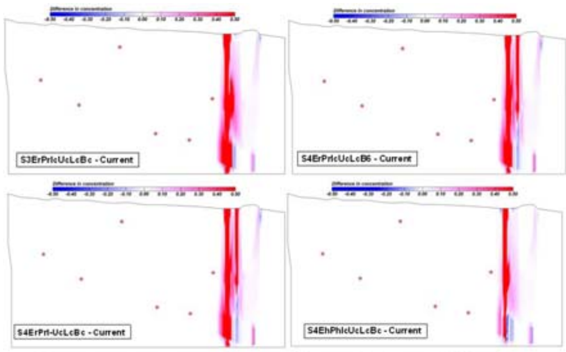


Fig.7 Difference in Groundwater Salinity between Runs of Current and Each Scenario with Different Components

5. Changes in groundwater table

According to the result of S3ErPrIcUcLcBc run, sea level rise of 0.88 m/century, increase in evaporation, and decrease in precipitation cause a slight decline of groundwater table. A build-up effect of groundwater table in the sand dune aquifer can be attributed to high salinity of groundwater beneath the lagoon and shrinkage of fresh water lens in the aquifer.

S4ErPrIcUcLcBc scenario is different from S3ErPrIcUcLcBc only in that projected sea-level rise of S4 is 0.37 m/century smaller than that of S3. The third and fourth projected results from the top of Fig.2 show that the amount of sea level rise will not affect much to groundwater table

S4ErPrIcUcLcB6 run indicates that decline of boundary head will cause significant dropdown of groundwater table.

According to the result of S4EhPhIcUcLcBc run, little increase in evaporation and little decrease in precipitation will not affect much on groundwater table. However, as shown in the fourth figure from the bottom of Fig.2 reduction of recharge from irrigation may cause groundwater table dropdown to some extent.

Enhanced groundwater abstraction can cause significant dropdown of groundwater table as shown in the last three figures of Fig.2. The shape of groundwater table and the degree of its dropdown depend largely on the amount of abstraction rates and its distribution.

6. Changes in groundwater salinity

In Figs. 6 and 7, changes in groundwater salinity for several scenarios are illustrated in terms of difference of concentration relative to the Mediterranean between the result of scenario runs and the current distribution shown in the lowest figure of Fig.3. These figures show finger-like, complicated distribution of salinized zone in groundwater beneath the lagoon. This can be attributed to the following factors. First, the width of the lagoon is currently 4,552m and will expand to 4,928 m in 2070. Second, the depth of the lagoon is less than 1 m and the bottom of the lagoon is relatively flat. Third, the lagoon is discharged in a complicated way by horizontal groundwater flow from inland and sand dune together with upward groundwater flow via an deeper aquifer of higher permeability.

groundwater flow via an deeper aquifer of higher permeability.

Impacts of abstraction on groundwater salinity are shown in Fig.6. Although the distribution and the rate of abstraction for scenario S4ErPrIcUcLcBc are the same as the current condition, high salinity zone in groundwater deeply penetrates beneath the lagoon. This is mostly attributed to condensation of salt in the lagoon water due to increased evaporation and decreased precipitation.

According as the abstraction rates increase near the lagoon, saline water in the lagoon infiltrates more into the aquifer and makes saline zone in groundwater beneath the lagoon deeper.

Higher sea level rise, as depicted by S3ErPrIcUcLcBc in Fig.7, may cause slightly larger salt-water intrusion compared to the result of S4ErPrIcUcLcBc of Fig.6. The impact of lowered inland boundary head and reduced recharge from irrigation on the formation of saline zone in groundwater does not seem to be recognizable.

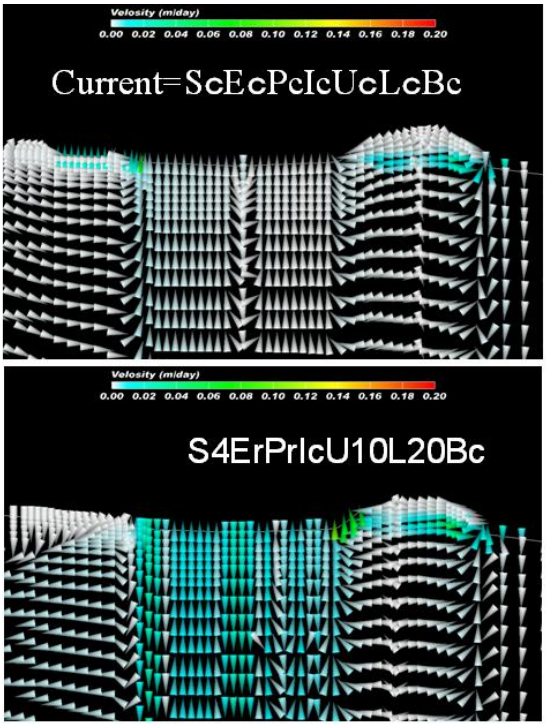


Fig.8 Distribution of Groundwater Flow Vectors

However, reduced evaporation and increased precipitation for S4EhPhIcUcLcBc compared to S4ErPrIcUcLcBc obviously reduces saline groundwater zone as shown in the bottom right figure of Fig.7.

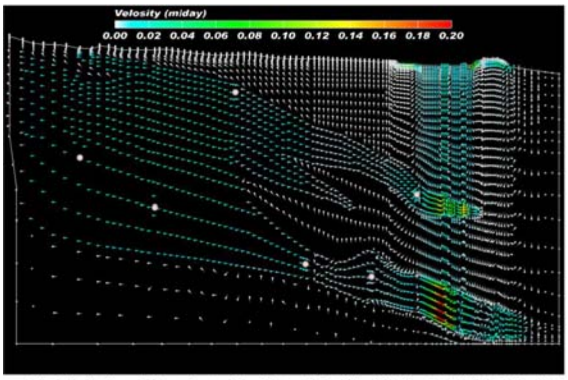


Fig.9 Distribution of Groundwater Flow Vectors in the Whole Region for S4ErPrIcUcLcB6

7. Groundwater velocity distribution

Fig.8 shows calculated groundwater flow vectors near the lagoon for the current stage and S4ErPrIcU10L20Bc. Due to high water table during the pre-irrigation stage, Groundwater discharges into the lagoon and there is no infiltration from the lagoon as shown in Fig.4. At the current stage, however, a slight downward vector can be seen near the center of the lagoon, which is attributed to the decline of water table from the pre-irrigation stage due to groundwater abstraction.

The result of S4ErPrIcU10L20Bc run exhibits more complicated flow pattern due to the significant decline of water table accompanied by enhanced abstraction. Discharge of fresh water into the lagoon from fresh-water lens of the dune aquifer is also enhanced.

Fig.9 shows groundwater velocity vectors in the whole analytical domain. The greatest velocity is seen in the lowest part of the aquifer beneath the lagoon. It can also be observed that fresh groundwater supplied along the mountainous boundary flows mostly in the high permeable zone toward the Mediterranean and flows upward beneath the lagoon.

8. Salinity of the lagoon

Salinity of the lagoon can be affected by evaporation, precipitation, run-off and overland flow, sea-water inflow, and groundwater discharge and recharge. As mentioned before, the amount of run-off and overland flow is unknown. Therefore, a factor ROF, defined by $(\Delta RO + \Delta RL) / \Delta RL$, was inversely identified so that the simulated salinity of the lagoon remains constant for a certain period of time. The identified ROF is 2.1404.

Fig.10 shows temporal changes in the salinity of the lagoon. Small change in ROF can affect the salinity as shown by the result of ScErPrIcUcLcBc-2.000, where ROF is 2.000. Reduced evaporation and increased precipitation of S4EhPhIcUcLcBc can speed down the accumulation of salt in the lagoon compared to S4ErPrIcUcLcBc. Salt accumulation in the lagoon can be delayed by sea level rise as shown by the result for S3ErPrIcUcLcBc, but eventually reaches to a higher salinity level compared to S4ErPrIcUcLcBc.

9. Salt accumulation on land

The amount of salt accumulated on land surface for scenarios S4ErPrIcUcLcBc and S4ErPrIcU20L10Bc is shown in Fig.11. In the low-lying area near the lagoon where groundwater seeps out, discharging groundwater transports

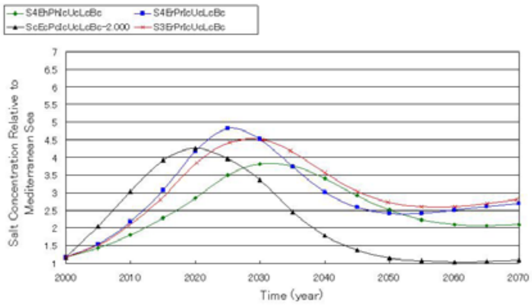


Fig.10 Temporal Changes in the Salinity of the Lagoon

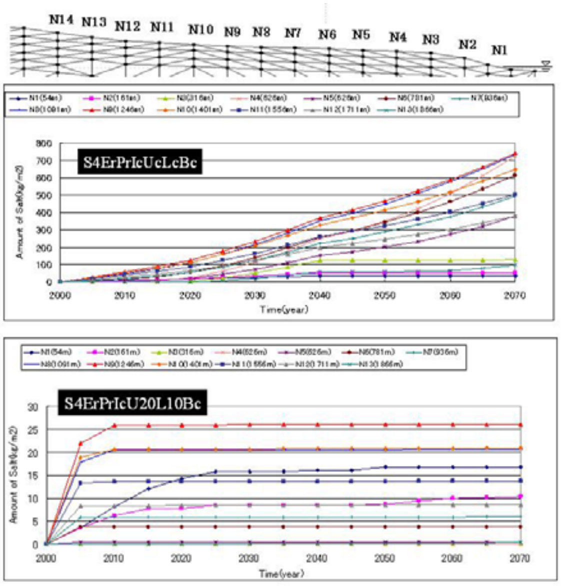


Fig.11 Accumulated Salt of Land Surface

salt on land surface and salt accumulates there due to evaporation. Since the mechanism for the accumulated salt to be carried away by overland flow or drainage into open channels has not been taken into consideration in the conceptual model, the salt transported by groundwater onto land surface remains there.

The maximum amount of the accumulated salt reaches more than 700 kg/m^2 for S4ErPrIcUcLcBc after 70 years time span since most of the low-lying area near the lagoon remains to be a seepage face, while, for S4ErPrIcU20L10Bc, accumulation of salt on land surface stops after a certain period of time due to dropdown of the water table caused by abstraction. The simulated amount of the accumulated salt has to be carefully evaluated. It should be noted that there are uncertainty in input data of initial salinity distribution in groundwater together with boundary conditions of prescribed flux and its salinity, which should be provided along land surface. To ensure the accuracy of projected results, input data should be based on a detailed field studies.

10. Summary

Followed by two-steps calibration processes, projections for assessing impacts of climate change on subsurface water environment of LSRB were performed for various scenarios based on sea-level rise, climatic elements, irrigation practice, river run-off, and groundwater abstraction. Outputs of the projections were explained in terms of salinity of Akyatan lagoon and groundwater, groundwater table and velocity, and accumulation of salt on lands. The results can be summarized as follows;

Combination of sea-level rise, increasing evaporation, and reducing precipitation can cause significant increase in salinity in the lagoon.

Increased salinity in the lagoon in turn deteriorates groundwater quality. Salinity of groundwater can also drastically increase beneath the lagoon.

Build-up of high-saline zone in the aquifer beneath the lagoon can impede fresh groundwater flow and can cause water logging on land surface.

Water logging and increased salinity in shallow groundwater can cause severe accumulation of salt on land surface. All of increasing evaporation, sea-revel rise, and increasing groundwater abstraction contribute for the salt accumulation on land. Thus, drainage practice is strongly recommended in the future to minimize impacts of salt accumulation on land surface.

Groundwater table can decline to the level 25 m below sea level in accordance with enhanced groundwater abstraction.

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Projection of the Impact of Climate Change on the Surface Energy and Water Balance in the Seyhan River Basin Turkey

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1. Introduction

In this study, estimation of the surface energy and water balance components and related hydrological variables of the Seyhan River basin Turkey is attempted through the off-line simulation of the LSM (Land Surface Model) forced by the product of the RCM (Regional Climate Model) for both present and future (warm-up) condition. To assess the impact of climate change on agricultural production system including human reaction (farm management, cropping patterns, etc.), three patterns of landuse scenario are used in the numerical simulation. Furthermore, two kind of future climate scenarios are applied to reduce the uncertainty in the assessment of surface energy and water balance.

2. Basin Characteristics

Detailed physical boundary of the Seyhan basin was carefully defined by Turkish group according to the large scale maps. Landuse/landcover dataset was produced from satellite images of Landsat (see the report of Vegetation sub-group). According to this dataset, current four major landcover conditions of the Seyhan basin are grassland (31.74%), dry cropland (22.22%), evergreen needleleaf forest (19.37%), and irrigated cropland (15.21%).

Several soil physical parameters such as porosity, field capacity, root zone depth, etc. are also extracted from ECOCLIMAP (http://www.cnrm.meteo.fr/gmme/). ECOCLIMAP is a new global dataset at a 1 km resolution. It is intended to be used to initialize model parameters in LSMs.

3. SiBUC and irrigation scheme

SiBUC (Simple Biosphere including Urban Canopy)[3)] land surface scheme was designed to treat the landuse condition (natural vegetation, cropland, urban area, water body) in detail. Especially irrigation scheme for the various kinds of cropland is implemented[4)]. Basic concept of the irrigation scheme is to maintain the soil moisture within appropriate ranges which are defined for each growing stage of each crop type. The irrigation rules for cropland are described by seeding (planting) date, harvesting date, the periods of each growing stage, lower limit of soil wetness in each growing stage, and amount of water supplied in one time. As a default parameter, lowest values of soil wetness for each growing stage and each crop type are prepared from agricultural manual in China.

In this study, maize and citrus are selected as representative of various irrigated crops. According to the information from Irrigation and Drainage sub-group, irrigation period for maize and citrus are from May 23 to Aug 6, from May 14 to Oct 9, respectively. For the future climate simulation, growing period is shorten by 10 days considering the faster growth in warmer condition. **Table 1** shows a date (DOY: day of year) of growing period used for present and future simulations.

Table 1 : Start and end of irrigation period

		start	end	period
present	maize	143	218	75
	citrus	134	282	148
future	maize	143	208	65
	citrus	134	272	138

4. Experimental design

The product of RCM (8.3km product) is utilized as forcing of land suface model. Seven meteorological components (precipitation, downward short-wave and long-wave radiation, wind speed, air temperature, specific humidity, pressure) are

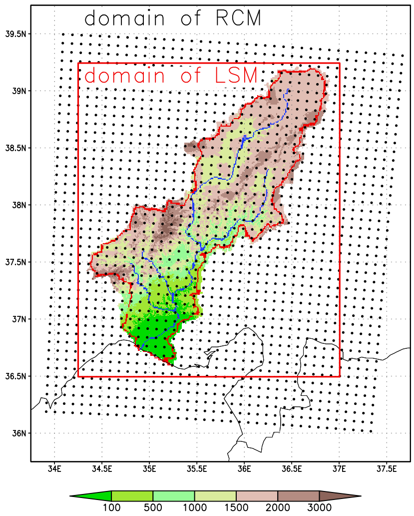

Fig. 1 : Model domain of RCM and LSM

available in hourly time interval.

The simulation period is from 1994 to 2003 for present climate condition. The amount of precipitation during this period is normal. Also, future climate condition (2070's) is produced by so called 'pseud warm-up' method. In this method, boundary condition for RCM is assumed by a linear coupling of the re-analysis data (observation) and the trend component of the global warming estimated by GCM. In this way, pseud warm-up utilizes the synoptic scale variability of the current condition (observation). Since the period is only ten years, the projected future climate condition does not necessarily mean the 'average' future condition. Considering that the original present condition is situated in 'normal' condition, provided future condition is also regarded to be normal.

For future climate condition, two products were produced from different GCM results (MRI and CCSR). For the landcover condition, three land use scenarios (A0:no adaptation, A1:adaptation 1, A2: adaptation 2) are provided. By the combination of climate condition and landuse scenario, 6 simulations were conducted for future. **Table 2** is a summary of the simulation condition and the name of each simulation.

Fig. 1 shows the model domain of RCM and land surface model (LSM). Model domain of RCM covers the whole Seyhan River basin, and 2.75 degree × 2.75 degree area (E34.25-37.0, N36.5-N39.25) is selected as simulation domain

Table 2 : Climate and landuse condition for each simulation

runname	climate	landuse
P0	present	current
M0	warmup (MRI)	no adaptation
M1	warmup (MRI)	adaptation 1
M2	warmup (MRI)	adaptation 2
C0	warmup (CCSR)	no adaptation
C1	warmup (CCSR)	adaptation 1
C2	warmup (CCSR)	adaptation 2

Table 3 : Fraction of four major landcover class for each landuse scenario

	Forest	Grass	Irrigated	Drycrop
A0	19.37	31.74	15.21	22.22
A1	19.37	53.97	13.45	0.00
A2	16.44	34.67	16.51	20.92

Forest: Evergreen Nedleleaf Forest
Grass: grassland, short vegetation
Irrigated: Irrigated farmland (total)
Drycrop: rain-fed wheat

for LSM. This area is divided by each 5 min (about 10km) grid boxes (33 × 33 grids). SiBUC uses mosaic approach to incorporate all kind of land-use. **Fig. 3** shows the fraction of four major landcover conditions for each landuse scenario, and basin average landcover fraction is summarized in **Table 3**.

5. Vegetation dynamics

Satellite derived vegetation indices such as NDVI (Normarized Difference Vegetation Index), especially its time series, is very useful and powerful for describing the actual land-surface status[1). Here, NDVI is a common index to express the activity of vegetation.

SPOT VEGETATION Product (http://free.vgt.vito.be/) is utilized to well express vegetation dynamics. This is a 10-day composite dataset which has about 1km resolution. The included cloud noises were removed by BISE[2) method. Furthermore, average seasonal cycle dataset was produced from the collected 6-years period (from 1999 to 2004). Leaf area index (LAI) is calculated from NDVI and vegetation class. Other time-varying vegetation parameters such as greeness fraction (Nc), vegetation coverage (Vc) are extracted from ECOCLIMAP database. Since SiBUC adopts mosaic scheme to take subgrid scale heterogeneity into account, these vegetation parameters are aggrigated within each landcover class in each LSM grid (10km). Owing to these datasets, spatial distribution and time evolution of vegetation parameters can be well described.

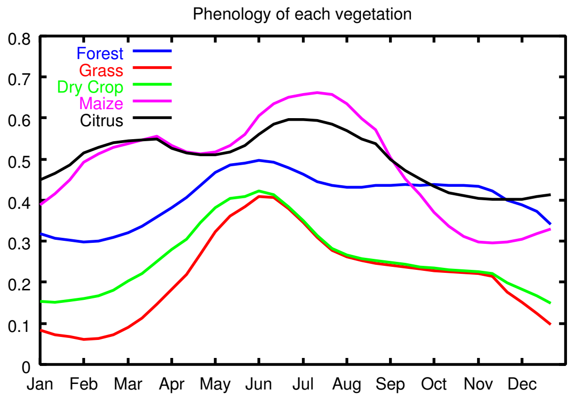

Fig. 2 : Average seasonal cycle of NDVI for each vegetation type

On the other hand, there is no reliable information about the vegetation status in future climate condition. As for future landuse, three scenarios are prepared (A0, A1, A2). To be consistent with landcover condition, vegetation parameters must be changed accordingly when that pixel is change from current landcover. According to current landcover information, average seasonal cycles of vegetation parameters (NDVI, Nc, Vc) are calculated for each vegetation type. Then, they are allocated to landcover changed pixels (1km) in A1 and A2 scenario. **Fig. 2** shows average seasonal cycles of NDVI for each vegetation type. Same parameter values are allocated to remaining pixels (same landcover as current). Finally, these parameters are aggregated for each landcover class in each LSM grid (10km).

6. Results and Discussions

Fig. 5 to **Fig. 8** show the annual (10-year average) water balance components (precipitation, runoff, snowfall, maximum SWE (Snow Water Equivalent), respectively) for present climate and their difference in **M0** and **C0** simulations. **Figs. 9** and **10** show the annual (10-year average) evaporation and irrigation water for present climate, and they compare the difference of climate change impact in **A1** and **A2** landuse scenario.

Annual precipitation of present climate is about 400mm in the upstream region, above 1000mm in the middle region, and about 700mm in the Seyhan delta (**Fig. 5(a)**). As for the impact, precipitation will decrease in the whole Seyhan basin, especially, reduction is more than 250mm in the middle and delta region for both **M0** and **C0** simulations. Runoff also decreases as a result of reduction of precipitation, and the impact is especially large in the high mountain region due to the increase of evaporation (**Figs 9(b)(c)**).

As for snowfall, reduction is larger in **C0** simulation mainly because of warmer temperature. As a result, maximum SWE is projected to decrease more in **C0** simulation. **Fig. 4** shows the seasonal evolution of total amount of water stored as snow in whole Seyhan basin for present and future climate. Maximum SWE is almost 0.4 Gt in present climate, while it will decrease as small as 0.1 Gt in future climate. Here future climate is a mean of **M0** and **C0** simulation.

As for the Seyhan delta (irrigated area), annual evaporation is about 800mm, and about 500mm of irrigation water must be supplied to keep the soil wetness during the growing season in hot and dry summer. Although precipitation will decrease in the whole Seyhan basin, some part of evaporation will increase. Such area coincides with the area where SWE will decrease so much. As a result of reduction of snow cover, those area will receive more short-wave radiation (albedo effect). These energy will contribute to the increase of evaporation in spring season (see **Fig .12**). The difference between **Fig .9(b)** and **Fig .9(c)** is large where irrigated area is abandoned and dry cropland is converted into grassland. Although the growing period is shorten, irrigation water is projected to increase by the higher evaporation demand in the growing season, and the reduction of soil moisture at the begining of growing period (see **Fig .13**).

As a basin average, annual water balance components for present and future climate condition for each landuse scenario are summarized in **Table 4**. Precipitation is projected to decrease about 170mm, while evapotranspiration and runoff decreases about 40mm and 110mm, respectively. Considering the amount of current water balance component, the impact on runoff is significantly large.

Table 4 : Basin average annual water balance components

unit:mm	Present	Future(A0)	Future(A1)	Future(A2)	diff(A0)	diff(A1)	diff(A2)
Prec	634.0	464.3	464.3	464.3	-169.7	-169.7	-169.7
Evap	411.3	373.9	365.4	378.9	-37.5	-45.9	-32.4
Runoff	281.6	168.9	168.1	170.4	-112.6	-113.5	-111.2
Irrig	53.8	69.7	60.4	76.4	15.9	6.6	22.5
delS	-5.0	-8.7	-8.8	-8.7	-3.7	-3.7	-3.6

To see the impacts from climate change for each landcover type, model outputs within the target basin are aggregated according to the dominant landcover condition (dominant landcover is larger than 0.8). **Fig. 11** shows the time series of energy balance components at different landcover (grassland, forest, dry cropland, irrigated crop). In this figure, lines are for present climate and dots are for future climate (average of **M0** and **C0**). In the grassland, net radiation and latent heat becomes larger in May, while sensible heat becomes larger from May to August. In the forest, impact on net radiation is very small. From May to August, latent heat becomes smaller and sensible heat vise versa. In the dry cropland, latent heat becomes larger in winter and spring, while it becomes much smaller in summer. Dry cropland gets much impact on all energy balance components is larger than other landcover. By the way, it must be noticed that most of the dry cropland area are located in the area where the reduction of precipitation is very large. Irrigated crop area is also located in the area where the impact of precipitation is very large. But the impact on surface energy balance is relatively small due to irrigation.

Acknowledgement

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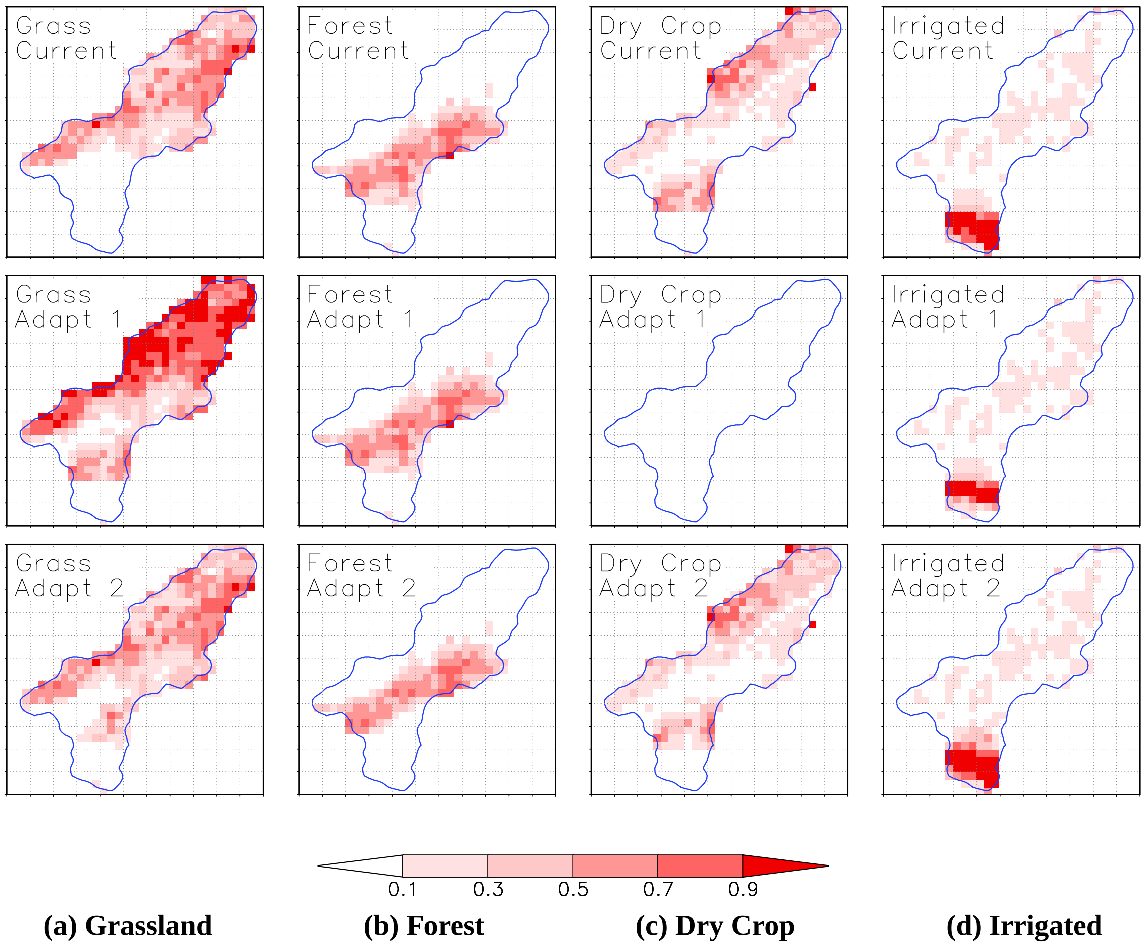


(a) Grassland **(b) Forest** **(c) Dry Crop** **(d) Irrigated**

Fig. 3 : Landcover fraction of each grid (top: Current, middle:Adapt 1, bottom:Adapt 2)

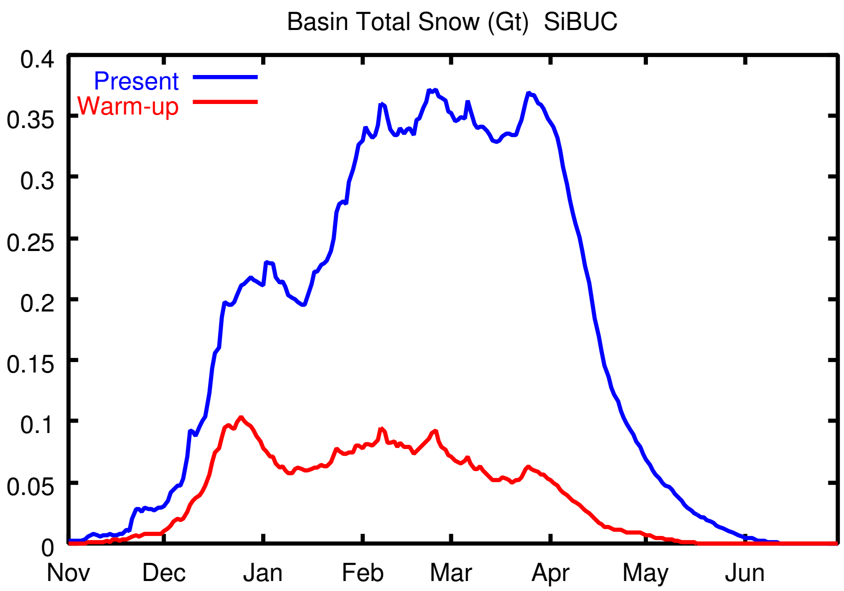
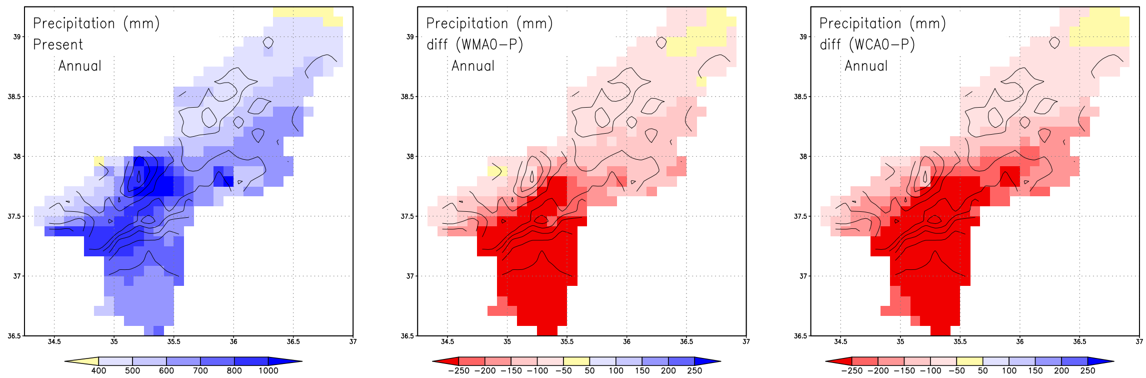
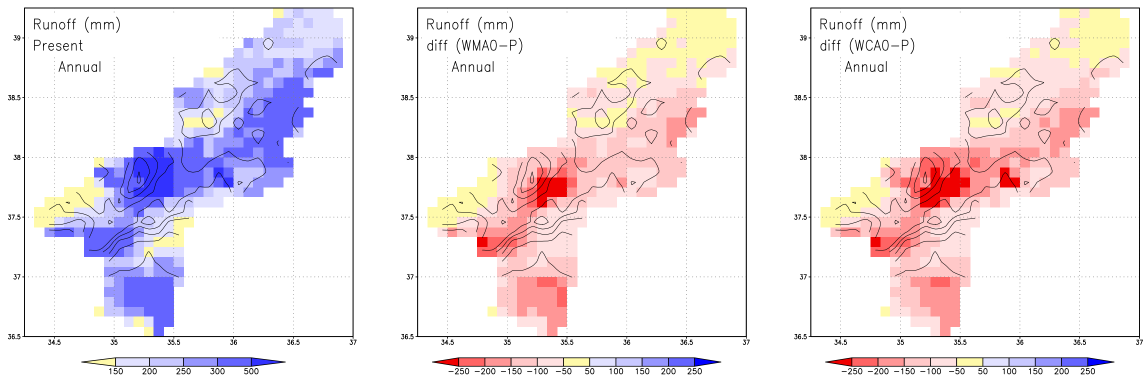


Fig. 4 : Basin total storage of snow (blue:present, red:future)



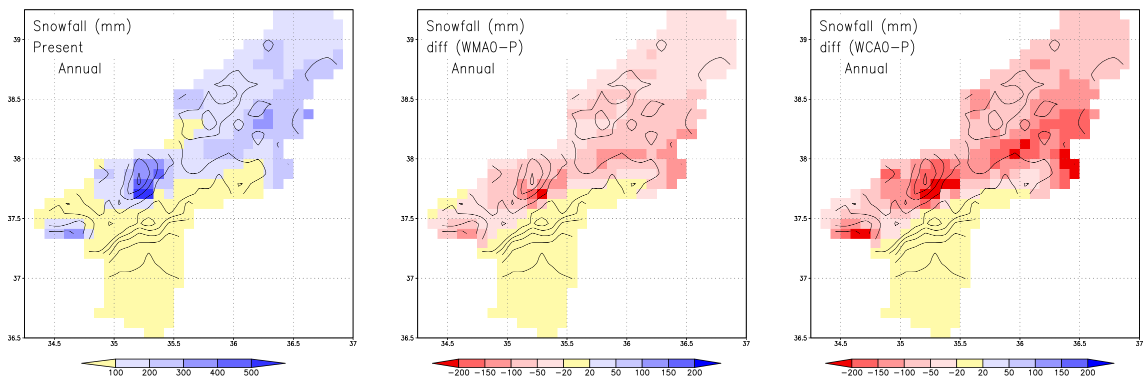
(a) Present (b) Diff(MRI) (c) Diff(CCSR)

Fig. 5 : Annual precipitation of present climate and its difference in MRI and CCSR run



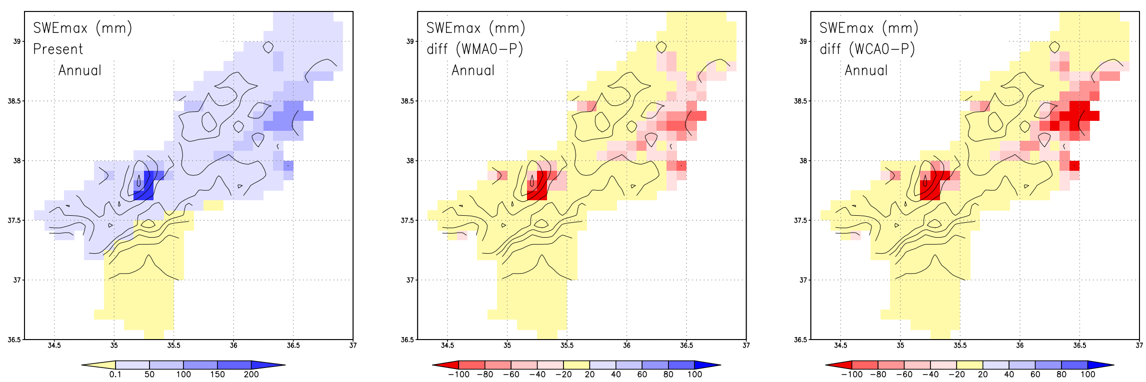
(a) Present (b) Diff(MRI) (c) Diff(CCSR)

Fig. 6 : Annual runoff of present climate and its difference in MRI and CCSR run



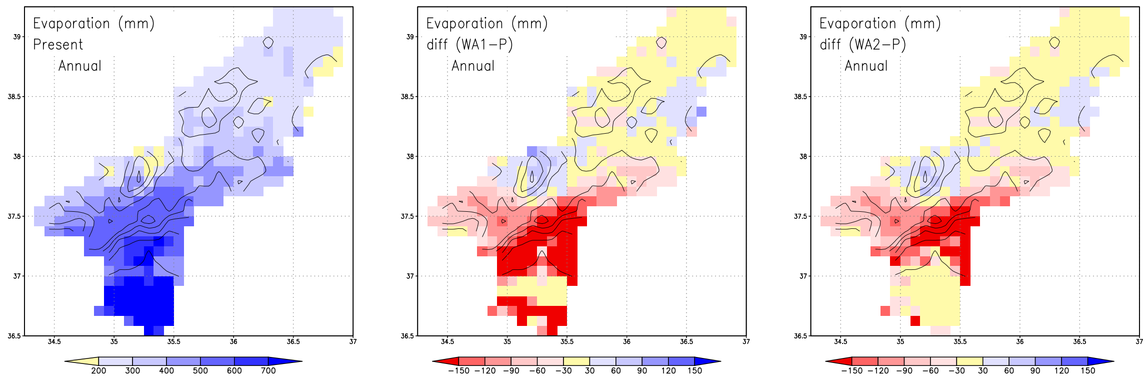
(a) Present (b) Diff(MRI) (c) Diff(CCSR)

Fig. 7 : Annual snowfall of present climate and its difference in MRI and CCSR run



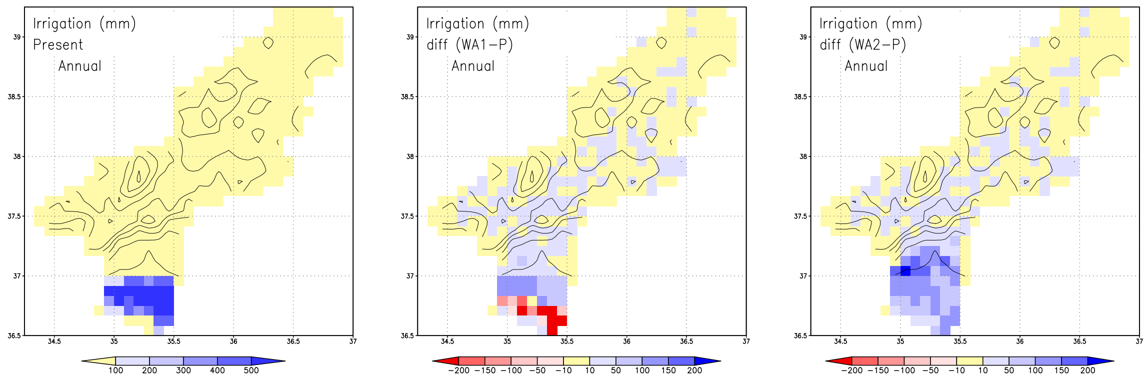
(a) Present (b) Diff(MRI) (c) Diff(CCSR)

Fig. 8 : Maximum SWE of present climate and its difference in MRI and CCSR run



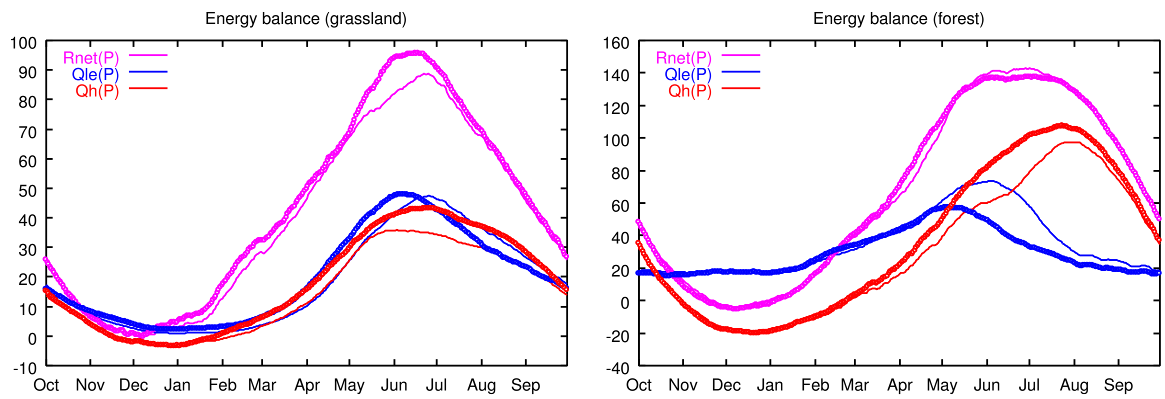
(a) Present **(b) Diff(A1)** **(c) Diff(A2)**

Fig. 9 : Annual evapotranspiration of present climate and its impact in A1 and A2 scenario

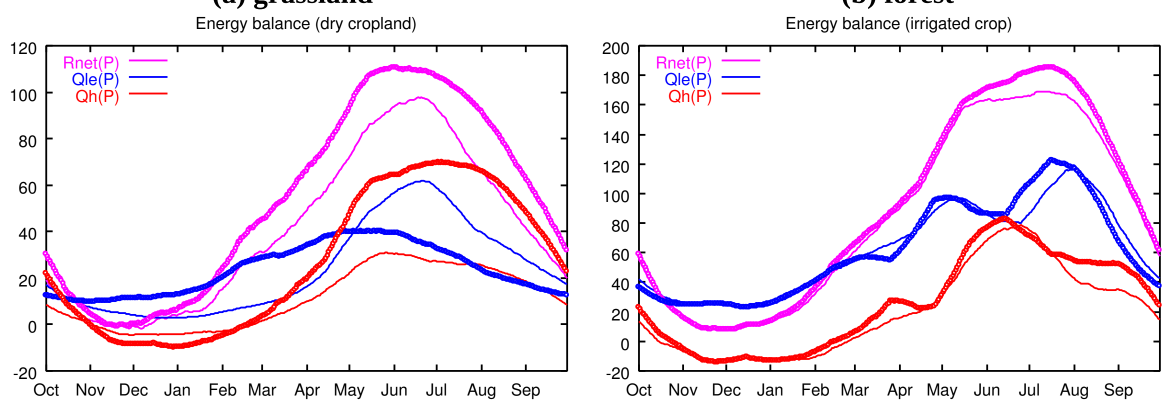


(a) Present **(b) Diff(A1)** **(c) Diff(A2)**

Fig. 10 : Annual Irrigation water of present climate and its impact in A1 and A2 scenario



(a) grassland **(b) forest**



(c) dry cropland **(d) irrigated crop**

Fig. 11 : Comparison of seasonal cycle of surface energy balance for present and future climate at four different landcover condition (Qle: latent heat, Qh: sensible heat)
lines: present, dots: future (average of M0 and C0 run)

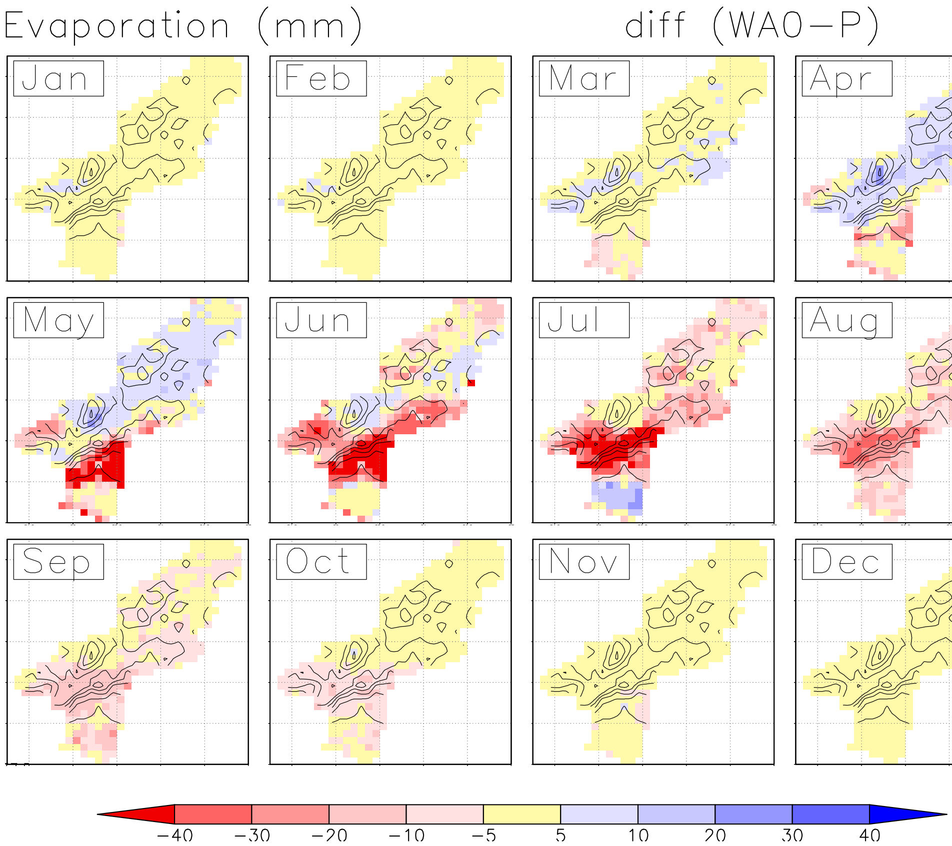


Fig. 12 : Impact of climate change on evaporation at each month

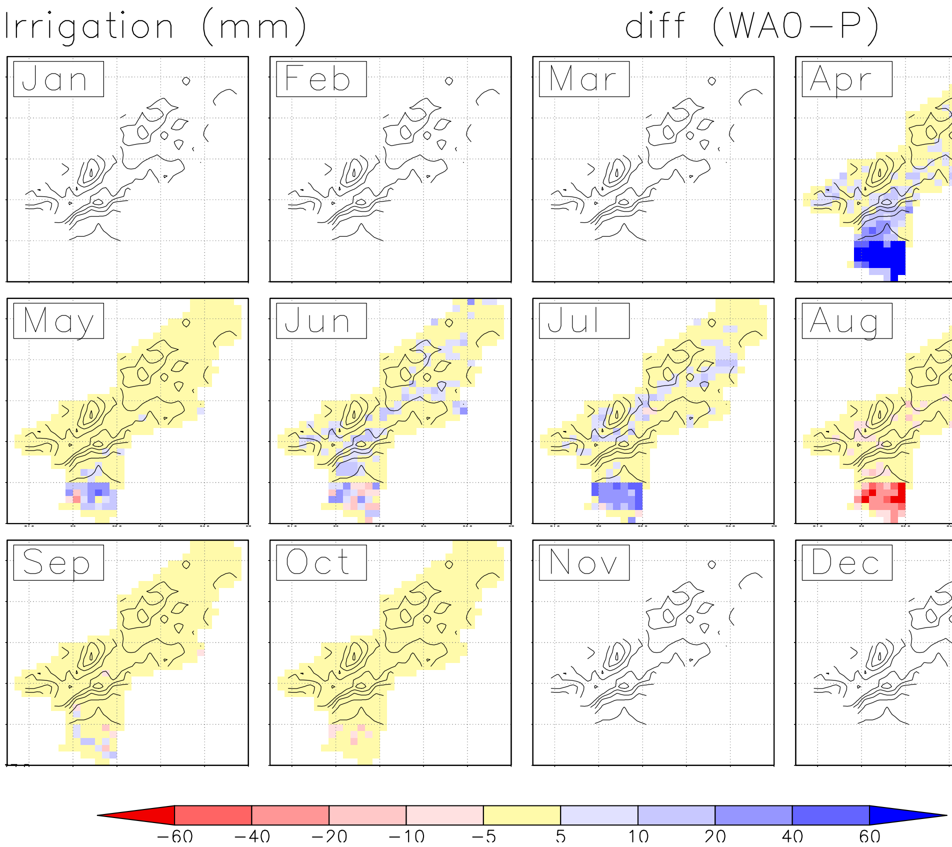


Fig. 13 : Impact of climate change on irrigation water at each month

Assessing the Impact of Climate Change on the Water Resources of the Seyhan River Basin, Turkey

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1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report concluded that there was evidence that most of the warming observed over the last 50 years is attributable to human activities. With the expected build-up of greenhouse gases in the atmosphere, it is anticipated that the climate will continue to change throughout the 21^{st} century. Moreover, it is thought that global warming will have a significant impact on the hydrology and water resources of river basins.

Basins that have a large fraction of runoff driven by snowmelt, such as the Seyhan River Basin in Turkey, will be especially sensitive to global warming, because the temperature determines the fraction of precipitation that falls as snow and the timing of snowmelt. In this paper, the climate projected using two general circulation models (GCMs) under the Special Report on Emissions Scenarios (SRES) A2 emissions scenario was used to drive hydrologic models to assess the impact of climate change on the water resources of the Seyhan River Basin.

2. Study Basin

The Seyhan River Basin (21,700 km^2) is located in southern Turkey between 34.25-37.0°E and 36.5-39.25°N. The lower basin is dominated by the Mediterranean climate, while the middle and upper basins are influenced by the Continental climate.

The annual precipitation is about 700 mm in the coastal area, increases to approximately 1,000 mm at higher elevations, and decreases to about 400 mm in the northern area. The annual inflow at the Seyhan Dam ranges between 3.7 and 7.3 Gm^3 and averages 5.5 Gm^3. The Seyhan and Catalan Dams have storage capacities of 0.8 and 1.6 Gm^3, respectively. The stored water is used mainly for irrigation. According to the 1990 statistics, the amount of irrigation water used annually is about 1.4 Gm^3, and it is increasing annually (**Figure 1**). The amount of domestic water used annually is 0.1 Gm^3 according to the 2003 statistics.

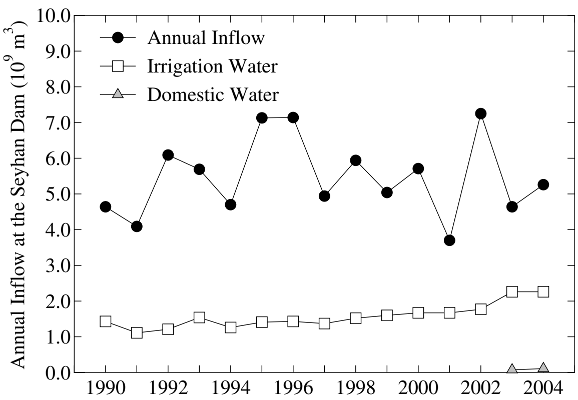
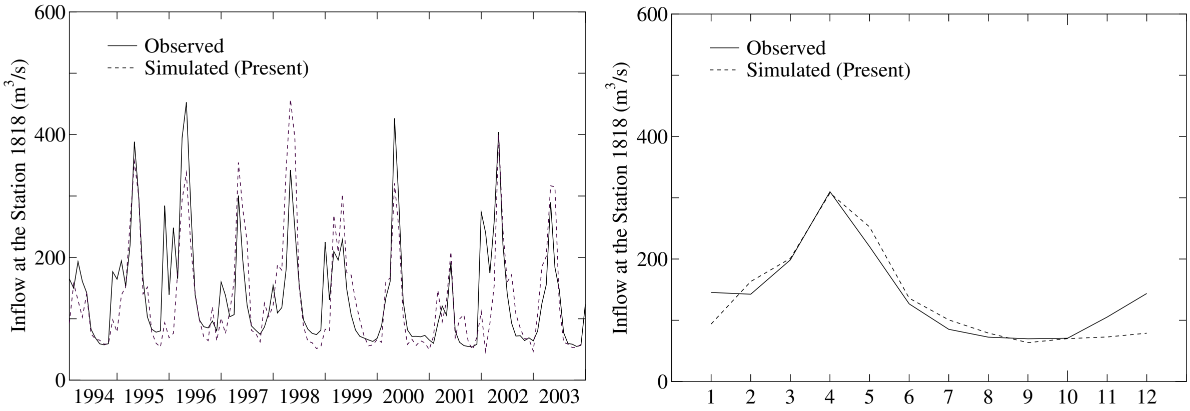


Fig.1 Annual inflow, irrigation water, and domestic water use at the Seyhan Dam.

3. Approach

3.1 Downscaling Method

The raw outputs of GCMs are inadequate for assessing the impact of climate change on the hydrology and water resources of river basins, because the temporal and spatial resolution of GCMs is too coarse compared to those of hydrologic models that are applied to river basins. This study applied a dynamic downscaling method called pseudo warming (Sato *et al.*, 2006) to connect the output of the raw GCMs and river basin hydrologic models.



(a) Monthly inflow (b) 10-year average monthly inflow

Fig.2 Simulated hydrograph at Station 1818.

The pseudo warming downscaling method is as follows. For the current climate simulation, the pseudo-warming method uses reanalysis data as a boundary forcing of the regional climate model (RCM). A specially created boundary condition, in which changes in meteorological variables projected in a GCM simulation are added to reanalysis data, is used to simulate global warming.

The GCMs used in this study were MRI-CGCM2 (Yukimoto *et al.*, 2001) and CCSR/NIES/FRCGC-MIROC (K-1 Model Developers, 2004) under SRES A2. The downscaled data covered two subset periods (the 10 years present and the 10 years future; Kimura *et al.*, 2007), and were used to drive hydrologic models to assess the impact of climate change on the water resources of the Seyhan River Basin.

3.2 Hydrologic Model

We used a land surface model (Simple Biosphere including Urban Canopy (SiBUC); Tanaka and Ikebuchi, 1994) to estimate the surface energy and water balance components. In addition, we used the stream flow rooting model of Hydro-BEAM (Kojiri *et al.*, 1998) to simulate river discharge and incorporated a reservoir model in this flow rooting model.

The region simulated was a 2.75 × 2.75° area (34.25-37.0°E and 36.5-39.25°N) with a 5-minute latitude-longitude spatial resolution (33 × 33 grids). The simulated hydrograph at station 1818 is shown in **Figure 2**. There were some discrepancies between the simulated and observed discharge. Nevertheless, since the input data were downscaled data, the hydrologic models reproduce the river discharge at station 1818. The annual inflow at the Seyhan Dam is shown in **Figure 3**. This figure shows that the simulated results agree with the observed data.

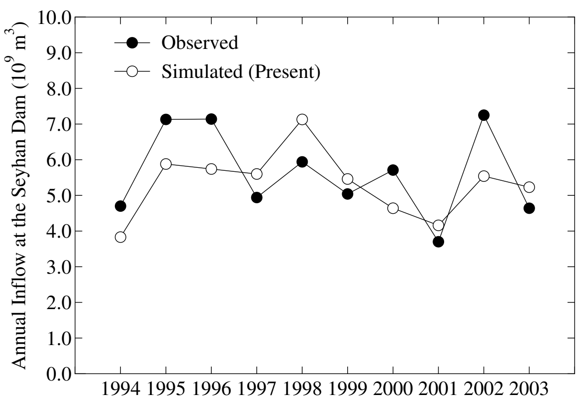
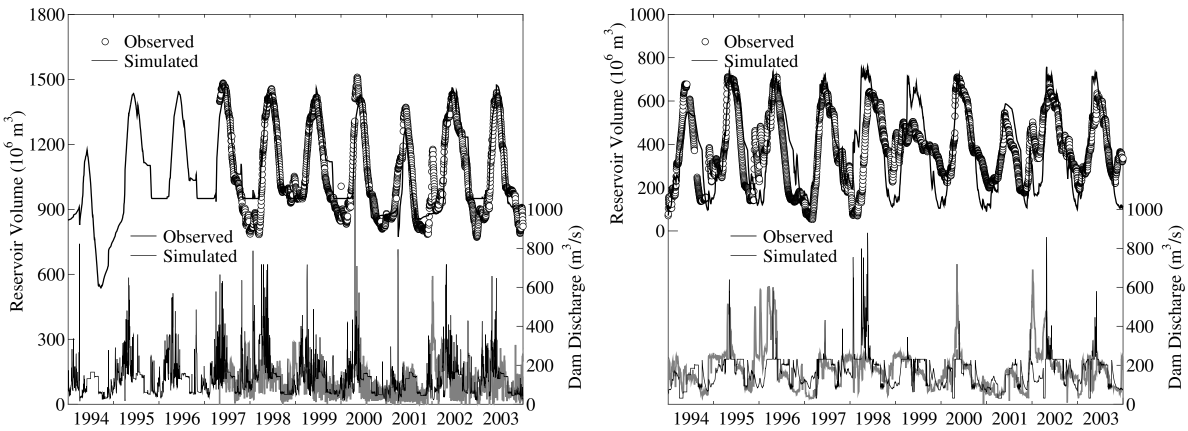


Fig.3 Annual inflow at the Seyhan Dam.

3.3 Reservoir Models

We developed reservoir models to simulate the reservoir operations of the Seyhan and Catalan Dams. We examined the historical record, including the inflow, water level, and dam discharge, and interviewed the dam operators about the actual operations. From these analyses, we used the following operational rule as a basic rule: water is stored to maintain a target operational water level and the demand water is released regardless of the level.

The simulated river discharge using the flow rooting model described in section 3.1 is input into the reservoir models. The target operational wa-



(a) Catalan Dam　　　(b) Seyhan Dam

Fig.4　Simulated reservoir volume and discharge.

ter level is the average of historical operational records, and the demand water is the actual water withdrawal for irrigation and domestic use.

The simulated reservoir volume and dam discharge at the Seyhan and Catalan Dams are shown in **Figure 4**. The simulated volume and discharge agreed with the observed values. Although no results are shown in here, we found that the established reservoir models also reproduced the hydroelectric generation quite well. **Figure 5** shows the simulated inflows with and without the reservoir models. This figure clearly indicates that the reservoir models can reproduce the actual reservoir operations.

3.4 Land and Water Use Scenarios

The land and water use at the present period were the actual conditions in the Seyhan River Basin. For the future period, the following three scenarios were used:

(a) Future: The land and water use are the same as at present.

(b) Adaptation 1: The land and water use are under low investment conditions. The cropping pattern in the Lower Seyhan Irrigation Project (LSIP) simulated by Umetsu *et al.* (2007) is used to estimate the water demand. In addition, the effects of global warming on the irrigation water requirements are considered using the SiBUC simulation.

(c) Adaptation 2: The land and water use are un-

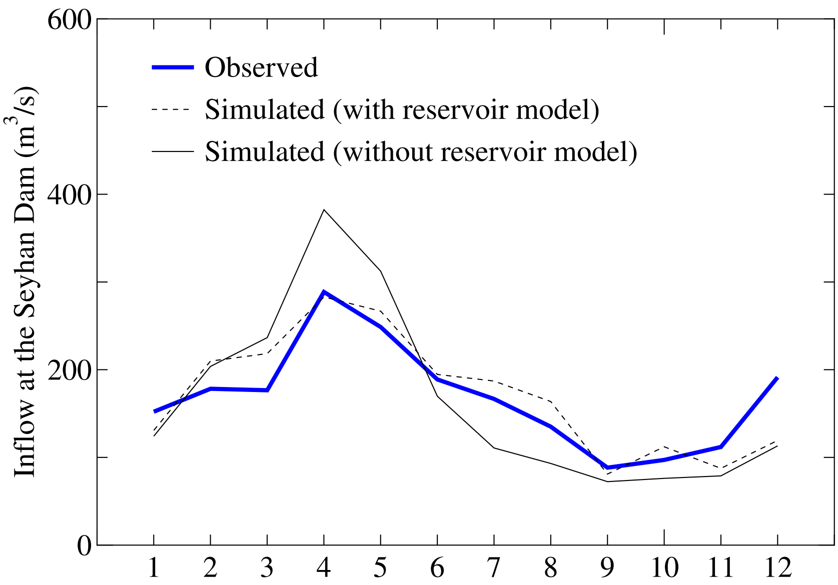


Fig.5　Simulated hydrograph at the Seyhan Dam.

der high investment conditions, in which 25% of the rain-fed winter wheat is converted to irrigated crop, and citrus is cultivated in this area. The cropping pattern in the LSIP simulated by Umetsu *et al.* (2007) is used as a future scenario to calculate the water demand. The effects of global warming on the irrigation water requirements are also considered using the SiBUC simulation.

4. Results

4.1 Temperature, Precipitation and Stream Flow Changes

The monthly mean temperatures are compared in **Figure 6**. The average annual temperature change for the Seyhan River Basin was +2.0°C in the Meteorological Research Institute GCM (MRI) and +2.7°C in the Center for Climate System Research GCM (CCSR). The monthly precipitation is compared in **Figure 7**. The average annual precipitation change for the Seyhan River Basin was -159 mm in MRI and -161 mm in CCSR. The decreases in precipitation in January, April, October, November, and December were greater than in the other months.

The monthly mean inflow at station 1818 is shown in **Figure 8**, which shows that the future inflow will decrease remarkably compared to the present. In addition, the decreases in the April, May, and June inflow are greater than in the other months, and the peak monthly inflow occurs earlier than at present.

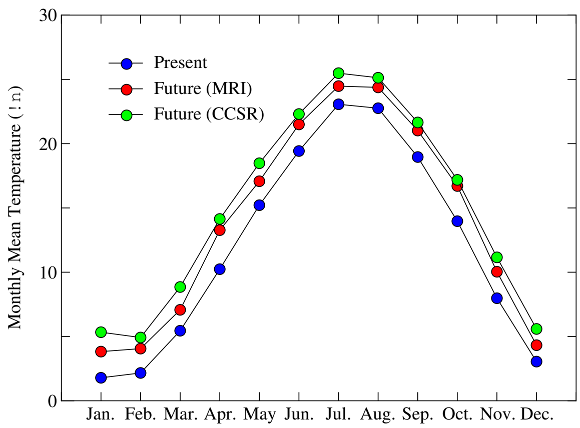


Fig.6 Temperature changes predicted under different models.

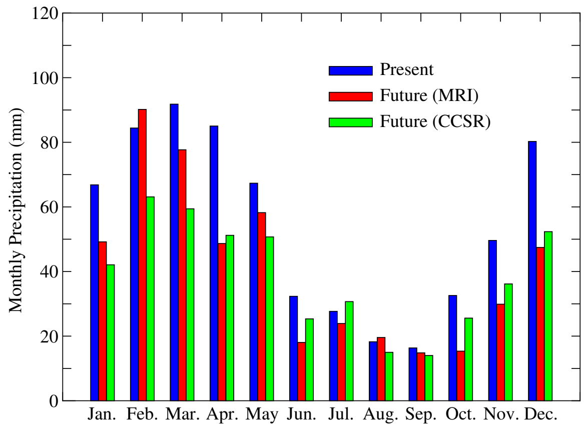


Fig.7 Precipitation changes predicted under different models.

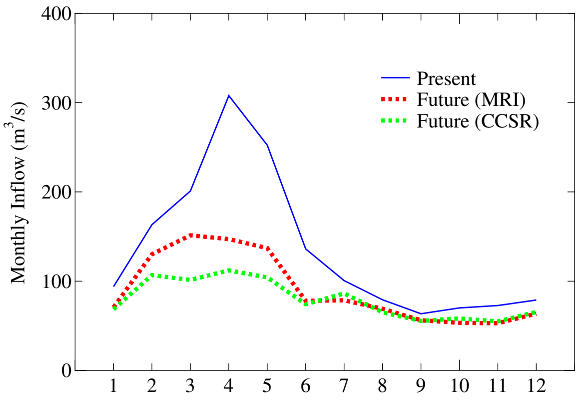


Fig.8 Stream flow changes predicted under different models.

4.2 Water Resources System Effects

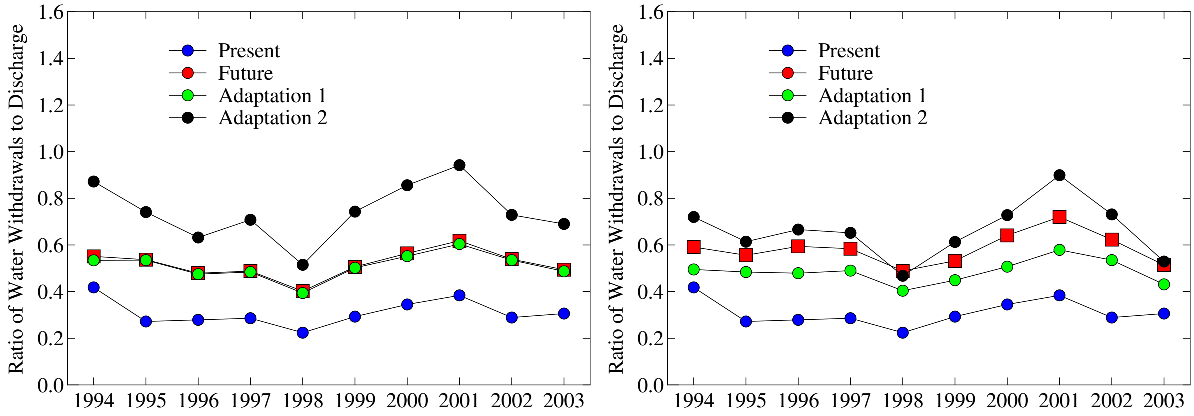
The ratio of water withdrawal to discharge is shown in **Figure 9**. Many studies (*e.g.*, Alcamo *et al.*, 2003; Oki and Kanae, 2006) have reported that a region is considered highly water stressed if this index exceeds 0.4. The ratio is less than 0.4 at present, while it ranges from 0.4 to 0.7 in the future period, from 0.4 to 0.6 for Adaptation 1, and from 0.5 to 1.0 for Adaptation 2.

The reservoir volume at the Seyhan Dam is shown in **Figure 10**. The reservoir volume for the future and Adaptation 1 is less than at present, and in a few cases, the reservoir is empty. By contrast, in Adaptation 2, the reservoir is frequently empty.

The reliability of the dams is shown in **Figure 11**. The reliability (R) is defined using the following equation:

$$R = V_s/V_d \tag{1}$$

where V_s is the volume of water supplied, and V_d is the volume of water demanded. The index at



(a) MRI (b) CCSR

Fig.9 Ratio of water withdrawal to discharge.

present is usually 1. This indicates that the dams can supply the entire demand. The value in the future and for Adaptation 1 is always 1 in MRI and ranges from 1 to 0.95 in CCSR. By contrast, for Adaptation 2, the reliability is from 1 to 0.7 in MRI and CCSR.

These results lead to the following conclusions. Although the ratio of water withdrawal to discharge will increase due to the effects of global warming (decreased discharge), it is possible to supply the demand for water from the water resources system in the future case and Adaptation 1. By contrast, the effects of global warming and the increased demand for water in the upper basin will lead to water scarcity at the LSIP in Adaptation 2.

5. Conclusions

In this study, the climate projected using two GCMs under SRES A2 was used to drive hydrologic models to assess the impact of climate change on the water resources of the Seyhan River Basin. The results showed that:

1. Compared to the present, decreased precipitation will result in a considerably decreased inflow, in which the peak monthly inflow occurs earlier than at present;

2. The ratio of water withdrawal to discharge will increase due to the effects of global warming (decreased discharge), although it is possible to supply the demand for water based on the water resources system in the future and using Adaptation 1; and

3. The effects of global warming and the increased demand for water in the upper basin will lead to water scarcity at the LSIP in the case of Adaptation 2.

Acknowledgments

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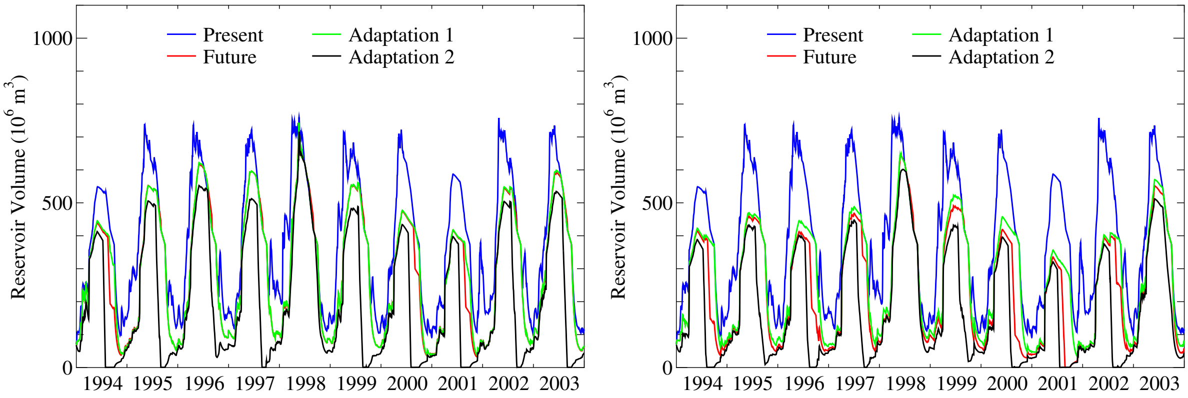
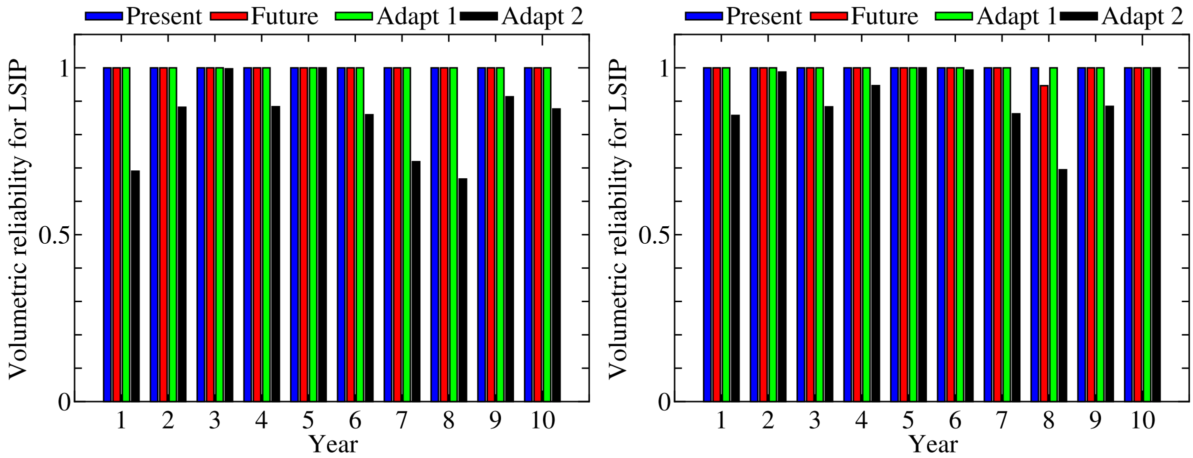


(a) MRI (b) CCSR

Fig.10 Reservoir changes.



(a) MRI (b) CCSR

Fig.11 Reliability changes.

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An Inverse Modeling Approach to Assess the Impacts of Climate Change on Water Resources Management at the Watershed Scale

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1. Introduction

Over the last several years, hydrologists have paid great heed to the potential impacts of climatic change on water resources and hydrological cycling, which are traditionally assessed using a top-down approach. With this approach, outputs from general circulation models (GCMs) are statistically or dynamically downscaled to the river basin scale, and the local climatic signal is then input to a hydrological model to assess the direct consequences in the basin. However, problems related to this approach arise from the incompatibility between the temporal and spatial scales of a GCM and a river basin. Because serious effort is required to validate GCM outputs and the downscaling techniques, many river basin authorities consequently remain skeptical of the possible impacts of climate change.

We attempted to improve understanding of the processes leading to local hydrological hazards by introducing an inverse (or bottom-up) approach to the modeling of flood risk and vulnerability to changing climatic conditions. The modeling approach was applied to the Seyhan River Basin, Turkey.

2. Methods

The inverse modeling approach is designed to assess the vulnerability of river basin hydrological processes to climate forcing from a bottom-up perspective. The theoretical concepts of this approach were developed at the University of Western Ontario, Canada, by Cunderlik and Simonovic (2004, 2005, in press). The approach consists of the following four steps and is illustrated in **Figure 1**.

1. Critical hydrological exposures, which may lead to local failures of water resource systems in a particular basin, are first identified. Critical exposures are analyzed together with existing guidelines and management practices. This step is accomplished in collaboration with local water authorities.

2. In the next step, the identified critical hydrological exposures (such as floods and droughts) are transformed into corresponding critical meteorological conditions (e.g., extreme precipitation events, sudden warming, and prolonged dry spells). A hydrological model is used to establish the inverse link between hydrological and meteorological processes.

3. General circulation model (GCM) outputs are analyzed to investigate future changes relative to the present conditions. Afterward, a stochastic weather generator, which is one of the downscaling methods, is used to generate the meteorological conditions under present and future scenarios.

4. In the final stage, the frequencies of critical meteorological events causing specific water resources risks are assessed from the weather generator outputs. The frequencies of critical hydrological events are obtained using the established inverse link.

The presented approach can be used to develop hazard risk management strategies under present and future climatic conditions for any water resource system. The main advantages of the inverse

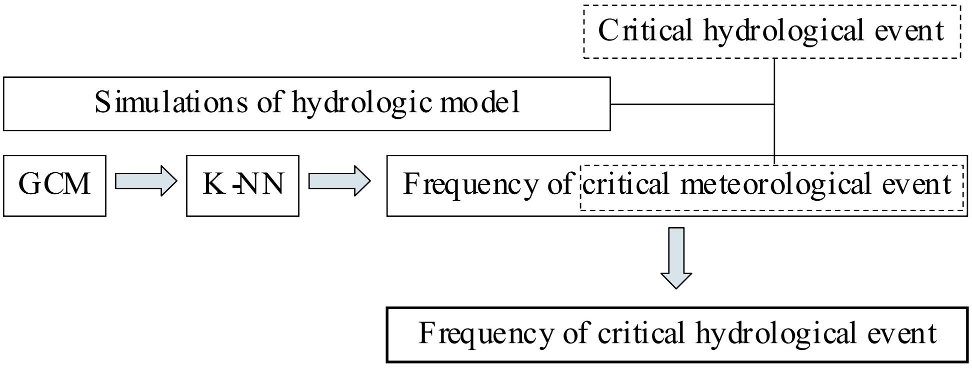


Fig.1 The Framework of this Study

approach over the traditional top-down approach are its focus on specific existing water and potential water resource problems, a direct link with the end user, and easy updating when new and improved GCM outputs become available.

3. Results

3.1 Identification of Critical Hydrological Events

3.1.1 Flood events

Adana, with a population of approximately 1.3 million, is the capital of Adana Province and the fourth largest city in Turkey. Socioeconomic activities in the lower area of the Seyhan River Basin are much more vital than those of the upper area. The urban center is located around and downstream from Seyhan Dam, which was constructed in 1956 to protect the city of Adana against floods.

The flood of 1980 was the biggest flood on record and also produced the most damage (Japan International Cooperation Agency, 1994). Flood damage occurred not only on the Cukurova Plain but also in upstream areas and around tributaries of the Seyhan River. Although the recently constructed Seyhan Dam was operating at the time, the flood of 1980 destroyed 21 buildings and damaged 76 others. The deluge was equivalent to a flood of 100-year probability.

The flood damage in 1980 accelerated the planning for and construction of the Catalan Dam. Dam construction began in 1982, and the Catalan Dam has been operating since 1997. The Catalan and Seyhan dams should be able to protect downstream areas against floods of 500-year probability. Based on these findings, 100-year and 500-year floods are identified as critical hydrological events in the Seyhan River Basin.

3.1.2 Drought events

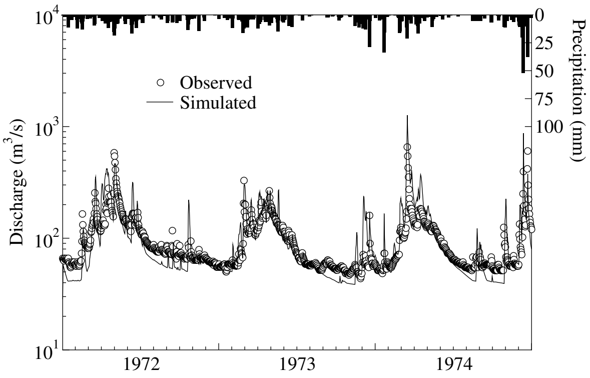
The Lower Seyhan Irrigation Project (LSIP) in Adana was initiated by the Turkish government as an important irrigation project covering an area of 204,000 ha. In 2002, approximately 1.8 Gm^3 of irrigation water was withdrawn from the Seyhan River for the LSIP. This withdrawal has increased annually, and region IV of the LSIP will be completed within several years. Therefore, water scarcity will be a major concern in the Seyhan River Basin. In this study, we employ the following index as a water scarcity index:

$$I_{ws} = \frac{W - S}{Q} \tag{1}$$

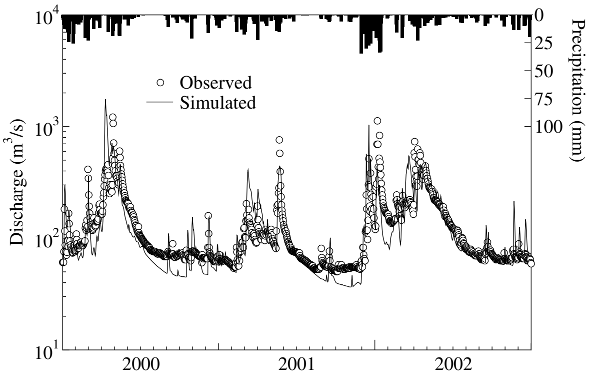
where W, S, and Q are the annual water withdrawals by all sectors, use of desalinated water, and the annual inflow at Seyhan Dam, respectively. When this index is higher than 0.4, the Seyhan basin is considered highly water-stressed (Alcamo et al., 2003; Oki and Kanae, 2006). Drought, represented by a water scarcity index (I_{ws}) value higher than 0.4, is identified as a critical event in the Seyhan River Basin.

3.2 Hydrological Model Application

The simulation region is an area of 2.75° $\times$ 2.75° (36.5°-39.25° and 34.25°-37.0°) with 5 min latitude/longitude spatial resolution (33 $\times$ 33 grids). Gtopo30 was used as the digital elevation model (DEM). The Global Land Cover Characterization version 2.0 (GLCC-v2) was selected for the basic land use data. However, the irrigated



(a) 1972-1974



(b) 2000-2002

Fig.2 Simulated Hydrograph at Station 1818

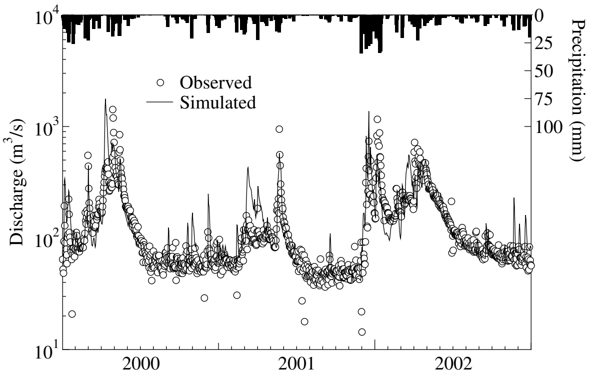


Fig.3 Simulated Hydrograph at the Catalan Dam (2000-2002)

cropland and forest areas in the original data set are clearly underestimated. Thus, the data set was modified by ground truthing and normalized difference vegetation index (NDVI) time series analysis.

Grid precipitation and temperature data for Hydro-BEAM (Kojiri et al., 1998) were created by interpolating data from 23 stations. The inverse distance method (IDM) was employed as the spatial interpolation method. Hydro-BEAM was then run using the grid meteorological data from 1972 to 2002 to calibrate the model parameters. The simulated hydrographs at station 1818 for the first and last 3 years are shown in **Figure 2**. These figures show that the river discharge at station 1818 was quite well reproduced by Hydro-BEAM. Moreover, the simulated hydrographs at the Catalan Dam for the last 3 years are shown in **Figure 3**. This figure also shows that the simulated result agreed with the observed data.

3.3 Inverse Linkage

3.3.1 Flood event

The 12 biggest floods from the historical record were selected as the representative flood events in the Seyhan River Basin. Analyzing the relationship between these floods and meteorological conditions, daily areal precipitation had a large influence on the floods. The inverse link between floods and areal precipitation was determined by the following procedures.

We created a synthetic precipitation data set to establish the relationship between the peak discharge and areal precipitation. Synthetic areal precipitation data sets (50, 100, 150, and 200 mm day^{-1}) were created by multiplying the ratio between observed areal precipitation corresponding to the flood event and the synthetic areal precipitation. Hydro-BEAM was run using each synthetic precipitation data value. **Figure 4** shows the relationship between the peak discharge and areal precipitation. After the average of peak discharge for each synthetic precipitation was obtained, the inverse linkage was established as follows:

$$Q = aP^2 + bP + c \tag{2}$$

where Q is the peak discharge at the Catalan Dam, P is the areal precipitation, and a, b, and c are parameters.

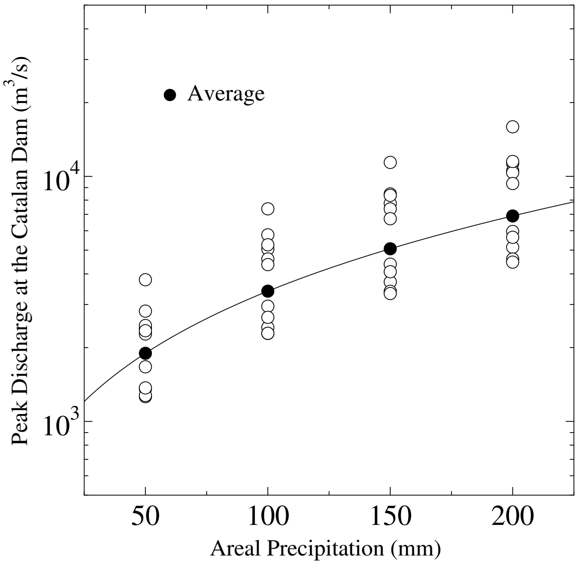


Fig.4 Inverse Link (Peak Discharge)

3.3.2 Drought event

In this study, the water scarcity index (I_{ws}) was used as the index of drought. An advance analysis revealed that the water scarcity index can be approximated by areal annual precipitation. The inverse link between water scarcity and areal annual precipitation was obtained by the following procedures.

Data for all years were used to establish the relationship between the water scarcity index and areal annual precipitation. To create synthetic data in which the annual precipitation was set to half the value of the original data, we multiplied by 0.5. Hydro-BEAM was then run for the data of all years and the synthetic data. **Figure 5** illustrates the relationship between the water scarcity index and areal annual precipitation. The inverse linkage was obtained as follows:

$$I_{ws} = \exp(aP + b) \tag{3}$$

where I_{ws} is the water scarcity index for a year, P is the areal annual precipitation, and a and b are parameters.

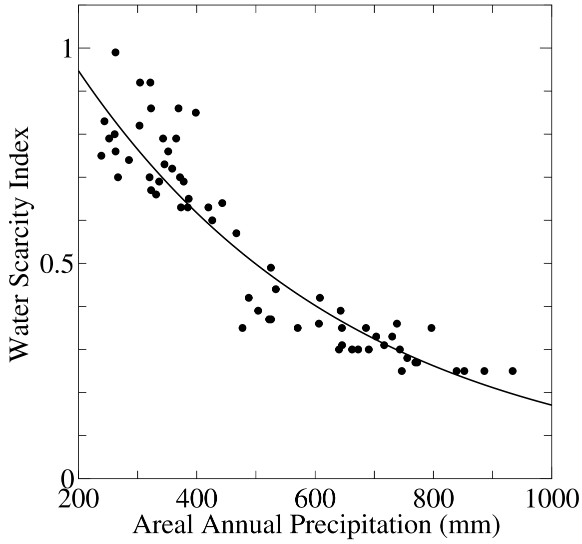


Fig.5 Inverse Link (Water Scarcity Index)

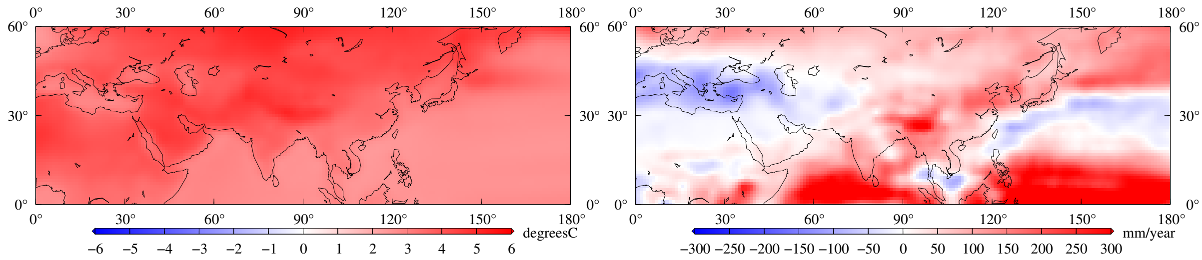
3.3.3 GCM Projections

This study employed nine state-of-the-art GCMs that were also used in the most recent phase of the Coupled Model Intercomparison Project (CMIP; Covey et al., 2003). From the atmospheric data set, monthly precipitation and monthly mean temperature data under IPCC SRES A2 scenario were collected for each model. Two subset periods (present: 1961-1990 and future: 2070-2099) were set to investigate the temperature and precipitation changes.

Figure 6(a) indicates the ensemble averaged annual temperature of the nine GCMs, which project the rising annual temperatures in all regions; **Figure 6(b)** shows the ensemble averaged annual precipitation of the nine GCMs, which project the decreasing annual precipitation in the Mediterranean region, including Turkey. The decreasing precipitation and rising temperature predicted for the Mediterranean region suggest that climate change will have serious impacts on the hydrology and water resources of the Seyhan River Basin. We set the decreasing precipitation scenario for the weather generator based on these GCM analyses.

3.4 Frequency of Critical Hydrological Events

We adopted a modified version of the k-nearest neighbor approach (Sharif and Burn, 2004, 2006), which is one of the stochastic weather generators. The k-nn approach was applied to gener-



(a) Temperature (b) Precipitation

Fig.6 Temperature and Precipitation Changes

ate the meteorological conditions corresponding to the scenarios (decreased precipitation) for a 100-year period. The frequency of critical meteorological events causing flooding was assessed from the weather generator outputs. The flood return periods, which were inversely estimated using equation (2), are shown in **Figure 7**. For 100-year flood, the future peak discharge is almost the same as that at present. However, the 500-year flood under present conditions will decrease to a flood of 250-year magnitude under the decreasing precipitation conditions. Thus, critical flood events will occur less frequently under the decreasing precipitation scenario.

The frequency of critical meteorological events causing drought was also assessed from the weather generator outputs. The return periods, which were inversely estimated using equation (3), are shown in **Figure 8**. Drought, indicated by I_{ws} higher than 0.4, has about a 6-year probability under present conditions. However, the decreasing precipitation scenario indicates that droughts will occur more often, at a 2-year probability.

4. Conclusions

This study introduced an inverse bottom-up approach to the modeling of flood and drought risk under changing climatic conditions. The approach is focused on specific extant water resource problems, has a direct link with end-users, and can be easily updated when new and improved GCM outputs become available because the analysis of GCM outputs is the last step in the proposed methodology.

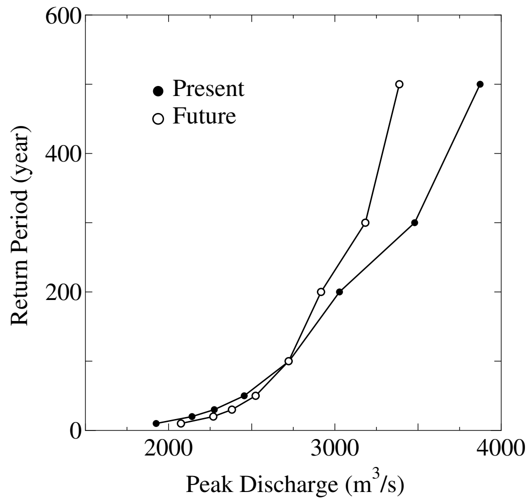


Fig.7 Return Period (Peak Discharge)

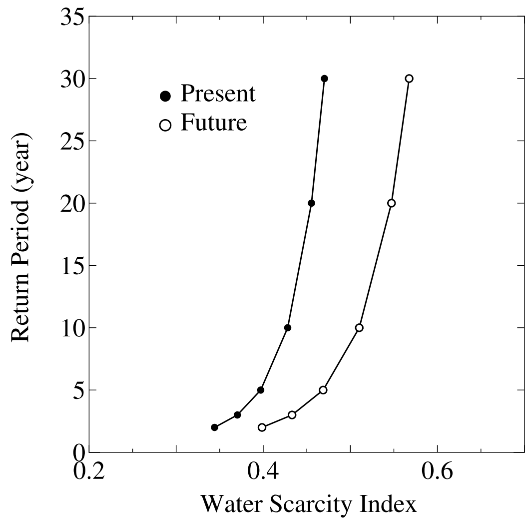


Fig.8 Return Period (Water Scarcity Index)

The study case presented one possible application through its assessment of flood and drought risk in the Seyhan River Basin, Turkey, under present and future climatic conditions. Based on data and reports for the Seyhan River Basin, 100-year and 500-year floods were identified as critical hydrological events. In addition, drought, indicated by I_{ws} higher than 0.4, was identified as a critical event in the Seyhan River Basin. The identified critical floods and drought were transformed into corresponding critical meteorological conditions using a Hydro-BEAM simulation. Based on analysis of the outputs of nine state-of-the-art GCMs, the decreased precipitation scenario was set for the weather generator. The k-nn was then used to generate meteorological conditions corresponding to the scenario for a 100-year period. The frequencies of critical meteorological events causing flooding and drought were assessed from the weather generator outputs. The frequency of flood and drought were then estimated using the established inverse link. The results suggest that the 500-year return period flood under the present condition will decrease to a 250-year return period flood under the decreasing precipitation conditions. Drought, with 6-year probability under the present condition, has 2-year probability under the future condition.

Acknowledgments

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Effect of climate changes on the species composition and productivity of plant communities in the eastern Mediterranean region of Turkey

Vegetation Sub-Group

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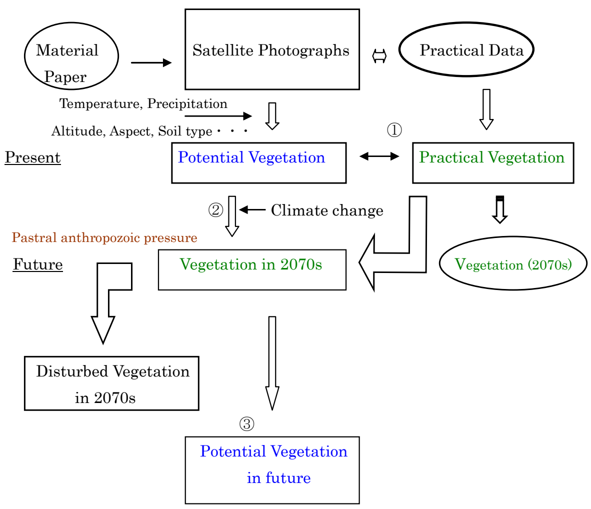
1. Introduction

Geographical distribution and productivity of plant communities are related to various factors. However major distribution of vegetation (climatic climax community) is most strongly associated with macroclimate (physical factors). Vegetation zones are determined mainly by thermal and water conditions in the reign.



① Difference between Practical and Potential vegetation in present

② Estimation of Vegetation in 1970s and compared with that in present
Productivity and spatial distribution of the vegetation

③ Estimation of Potential Vegetation in 1970s by Climate Change
In addition to ②, disappearance of boreal forests from Cukurova Basin

Fig.1 Research procedure

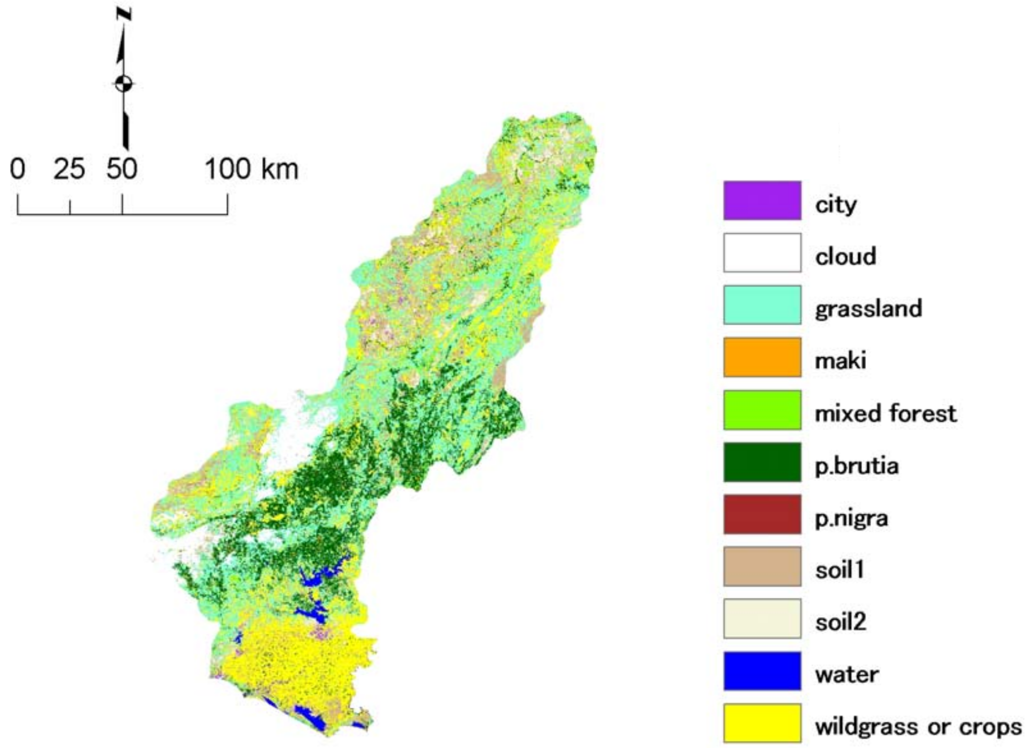


Fig.2 Present vegetation map of the study area (13 June 2000)

We estimated vegetation types, and their biomass and productivity in the eastern Mediterranean of Turkey from air temperature and precipitation.

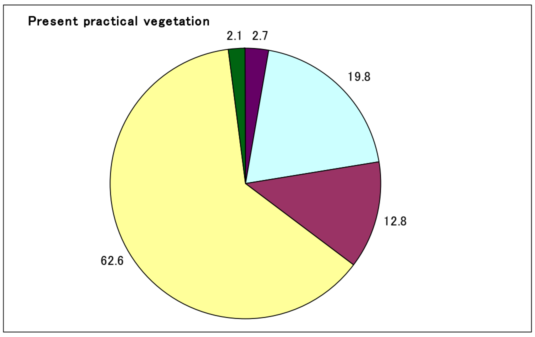
Our study focus is to analyze impact of climate changes on geographical vegetation and its structure in semi-arid region of Turkey by air temperature and precipitation in present and future (Fig.1).

2. Vegetation types and community structure

1) Present vegetation

Practical present vegetation types were estimated using by satellite photographs (LandsatETM+13 June 2000) and actual survey data, and we drew vegetation map in the eastern Mediterranean region of Turkey （Fig.2）. A large part of flat areas in 0-600m above sea level was almost occupied by crop field, and natural vegetation was remarkably destroyed and replaced *Pinus brutia* forest with *Maquis* elements as dominant community.

Potential vegetation in present (Fig.3) was estimated from Thornwaite p/e Index (PEI,Thornthwaite 1931,1948)(see Appendix I,II) and Warmth Index(WI,Kira 1945,1976) calculated



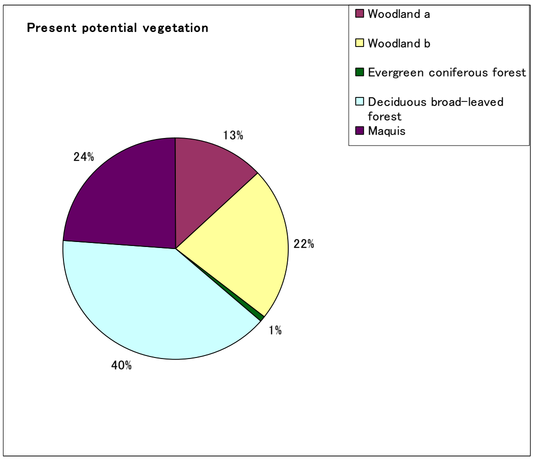
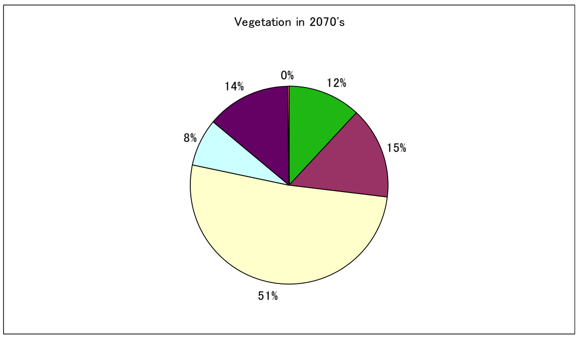


Fig.3 The percentage of area occupied by five vegetation types in practical and potential present.



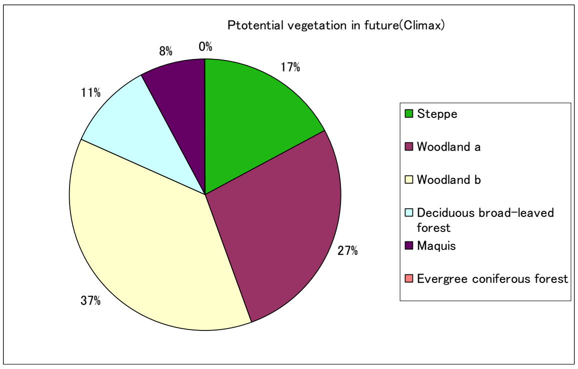


Fig.4 The percentage of area occupied by each vegetation type in 2070's and climax stage (Potential vegetation in future).

From the climate data at present provided by Climate Sub-group for ICCAP (K-1 Model Developers 2004).

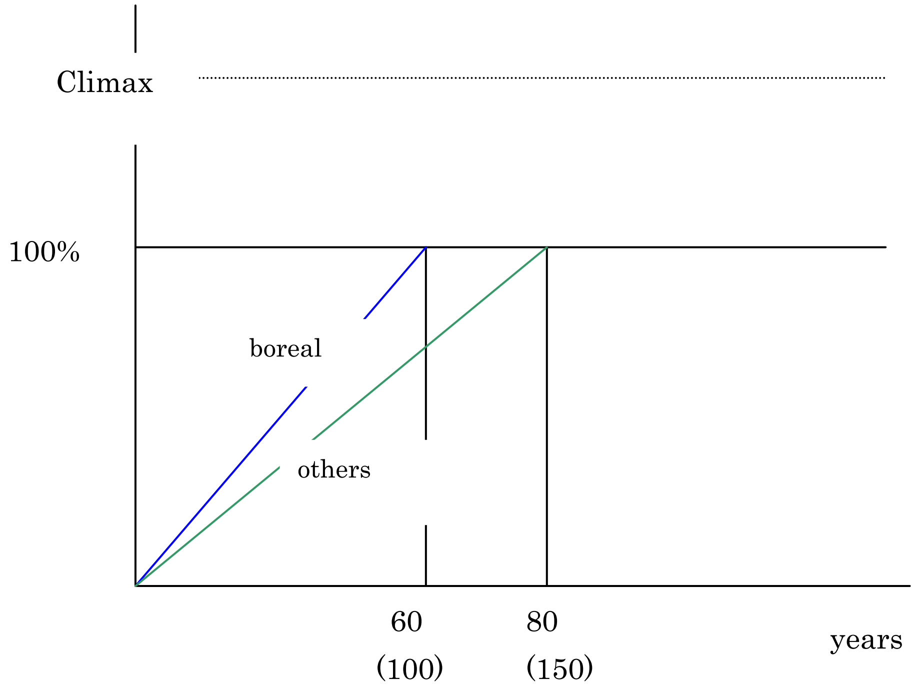
Areas of Maquis and Deciduous broad-leaved forest in present potential vegetation were smaller than in present practical one. Maquis area in the potential vegetation was used as crop field now and Deciduous broad-leaved forest area occupied by secondary forest of *P.brutia* (Woodland b). Sub-alpine forest (Evergreen coniferous forest) was distributed between ca.1000m(～1500m) and 2000m(～2500m) above sea level

□ Secondary Succession

(Sano et al. 2003), but this vegetation may lay downward the original position estimated from WI and P/e index because of the edaphic complexity (lime stone) (San et al. 2003).

2) Vegetation in 2070's

We estimated vegetation in 2070's from WI and P/e Index using by the climate data provided from the Climate Sub-group of ICCAP (K-1 Model Developers 2004) in this area (Fig.4). Vegetation in 2070's was not perfectly shifted to climax one under the estimated climate conditions. Recover of original vegetation from disturbed or destroyed one may demand 60-80years (Fig.5).



□ Climate Change (Disperse, Moving)

Boreal forest: □+20 years

Others :□+30(50) years

Ex. Others in 2070's 70/(80+30) = 70/110 (changed vegetation !)

Fig.5 Hypothetical scheme of recovering of disturbed or destroyed vegetation.

In addition to recovering time, 20-30 years will be demanded to establish the other new vegetation caused by physical elements as climatic changes. There will be about 100 years to be changed a large part of vegetation to the other vegetation type in a certain area. According to dynamics of vegetation analyzed by collecting data (Table 1) and Fig.5, present vegetation will remained in one third of the area where should be changed to other vegetation types in climax stage, and the areas of Steppe and Woodland a were smaller than those of potential one (climax stage). On the other hand, areas of Woodland b and Evergreen coniferous forest became larger.

3. Biomass and productivity

Total biomass and productivity of this area in present and 2070's were estimated from satellite photographs, reported materials (Cannel 1982, Tamai et al. 2004,2005) and relationship of leaf biomass and relative light intensities measured in many stands of this area (Tamai 1974). Leaf area index in each

Table 1 Succession in Watershed of Cukurova Plain

Elevation	Present	After 30 yrs	After 50 yrs	Climax
0– 50 m	*P.halepensis, P.brutia* with Maquis	*P.brutia :recession*	Maquis	*Quercus infectoria*
		Maquis	*Phryigana*	
		Phryigana	*P.brutia*(re)	
50– 600m	*P.brutia*	*Q.coccifara*	*Q.coccifara*	*Quercus infectoria*
	Q.infectoria	Maquis	Maquis	
	Q.coccifera	*P.brutia*	*P.brutia*(re)	
600– 1000m	*P.brutia* mixed with *Corinus, Sorbus,*	do	do	*P.brutia* mixwd with them (*)
	Fagus, Carpinus, Acer (*)			
1000m–	*P.nigra, Abies cillicica, Cedrus libani*	*A.cillicica*	*A.cillicica*	*A.cillicica*
			higher northface: *P.nigra*	
			rocky south or west face: *Juniper*	

vegetation type was also calculated from satellite photographs and biomass estimated in the world (Cannel 1982).

We made two scenarios to estimate biomass in 2070's and future, which were estimated as the same biomass per unit area in each vegetation type as those in present (Case I) and those of 1.5 times as much as present biomass per unit area (Case II).

Case I:

Biomass in present and 2070's were estimated and shown in Fig.6.

Biomass of evergreen coniferous forest in present, most of which was dominated by *Pinus nigra,* was remarkably high though its area was very small, and it depended on higher average biomass per unit area. Biomass value of Woodland a in present was due to relatively high average biomass of this vegetation type in this area. On the contrary, biomass of Woodland b showed lower though its area was the largest among five vegetation types in present here. Biomass of Evergreen coniferous forest in 2070's was remarkably low, compared with that in present and it caused by decrease of the area in the 2070s. Higher biomass of Woodland a and Maquis reflected increase of their distribution areas.

Biomass of total for five vegetation types in 2070's was 45% of that in present. Decrease of the total biomass in 2070's was due to increase of area for Steppe, which was lower biomass per unit area and decrease in area of Evergreen deciduous forest with higher biomass.

Total net production in this area was estimated and show in Fig.6.

Net production patterns among vegetation types look to be almost reflected similar to biomass patterns. However difference in net production of this area among vegetation types became smaller than in biomass. For example biomass of Woodland a in 2070's was about two times of Maquis, but difference of

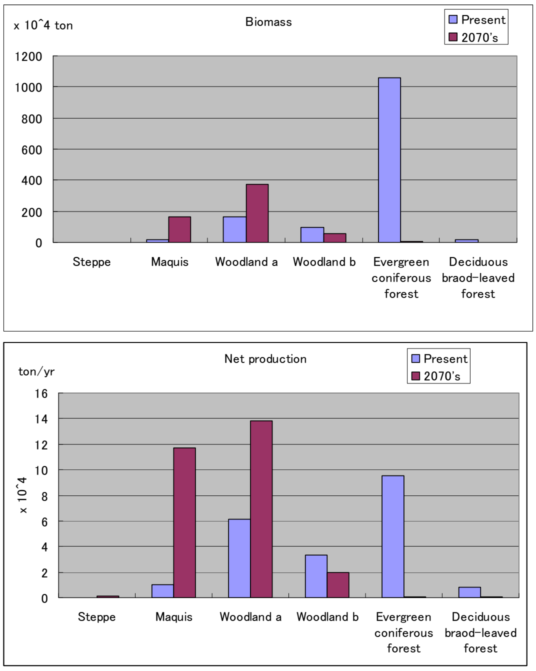


Fig.6 Biomass and net production of each vegetation type in present and 2070's.

the net production was only 1.1 times between them.

Total net production of this area in 2070's was 1.3 times of that in present. Biomass of this area in 2070' decreased while the net production increased, compared with those in present, and so biomass in future may gradually increase in the area investigated.

Net production of Maquis in 2070's increased and was 11 times of that in present. Increase of the production of this vegetation type mostly depended upon an increase of the area (five times) and its productivity.

<u>Case II:</u>

Biomass and net production in 2070' were estimated when net production of each vegetation type except Evergreen coniferous forest increased 50% of that in present. Productivities of species in evergreen coniferous forests where we actually measured in this area were higher and almost same as the productivity in the other place (Cannel 1982), and then we did not increased productivity of Evergreen coniferous forest to estimate its biomass and productivity in Case II (Fig.6).

Proportion of biomass and net production among vegetation types in Case II were scarcely different from that in Case I because of smaller area occupied by Evener green coniferous forest.

Total biomass of and net production of Case II in this area were 67% and 200% of those in present, respectively.

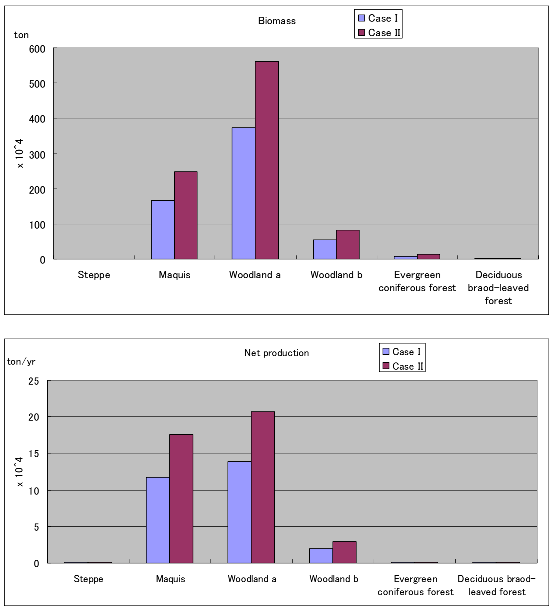


Fig.7 Biomass and net production in Case I and Case II.

4. Conclusion

Practical present vegetation was remarkably changed from potential one by anthropozoic pressure, especially in lower level areas.

Climate changes were not strongly affected on area occupied by each vegetation type in this area except Evergreen coniferous forest. Every vegetation type in future will shift from present area to more northern or higher areas in altitude. The area of Steppe will increase and Evergreen coniferous forest will decrease.

Biomass in this area will decrease, compared with that in present, but net production will increase in 2070's.

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Appendix I

Thornthwaite *p/e* Index (PEI) and Warmth Index (WI) calculated from the
climate data in present and the future (2070's) provided from the Climate Sub-group of ICCAP (Kimura et al.2006).
The definition of each index is as follows;

Thornthwaite *p/e* Index :

$p/e = 0.164\{p/(t+12.2)\}^{1.11}$ PEI= $10\Sigma p/e$

PEI

T10: <16: Perarid

T20: 16-32: Arid

T30: 32-64; Semi-arid

T40: 64-: Humid

(Thornthwaite, 1931, 1948)

Warmth Index (WI):

WI=Σ(t-5) t>5□

W1: 15-45: sub-arctic zone, evergreen coniferous forest

W2: 45-85: cool-temperate zone, broadleaved deciduous forest

W3: 85-180: warm-temperate zone, evergreen forest

(Kira, 1976)

We combined these two indices for classification of potential vegetation.

T10W3 (13): Desert

T20W3 (33): Steppe

T30W2 (32): Woodland a

T30W3 (33): Woodland b

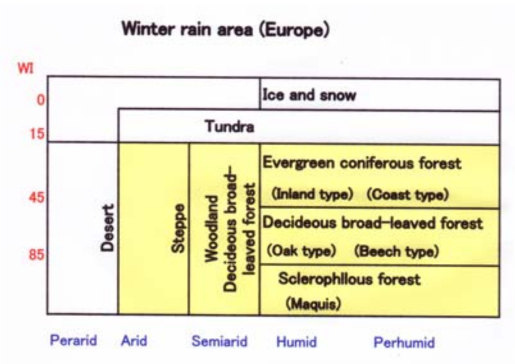
T40W1 (41): Evergreen coniferous forest

T40W2(42): Broadleaved deciduous forest

T40W3 (43): Maquis

Appendix II

Classification of potential vegetation from Thornthwaite Index and WI.



Possible Scenario for the Vegetation Change in Seyhan River Basin and Role of Land Uses "Anthropozoic Pressures"

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1. Introduction

Becoming a greater concern to scientific era, impacts of climate change have been studied thoroughly in different geographies (Reid et al, 2000, DeLuis et al, 2001, Vilalta, 2002). Mediterranean Basin presents the best example for the human impact on natural structure particularly natural vegetation (Atmaca et al, 2005). But recently climate change is another phenomenon that according to Tamai et al (2005) climate changes, especially precipitation and air temperature in semi-arid areas will likely effect the quality and the quantity of the vegetation.

In this joint work, potential impact of climate change on natural vegetation in Seyhan River Basin (Figure 1) within the framework of the Japanese-Turkish international research project 'Impact of Climate Change on Agricultural System in the Arid Areas' was discussed. Based on expected changes mainly on precipitation and temperature derived by Climate Group of the project, different scenarios on the potential impact of the climate change were indicated in terms of vertical distribution of the vegetation and more emphasis were put particularly on the role of land uses "anthropozoic pressures".

2. Different Scenarios on the Impact of the Climate Change on the Vegetation in Seyhan

Arid regions are expected to undergo significant changes under a scenario of climate warming, but there is considerable variability and uncertainty in these estimates between different scenarios (Lioubimtseva, 2004). Relatively there are THREE main Scenarios that will be adapted by the Vegetation Group. ***The first scenario*** stands on the idea that such differences as 1.87 ^{o}C degree increase in temperature by 2070s would not cause substantial change on the vegetation. To have serious change on vegetation cover, vegetation distribution and plant productivity there is need at least 100-150 years of time. From that point, the 1st scenario formulated on the prediction "No Change o Vegetation" (Table 1).

Here still land use impacts need to be taken into consideration. Because human pressure will remain in the river basin, and so the athropozoic pressures.

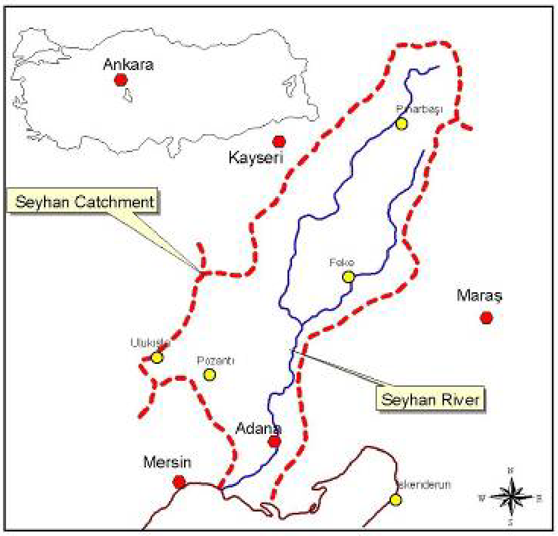

Figure 1. Location of Seyhan River Basin

The second scenario is precise that expected change in climate conditions 1.87 °C degree increase in temperature and –322.72 mm decrease in precipitation level will have impact particularly on the vertical distribution of the vegetation. Hereby altitude and distribution of different vegetation belts is the basic approach to overlap spatial temperature and precipitation data. According to altitude map nearly 70 % of the research area covers 1000 meters and higher elevations.

Having different study approaches both Turkish and Japanese Vegetation Groups worked on the vegetation on 1000 meters and above. Considering Second scenario we expect that rainfall change around 900-1000mm together with temperature would be effective on the vegetation on the lower basin area. Altitude and precipitation info showed us that rainfall change is happening around 900-1000 meters. Accordingly from sea level (0) to around 1000 meters there will not be concrete change on the vegetation belts but change on some typical species. However possible changes on the typical species and species combination that representing plant formations will be expected. A vertical distribution of present and expected future main vegetation types is given in Table 2. Main vegetation type will be Pinus brutia and macchia between 0-600 meters and Pinus brutia mixed forest between 600-1200 meters. Above Conifer forest mix with deciduous trees and after higher altitudes 1600 meters and above Conifer forest will remain (Table 2).

Apart from vertical distribution, according to more detail vegetation distribution (Table 3) we expect that some characteristic species will move from one elevation to another. With respect to the site aspects and direction, northern aspects are limiting factor of species diversity in the macchia vegetation where shade tolerant species form very thick cover and do not allow many others species survive. Nevertheless long-term changes need to be monitor in detailed level, covering all plant forms in the vegetation. Turkish Vegetation Group set up a constant monitoring parcels' system so far and further researches can easily be integrated about the change on vegetation. Plant analysis that will be carried out on these regular monitoring on these parcels in the future and the comparative studies with project results will supply more precise picture about the future vegetation. Hence constant monitoring parcels' system is an useful contribution, monitoring studies must carried out with certain intervals in the future.

The third scenario will cover both impact on the climate change and impact of anthropozoic pressures and relevantly, scenario for disturbed vegetation in 2070s (Table 1). There are already existing rural land use types of agriculture, stockfarming, forestry, mining, recreation, settlements which will remain in the future. But in terms of severe drought on the lower parts of the river basin would force further land use demands on the upper river basin areas and drastic change on both landscape and the vegetation by the possible conversion from crop fields to pastures or conversion from forest sites to agricultural field.

We expect that ant pressures will be more

Table 1. Three Scenarios adopted by Vegetation Group

1. Scenario	**2. Scenario**	**3. Scenario**
The first scenario is that there will be no change on Climate Conditions and relatively NO CHANGE on the Vegetation	The second scenario is that there will be change On the Climate Condition (1.87 °C degree increase in temperature and –322.72 mm decrease in precipitation level) and relatively CHANGE on the Vegetation	The third scenario is that there will be change On the Climate Condition (1.87 °C degree increase in temperature and –322.72 mm decrease in precipitation level) TOGATHER with Human Impact and relatively CHANGE on the Vegetation
As a result Potential Vegetation that present today will be the ***Practical Vegetation in 2070s***	As a result Potential Vegetation that present today will be the ***Potential Vegetation in future*** by 2070s	Impact of the climate change on the Vegetation will be exaggerated by anthropozoic pressures and change on Vegetation will be further in 2070s
	In terms of Climate Conditions, Change in **Temperature and Change in **Precipitation** will be two main driving forces in Vegetation Change by 2070s and onwards	As a result Potential Vegetation that present today will be the ***Disturbed Vegetation in 2070s***

exaggerated by human settlements and agricultural land use demands on the lower part of the basin and rural land use and stockfarming on the upper part, particularly grazing around the timberline which would pull down the forest cover.

*Linear correlation between Plant Productivity and Temperature allows us to assess the Vegetation Change by the change in Average Temperature, which has already been expected to be increasing with 1.87 ^{o}C degree by the year 2070s. Here when the temperature increases so the photosynthesis increases and relatively the plant productivity.

**But relationship between Plant Productivity and Precipitation is rather complex. There is a linear correlation between Plant Productivity and Precipitation with around 400-600 mm, which turns out to be non-linear by 800-1000 mm of rainfall. And there is also a similar linear relationship between Vegetation Cover (%) and Precipitation in some degree of rainfall. Vegetation cover increases in parallel with the rainfall and stands still and does not change with non-linear correlation when the rainfall reaches up to some certain amount. More precisely;

- Average rainfall will be 650-322,72 = 327,28 mm in the lower basin which would create considerable change on the vegetation. It is vague whether macchia and Pinus brutia will survive under this circumstance but there will be clear change on the species within the plant formations. For example it is imprecise if such species as *Oleae europea var. oleaster, Daphne sericea, Laurus nobilis, Cercis siliquastrum, Phillyrea latifolia, Quercus coccifera, Stryrax officinalis* would maintain their woody forms under such amount of rainfall.

- Average rainfall will be 800-1000-322,72 = 477,28 - 677,28 mm in the upper basin. Under this circumstance its is unknown if submediterran deciduous species such *Fraxinus ornus, Ostrya* carpinifolia and deciduous oaks will survive

- Moreover one particular nature of Seyhan River Basin is the severe arid periods. Relatively number and the duration of the arid periods based on climate change for 2070 predicted by Climate Group of the project will be another factor on vegetation change. General expectation is that duration of the arid period will be longer with the sudden showery rains.

Plant growth and productivity are increasing when the amount of rainfall increases. But when the precipitation reaches at and above 1000 mm there will be no consequent change in either plant growth or productivity. Therefore draft estimation was carried out for the lower parts of the Seyhan River Basin based on both the prediction of Climate Group, which has already been expected to be decreasing by – 322.72 mm. Considering that average amount of annual rainfall in the area is around 750 – 950 mm, such decrease by -322.72 mm will be a strong impact on the vegetation.

Vegetation Change on the Lower Seyhan River Basin

The Vegetation of Lower Seyhan River Basin is evaluated in different zones starting from sea level rising up to 800-1200 meters. Here we took account increasing temperatures and decreasing rainfalls. Lower Seyhan River basin is more characterized by *Pinus brutia* and macchia species. Between sea level and 100 meters *Pinus halepensis*, limited locations in Çamlık, Pinus brutia and macchia, where we can find sand dunes, marshland and reed beds in Çukurova Delta, on the lower basin. Because of intensive agricultural activities natural vegetation in this part of the basin almost disappeared. And remaining islets of natural vegetation is under heavy human impact. Up to 700 meters macchia cover either in primer or seconder form, has wider distribution mixed *Pinus brutia* (Table 2).

Above 700 meters submediterran species become apparent due to increasing amount of rainfall and decreasing temperatures. Here *Pinus brutia* is the dominant species with extensive distribution between 1200-1300m and forming close stands on the upper parts. Within humid valleys and particularly northern slopes typical submediterran species such *Quercus infectoria ssp. boisseri*, *Q. Cerris, Q, pubescens* deciduous trees with *Ostrya carpinifolis, Fraxinus ornus* and *Carpinus orientalis* are found. Then *Pinus brutia* leaves its place to macchia in some locations with *Pistacia terebinthus, Arbutus andrachne, Fountanesia phillyroides, Styrax officinalis, Laurus nobilis, Cercis siliquastrum* (Table 2). However general vegetation distribution along this altitude is not expected to change much but the species composition will change moving either to higher elevation or disappearing.

3. Role of Land Uses "Anthropozoic Pressures"

Vegetation in the eastern Mediterranean severely disturbed by anthropozoic pressure and it is very hard to estimate vegetation in the past (Tamai et al, 2005). But learning from the past, land use pattern will keep its critical role in terms of change of the vegetation.

Table 2. Present and expected future main vegetation types with characteristic species in eastern Mediterranean

Elevation (meter)	Present Vegetation Characteristic species	Main Vegetation TYPE	Expected Change	Main Vegetation TYPE	Expected Future Vegetation Characteristic Species
0 – 100	Pinus halepensis (limited location in Çamlık) Pinus brutia, Quercus coccifera, Olea europea, Pistacia lentiscus, Phillyrea media, Myrtus communis, Cistus creticus and other macchia species	***Pinus halepensis, P. brutia*** **forest + Macchia**	*1.87 °C temperature **increase** + *–322.72 mm precipitation **decrease**	***Pinus halepensis P. brutia*** **+ Macchia**	Pinus halepensis, (limited) Pinus brutia, Quercus coccifera, Calycotome villosa, Paliurus spina-cristi, Olea europea var. oleaster, Phillyrea latifolia, Myrtus communis, Cistus creticus
100 – 400	Pinus brutia mixed Macchia species; Quercus coccifera, Olea europea, Pistacia lentiscus, Pistacia terebinhus, Laurus nobilis, Phillyrea latifolia, Daphne sericea, Myrtus communis Ceratonia siliqua, Cercis siliquastrum	***Pinus brutia*** **forest + Macchia**		***Pinus brutia*** **forest + Macchia**	Pinus brutia and macchia species; Quercus coccifera, Olea europea var. oleaster, Pistacia lentiscus, Pistacia terebinhus, Phillyrea latifolia, Ceratonia siliqua, Rhamnus alaternus, Calicotome villosa, Myrtus communis
400 – 700	Pinus brutia, Quercus coccifera, Quercus infectoria ssp. boisseri, Pistacia terebinhus, Laurus nobilis, Arbutus andrachne, Fontanesia phillyrioides, Ostrya carpinifolia, Styrax officinalis, Cotinus coggyria, Daphne gnidium, Cercis siliquastrum	***Pinus brutia*** **forest, decisuos species + Macchia**		***Pinus brutia*** **forest + Macchia**	Pinus brutia; Quercus coccifera, Quercus infectoria ssp. boisseri, Pistacia terebinhus, Phillyrea latifolia, Myrtus communis, Ostrya carpinifolia, Cotinus coggyria, Daphne gnidium
700 – 900	Pinus brutia, Pinus nigra, Juniperus oxycedrus, Quercus infectoria ssp. boisseri, Quercus cerris, Quercus pubescens, Pistacia terebinhus, Arbatus andrachne, Fontanesia phillyrioides, Ostrya carpinifolia, Styrax officinalis, Carpinus orientalis, Laurus nobilis, cercis siliquastrum	***Pinus brutia*** **mixed forest**		***Pinus brutia*** **mixed forest + Macchia**	Pinus brutia, Quercus infectoria ssp. boisseri, Quercus cerris, Pistacia terebinthus, Myrtus coomunis, Phillyrea latifolia Arbatus andrachne, Fontanesia phillyrioides, Ostrya carpinifolia, Styrax officinalis
900 – 1200	Pinus brutia, Pinus nigra ssp. pallasiana, Juniperus oxycedrus, Juniperus exelsa, Ostrya carpinifolia, Quercus cerris, Quercus pubescens, Carpinus orientalis	***Pinus brutia*** **mixed forest**		***Pinus brutia*** **mixed forest + Macchia**	Pinus brutia, Juniperus oxycedrus, Ostrya carpinifolia, Quercus cerris, Quercus infectoria ssp. boisseri
1200 – 1600 ↓ > 1600	Pinus brutia, Pinus nigra ssp. pallasiana, Cedrus libani, Abies cilicica, Juniperus oxycedrus, Juniperus exelsa, Juniperus durupacea. + Decidous trees; Ostrya carpinifolia, Carpinus orientalis, Quercus cerris, Quercus pubescens	**Conifer forest Mixed deciduous Trees** **Conifer Forests**		**Conifer forest Mixed deciduous Trees** **Conifer Forests**	Pinus brutia, Pinus nigra ssp. pallasiana, Cedrus libani, Abies cilicica, Juniperus oxycedrus, Juniperus exelsa, Juniperus durupacea; Ostrya carpinifolia, Quercus cerris, Quercus pubescens, Quercus infectoria ssp. boisseri (Likely escalation of timber line)

Occupation of the Area: Occupation of the area traces back as earlier as to neolitic periods and Hittites in 1000s BC and the use of natural forest as earlier as antic times to Phoenician, Egyptians, and Romans. They used *Pinus nigra* forest to build ships. The forest itself was very dense and productive one and known with its high quality. After Hittites, Romans and Byzantines, Turks came from Asia and settled in Anatolia around 12th Century (Ener, 1990). Around 1930s there were 7 villages in and around Aladağ (Yalgın,1950). Today there are 26 villages with direct impacts on forests, nomadic and semi-nomadic lifestyle has been continuing on the upper basin Agriculture: Most of the agricultural fields in the area stand on the slope lands. They are usually stony and have boulder surfaces and poor. Availability of the flat field for agriculture is quite limited which is likely lead to surface erosion (Picture 1). Using fallow fields for grazing, meeting the need for animal forage and also preventing surface erosion, forage cultivation is supported by the government. Relatively the size of the cultivation area was extended. Yards and gardening practices are more based on Cherry production which is an important income for farmers. Impact of agriculture on the natural environment becomes more apparent that dense agricultural practices on the slopes damage the soil surfaces.

Picture 1. Agricultural land use patterns in Posyağbasan Village (Deneri, 2006)

Stock farming: Stock farming is carried out in the area in two terms; nomadic way of stock farming and sedentary stockfarming. Nomadic way has been the oldest traditional type that people take their animals to Taurus Mountains for grazing for at least one season starting from very early spring to late autumn. Moving from one location to another nomadic life style shapes the land use patterns (Picture 2). In terms of environmental effects goat herding is the major concern in stock farming nearly in 65 %.

Although the decrease on nomadic stock farming comparing to past, local people still take their animals to the plateaus for grazing between May to September. In sedentary way, locals stay in the villages and use forest around the village for grazing. Which are subjected to high grazing pressure with the degradation on natural vegetation. During the winter time with heavy snowfall when the villagers are not able to take their animals to grazing, they cut the young branches of old trees providing food for stocks (Picture 3). Consequently typical forms of particularly fir (*Abies cilicica*) and cedar (*Cedrus libani*) and juniper (*Juniperus oxycedrus, J., exelsa*) disappear, productivity and vitality of trees decreases.

Picture 2. Way and the impact of grazing in the area (Deneri, 2006)

Picture 3. Tree cutting for stockfarming (Deneri, 2006)

Forestry: Natural forest in the area called "Pos", which comes from the local identification of black pine (*Pinus nigra*). Old documents indicate that the area was covered by dense vegetation of Red pine (*Pinus brutia*), Black pine (*Pinus nigra*), Juniper (*Juniperus oxycedrus, J. exelsa*) and Oaks (Yalgın, 1950). According the forest classification, timber productivity and quality is valued rather than diversity, and 23 % of the forest described as distorted forest. Tree plantation, forest regeneration and seedling is carried our by forestry service. But afforestation works have been rather based on certain species; Pinus brutia in lower areas and Pinus brutia, Pinus nigra and Cedrus libani in upper parts of the Seyhan River Basin which is rather monoculture and would restrain the species diversity in the vegetation.

Mining: Mining activity has a long history in the area. There are very old mine spots where people took the material out and basically used the natural forest and timber to work on mines for useful production. The wood from the natural forest was the basic source to produce items from the mines (Picture 4). Mining activity is based on chrome, plumbic (lead) and iron (Akyel, 2004). Authority of the mines belongs to Forestry Service as all mines are in forest sites, which can provide control and limits environmental impacts.

Picture 4. Impact of mining in the area

4. Discussions

Climate is the main farce on the distribution of vegetation. DelBarrio et al, (2006) indicated two general conclusions that despite the uncertainties; climate change involves the development of transient conditions and fragmentation within the core of species distributions. According to the scenarios on the vegetation change adapted by ICCAP Vegetation Groups main vegetation types along altitude is not expected to be changed by 1.87 ^{o}C temperature increase and –322.72 mm precipitation decrease. But some characteristic species (core species) would move into higher elevations or would not appear.

- *Pinus brutia* forest on the lower part of Seyhan River Basin will survive. However there will be potential risk for the existence of *Pinus brutia* forest in case of unfavourable environmental condition such as thin layer of soil, poor water holding capacity and sloppy-rocky south aspects

- macchia vegetation generally will remain and will move higher elevation by temperature increase and rainfall decrease. Species composition of macchia is expected to change towards humid tolerant species.

In this joint work, Japanese and Turkish vegetation groups developed there main scenario about the vegetation change based on the potential impact of climate change the 2070s and onwards. According to the first scenario there will not be a substantial change on the climate and so the vegetation (Figure 2).

According to the second scenario that expected change in climate conditions will be 1.87 ^{o}C degree increase in temperature and –322.72 mm decrease in precipitation level so we don not expect a substantial change on vertical distribution of the vegetation, but upwards movement in some vegetation belts such *Pinus brutia* mix forest, Conifer forest mixed deciduous trees as well as conifer forest by changing so characteristic species (Figure 3).

Apart from climate based environmental conditions there will be continuing human land uses and anthropozoic pressure on the vegetation, which need to be taken into account along with the climate change. Altan (2000) informed that forest degradation in Turkey basically stands on forest fires, grazing in the in the forest sites, land reclamations for agricultural lands and over use of forest resources. An exemplifying process on degradation levels of Mediterranean Vegetation is given in Figure 4.

The third scenario of the vegetation group is the potential impact of the climate change and impact of anthropozoic pressures (human use) on the natural vegetation. We expect that existing rural land use types of agriculture, stockfarming, forestry, mining, recreation, settlement developments will remain in the future. Güney et al (2006) suggested that bush and scrublands are densely used in the mountainous areas with the rising numbers of stocks. In terms of severe aridity, it would be possible to see such land conversion from forests to agricultural fields or pastures in the basin.

According to third scenario, we expect some changes with the main vegetation zones. For example timber line zone can be reduced by the nomadic land use in the plateaus, more by grazing on the upper parts and by the change in air temperature on the lower parts. In some cases second house developments and recreation would be another driving force on the declining timber line (Figure 5).

Whatever the change on the vegetation will be

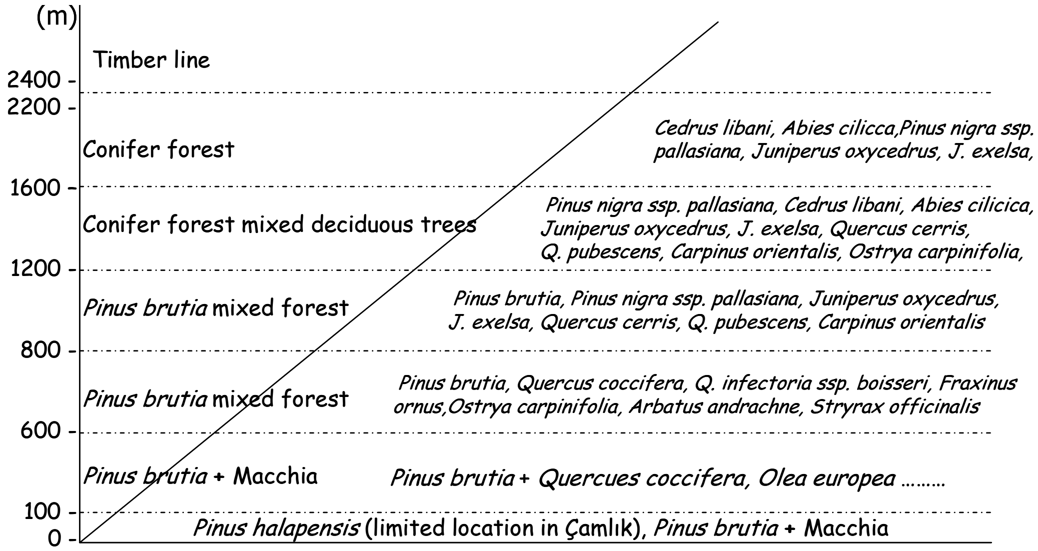

Figure 2. Expected change on vertical distribution of vegetation according to first scenario

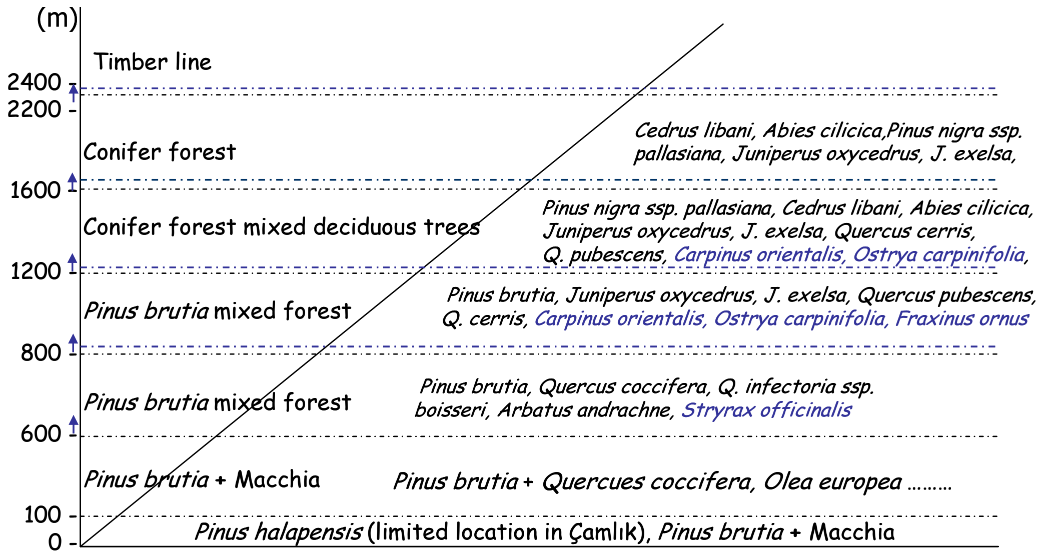

Figure 3. Expected change on vertical distribution of vegetation according to second scenario

in the future based on either climate change on land use demands, long-term monitoring on site will be needed for the exact change that the area will experience. Such changes can be monitor in used and un-used areas to see the impact of climate of its own and, impacts of anthropogenic pressures on the vegetation. Constant monitoring Parcels' System set up by Turkish vegetation group in Seyhan River Base can be used for farther studies. Plant analysis that will be carried out on these regular monitoring on these parcels in the future will provide precise information about the vegetation change by 2070s and onwards.

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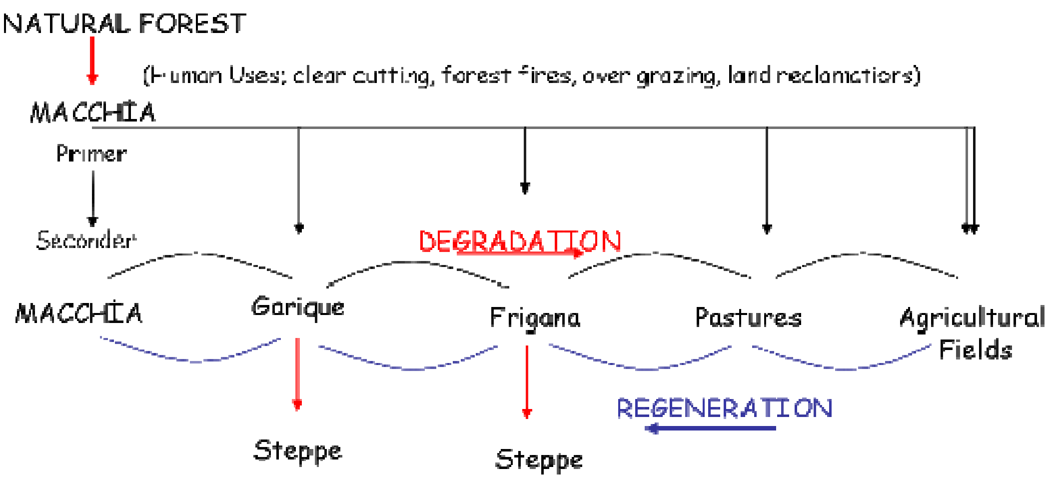

Figure 4. Degradation Levels of Mediterranean Vegetation (Altan, 2000)

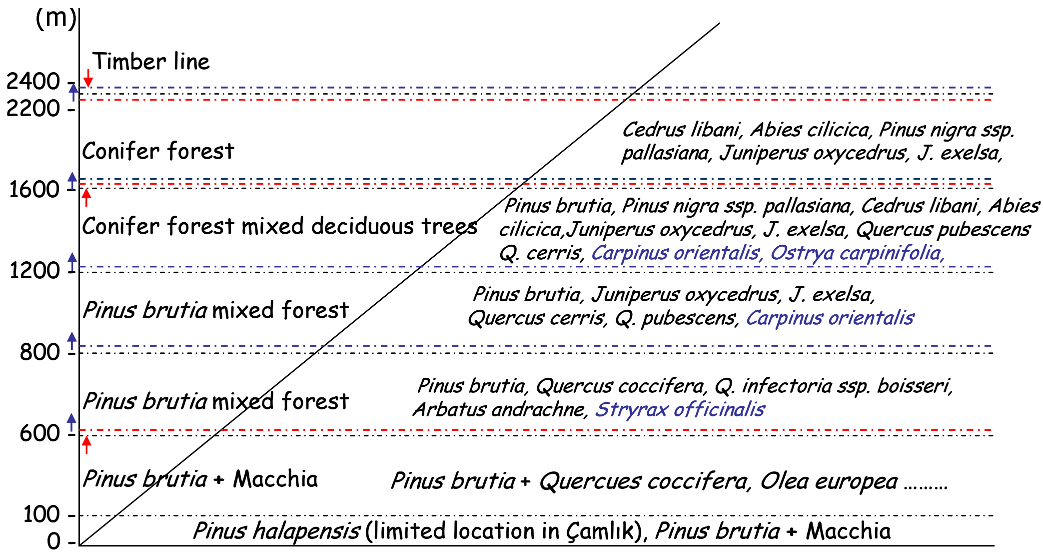

Figure 5. Expected change on vertical distribution of vegetation according to third scenario

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Field Research of Dominant Vegetation and Environmental factors on the Basis of Projection on the Vegetation Change after Global Warming in the Eastern Mediterranean Region of Turkey

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1. Introduction

Climate changes especially global warming are increasingly threatening natural ecosystems as well as human-induced disturbances (Evrendilek and Wali, 2004). Our purpose is to clear the relationship between global warming and vegetation change in relation to anthropogenic impact in the eastern Mediterranean region of Turkey. We researched the species composition and structure of dominant vegetation types and some environmental factors from the coastal line to the timber line. There are various vegetation types along the climatic and topographic gradient in Turkey (Yilmaz, 1998). In this region, the most frequently occurring evergreen forests are *Pinus brutia* secondary forests. Other confers are *Pinus halepensis* in the coastal regions, and *Abies cilicia* and *Cedrus libani* in the higher part of mountains. The most commonly occurring deciduous forest trees are various kind of *Quercus* species such as *Q. coccifera, Q. infectoria and Q. cerris*. Other common trees, mostly seen in mid-altitude mixed forests, are *Carpinus*, *Fraxinus*, *Styrax* and some maquis species such as *Arbutus andrachne* and *Q. coccifera* (Sano et al. 2003; Ando et al. 2004). Steppe-type vegetation is widespread in the dry and cold climatic zone, although anthropogenic, or man-made destruction is clearly visible as well as the lowlands of Central and Western Europe (Vera 2000).

2. Study area and methods

In 2003 and 2004, species composition, stand structure and environmental factors were measured at fourteen plots (Table 1 and 2) under relatively good conditions left from the Mediterranean coast to the mountain (ca. 0-2000 m a. s. l.) in the following regions; (1) Yumurtalik and Adana, (2) Catalan, (3) Karatepe, and (4) Aladag. We measured DBH and tree height for each individual, and slope direction, inclination, altitude, latitude and longitude for each plot. Cores with increment borers and hemispherical photographs using NIKON Coolpix 950 digital camera with a fisheye converter were taken in each plot.

Table 1 Stand characteristics of research plots in 2003

Plot	1 Yumurtalik	2 Catalan	3 Karatepe 1	4 Karatepe 2	5 Aladag 2	6 Aladag 3	7 Aladag 1
Dominant species	*Pinus halepensis*	*Pinus brutia*	*Pinus brutia*	*Arbutus andrachne*	*Pinus brutia*	*Abies cilicica*	*Cedrus, Abies*
Size mxm	50x40	20x20	30x20	15x6	50x30	40x40	30x20
Inclination	2	10	21	21	10	26	12
Direction	N50W	N40W	N45E	N30W	N65W	N60W	S35E
N	36°44′49.2	37°12′04.4	37°17′45.4	37°15′48.4	37°33′32.9	37°28′06.4	37°36′20.8
E	35°37′40.4	35°15′22.4	36°15′02.7	36°13′35.5	35°23′31.7	35°19′10.1	35°29′17.3
Altitude	3	151	253	559	793	1223	1532

Table 2 Stand characteristics of research plots in 2004

Plot	8 Catalan 1	9 Catalan 2	10 Aladag 1	11 Aladag 2	12 Aladag 3	13 Aladag 4	14 Adana
Dominant species	*Pinus brutia*	*Pinus brutia*	*Pinus nigra*	*Pinus nigra*	*Cedrus libani*	*Abies cilicica*	*Quercus coccifera*
Size mxm	20x20	20x20	20x40	20x20	20x40	20x40	10x10
Inclination	18	22	18	20	10	15	32
Direction	S70W	S55W	N60E	N70W	N80E	N80W	N80E
N	37°16′47.9	37°16′03.4	37°37′28.6	37°37′31.7	37°36′28.8	37°36′25.9	37°03′51.1
E	35°11′16.6	35°11′37.6	35°28′13.7	35°28′43.2	35°28′53.7	35°28′51.0	35°21′18.2
Altitude	263	329	1951	1840	1403	1379	102

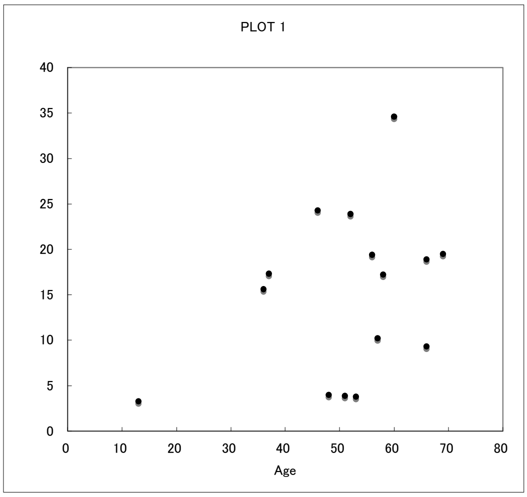
3. Results and discussion

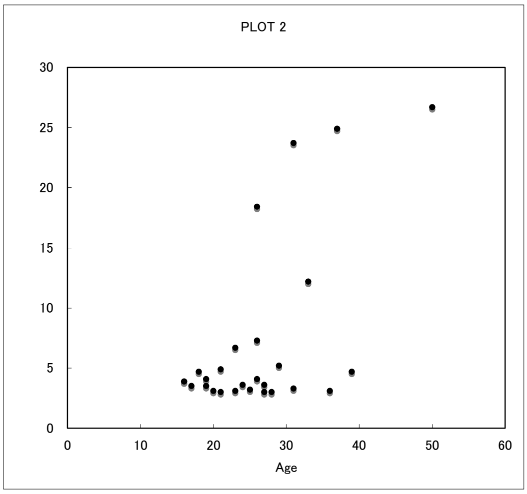
Tree species composition with relative basal area (BA%) in each plot is shown as Table 3. There were 22 species occurred in our research plots. Dominant tree species were *Quercus coccifera* with many maquis species in low land area, *Pinus brutia* in the mid-altitude regions, *Abies cilicica, Cedrus libani* and *Pinus nigra* in the subalpine region. *Pinus nigra* was found on relatively high-altitude area, which formed pure stands.

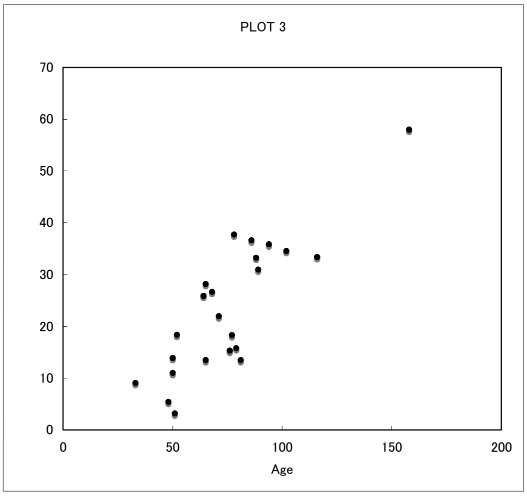
Table 3 Species composition and dominance (BA %) of trees in each plot along elevation

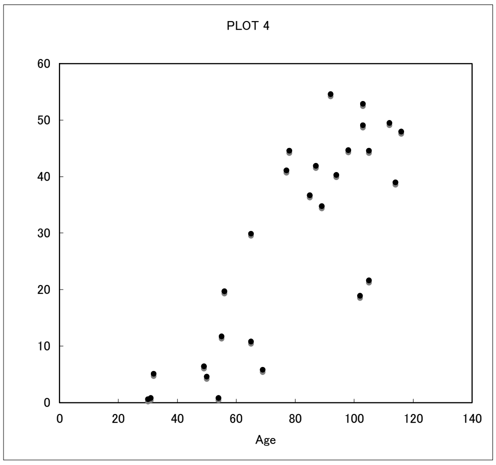
Plot Altitude m	1 3	14 102	2 151	3 253	8 263	9 329	4 559	5 793	6 1223	13 1379	12 1403	7 1532	11 1840	10 1951
Pinus halepensis	100.0													
Quercus coccifera		78.6	0.5	2.1	0.0		20.3							
Cistus creticus		3.1												
Pistacia terebinthus		1.6												
Phillyrea latifolia		2.4			0.3									
Pinus brutia		14.3	98.9	95.2	99.6	100.0		100.0						
Fontanesia phillyrioides			0.5											
Olea europea			0.2											
Arbutus unedo					0.1									
Arbutus andrachne				1.8			57.7							
Myrtus communis					0.1									
Quercus infectoria				0.3			13.6							
Styrax officinalis				0.5			2.8							
Fraxinus sp.							5.6							
Carpinus betulus									3.3					
Carpinus orientalis									2.0					
Quercus cerris									1.9					
Abies cilicica									92.5	35.5	2.4	43.9		
Juniperus oxycedrus									0.3			14.3		
Juniperus excelsa										11.8				
Cedrus libani										24.9	87.2	35.1		
Pinus nigra										27.9	10.4	6.8	100.0	100.0
BA (m2/ha)	8.8	1.2	16.0	42.4	31.1	8.1	20.6	36.5	36.4	40.1	40.8	43.0	73.3	46.6

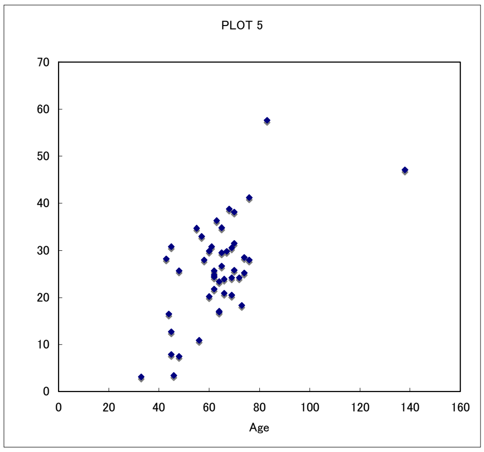
Relationship between tree age and size (DBH) in each plot is shown as Figure 1. Generally showing positive relations that size increased along age, it had great variance of size for a given age, which means difference of growth in each tree.

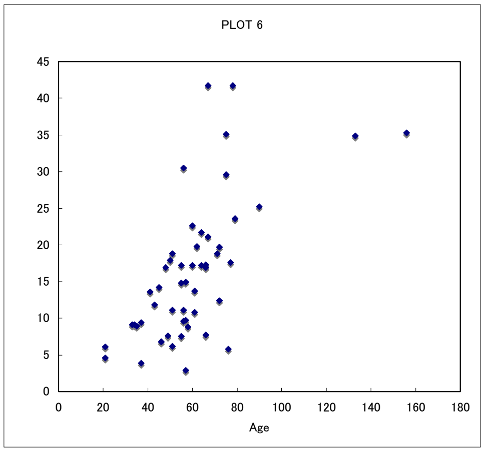












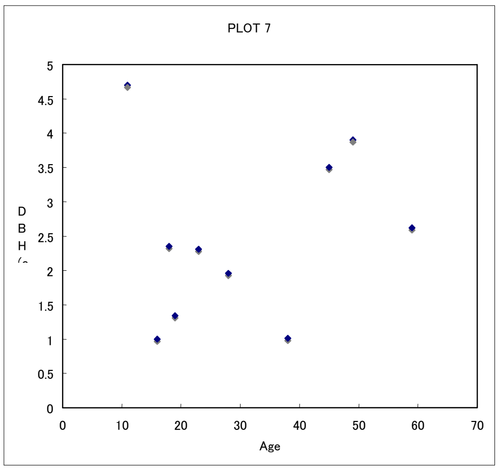
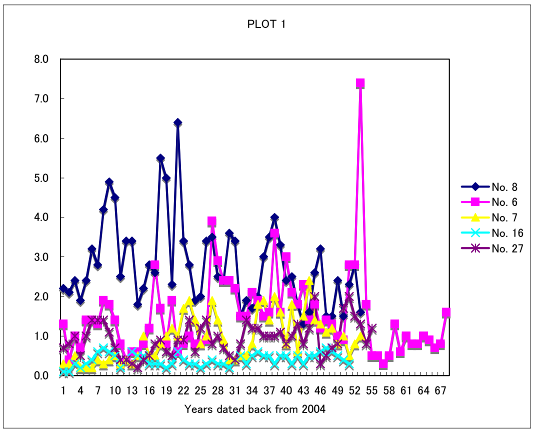
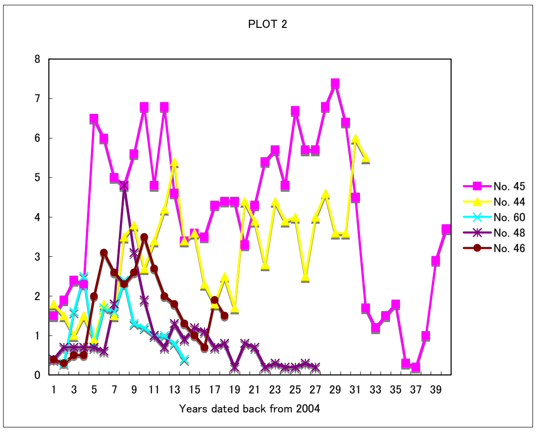
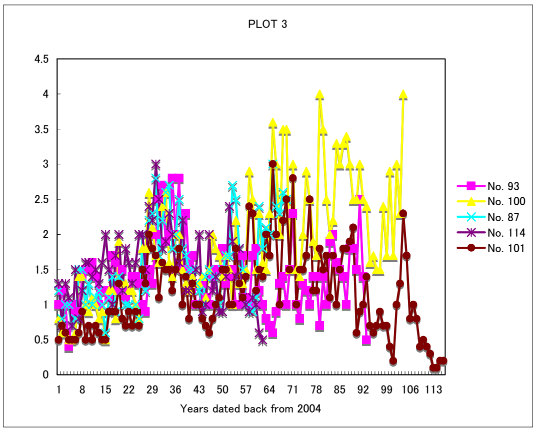


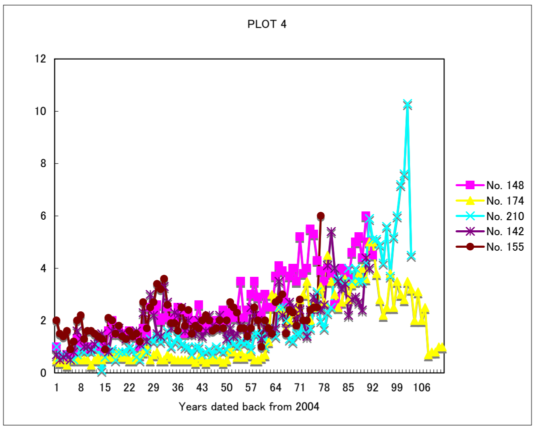
Fig. 1. Relationship between tree age and DBH in each plot

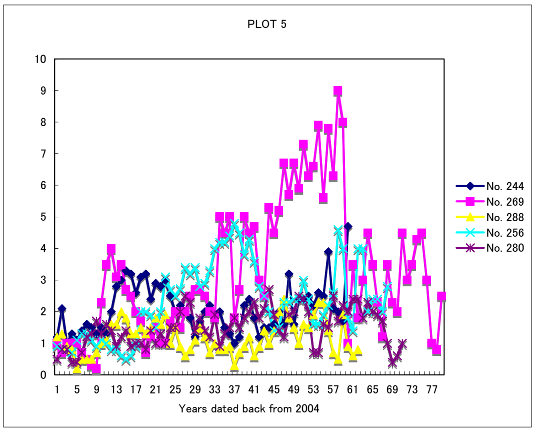
Annual tree growth of radius in each plot is shown as Figure 2. It had growth variations year by year. The fluctuation, however, did not show the obvious pattern of the evidence of climate change. Further research and analysis are required to reveal the issues on the relationship between tree growth and climate.

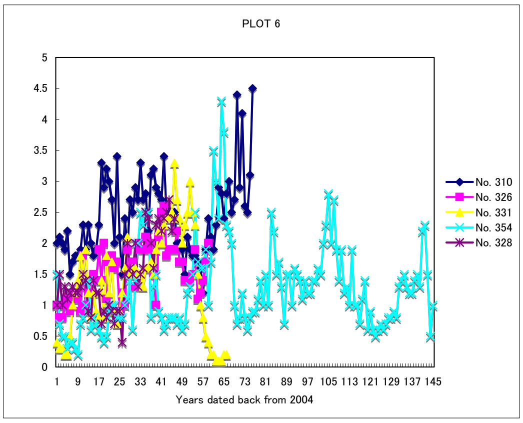












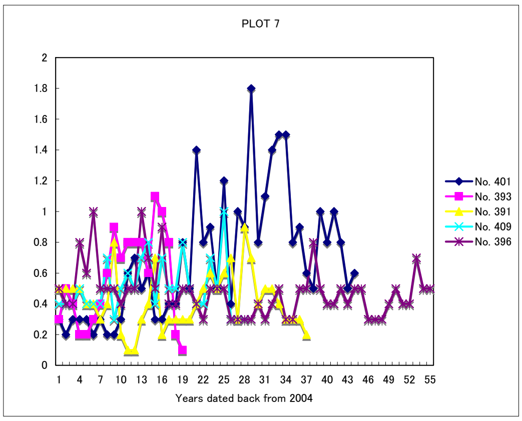


Fig. 2. Annual growth of radius along age in each plot

Table 4 Canopy cover (%) in each plot

Plot	1 Yumurtalik	2 Catalan	3 Karatepe 1	4 Karatepe 2	5 Aladag 2	6 Aladag 3	7 Aladag 1
Date	20030823	20030829	20030827	20030828	20030825	20030825	20030824
Mean	49.024	72.587	71.745	78.139	64.862	84.502	80.718
SD	12.111	2.642	3.638	4.957	3.593	3.082	3.870
CV	24.704	3.640	5.070	6.344	5.540	3.648	4.794
Max	62.190	76.021	76.735	86.375	71.074	88.626	87.878
Min	24.698	69.642	67.141	73.160	57.988	81.607	77.497

Canopy cover in each plot is shown as Table 4. It seems to be depend on elevation.

Canopy cover was extremely low at Plot 1 in Yumurtalik because of scarce distribution of canopy trees dominated by *Pinus halepensis* (Figure 3a). On the other hand, relatively high covers of canopy trees were shown at Plot 6 and 7 in Aladag, higher part of this region (Figure 3b).

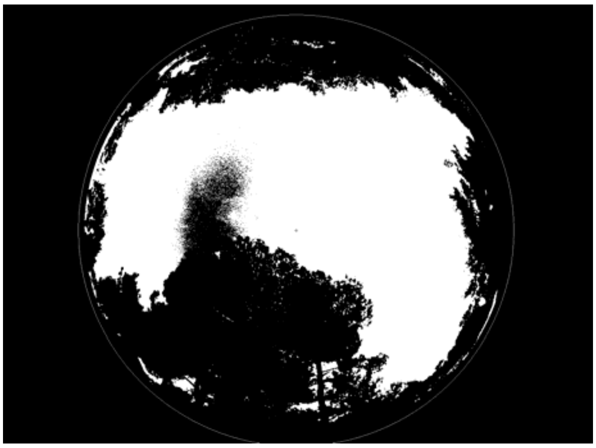


Fig. 3a. Hemispherical photograph at Plot 1 in Yumurtalik

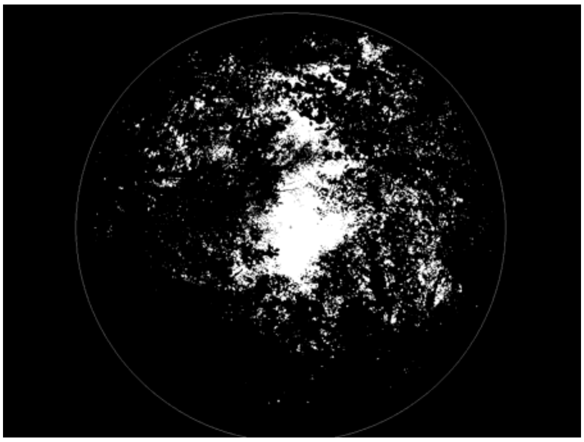


Fig. 3b. Hemispherical photograph at Plot 7 in Aladag

Long-term monitoring and sustainable management of natural resources are required for future generations (Kilik et al. 2003). We should pay attention to the vegetation change with climate change in future.

4. Acknowledgements

We sincerely thank to Professor Dr. Tuker Altan, Dr. Mustafa Altar and their student Volkan Deneri at the Cukurova University; Drs. Ekrem Aktoklu, Mustafa Atmaca and Kayhan Kaplan at the Mustafa Kemal University; Dr. Meryem Ayik at the Akdeniz University: Mr. Ramazan Gokdemiraglu at the Forest Office in Aladag, and many people in Turkey for their arrangement and help of our field research and useful discussion. Also we greatly thank to Professor Dr. K. Tuluhan Yilmaz, Dr. Hakan Alphan and Yuksel iZcankurtaran for their help to our preliminary research; Professor Dr. Tsuguhiro Watanabe, the Project leader of ICCAP, Drs. Takanori Nagano, Yoichi Fujihara, Ms. Noriko Sasaki, Naho Kawadura and many staff of RIHN, Dr. Fujio Kimura at Tsukuba University and Dr. Kenji Tanaka at Kyoto University and all ICCAP members for their great help and support to our research, and Tottori University students, Mr. Keisuke Kato and Ms. Yuki Kishibe for their data analysis especially on the land-use pattern using a Landsat image and on the potential vegetation patterns in present and future.

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The Vertical Distribution of the Vegetation on Cukurova Plain in the Eastern Mediterranean Region of Turkey

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1. Introduction

There are various vegetation types along the climatic and topographic gradient in Turkey (Altan, 2000). Especially in the eastern Mediterranean region of Turkey, they contain a number of differing biotopes such as grassland above the timber line, evergreen coniferous and deciduous broad-leaved forests, scrubland, river beds, lagoons, coastal saltmarshes, coastal woodland, and sand dunes. And, the cold climate in the north and arid/semi-arid zones in the south, help to enhance the ecological diversity of the Anatolian Peninsula and there is a considerable diversity of flora in the mountainous region (Yilmaz, 1998). If global warming occurred, it will most likely affect the vertical distribution of the vegetation of this region through changing complexly the distribution of each species.

2. Investigation site

This region has been strongly affected by past human activities since at least the early Neolithic period. Though it is known that not only the mountainous part of the region but also the present Ceyhan and lower Seyhan plains were covered with dense oak forests in the eighteenth century, it is difficult to find natural vegetation, especially in the plains and the low elevation area of the mountains now(Yilmaz, 1998).

The field surveys of vegetation distribution and land use were done on the basin of the Seyhan and Ceyhan rivers from 2002 to 2006, and 14 permanent plots were set to investigate the stand structure of main forests in the area where natural state were remained comparatively from the Mediterranean coast to the mountain region(ca. 2,000m a. s. l.).

3. Vertical Distribution of the Vegetation

Above the timberline, which is at about 2,000m above sea level, sub-alpine grasslands, characterized by thorn-cushion formations of *Astragalus* sp. and *Acantholimon* sp., dominate.

Between 1,000(1,200)m and 2,000m, *Pinus nigra*, *Cedrus libani*, *Abies cilicica*, *Juniperus excelsa*, *J.oxycedrus* and *J.drupacea*, form a montane forest type. Various species of deciduous oak, such as *Quercus cerris*, and others like *Ostrya carpinifolia*, *Carpinus orientalis*, *Fraxinus* sp. and *Sorbus* sp. mix with conifers or dominate. *Fagus orientali*s and *Quercus libani* appear partly at the middle and lower parts of this range. *Styrax officinalis, Daphne oleoides*, *Sambucus nigra* etc. are seen at lower tree layer and the shrub layer, too.

Coniferous forest dominated *Pinus brutia* is to be found up to an altitude of 1,000(1,200)m. and is replaced by *Pinus nigra*. *Platanus orientalis* dominates in the riparian forest, and *Tamarix* sp., *Nerium oleander* and *Cotinus coggyria* appear. Furthermore, up to an altitude of 600m, a dense, xerophyll scrubland, called maquis, dominates and understory vegetation of *Pinus brutia forest becomes rich*. Maquis mainly consists of several species of evergreen shrub. The most common species in the maquis region is *Quercus coccifera* and mixes up *Phillyrea latifolia*, *Myrtus communis*, *Arbutus andrachne*, *Erica manipuliflora, Pistacia terebinthus, Pistacia lentiscus* etc. or deciduous trees species such as *Styrax officinalis*, *Cercis siliquastrum Cotinus coggyria etc*. If *Pinus brutia* forest and maquis are degraded, they are replaced by garrigue formation consisting of several dwarf species such as *Cistus* sp.(*C.salviifolius* and *C.creticus*), *Lithodora hispidula, Rubus sanctus,* thorn tree *such as Calicotome villosa, Capparis spinosa* and *Paliurus spina-christi* as well as *Myrtus communis* and *Erica manipuliflora.* Garrigue formation is common from the coast up to approximately 500m above sea level. This is due mainly to the intensive influence of man in this region.

On the plain, where cultivation is intensive, it is not easy to find any patches of natural vegetation. Few old, solitary trees of *Quercus ithaburensis* ssp. *macrolepis* from the former oak forest remain and *Prosopis farcta* penetrates on the cultivated land.

The margins of stream in the plain and the wetlands around coast are covered with dense reed beds (*Phragmites australis*).

Around the river estuaries, salt marshes cover large areas on the hydromorphic alluvial soils. This type of biotope has an almost uniform vegetation aspect, consisting of hallophytes such as *Arthrocnemum* sp., *Salicornia europaea* and *Atriplex portulacoides* in variable dominance. A patch of coastal woodland, remaining from a former evergreen forest, is located at Yumurtalik Bay. This woodland community, which is surrounded by the saltmarsh, is dominated by *Pinus halepensis*. However, due to intensive grazing, the undergrowth has largely been degraded to garrigue-type vegetation with *Erica manipuliflora, Myrtus communis, Cistus* sp., *Pistacia terebinthus, Pistacia lentiscus, Tamarix smyrnensis, Juncus maritimus, Vitex agnus-castus, Imperata cylindrica, Nerium oleander, Cionura erecta* etc.

In the foredune zone, which is influenced directly by the sea, *Cakile maritima-Salsola kali* communities dominate. Other common species include *Ipomoea stolonifera*, *Pancratium maritimum*, *Euphorbia peplis*, *Medicago marina*, *Zygophyllum album*, *Cionura erecta*, *Echinops ritro* and *Eryngium maritimum* (Yilmaz, 1998, Yilmaz and Altan personal communication, 2002-2006, Sano et al. 2003, 2004, 2004, Ando et al. 2004, Aktoklu et al.2004, Atomaca et al.2005）.

Thus, the lower area on the basin of the Seyhan and Ceyhan rivers is already considered to be close to the lower limit of the forest and to be very sensitive to environmental change.

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In addition, this report added the investigation results in 2004 and 2005 on the basis of the report by Ando et al. in 2004. Identification of plants referred to Davis (2000) and Yilmaz (2001).

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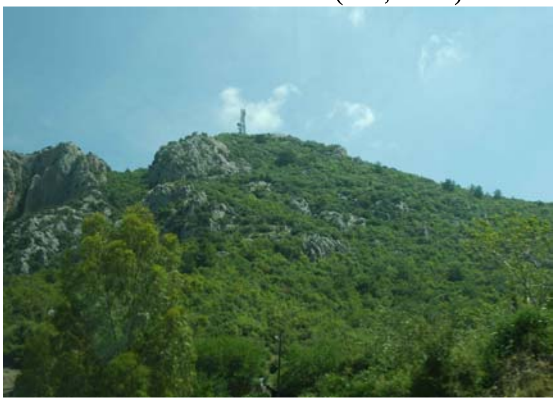
Pinus nigra at the timberline of Mt.Akinek(2,023 m)

Cedrus libani forest at KeciKelesi(ca 1,400 m)

Pinus brutia forest at Aladag（793 m）



Maquis at Mt.Karli Kayatepe(600 m)

Halophyte community at the mouse of the Ceyhan River

Dune at the Mediterranean Sea coast


Astragalus sp.


Acantholimon sp.


Pinus nigra


Cedrus libani


Abies cilicica


Juniperus excelsa


Juniperus oxycedrus


Quercus cerris


Ostrya carpinifolia


Carpinus orientalis


Fagus orientalis


Styrax officinalis


Daphne oleoides


Sambucus nigra


Pinus brutia


Platanus orientalis


Tamarix smyrnensis


Nerium oleander


Cotinus coggyria


Quercus coccifera


Phillyrea latifolia


Myrtus communis


Arbutus andrachne


Erica manipuliflora


Pistacia terebinthus


Pistacia lentiscus


Cercis siliquastrum


Cistus sp.


Lithodora hispidula


Rubus sanctus


Calicotome villosa


Capparis spinosa


Paliurus spina-christi


Quercus ithaburensis


Prosopis farcta


Phragmites australis

Arthrocnemum fruticosum

Salicornia europaea

Atriplex portulacoides

Pinus halepensis

Juncus maritimus

Vitex agnus-castus

Imperata cylindrica

Cionura erecta

Cakile maritima

Salsola kali

Saccharum ravennae

Ipomoea stolonifera

Pancratium maritimum

Euphorbia peplis

Medicago marina

Zygophyllum album

Echinops ritro

Eryngium maritimum

Past, present and future perspectives of indigenous livestock production systems in the seyhan basin, southern turkey

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1. Introduction

Climate change is particularly threatening agriculture in undeveloped and developing countries because sustainable water management measures are not developed together with land management policies.

An internationally recognized method for assessing the environmental effects of livestock production should follow a standard pattern and should be applicable to all sites and to an integrated system of agriculture. In order to satisfy these requirements, relevant key indicators are selected for the respective site conditions. The method for testing the environmental impact is demonstrated above in the flow-chart for selected indicators (Figure 1). Livestock activities influence ecosystems which lead to a change in societal responses and subsequently, the market structure and prices that are affected by the society itself. Since natural resources are strongly influenced by these changes, some precautions have to be taken in the management of the livestock. The advantages of this method are that it provides a transparent evaluation and takes account of the sensivity of the resources.

The ICCAP (Impact of Climate Changes on Agricultural Production System) project focuses on predicting the future situation of agricultural production systems in 2100 under the above mentioned conditions of climate changes in the Seyhan basin (Southern Turkey). Livestock products provide self-sufficiency for families, in situations where the land is of poor quality and crop cultivation is often difficult and constrained by several environmental factors such as rainfall, very high temperature and poor soil fertility. Diversification in farming is a difficult task to attain, however integration of livestock production to the system would make significant contribution to poor farmers and the stability of small farm systems. It is evident that livestock husbandry/pastoralism will continue to be important for the food producing system in the 21st century throughout the world.

The purpose of this study is to determine the current livestock activities in the Seyhan basin and predict its changes due to the climate in 2100. The current and past perspectives of the livestock production systems will primarily be evaluated in the period of 2004-2005, together with future changes.

The following items of priority were specified for this aim;

- To determine the current situation of the grazing pattern, grazing area and feed resources
- To determine the current situation of crop cultivation
- To determine the current economic situation related with the livestock production system
- To determine the current social relationships on farm/village and inter-village levels
- To determine the past situation of pastoralism

2. Methodology and materials

Material

Data collection was done with a questionnaire* interviewing the farmers about their family background in this study. On the other hand some points are noted for the Project implementation as well.

Survey Area

The survey area of the Project is indicated below.

in the following points.

Zones	Elevation	Towns	Total Number Villages	Selected villages	Names of villages
I	1300-1400	Tufanbeyli	14	2	1.Kirazlıyurt 2. Kayarcik
II	1000	Saimbeyli	9	1	1. Himmetli
III	700	Aladag	18	2	1.Kökez 2.Dölekli
IV	400	Karaisali	37	3	1.Gildirli 2.Bolacalı 3.Güvenç
V	0	Karatas	6	1	1. Ataköy
		Total	84	9	

* Questionnaire form is enclosed at the end of the text

Method

Kind of livestock, daily patterns of grazing (time to go out and come back) and feeding (time and amount per livestock), grazing areas (natural rangeland and/or cultivated field and/or pen) as well as the annual period of its utilization was surveyed by interviews in the winter of 2004 and summer of 2005. The distribution of the grazing areas was also drawn on topographic maps (1/25.000).

1. To determine the current situation of crop cultivation

Types of crops, patterns (time of seedling and harvesting) as well as the area and production of each crop cultivation/yield were surveyed by interviews in the winter of 2004 and summer of 2005.

2. To determine the current economic situation related to the livestock production system

Income resources, such as the income obtained from milk-meat products, crops and labor.

3. Determination of the current social on farm/village structure

Compiling information on the current education level and structure of families and sizes of the households and management of plant residues (stubble, forage etc.) by cooperative action. Determination of intra and inter numbers of people employed.

4. Determination of indigenous pastoralism

Patterns of migration in the area were considered as

-Migration patterns in the Seyhan basin partly depend on available natural resources, communal politics and etc. The migration patterns of several indigenous groups differ according to temporal variations.

-Migration routes

-Composition of migrated flocks

-Seasonal movements of the flocks will be followed during the field survey.

-Migration patterns of the historical changes i.e. time serial changes and transitions in grazing patterns will be determined.

The public survey has been carried out in the villages of 5 districts within the borders of Adana province and in the Seyhan basin. The altitude and animal population have been taken into consideration while defining the villages and districts. These data have been obtained from The Directorates of Agriculture in districts and provinces and from the mukhtars. In this context, the animal farmers in villages of Kirazliyurt and Kayarcik in Tufanbeyli, Himmetli in Saimbeyli, Kökez and Dölekli in Aladag, Gildirli, Bolacali and Güvenç in Karaisali, and Ataköy in Karatas have been interviewed. (See Figure 2) The public survey has been carried especially on the animal farmers out of the 10 % of the total house number in each village by Intentional Illustration Method. The numbers and the frequency of the questionnaires administered are given in Table 1.

Table 1. Questionnary Numbers And Distribution By The Villages And Districts (The Data Were Collected By Garmin GPS Device).

Research Area	Frequency	%	Altitude	Position
Tufanbeyli	**37**	**31,4**		
Kirazliyurt	12	10,2	1474m	N38 06.239 E36 17.514
Kayarcik	25	21,2	1463 m	N38 10.212 E36 16.860
Saimbeyli	**17**	**14,4**		
Himmetli	17	14,4	680 m	N37 51.936 E36 03.495
Aladag	**26**	**22,0**		
Dölekli	12	10,2	786 m	N37 35.257 E35 18.234
Kökez	14	11,9	1083 m	N37 35.937 E35 15.147
Karaisali	**27**	**22,9**		
Gildirli	9	7,6	728 m	N37 21.625 E35 03.042
Bolacali	7	5,9	512 m	N37 13.741 E34 59.285
Güvenç	11	9,3	236 m	N37 13.606 E35 05.339
Karatas	**11**	**9,3**		
Ataköy	11	9,3	22.5m	N36 45.207 E35 06.811
Total	**118**	**100,0**		

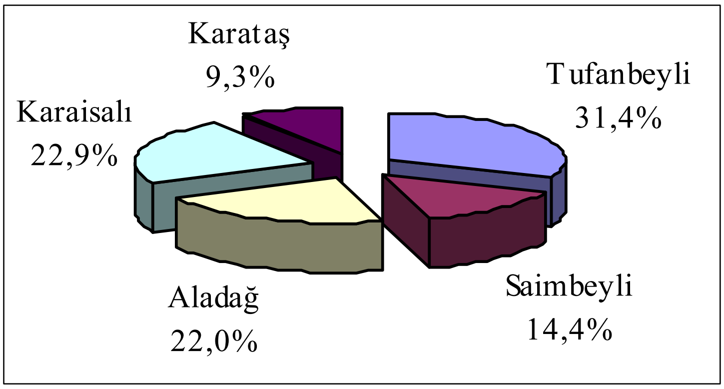

Fig. 3. Frequency of Questionnary

Totally 118 questionnaires have been carried on aimed at the farmers in the area. As mentioned before, the frequencies and percentages shown in the Table 1 and Figure 2 have been realized on the basis of the data obtained from the mukhtars. Therefore, 37 questionnaires in Tufanbeyli, 17 questionnaires in Saimbeyli, 26 questionnaires in Aladag, 27 questionnaires in Karaisali and 11 questionnaires in Karatas have been carried out.

Vegetation analyses

Plant cover, botanical composition, and grazing capacity of these pastures were determined at June 2005. The nets (60 x 80 x 100 cm) were nailed on to the different parts of pastures at February 2005, before the grazing period, for determination of the pastures fodder yield and so grazing capacity. Three nets were placed to the different directions of the pastures for each village. At the end of the grazing period, the nets were removed and the space inside of a quadrate (33 x 33 cm) was harvested from the soil surface. This is replicated three times for each net. The plant material harvested was weighted and the obtained value was converted to the yield for 1 hectare.

Vegetation measurements were done with the loop method modified from the dot quadrate techniques especially for the arid and semi arid regions. In this technique, each 20 cm from the line of 20 m was identified in relation with plant species. Accordingly a hundred records were obtained along a line around the each net.

Identification of plant species

Undefined plant species during the measurement were collected, mounted and identified as herbarium specimen. The codes temporary given in the field for the undefined ones were replaced the corrected names after identification.

Plant Cover

The equation below is used to calculate how much land covers with the plant.

$$\text{Plant Cover (\%)} = \frac{\text{Total Plant Cover}}{\text{Investigated land}} \times 100$$

On the other side the place without plant was determined with the help of the formula below;

Surface without plant (%) =100 – total plant cover

Calculation of botanical composition

The percentage of a species among the total is expressed as botanical composition for that species. And it is calculated using this formula.

$$\text{Botanical Composition (\%)} = \frac{\text{Plant cover of species 'A'}}{\text{Plant cover of whole species}} \times 100$$

3. Results

3.1 Past and Current Situation of the Land Using System in the Seyhan Basin

Generally, from 1991 to 2002 total forest area of the Seyhan basin has increased. The percentage of this increment is aprox. 6 %. Decreasing has only been observed in Pozanti district. If we would like to criticize this situation, it can be said that these area is using for building summer houses. Especially in summer season people, live in city center; prefer to stay at upland regions of Pozanti. Due to this reason new buildings have been established for summer tourism.

Totally 48.970 ha land is used for shrub and grassland in the area. As it is expected, shrub and grassland area is larger at Tufanbeyli and Saimbeyli than the other towns. Tufanbeyli and Saimbeyli towns are plain area. The hilly and mountainous lands of these two towns are lower that the others.

According to farmer's reports, the grazing starts in March and ends at the end of November or beginning of the December. Only in Aladag, the period is different due to the altitude. Aladag is hilly and mountainous region and snowing starts earlier than the other regions. In Aladag, Tufanbeyli, Kozan and Karaisali, flocks have transferred to grassland during to daytime both in winter and summer while flocks of Saimbeyli and Karatas have transferred both in day time and night time. Herds of all towns have been grazed even in winter season in whole area.

In high lands grazing starts at August and ends in September for all species. But in low-land areas such as Kozan, Karatas and Karaisali, grazing starts and ends earlier than the others. Both grazing in grasslands and harvested areas stated in day-time.

The number of goat, sheep, cattle, horse and donkey slump down during 18 years. The reasons of this decrement are political and socio-economical which will be discussed following sections.

In the scope of ICCAP, the results of the public survey on the animal raising have been evaluated and the findings have been summarized as below.

Table 2. Changing In Forest Area Of Seyhan Basin From 1991 To 2002 (Ref. Ministry Of Forest, Adana Branch.)

TOWN	YEARS	
	1991 (Ha)	2002(Ha)
ADANA	29.330	37.113
FEKE	22.269	22.589
KOZAN	8.645	8.922
İMAMOĞLU		11.355
ALADAĞ	13.492	13.866
POZANTI	20.634	13.394
TUFANBEYLİ	18.444	24.889
SAİMBEYLİ	21.867	22.676
KARAİSALI	24.847	25.656
ADANA TOTAL	**550.473**	**582.374**

Table 3. Shrub-Grassland Area At Seyhan Basin From 1991 To 2002 (Ref. Ministry Of Forage, Adana Branch)

TOWN	YEARS 2004(Ha)
ADANA (TOTAL)	**48.970**
Feke	5000
Kozan	1770
İmamoğlu	250
Aladağ	1600
Pozanti	3500
Tufanbeyli	10600
Saimbeyli	11700
Karaisali	3400

Table 4. Grazing Periods And Duration Of Grazing In Seyhan Basin (Ref. Interview Of Farmers)

TOWN	Grazing Season	Months	Grazing Hours		
			Goat	Sheep	Cattle
Tufanbeyli	Summer	April-End of Dec	07-19	08-15 21-05	07-19
	Winter	Jan-March	07-16	09-16	09-15
Saimbeyli	Summer	April-Dec.	03-10 14-21	17-08	13-17
	Winter	Jan-March	07-16	07-16	07-16
Aladağ	Summer	April-Sept.	08-12 15-18	08-17	08-17
	Winter	October-March	08-15	08-15	08-15
Kozan	Summer	Always	08-17	08-17	08-17
	Winter	Always	08-16	08-16	08-16
Karaisalı	Summer	March-Dec.	08-12 13-18	08-12 13-18	08-15
	Winter	Jan-Feb	08-13	08-13	08-13
Karataş	Summer	March-Novem.	06-22	06-20	06-18
	Winter	Dec.-Feb.	07-20	07-18	07-18

Table 5. Period And Duration Of Grazing In Harvested Lands Ref. Interview Of Farmers)

TOWN	**Months**	**DURATION (h.)**		
		Goat	**Sheep**	**Cattle**
T.BEYLİ	August-Sept.	07-19	08-15 21-05	07-19
S.BEYLİ	August-Sept.	07-10 14-21	17-08	13-17
ALADAĞ	August-Sept.	08-12 15-18	08-17	08-17
KOZAN	July-August	08-17	08-17	08-17
K.İSALI	July-August	08-12 13-18	08-12 13-18	08-15
KARATAŞ	June-July	06-22	06-20	06-18

Table 6. Changing In Livestock Population In Seyhan Basin (Ref. Ministry Of Agriculture)

Years	**Species**	**Aladağ**	**Karaisali**	**Karataş**	**Kozan**	**S.Beyli**	**T.Beyli**
1984	Sheep	-	30442	16397	41540	22811	31703
	Goat	-	101621	644	69177	35290	10601
	Cattle	-	21838	18964	33717	7823	13230
	Horse	-	1442	191	22059	1129	116
	Donkey	-	4224	180	3137	1675	1938
	Donkey	699	400	17	1720	1985	1330
2002	Sheep	17448	23450	9081	46000	17465	6200
	Goat	32749	41750	220	48000	59910	6700
	Cattle	7854	8935	7022	28055	2095	9300
	Horse	490	622	50	1145	990	95
	Donkey	700	408	9	1720	1970	1330

3.2 Village Questionnary

Some general information's according to villages are given below, as well.

As it is shown that, the larger villages are Kirazliyurt, Gildirli and Güvenç. Household number of Himmetli village is higher than the others. Additionally Kayarcik is the most crowded village in the survey area. Kirazliyurt, Kökez, Gildirli, Güvenç, Bolacali and Kayarcik are the mountainous villages. Total surface areas of these villages contain forest, shrubs areas spread on the high mountains. Due to this fact the total surface area of these villages are seems to be higher.

Mosque, electricity and communication are available in all villages of the survey area. School and clinic are not available in Bolacali while only clinic is not established in Ataköy and Gildirli villages. River and springs are reported as water resource of some village such as Gildirli, Bolacali and Kirazliyurt.

3.3 Animal Keepers Questionnary

The applying methods of the Animal keepers for using natural pasture are stated in the Figure 2. It has been noticed that there is a conflict about the natural pasture areas between the data obtained from the villages in which the study are being carried out and the reports obtained from the Directorates of Agriculture in districts and provinces. The findings which were stated in this table have been obtained completely from the statements of the farmers. Therefore, it is seen that majority of the farmers feed their animals in the pastures that are the common properties of the village. As the majority of these areas are used for vegetal production, the areas being talked of are the areas that aren't used by the farmers and that are in the extent of the forests).

The maximum level of the frequency of grazing in the field edges and harvest residues (stubble) also verify these results. Consequently, it is seen that grazing in the residues after the harvesting of crop production is more common than grazing in the natural areas. Also grazing in fallows supports this explanation.

The villages in which bush and shrub areas are densely used by the mountainous villages, which have high altitudes. In these villages, sheep and goats raising are performed more densely. As a result of the interviews with the farmers, it is determined that especially goats are pastured in these areas.

Although it is forbidden to graze in the forestry area, usage of these areas in a density which can not be underrated in the activities of sheep and goats raising -carried out especially in Aladag and Tufanbeyli- attracts high attention. Another point which must be emphasized is that the rate of the animals which are kept in the barns is 13.6 %. These animals contain rather the cattle which are kept in the plains. It is also stated in the table that only one farmer hired a pasture.

According to the statements of the farmers, the changes in the grazing capacity in the pastures in the working area and their frequencies are given in the Table 11.According to the findings obtained, the number of farmers who state that grazing capacity in the grassland change in the last 25 year is 80 and the rate of it is 67, 8 %. However, another finding which attracts attention is that some of the farmers declared that there is no change in the grazing capacity (32, 2 %). It can be said that this condition results from two causes: (a) the farmers take their animals to the higher areas during the summer months that these areas have already been used for animal production only.

Depending on the reduction in the number of animals, in a parallelism with this, the number of animals which use these areas is much less than before; (b) Because the usage of the pastures are so seldom in cattle raising in which the pastures are not so common, the farmers have less information about this.

Depending on the statement above, the opinions of the farmers about the aspects of these changes are given in the Table 12. The data in the Table 12 are obtained from the basis of the statements of the farmers about the change in Table 11.

The 88, 8 % of the farmers who declared that there has been a change in the grazing capacity stated that there has been a reduction in the grazing areas, and 8% stated that there has been an increment and 7, 5% stated no reason.

The reality about the reduction in the grasslands is not only special to this particular area but also to the whole area and the causes of this have been debated above. And it is also seen that the number of the farmers who claim that there has been an increase in the pasture capacity is so few. It can be said that this claim results from the reduction in the number of animals grazing in the working area (A table or a graphic related to the previous reports stating the reduction in the number of animals in the district in the last 25 year can be given here). In the Table 13, changes in pasture capacity in village grassland are given according to the Table 11 and 12.

The fact that most of the farmers who claimed that there had been a change in pasture capacity are from Tufanbeyli and Saimbeyli attracts attention. According to the farmers' point of views, it can be seen that the minimum change occurred in Karaisali. The causes of this change will be evaluated in the light of the data in the Table 14.

The farmers that have been interviewed claimed that the change in the capacity of grassland depends on the reduction in the number of animals and reduction in the annual precipitation. This declaration overlaps with other situations in most of the regions. However, when Table 14 is studied it is seen that the most important factor is that the grasslands are converted to crop production fields (30%). The farmers stated the government's enlarging the cultivated forest areas and banning the goats to be grazed in the forests (32, 5 %) as another reason for the reduction in the grazing areas. A few group of the farmers stated that the grazing areas were reduced because of the drought and reduction in the precipitation (22, 5 %).

During the process of getting the opinions of the farmers, it was stated that there have been some changes in the revival of the vegetation as a result of the change in the time of the precipitation.

When the Table 15 is taken into consideration, the existing situation of the grazing season in animal species terms can be seen.

It was determined that economic potential the goat farmers who allow their animals to the grasslands during all year was 48,8 % and the level of the goat farmers who take their goats to the grasslands during all months except from winter months was 51,2 %. As it was expected, it is seen that only small number of the cattle breeders take their animals to the grasslands during all year (10,8 %) and the majority of them (89, 2 %) take their animals to the grasslands during all seasons except from winter-time. It is understood that constant grazing is realized in the level of 25 % and grazing in all seasons except from winter months is realized in the level of 75,1 %.

The distribution on account of grazing time in the species basis is shown in the Table 16. It is seen that a majority of the goats go to the grasslands in the early morning and stay there till evening (67, 6 %). It was determined that the rest of them take their goats to the grasslands in the early morning (like 3 a.m. at night) till 10 a.m. in the morning. These flocks are generally stayed at the pastures and grazing in the hours when the atmosphere heat is high is not seen.

When the Table 16 is examined, it can be explained that 63, 2 % of the cattle are stocked to the grasslands from the early morning till late evening, and the rest of them are taken to the grasslands, like goats, from the early morning till noon. It is also seen that the 77, 8 % of the sheep are taken to the grassland from the morning till evening, and the rest of them are taken to the grasslands in the duration from the early morning till noon.

The distribution of the feeds that are used in barns is summarized in the Table 17. Feeding the sheep or goats in barns is realized rather in winter months. During the insufficient times of the grasslands, the sheep or goats are kept inside and meanwhile they are fed by some kind of feeds. Additional feeding in cattle is seen generally during the whole year and is done addition to the grazing. It is determined that feeding in barn is based on mostly to pulp (77, 1 %) and to straw (75, 4 %) but at the same time, concentrate feeds prepared by the factories are also given highly (72 %). In addition to these, using the various seeds, grass and dry grass attract attention. Some of the farmers stated that they only gave their animals only grains and straw twenty years ago. However, because of the increase in the performance capacity of the animals and increasing number of the crossbred animals, indoor feeding has increased as well.

The data about the changes occurred in feeding in barn in the recent 25 year shown in Table 17 are dealt with in Table 10. Depending on this, the proportion of the farmers who declared that there has been a change in hand-feeding in the recent 25 year was 57, 6 %, the proportion of the farmers who declared that there haven't been any changes was 30, 5 %. The farmers declared that the changes occurred in feeding resulted from the reduction in the number of grasslands and animals' hunger because of this. Some of the farmers reported that they gave less feed to the animals because of the increase in the prices of the feeds.

It can be seen in the Table 19, a great amount of the farmers reported that there have been some changes in animals' feeding behavior. 69 persons in 71 (97 %) who reported that there have been some changes in animals' feeding behavior stated that this resulted from the reduction in the number of the grasslands and hand-feeding increased because of this.

As it was mentioned above, the responses of the farmers to the question about the terms of giving concentrate feeds to the animals are summarized below (Table 20). Hand-feeding is generally applied more often during the winter months when the grazing is not possible. Nevertheless, feeding is realized limitedly but at a specific level in the cattle production in the durations of pregnancy, estrus and lactation.

The data related with the distribution of the animal species in villages are summarized in the Table 21. It can be seen that the cattle breeding is realized more often through the dairy cattle and the breeding through stock farming is realized at a low level. According to these data, it can be said that cattle feeding is only common in grasslands. Dairy cattle feeding are intensely seen in grassland, Ataköy but in the other villages it can also be seen at a specific level. Sheep or goat production is densely populated in the villages of Karaisali, Saimbeyli and Tufanbeyli and is not preferred in the mountain villages. Another topic that must be taken into consideration is that goat raising is a branch of animal production which is intensively carried out in the area. Also, some findings were obtained which support the literature declarations. It was appeared here once again that goat raising is an activity which is preferred by the people living in highlands.

In the Table 22, the changes in number of animal species during last 25 years were stated

After studying all the findings, it can be inferred that there haven't been many changes in the cattle population, but on the other hand, a considerable decline in sheep and goat numbers could be observed. The decline in sheep and goat numbers wasn't reflected to the cattle production. Consequently, it can be said that there has been an evasion from the stock-breeding and this has been resulted from various factors. These factors are resulted from the changes in the social and economical extents. But if it is studied on the basis of villages, it is seen that some data occur in opposition to those obtained generally. There have been some small developments in sheep production thanks to some incentives related to the policies of the government. It can be seen that, although all these negative conditions in goat production, in the mountain villages like Kökez and Güvenç, the people didn't abandon from this production activity and even the goats increased in number. The causes of the changes according to the farmers are given in the Table 23.

The farmers' transferring their animals because of being no economical depending on the various factors is considered to be one of the most important causes of the reduction in number of animals. In addition to this, the changes resulting from social facts became a cause for farmers' renouncing from animal production. These factors are dealt with in a detailed way in the Table.

The farmers' taking their animals to the cooler areas with them or hiring a shepherd to take them to the cooler areas especially during the summer months have been a strategy for long years. However, as it can be seen in the Table 24, the farmers have been renouncing from this application gradually. The statements related with the changes in the migration routes are given Table 25.

There has been a change in the migration routes of the flock owners related with the previous table. But this change is a very small. The flock owners showed the causes of this change like this; crop production on the areas which they used to go, offended grasslands, the high cost of migration and security problems.

As it was emphasized before, when the economical affects of the migration have been asked to the migrating farmers, 37, 5 % of them stated that migration didn't bring an extra cost to them and their migration routes were to the near surroundings. They also emphasized that as the migration prevented some negative conditions, it also became a benefit economically. Only 27, 5 % of the migrating farmers stated that migration to the farther surroundings bring out some extra costs. From the farmers' point of view, the changes occurred during young animals' weaning time is given in the Table 27.

When it is studied generally, it can be seen that there has been a change in suckling periods of all animal species in the last 25 year. This change has been realized in cattle production because of getting milk at a high level. Generally, sheep or goats are being sucked for 3 months fully according to their birth season and then they are fed with residual milk (after milking). The farmers said that, in the past, they used to use milk for only their own needs and it was enough for both young animals and themselves. However, they declared that now they are used to use some of the milk for cheese making and some amount of it for marketing. Consequently, it is understood that they weaned the young animals in the early stages and they increased the milk production. The seasonal changes that occur related with the estrus and weaning periods are given in the Table 28.

As it can be seen in the Table, most of the farmers are not aware of this subject. Only 27 % of them could give a reason for this change. These reasons were declared as climate conditions (13, 5 %), changes in feeding sources and feeding conditions (10, 2 %) and changes in genotype of animals (4, 2 %). The changes in feeding conditions and grasslands result from the seasonal changes. A considerable finding is that the farmers who declared that there has been a change said that this change resulted from the climates. The proportional distribution of the farmers' responses about what the basic objective is in animal production is seen in the Table 30.

Most of the animals are generally raised for milk production. (42, 4 %) But it is also seen that in some of the business enterprises meat production is also important addition to the milk (41, 5 %). The level of the business enterprises which are using animals for breeding and stud is 11 %. Consequently, it is realized that buying of the studs depend on the public sector. And it was also determined that the business enterprises which are active in meat production were in the sheep raising sector.

It is seen in the Table 31 that the farmers didn't make much changes in their production aims in the last 25 year. Only about 12 % of them changed their production aims.

The milk amount due to species today and 25 years ago has been asked to the farmers who kept milk type animals and the distribution of the responses are given in the Table 32.

Milk is processed in different ways in the business enterprises which kept milk type animals (Table 34). Generally, no change in the milk yield of the sheep and goats is seen depending on their genetic capacities. On the other hand a change in cattle in the level of 135, 2 % is seen. This change results from both feeding the animals with concentrate feed in the covered areas and crossing with exotic breeds such as Holstein Friesian. The responses of the farmers about this change are seen in the Table 33. The declarations of the farmers get along with the declarations above (Improvement in the nourishment conditions 14, 3 %, change resulting from genotype 42, 9 %).

Totally 55, 9 % of the farmers process the milk as cheese and an important part of them sell raw the milk directly. Some of the products given in the table are used for the family's own needs and the rest of it is sold for income. Most of the farmers stated that the cooperatives or merchants bought the milk in a very low price and even they could buy only 1 kg of feed by the income of 1 kg milk. Consequently, they stated that fresh milk selling wasn't economical.

The proportional distribution of the dairy products depending on the previous table is given in the Table 35. According to this table, milk is mostly used for cheese making (70, 3 %), and the rest of it is used for making yoghurt, butter and çökelek. An income is being got by selling the most of the cheese. White cheese and cheese encased in a goat skin is generally produced.

Commercial yeast is also used for cheese making in addition to the traditional yeast (Table 36). The number of farmers who use commercial yeast is more than the proportion of the farmers who use natural yeast. Plug milk, sarkanak (kind of animal tissue) and dried fruit are intensively used as traditional yeasts.

Questions about the changes in the technologies used in processing milk were asked to the housewives and the proportional distribution of their responses was summarized in the table 29. 50 % of the women in farm stated that they used the same ways. 28, 8 % of them stated that there has been a change and added that they used to use traditional ways but now they are used to use commercial yeasts as they are more practical.

It was determined in the working area during different periods that there have been some changes in preservation methods of the processed dairy and meat products. It was seen that they are preserved in the refrigerator as they were spoilt in the past because of being embedded under snow or soil and being kept in caves. After the questions related with this topic, it was determined that 77,1 % of the farmers no longer use the traditional ways and 27 % of them use only caves and skins of the animals.

It was determined that most of the farmers (48, 1 %) use the refrigerator, and rest of them uses the traditional methods for preservation of their products.

It was determined that in the table 32, 16 % of the farmers still use the traditional methods and the rest of them used to embed their products into the soil (29,9 %), preserve them in skins (13,8 %), in caves (6,9 %), in highlands (3,4 %) but now they no longer use these methods.

Most of the farmers stated that their preservation methods have been changed due to technological improvement. And 20, 5 % of them thought that as the reason of this changing are climate changes. The proportional distribution of the farmers statements related with this subject was given in the Table 41.

The proportional distribution of the problems occurring in the animals which are raised in the working area was given in the Table 42. According to the farmers, the proportion of the epidemic diseases is 36, 4 %. Abortion and infertility follow the epidemic diseases. These two problems generally result from the Brucella disease and it is very common in the area. In addition, the farmers' complains about their animals' low productivity is understood from their responses (16, 9 %).

The farmers stated that generally the cause of the diseases that appear at their flocks was the insufficient feeding. And they declared that their animals came down with a disease because of infection or problems that occur during the grazing.

It is seen that the proportion of the diseases resulting from climate conditions is 9, 3 %. It is a well-known reality that there have been problems in health protection in the working area. Especially, vaccination with money is one of the basic causes of their non-vaccination. The costs per animal are given in the Table 44 related with the vaccination. It is seen that the vaccination program is only applied in cattle; the number of farmers who apply the vaccination program to their sheep or goats is very low (2, 8 %). The reason of this, sheep or goat farmers generally work with local animals but on the other hand the cattle farmers work with crossbred animals. Because the crossbred animals are not as resistant as the local animals, the farmers apply the vaccination program only on cattle against different diseases.

The farmers declared that there has been a change in the health protection programs in the last 25 year. These business enterprises are the enterprises who generally work with crossbred cattle. As the crossbred animals are more sensitive than the local animals, it is unavoidable to apply the vaccination program to them. The costs increased in parallel to the health protection application (Table 45). Most of the farmers who were interviewed declared that the cost has changed in the expenditures for health protection.

When the causes of the change during the health protection program were asked to the farmers (Table 46), most of them declared that the fee of the vaccines, medicines and veterinary service prices that are used for this program has increased (56, 2 %), an other part of them declared that in the past there weren't too much diseases but today the proportion of the disease are much higher than the past (49, 4 %). Some of them declared that also lack of the knowledge and changes in genotype of the animals are affective in these problems.

The opinion of the farmers about the change in the size of animals in the last 25 year is in Figure 6. Most of the farmers observed a change in the size of animals in the last 25 year (61, 9 %). The proportion of the farmers who declared that there hasn't been a change can not be undervalued.

Most of the farmers who declared that there has been a change in the size of animals in the previous table stated that this development results from genetic improvement (42.5%). About 32, 9 % of them showed the decreasing to pasture land as the cause of these changes in the size of the animals. While defining the cause, the causes depending on feeding as a result of the reduction in natural feed sources were considered.

The findings about employment in the business enterprises who are dealing with stockbreeding take place in the Table 48. Only 11 % of the business enterprises give employment and the rest of them don't. The farmers define the shepherds as the workers. The shepherds are generally the workers who are hired in common when the flocks are taken to the higher lands during the summer months. They are hired only as seasonal workers.

The sources of income of the business enterprises who are dealing with livestock production are given in the Table 49. It is seen that the incomes of most of these enterprises are from stockbreeding. However, it is understood that crop production is also an important source of income (69, 5 %). A small amount of the farmers works at a paid work. Especially, the villagers from Bolacalı and Güvenç became skilled and preferred at some kinds of work such as whiteners or woodcutters.

When the money which is separated for animal production incomes from the total income due to the villages is studied, it can be seen that the proportion in plain villages and in the villages in which the business enterprises on livestock production are active is higher. This is an anticipated situation. As it was emphasized before, cattle raising is being executed in a vertical system. In addition, as the animals are crossbred, the costs for their welfare are higher. But it is seen that incomes are generally at minimum levels when the mountain villages in which sheep or goat raising is executed intensively are studied. The farmers' opinions about the change in the allocated funds for animal production in the last 25 year were given in the Table 51. 68, 6 % of the farmers declared that expenditures for animal production increased in the last 25 year. The others declared either no idea or a decrease. Most part of farmers declared that there has been a change in allocated funds from the total income for the animal production (92 %) showed the reasons of this change as; the small amount of the grasslands and so usage of feed highly because of this and the low price of the productions.

The opinions of the farmers about the changes in climates were given in the Table 52.

About 87, 3 % of the farmers declared that there have been changes in climate in the areas on which they live. When they were asked about the causes of these changes (Table 53), most of them stated that the temperature of the atmosphere increased (82, 5 %) and some of them stated that the temperature of the atmosphere decreased (2, 9 %). However, the farmers gave responses to these questions by stating their opinions about how the changes in climates affected the animal and crop production. The responses which were given in this way can not be undervalued. It is generally understood from the responses that because of the negative conditions of the climates, plant and animal production degraded The farmers who are active in the working area were asked a question about the number and species of the wild animals and the proportional distribution of their responses were given in the Table 54.

87, 4 % of the farmers who declared that there has been a change in climate also said that there has been a change in the number and species of wild animals. 100 % of the farmers who declared that there hasn't been a change said that there has been a change in the number and species of the wild animals. Generally the farmers stated that the number and the species of the wild animals decreased. A question about the direction of this change was asked to the farmers who declared that the number and the species of wild animals increased. It is understood from their responses that the number of wolves and wild pigs increased because of the hunting ban not the changes in climate. In addition, they stated that especially some of the wild winged animals became extinct. Besides, some animals like foxes, wild rabbits and deer became extinct.

Table 7. Number Of Household, Population And Square Measure Of The Villages

Name of Villages	Square measure (ha)	Number of Household	Population
Kirazliyurt	52000	120	870
Dölekli	200	120	900
Kökez	3300	210	1260
Gildirli	8500	80	250
Bolacali	6000	14	160
Kayarcik	6000	240	2000
Ataköy	1500	150	1000
Himmetli	2300	342	948
Güvenç	8000	100	600

Table 8. Infrastructure Of Villages In Survey Area

Infrastructure	Number	%
School	8	88,9
Clinic	7	77,7
communication	9	100,0
Electricity	9	100,0
Water establishments	8	88,9
Access road	8	88,9
Mosque	9	100,0

Table 9. Frequency And Distribution Of Grassland Areas By Farms

Grasslands	Frequency	%
Harvest residues and field edges	62	52,5
In-village common property	59	50,0
Shrubs	34	28,8
Housed (not grazed)	16	13,6
Grasslands in forest	19	16,1
In fallow	19	16,1
Hired areas	1	0,8
In horticulture areas	4	3,4
In private property	5	4,2

Table 10. Frequency And Distribution Of Grassland In Farms

Grasslands	Frequency	%
Harvest residues and field edges	62	52,5
In-village common property	59	50,0
Shrubs	34	28,8
Housed (not grazed)	16	13,6
Grasslands in forest	19	16,1
In fallow	19	16,1
Hired areas	1	0,8
In horticulture areas	4	3,4
In private property	5	4,2

Table 11. Change In Farm-Grassland Capacity In The Last 25 Years

Change	Frequency	%
Yes	80	67,8
No	38	32,2
Total	118	100,0

Table 12. Change In Farm Pasture Capacity Of Grasslands**.**

Change	Frequency	%
Reduction in grassland	71	88,8
Increasing in grassland	3	3,8
Unknown	6	7,5
Total	80	100,0

Table 13. Change In Pasture Capacity In Village Grassland

Villages	Change in grassland capacity					
	Yes		No		Total	
	Frequency	%	Frequency	%	Frequency	%
Kayarcik	21	26,3	4	10,5	25	21,2
Himmetli	12	15,0	5	13,2	17	14,4
Kirazliyurt	11	13,8	1	2,6	12	10,2
Kökez	11	13,8	3	7,9	14	11,9
Ataköy	8	10,0	3	7,9	11	9,3
Dölekli	6	7,5	6	15,8	12	10,2
Bolacali	4	5,0	3	7,9	7	5,9
Gildirli	4	5,0	5	13,2	9	7,6
Güvenç	3	3,8	8	21,1	11	9,3
Total	**80**	**100,0**	**38**	**100,0**	**118**	**100,0**

Table 14. Cause Of Change In Grassland

Reasons	Frequency	%
Pastures converted to cultivated areas	24	30,0
Forestation activities	20	25,0
Decrease in pasture land due to climate change	18	22,5
Unknown	6	7,5
Prohibition of grazing in forests	6	7,5
Decreasing of pasture land due to erosion	2	2,5
Increasing in pasture land due to the decreasing animal intensity	2	2,5
Decreasing of pasture land due to increasing animal intensity	1	1,3
Increasing in pasture land due to increasing in vegetable growing	1	1,3
Total	80	100,0

Table 15. Grazing Seasons Of Different Species

Grazing Season	**Goat**		**Cattle**		**Sheep**	
	Frequency	%	Frequency	%	Frequency	%
Spring,summer,autumn	11	25,6	38	58,5	9	56,3
Spring	1	2,3	-	0,0	2	12,5
Spring, summer	10	23,3	14	21,5	1	6,3
Autumn, summer	-	0,0	6	9,2	-	0,0
Continuous	21	48,8	7	10,8	4	25,0
Total	43	100	65	100	16	100

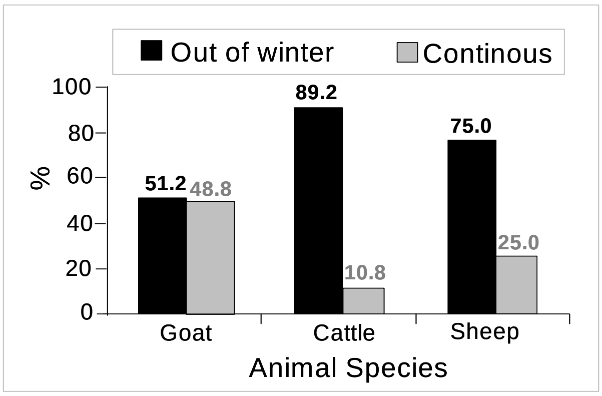

Fig. 4. The percentage of the grazing season in the species basis

Table 16. Daily Grazing Times Of Different Species

Grazing Period	Goat		Cattle		Sheep	
	Frequency	%	Frequency	%	Frequency	%
From morning to evening	25	56,8	28	57,1	6	66,7
From morning to afternoon	-	0,0	9	18,4	0	0,0
From dawn to morning	9	24,3	7	14,3	2	22,2
From dawn to afternoon	3	8,1	2	4,1	0	0,0
From dawn to evening	4	10,8	3	6,1	1	11,1
Total answered	37	100	49	100	9	100

Table 17. Type of feeds in barn

Feed stuff	Frequency	%
Pulp	91	77,1
Straw	89	75,4
Concentrate	85	72,0
Cereals	43	36,4
Grass	43	36,4
Dry grass	42	35,6

Table 18. The Recent 25-Year Changes In Hand-Feeding

Change	Frequency	%
Yes	68	57,6
No	36	30,5
Unanswered	14	11,9
Total	118	100,0

Table 19. Change Of Animal Behavior In Feeding

Change	Frequency	%
Yes	71	60,2
No	47	39,8
Total	118	100,0

Table 20. Additional Feeding Periods

Periods	Frequency	%
In winter time	86	72,9
In pregnancy	45	38,1
In lactation	40	33,9
In estrus duration	15	12,7

Table 21. Average Number Of Animal Species In Villages (X 1000 Heads)

Villages	Dairy Cattle	Breeding Bull	Sheep	Goat
Kirazlıyurt	1.3	0.0	12.5	48.8
Dölekli	2.6	0.0	2.5	0.4
Kökez	1.8	0.1	1.4	35.9
Gildirli	2.0	0.0	0.0	17.4
Bolacalı	1.4	0.0	0.0	34.3
Kayarcık	3.1	0.6	0.0	0.0
Ataköy	6.4	11.0	4.5	4.5
Himmetli	2.2	0.0	12.4	26.2
Güvenç	0.8	0.3	15.1	56.1
Average	2.5	1.2	5.3	22.0

Table 22. Numeral Changes Of Animal Species In Last 25 Year

Villages	Dairy Cattle		Breeding bull		Sheep		Goat	
	1980	2005	1980	2005	1980	2005	1980	2005
Kirazlıyurt	0,8	1,3	0,0	0,0	8,3	12,5	88,8	48,8
Dölekli	3,0	2,6	0,0	0,0	125,0	2,5	47,5	0,4
Kökez	1,4	1,9	0,0	0,0	69,6	1,8	28,9	35,9
Gildirli	2,6	2,0	0,0	0,0	5,6	0,0	18,3	17,4
Bolacalı	3,3	1,4	0,0	0,0	7,1	0,0	92,9	28,6
Kayarcık	4,4	2,9	0,2	0,4	15,8	0,0	10,4	0,0
Ataköy	8,4	6,3	7,7	9,1	27,3	4,5	13,6	4,5
Himmetli	4,2	1,9	0,0	0,0	10,0	12,4	67,4	20,3
Güvenç	0,3	0,6	0,0	0,1	7,2	11,7	37,3	55,6
Average	3,3	2,4	0,8	0,9	30,7	5,0	40,8	20,8

Table 23. Causes Of Change In Animal Species Pattern In The Last 25 Years

Reasons	Frequency	%
Decreasing in pasture land and increasing in feed prices	30	35,3
Lack of labor power	18	21,2
Sold due to economic problems	10	11,8
Began production after the 1980s	8	9,4
Increasing in number of animals due to prolification	7	8,2
Increasing number of animals for living standards	6	7,1
Shift to other species due to decreasing profit	3	3,5
Increasing of number of animals due to direct income payment for cattle	2	2,4
Sold due to migration	1	1,2
Total answered	85	100,0

Table 24. Role Of Migration For Feeding

Migration	Frequency	%
Yes	40	33,9
No	78	66,1
Total	118	100,0

Table 25. Change In Migration Routes

Change	Frequency	%
Yes	6	15,0
No	34	85,0
Total	40	100,0

Table 26. Cost Of Migration

Reasons of Cost	Frequency	%
No cost	15	37,5
Cost of fuel and transportation	11	27,5
Unanswered	14	35,0
Total	40	100,0

Table 27. Weaning Time Due To Species (Month**)**

Species	1980	2005
Cattle	6	5
Sheep	5	4
Goat	5	4

Table 28. Seasonal Movements Of The Flock Different Physiologic Stage Of Animals

Seasonal changes	Estrus period		Lactation season	
	Frequency	%	Frequency	%
Move from winter to spring	1	0,8	2	1,7
Move from spring to summer	13	11,0	8	6,8
Move from summer to autumn	10	8,5	3	2,5
Move from autumn to winter	3	2,5	2	1,7
No changing	60	50,8	64	54,2
Unanswered	31	26,3	39	33,1
Total	118	100,0	118	100,0

Table 29. Cause Of Changes At The Estrus Period

Reasons of Changes	Frequency	%
No changing	44	37,3
Unanswered	41	34,7
Increasing ambient temperature	15	12,7
Changing in feeding conditions	12	10,2
Changing of genetic capabilities of animals	5	4,2
Decreasing ambient temperature	1	0,8
Total	118	100,0

Table 30. Aim Of Livestock Production In The Farms

Main purpose	Frequency	%
Milk	50	42,4
Milk+meat	49	41,5
Milk+meat+stud	13	11,0
Meat	5	4,2
None	1	0,8
Total	118	100,0

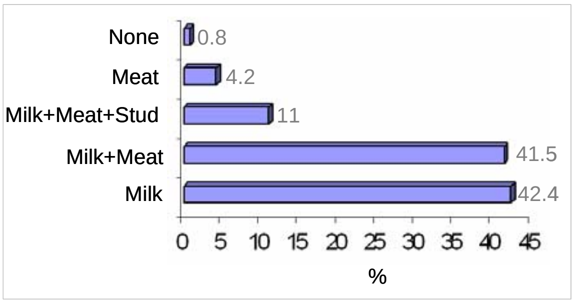

Fig. 5. The percentage of the basic aims of the animal production in the business enterprises.

Table 31. Changing Purpose Of Livestock Production

Changing	Frequency	%
Yes	14	11,9
No	104	88,1
Total	118	100,0

Table 32. Change In Milk Production At Different Species (Kg/Animal/Lactation)

Species	1980	2005	Changing (%)
Cattle	7,1	9,6	135,2
Sheep	0,7	0,8	111,6
Goat	0,8	0,8	100,0

Table 33. Cause of change in milk productivity due to the years

Reasons of changing	Frequency	%
Genetic improvement	30	42,9
Decreasing rangeland	22	31,4
Well managed	10	14,3
Climatic reasons (high ambient temp.)	6	8,6
Grazing in up-land	1	1,4
Some problems of crossbred animals	1	1,4
Total	70	100,0

Table 34. Evaluation Of Raw Milk, Produced In The Farm

Processing Type	Frequency	%
Cheese	66	55,9
Saleable milk	47	39,8
Yogurt	36	30,5
Butter	19	16,1
Drinking milk(home consumption)	15	12,7
Traditional Cheese	6	5,1
All	14	11,9

Table 35. Processed Milk Of Milk Products

Products	Frequency	%
Cheese	83	70,3
Yogurt	50	42,4
Butter	27	22,9
Traditional Cheese	8	6,8

Table 36. Types Of Yeast Used In Animal Products

Types of yeast	Frequency	%
Artificial yeast	44	69,8
Sarkanak (traditional type)	17	27,0
Dried fruit	2	3,2
Total answered	63	100,0

Table37. Change In Methods Of Processing Methods Of Milk

Changing	Frequency	%
Yes	34	28,8
No	59	50,0
Unanswered	25	21,2
Total	118	100,0

Table 38. Preservation Of Processed Products By Traditional Methods

	Frequency	%
Yes	27	22,9
No	91	77,1
Total	118	100,0

Table 39. Traditional Methods Used In Processed Milk Products

Methods	Frequency	%
In refrigerator	13	48,1
In caves	6	22,2
Preserved in skin	3	11,1
Preserved in salted water	2	7,4
Unanswered	3	11,1
Total	27	100,0

Table 40. Change In Preservation Methods Of Processed Animal Products

Changing	Frequency	%
Bury into soil	26	29,9
Cold places at home	17	19,5
No changing	14	16,1
Preserved in skin or pot	12	13,8
Preserved in rock cavities	6	6,9
Daily production and marketing	5	5,7
Preserved in salted water	4	4,6
Preserved under snow at high lands	3	3,4
Total answered	87	100,0

Table 41. Changes Due To Preservation Methods Of Milk Products

Reason of changing	Frequency	%
Technological improvement	64	87,7
Climate change	15	20,5
Changing in consumption behavior	1	1,4
Positive responded	73	100,0

Table 42. Health Problems In Flocks

	Frequency	%
Epidemic diseases	43	36,4
Abortion	36	30,5
Sterility	28	23,7
No problem	25	21,2
Sudden mortality	22	18,6
Low production	20	16,9
Defect at birth	18	15,3

Table 43. Reasons Of Diseases In The Region

Reasons	Frequency	%
Insufficient Feeding	32	27,1
Weeds	25	21,2
Insufficient hygiene	12	10,2
Adaptation	11	9,3
Climate	11	9,3
Unknown	8	6,8
Management systems	5	4,2

Table 44. Cost Of Health Expenditures Due To Species (YTL/Animal)

Species	Average
Cattle	96,6
Sheep, goat	2,8

Table 45. Annual Change In Cost

Change	Frequency	%
Yes	89	75,4
No	29	24,6
Total	118	100,0

Table 46. Change In Costs

Reasons	Frequency	%
Feeds, veterinary services, vaccination etc.	50	56,2
No health problems initially	44	49,4
Lack of knowledge	15	16,9
Improvement in technologies	4	4,5
Genetic improvement	2	2,2
Answered as yes there is total change	89	100,0

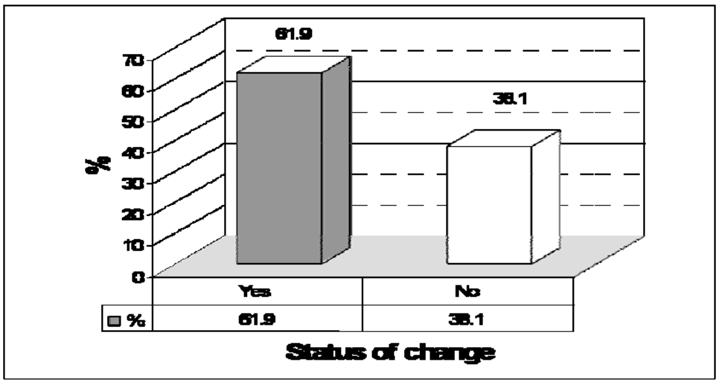

Fig. 6. Changes in the size of animals in the last 25 year

Table 47. Change In The Size Of Animals In The Last 25 Years

Reasons	Frequency	%
Genetic improvement	31	42,5
Smaller body due to decreasing pasture land	24	32,9
Larger body for good managed	8	11,0
Smaller body due to genetic capacity	5	6,8
Smaller body due to disease	1	1,4
Smaller body due to climate	1	1,4
Unanswered	3	4,1
Total	73	100,0

Table 48. Labor Utilizing

	Frequency	%
Yes	13	11,0
No	105	89,0
Total	118	100,0

Table 49. Income Sources For Farms

Income sources	Frequency	%
Livestock Production	116	98,3
Crop Production	82	69,5
Work against payment	13	11,0
Rent	2	1,7
Hand scale	1	0,8
Other	10	8,5

Table 50. Average Of Allocated Funds For Animal Production Input In Terms Of Total Income In Villages (%)

Village	Average (%)
Ataköy	70.5
Dölekli	52.9
Kirazlıyurt	56.3
Gildirli	47.8
Kökez	50.4
Kayarcık	43.8
Bolacalı	40.7
Güvenç	41.4
Himmetli	25.6
Avarage	46.5

Table 51. Change In Allocated Funds For Animal Production Input In Terms Of Total Income

Change	Frequency	%
Increased	81	68,6
Decreased	5	4,2
No change	24	20,3
No idea	8	6,8
Total	118	100,0

Table 52. Opinions On Climate Change In The Last 25 Year

Climate Change	Frequency	%
Yes	103	87,3
No	15	12,7
Total	118	100,0

Table 53. Opinion Of The Farmers For The Climate Change On Various Parameters.

Effects of Climate Change	Frequency	%
Increase in ambient temperature	85	82,5
Decreasing in crop production productivity	62	60,2
Increasing in animal disease and decreasing in production	50	48,5
Decreasing in ambient temperature	3	2,9
Climate had nor been effected to animals due to well management conditions	1	1,0
The change in climate	103	100,0

Table 54. Variation In Wild Animal Species Due To The Climate Change

Climate Change	Variation in animal species and numbers				Total	%
	Yes		No			
	Frequency	%	Frequency	%		
Yes	90	87,4	13	12,6	103	100,0
No	0	0,0	15	100,0	15	100,0
Total	90	76,3	28	23,7	118	100,0

3.4 Investigations on Available Grassland Potential in the Project Area

The village Gildirli

This village is dominated with forestland, and has very typical maqui vegetation in the slope lands. A moderate grazing was observed in the area. The dominant plant species was determined as Aegilops ovata L which is regarded as an invasive plant group for the pastures. The observed plant species in this village and their families comprised 13 families and 37 different species.

The plant cover, botanical composition and the characteristics of the species were determined by the undertaken vegetation measurements. The plant cover was determined to be 71.53% for the pastures of this village. But the species in this percentage are not totally the climax. The botanical composition of the climax species was calculated as 44.93 %, whereas the upward species were 10.07 % and the invasive ones were 44.91 %. The higher percentage of the invasive species is one of the indicators of pasture deterioration. Consequently the range conditions were determined to be at a moderata level based on the botanical composition and distribution of the species.

The village Kökez

The pastures of this village are generally inside or under the forest. The dominant type and the climax plant species was Bothriochloa ischaemum in the moderately grazed pastures of the area.

The plant species observed in this village and their families were composed of 27 different species determined from 15 families.

The plant cover of the pastures in Kökez was calculated as 65.85 %. The 36.48 % of the whole species were determined as climax for this village while the percentage for the upward species is 28.38 % and 35.14 % of this are the invasive species.

The results of the botanical composition has revealed that pasture deterioration is in a critical level in this village as well.

The village Kirazlıyurt

This is the village, located at the highest elevation among the investigated ones. It is observed that a large percentage of the pastures have been cleared for agriculture. Grazing is conducted between the fields and in the slope lands that are uncultivated.
The species Lolium perenne is the dominant in the pastures heavily grazed.The plant species observed in this village and their families belong to 28 different species that were determined from 10 families.

The plant cover of the pastures in Kirazlıyurt was determined as 81.04 %, despite the decline observed in the distribution of the climax vegetation, and the increase of the upward and the invasive species getting dominant in the botanical composition. The 19.09 % of the whole species were determined as climax for this village while the percentage for the upward species is 40.42 % and 40.49 % for the invasive. Consequently the status of the pasture is at a moderate level facing degradation.

4. Conclusion and recommendation

This study is unique because of this is the first study on global warming and its possible effects on livestock production that designed by notification of rural people live in research area. While the results were interpreted, new approaches of technology and some political applications were concluded as well. Evaluated data are given below.

1- Grazing in the field edges and harvest residues (stubble) is at the maximum level. Consequently, it is seen that grazing in the residues after the harvesting of crop production is more common than grazing in the natural areas. Grassland capacity and grassland areas decreased almost 67,8 % and 88.8 % during to last 25 years, respectively. The reason of slumping in annual precipitation, cultivation in these areas, early grazing and over-grazing and some regulations for grassland using. The pastures of the village Gildirli was converted with the percentage of 71.53% by 13 families and 37 different plant species. The dominant plant species was determined as Aegilops ovata L. The pastures of village Kökez was covered with the percentage of 65.85% by 27 different species from 15 families. The dominant plant species was determined as Bothriochloa ischaemum. The pastures of the village Kirazlıyurt was covered with the percentage of 81.04 % by 28 different species from the 10 families. The species Lolium perenne was determined as the dominant. Grazing starts in March and ends at the end of November or beginning of the December. But in Aladag, due to snowing, grazing starts and ends earlier than the other regions.

2- Due to economic reasons(such as feed expenses and low price of some products in the market) the farmers eventually could give up animal production. During the insufficient times of the grasslands, animals are kept inside and meanwhile fed by concentrate feeds. Feeding in barn is based on mostly to pulp (77, 1 %) and to straw (75, 4 %) but at the same time, concentrate feeds prepared by the factories are also given highly (72 %). The farmers declared that in the past they used to take their animals to the plains at the end of the winter because the vegetation awakened early, after the reduction of the sources in the plains, they used to go to the backward highlands and pasture their animals.

3- About 87, 3 % of the farmers declared that there have been changes in climate in the areas on which they live. Most of them stated that the temperature of the atmosphere increased (82, 5 %) and some of them stated that the temperature of the atmosphere decreased (2,9 %). However, the farmers response to these questions by stating their opinions about how the changes in climates affected the animal and crop production. It was determined that 77,1 % of the farmers no longer use the traditional ways and 27 % of them use only caves and skins of the animals. Milk products technologies and other conservation methods have developed in the region due to the climate changes. As an example, cheese is produced on daily conditions instead of traditional methods. Only, in a few regions cheese fermentation is still done by the traditional methods. In the past, products were digged into ground or into the snow in highlands where it's impossible these days.

4- Small ruminant owners indicated a seasonal change in estrus and it has moved from spring to summer. Additionally, some of the farmers mentioned about the positive (1, 4 %) and negative (8, 6 %) affects on the milk productivity occurring in the change of climate conditions.

5- Most of the goat farms were family managed. Besides, whole family took part in goat production; particularly women and daughters were responsible for the flocks and production. Male teenager was also helping their mothers by holding animals in milking time. The most common type of business is the family type. Woman continued to work in livestock production even if she was pregnant. Few male took part in livestock production. Livestock production was unique source of family livelihood in this area. They did not have any other alternatives because of land structure, infrastructure and economic conditions. A main income of families was based on goat and sheep production. According to questionnaire results, goats spend the days in higher zones between spring to winter (nomadic system). Greatest part of farms is involved in housing for their livestock in winter.

6- Main dairy products of the farms were milk, cheese and yogurt. Farmers' family consumed average 25 % of the whole milk. Families prefer to sell their milk as a cheese because of high income opportunity. Animal keepers produce white cheese, tulum cheese, lor, çökelek and butter.

7- The number of cattle, sheep and goats decreased sharply during to last twenty years. The most important reasons of this decrease were socio-economical and political. Goat production has been forbidden in forest area by government. This was the most effective obstacle in goat production sector in Turkey. Besides migration of rural people, from rural to urban had also negative effects on animal production. In fact, livestock farming is the most important animal production activity in mountainous area of Mediterranean Region of Turkey.

8- It's obviously clear that, climate has significant effects on livestock production. Type of grasses, grassland potential, processing of products and especially some Physiological aspects of farm animals has been affected adversely. For this reason following adjustments should be urgently realized in the region. The future development of livestock farming systems in mountainous area of East Mediterranean part of Turkey in term of intensive systems will largely depend on the application of modern management strategies, especially for planning and monitoring functions together with political and financial adjustments. Grazing should be planned with new regulation in the area. It has to be emphasized here that, small ruminant production is essential for this area. People living in this area do not have any other alternatives for the sake of life. Moreover, educational studies should be started at utmost priority right away. People should be acknowledged on new technologies. And lastly some heat-resistant farm Animal species and genotypes should be adapted in the region.

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Estimation of Crop Production by the Future Climate Changes in Surrounding Areas of the Seyhan River in Turkey

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1. Introduction

In Turkey wheat is the most dominant crop. Since five decades wheat production has increased from 7000 to 18000 kt and yield from 0.91 to 2.09 t ha^{-1} although cultivated area has a few increased (USDA, 2006). Second dominant crop is barley and its total production is less a half of the wheat total production and the production has increased during 50 years probably because of increased requirement of livestock fee for meet production (USDA, 2006). Most of these winter crops are grown in rain-fed area except of a few areas under irrigation system. The other important crop for livestock fee is maize and its total production is 18% of the wheat production now. Maize can be grown in irrigation areas because of growth terms in summer season when rainfall is very few.

We estimate the impact of climate change on crop production, particularly for wheat in winter crops and maize in summer crops, in the future for surrounding areas of the Seyhan River including rain fed areas of the upper Seyhan and irrigation areas of the lower Seyhan in Turkey.

2. The estimation Concept of Crop Production in the Future

The estimation of crop production in the future was from crop growth models of tow different concepts.

The first model employs a simplified process approach to simulate crop growth and development (Sinclair, 1994; Horie 1995). This model uses environmental variables of temperature, radiation and day length. Model parameters were decided for Turkish spring wheat by field experiments under irrigated conditions in Adana of Turkey and Ishikawa of Japan. Soil desiccation was incorporated by the model that suppression of transpiration rate coincides with that of biomass while soil desiccation rate was supplied from other environmental simulation models.

The second model is from the SWAP (Soil-Water-Atmosphere-Plant) model which was developed in the Netherlands. The parameters were decided based on the observed data.

The effect of temperature elevation would be immediately calculated by these models but the effect of CO_2 elevation was incorporated by changes of radiation use efficiency from other past experimental results. Estimated data in the future (MRI and CCSR) were input these model and results were output.

3. Predicting the Impact of Global Warming on Crop Production

(1) Estimation with the Simple Model

The impact of global warming on wheat production in Adana was predicted by using a wheat growth model, SimWinc, outputs of climate models for 9 years (MRI and CCSR) and soil water conditions simulated by SiBUC. SimWinc was parameterized with the growth data of wheat crops grown under nearly ideal conditions at Çukurova University in Adana. In the model, a change in CO_2 concentration from 370 ppm (the current level) to 690 ppm (an assumed level in 2070s) enhances biomass production by 23.6%. Simulated yields can be converted into actual farmers' yields, multiplied by 'technological coefficient (TC)', which is the ratio of actual farmers' yields to simulated yields.

The values of TC under the current climate conditions were relatively stable (51 to 65 %) in the districts of the plain area in Adana and ranged 28 to 57% in the mountainous area. We simulated wheat yields under the future climate conditions, assuming that the value of TC would be unchanged in each district.

Without the CO_2 effect, wheat yields were expected to be decreased by MRI and CCSR climates in the plain area mainly due to decreases in precipitation, and to be increased by both climates in the mountainous area due to increases in temperature. At the simulation runs with the CO_2

effect, wheat yields in every district were expected to be increased by global warming, excluding one district under the CCSR climate. The average predicted yield was 4.03 t ha^{-1} in Adana Prefecture under the current climate. Reductions of 8.1 and 9.5 % in average yield in Adana were predicted for MRI and CCSR climates without CO_2 effect, respectively. The predicted yield reduction of CCSR was larger than that of MRI, because precipitation in CCSR decreased from the current level more than that in MRI. When we included the CO_2 effect in simulation runs, average yields were predicted to increase by 13.5 and 11.9 % for the two pseudo-warming climates, respectively. The yield variability was predicted to increase in the plain area under the future climates, while to decrease in the mountainous area.

In conclusion, a decrease in precipitation by global warming would have a possibility to reduce and destabilize wheat yields in the plain area of Adana, although CO_2 fertilization effects will be able to partly compensate for the negative effect of global warming. In the mountainous area with severe winter, an increase in temperature would improve the wheat production under the future climates.

(2) Estimation with the SWAP Model

Four kinds of GCM data, CGCM2 model of Canadian Center for Climate Modeling and Analysis (CCCma), ECHAM4/OPYC3 model of Max Planck Institute für Meteorologie (MPIfM), CGCM2.2 model of Meteorological Research Institute (MRI) and AGCM + CCSR OGCM model of Center for Climate System Research and National Institute for Environmental Studies (CCSR/NIES) were downscaled for Adana as the study area using the projected values at the four nearest neighboring grid points using the inverse distance weighted method. Annual temperature increases gradually for 111 years from 1990 to 2100. According to the linear regression equation, averaged surface temperature is estimated to increase by 3.1-8.6 ℃ over the period of 1990 to 2100. Among the four models, the CCSR/NIES and MRI data denote the highest and lowest increase, respectively. Although annual precipitation denotes noticeable variations year by year, it is not likely that it will have increased in the future.

A simulation study was carried out to predict future changes in climate, irrigation water demand and crop growth in a Mediterranean environment of Turkey. Climate changes were projected by using data of one GCM data: CGCM2 model of CCCma (hereafter referred as GCM) and two RCM data: CGCM2.2 model of MRI (hereafter referred as MRI) and AGCM + CCSR OGCM model of CCSR/NIES (hereafter referred as CCSR) for a time period of 2070-2079 when CO_2 concentration is supposed to increase up to doubling concentration under the A2 scenario of Special Report on Emissions Scenarios (SRES). The effects of projected climate change on water balance components and yields of spring wheat and second crop maize were predicted using the detailed crop growth subroutine of the SWAP (Soil-Water-Atmosphere-Plant) model which was developed in the Netherlands. Projected climate data and collected soil and crop management data for the study location were used to run the SWAP.

Three climate models projected air temperature rises by 2.8, 1.4 and 2.4 ℃ for a period of 2070-2079 relative to a period of 1994-2003 as the baseline for GCM, MRI, and CCSR/NIES, respectively. Precipitation is projected to decrease by about 56, 303 and 279 mm, respectively.

In order to evaluate the positive effect of elevated CO_2 concentration and the negative effect of risen air temperature on crop yields, simulation was done by doubling CO_2 concentration and by increasing maximum and minimum temperature by 1, 3, 5 ℃ relative to the current condition.

From results of calculated yields as well as evapotranspiration (ET) for wheat and maize, increase of biomass due to doubling CO_2 concentration is about 15% and 6% for wheat as a C3 crop and maize as a C4 crop, respectively. On the other hand, ET does not similarly increase and even decreases for maize, probably due to temporal water stress resulted from active crop growth. Decrease of biomass and ET following temperature rise is clearly shown in that temperature increase of 3 ℃ results in biomass decrease for 17% and 20%, respectively. ET decreases similarly as biomass does. Thus, increased yields by doubling CO_2 concentration are counteracted by temperature rise of 3 and 1 ℃, respectively for wheat and maize. More than 1 ℃ of temperature rise is estimated in 2070s when CO_2 concentration is supposed to increase up to doubling concentration, although much variations of temperature rise is recognized among models.

The average values and standard deviations of the water balance components for the periods of 10 years from 1994, and from 2070 together with biomass, grain yield and growing duration for wheat and second crop maize are calculated. Although rise in temperature results in a higher evaporative demand of the atmosphere in the future, actual ET for a time period for 10 years from 2070 under a doubling CO_2 concentration shows the decrease of 28%, 8% and 16%, respectively for wheat and 24%, 28% and 26%, respectively for maize, for the GCM, MRI and CCSR/NIES data reflecting the different rise in air temperature in the future.

Future air temperature rise results in increase in evaporative demand of the atmosphere. However, decrease in actual ET for both wheat and maize can be attributed to reduction of growing days and LAI due to temperature rise and transpiration reduction due to stomata closure regardless of increase in evaporative demand. Irrigation water demand was estimated to increase in the future for wheat mainly due to decrease in precipitation. On the contrary, it was estimated to considerably decrease for maize, reflecting decrease of actual ET due to stomatal closure.

If there would be no transpiration reduction at elevated CO_2 concentration, actual ET would increase by 32 and 79 mm for wheat and maize. As the result, irrigation for maize would increase by 73 mm (equivalent to 23% increase).

The duration of the regular crop-growing season for wheat is 14, 7 and 11 days shorter in the future. This change is caused by the projected air temperature rise of 2.2, 1.6 and 2.4 ℃ for a growing period by the 2070s for GCM, MRI and CCSR/NIES. Duration of growth period for maize becomes shorter by 9 days for GCM and CCSR/NIES while only 3 days for MRI. Projected air temperature rise was 3.5, 1.4 and 3.0 ℃ during growing period of maize. In other words, high temperatures accelerate the phenological development of plants, resulting in quicker maturation.

In case of wheat, biomass decreases for GCM, but increases for both of RCMs. Grain yield increases for all the models. In case of maize, both biomass and grain yield decrease for GCM and CCSR/NIES, but increases for MRI because of less rise in temperature than those for GCM and CCSR/NIES.

In this study, RCM data corrected based on observed values were used. The difference between the current and future annual mean air temperature is 2.4 and 1.4 ℃ for the original and corrected MRI data and 3.6 and 2.3 ℃ for the CCSR/NIES data. It seems that simulated results using the corrected RCM data would not reflect correctly the effect of air temperature on crop growth and water balance components.

4. Future Overview of Crop Production in Surrounding Areas of the Seynan River

From results with two simulation models wheat and maize yields in Adana areas increase at most by 15% of current yield in the future climate change conditions, although wheat yields in one model decrease by 10% if CO_2 concentration is not incorporated for the estimation. These results suggest that in the future grain production in dominant crops will be maintained in surrounding areas of the Seynan River. However, these results should not promise stable crop production in the future, because drought would be a key factor reducing the potential production and hence the estimation accuracy for precipitation and evaporative demand becomes critical for the yield more than temperature.

Furthermore, the model estimation includes some problems that should be improved for more accurate estimation of the yields. The effect of temperature and drought on harvest index (a ratio of grain yield to biomass) is not adequately incorporated in the models. For grain crops pollination and grain-filling are the most critical phases under high temperature or drought conditions (Levitt et al. 1980) and harvest index should be highly affected by stresses in the phases**.** Other factor affecting harvest index in winter wheat is a low temperature requirement during winter seasons for flower initiation. Particularly in mountain areas temperature elevation during winter season in the future would inhibit flower initiation to decrease harvest index to zero. This suggests that farmers in winter wheat cultivation areas will have to change wheat cultivar. If these factors are adequately introduced into the models the reliability of the estimation will be expected to increase more.

See the individual report for detail for each result.

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The effect of desiccated soils on transpiration in spring wheat subject to elevated temperature and CO_2 concentration

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1. INTRSUCTION

The dry matter production (DMP) for a time interval is indicated by

$$DMP = WUE \times T/VD \qquad (1)$$

where WUE is water use efficiency, T transpiration and VD vapor deficit (Tanner and Sinclair, 1983). When plants are well irrigated, DMP_0, WUE_0, and T_0/VD are given. The ratio of DMP to DMP_0 is

$$DMP/DMP_0=(WUE/WUE_0)\times(T/VD)/(T_0/VD)$$
$$=(WUE/WUE_0)\times(T/T_0) \qquad (2)$$
$$DMP=DMP_0\times(WUE/WUE_0)\times(T/T_0) \qquad (3)$$

In diverse crop plants it is expected that the WUE/WUE_0 scarcely changes with soil desiccation and is similar among cultivars but the T/T_0 is severely suppressed by soil desiccation (Tanner and Sinclair, 1983). Hence the response of T/T_0 to soil desiccation is one of the most important factors deciding the DMP. The DMP_0 is a potential productivity under well irrigated condition. The DMP_0 is expected to be estimated from a simulation model (Nakagawa and Horie 1997).

Empirically there was a close curve liner relationship between normalized transpiration rate (T/T_0) and fraction of transpirable soil water (FTSW) in most crop species. The FTSW is ratio of soil water to transpirable soil water (Ray and Sinclair, 1998). Hence T/T_0 is the important factor to estimate the suppression of DMP_0 under soil desiccated conditions.

However, it is unknown the effect of soil water deficit on T/T_0 in spring wheat of Turkey subject to elevated temperature and CO_2 concentration.

2. MATERIALS and METHODS

Plant materials

Adana99 of one of the dominant cultivar from Mediterranean area, Adana, Turky was grown in pots under glass house. Seedling soil for rice including fertilizer of 0.28 g of N, 0.33 g of P_2O_5 and 0.3 g K_2O per l (Green soil, Izumo Green Co.) was put into pots. Pot volume was 1.5 or 8 l. One or two plants were grown in a pot.

Soil desiccation treatments

(1) Vegetative stage

In 2003 and 2004 plants were growth cabinet of Tottori Dryland Research Center after one week naturalization at the late vegetative stage from natural light glasshouse (Fig. 1- A&B). Temperature in ambient chamber was 20/15 °C, day time vapor deficit 11.9 g m^{-3} and CO_2 concentration 414±20 µmol l^{-1} and in an elevated chamber temperature 24/19 °C, day time vapor deficit17.4 g m^{-3} and CO_2 concentration 589±27 µmol l^{-1}. Watering was stopped for two weeks.

In 2005 plants were grown in temperature and CO_2 controlled chambers. The camber was covered with clear plastic film (Six-Light, Taiyo-Kogyo Co. Tokyo) and a temperature exchange fan and heater with a controller (Fig 1.-C). Temperature and CO_2 were controlled by several degrees higher than outside ambient and 600-700 µmol mol^{-1}, respectively. Watering was terminated from the late vegetative stage for three weeks. Two chambers were used as replications.

(2) Reproductive stage

In 2006 plants grown in 8 l pot was used. Watering was withheld from the flowering stage to maturity in non temperature controlled glasshouse in ambient CO_2 concentration.

In both stages soil surface was covered with clear plastic beads to protect soil evaporation and pot weight was measured every day to estimate transpiration rate and soil water contents.

FTSW was calculated from the equation.

$$FTSW=SWa/SWmax \qquad (1)$$

where SWa is the actual water weight per pot and

SW0max is the available soil water weight per pot. SWmax is decided by the difference between soil water weight at the field capacity and at the permanent wilting point. The filed capacity is soil water weight at soil water potential of -0.03 MPa and the wilting point at -1.5 MPa (Kramer and Boyer, 1995). The soil moisture characteristic curve was decided for the soils with the thermocouple pshychrometer methods (Boyer, 1995).

3. RESULTS and DISCUSSION

Transpiration rate decreased with a decrease of FTSW and there was a curve liner relationship between T/T_0 and FTSW in both growth stage experiments (Fig. 1).

In the vegetative stage experiment the relationship under ambient and elevated conditions was similar within same experiment (Fig.1). However, precisely the curve should differ among experiments. Under climate change conditions plants suffer higher temperature and CO_2 concentrations from emergence and hence the plant may adapt to the environment. From the results the long term experiment in a chamber would be reliable because the plants have been elevated conditions since emergence (Fig.1-C).

Actually wheat in the Mediterranean zone sometime suffers from terminal drought, that is, the soil desiccation during the grain-filling period (Turner, 1997). Drought response during the grain-filling period is the most important performance in wheat in Adana areas (personal communication by Dr. Genc). When watering was withheld from pots at flowering, T/T_0 decreased with a decrease of FTSW similar to that at vegetative stage (Fig. 1-D). The result did not include the effect of elevated condition but the response of T/T_0 to FTSW in the reproductive stage should not differ between ambient and elevated conditions due to that in the vegetative stage.

The results suggest that under elevated temperature and CO_2 conditions in the future the response of T/T_0 to FTSW would be similar to that under ambient conditions and therefore the response curve should be available for sub-model to estimate the suppression of estimated biomass production by soil desiccation.

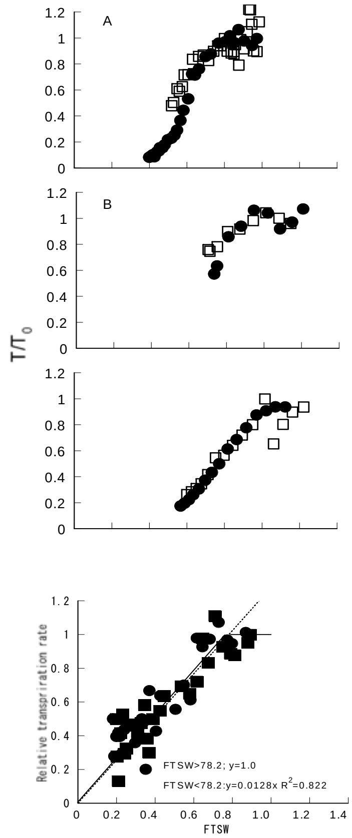

Fig.1. Transpiration ratio (T/T_0) and FTSW in Adana99 under ambient (■) and elevated (□) temperature and CO_2 concentration during vegetative (A-C) and reproductive (D) stage. From A to C each point indicates average of three observations and for D an individual plant. The equation in D was used for a model.

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Predicting the Impact of Global Warming on Wheat Production in Adana

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1. Introduction

Adana Prefecture (Adana) is faced to the Mediterranean Sea and the coastal area belongs to Mediterranean climate with mild winter, although the other end extends deeply into the inland mountainous area, which experiences severe winter, along the Seyhan River. The average of total precipitation during the growth period of wheat is about 650 mm on average for 16 locations spread over Adana, which is sufficient for wheat cultivation for normal years, although wheat crops sometimes suffer drought stress in dry years.

Climate models, MRI-GCM (MRI) (Yoshikane et al., 2001) and CCSR/NIES-GCM (CCSR) (Yukimoto et al., 2001), projected increases in temperature and decreases in precipitation under an elevated atmospheric CO_2 concentration (690ppm) in 2070's in Adana. Those climate changes should give impacts on the production of wheat, which is the most important crop in Adana.

In this report, the impact of global warming on wheat production in Adana was predicted by using a wheat growth model, SimWinc (Nakagawa and Kobata, 2005), outputs of climate models, MRI and CCSR for 9 years and soil water conditions simulated by SiBUC (Tanaka and Ikebuchi, 1994). We first conducted district-based analyses, followed by the integration into the prefecture level, for Adana includes regions with diverse climates.

2. Current Wheat Production in Adana

Total wheat production in Adana is about 1.3 million tons on average for recent seven years, produced from the cultivated area of 0.31 million ha with the average yield of 4.0 t ha^{-1} (Table 1). 95 % of wheat production is concentrated in districts in the pain

Table 1. Wheat cultivation area, average yield and production in each district in Adana Prefecture (calculated from Agricultural Statistics in Adana during 1999-2005). The number of each district corresponds to that in the map of Fig. 1.

No.	District	area (x10^3 ha)	yield (t ha^{-1})	production (x10^3 t)
1	Tufanbeyli	15.4	2.06	31.7
2	Saimbeyli	2.5	1.50	3.7
3	Feke	3.8	1.61	6.1
4	Pozantı	1.9	2.14	4.2
5	Aladağ	5.4	3.01	16.4
6	Kozan	41.0	3.79	155.2
7	İmamoğlu	30.6	3.79	115.9
8	Karaisalı	19.1	3.42	64.9
9	Seyhan	9.0	4.92	44.2
10	Yüreğir	64.4	4.63	298.1
11	Ceyhan	83.4	4.26	352.5
12	Karataş	16.2	4.79	77.2
13	Yumurtalık	20.7	4.32	87.9
total/mean		313.3	4.01	1258.0

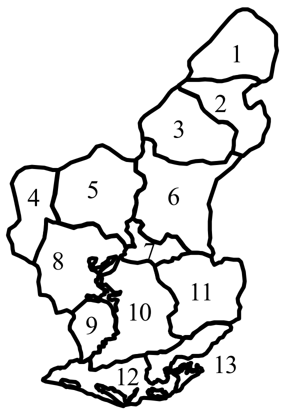

Fig. 1. Districts in Adana with the reference numbers of Table 1.

area (district number 6 - 13 in Table 1). Average wheat yield is 4.2 t ha^{-1} in the plain area, while 2.1 t ha^{-1} in the mountainous area. However, wheat production in mountainous districts (district number 1-5) is still important, because their farming is rather for their subsistence and more directly linked to their lives.

For example, a mixed cropping system with common and durum wheat, barley and rye was found in a mountainous area between Feke and Saimbeyli in our field survey for cropping system. We heard farmers there sowed and harvested mixed-species all at once, and made bread from the mixed flour. That production system, possibly with long history, seemed to be mainly for their own consumption.

Wheat crops are cultivated mostly under rainfed conditions, excluding additional irrigation in some dry years in irrigation areas. The irrigated wheat area is restricted to only a few percentage. Spring and winter wheat cultivars are sown in autumn in the plain and mountainous areas, respectively.

3. The Wheat Model SimWinc and its testing

SimWinc is a simplified process model for simulating the growth of winter cereals, such as wheat, under drought-prone environments. The model consists of four sub-models related to phenology, LAI growth, biomass production and yield formation process.

Biomass production is simply expressed by the product of intercepted solar radiation and radiation use efficiency (*RUE*) as a function of atmospheric CO_2 concentration ($[CO_2]$) and fraction of transpirable soil water content (*FTSW*):

$$RUE = RUE_{370} \cdot \{1+0.3784 \cdot \ln([CO_2]/370)\} \times f\,(FTSW) \qquad (1)$$

The effect of CO_2 on biomass production was parameterized after the results of FACE experiments for wheat (Kimball et al., 1995). *f (FTSW)* was determined by a pot experiment for wheat (Kobata et al., unpublished). Other parameters in SimWinc were determined with the results of field experiments at Çukurova University in Adana and at Ishikawa Prefectural University in Japan.

Attainable yields under rainfed conditions were simulated by SimWinc for each district in Adana between 1994 and 2002. The average attainable yields for 9 years were compared with actual farmers' yields in statistics averaged over 7 years from 1999 to 2005 (Fig. 2). Simulated attainable yield was tuned to a yield level observed under nearly ideal conditions at the experimental field of Çukurova University, and was always larger than farmers' average yield. There was a close relationship between actual and attainable yields excluding several districts in the mountainous area, indicating that SimWinc could partly explain the location-to-location yield variation in Adana. Farmers' yields were 59% of attainable yields on average for the districts in the plain area. Simulated yields (Y_p) can be converted into actual farmers'

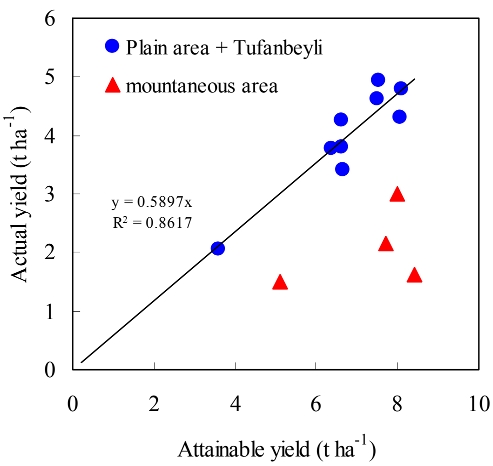

Fig. 2. Comparison between reported wheat yields (the average during 1999-2005) and attainable yields simulated by SimWinc (the average during 1994-2002) for every districts in Adana. A line that coincided with the origin was fitted to the data from districts in plain area and Tufanbeyli.

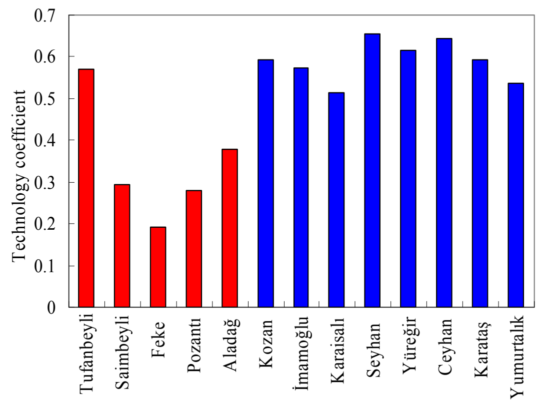

Fig. 3. Technology coefficients, which are used to convert attainable yields to farmers' yield levels. Red and blue bars denote districts in the mountainous and plain areas in Adana, respectively.

yields (Y_a), multiplied by 'technological coefficient (TC)', which is the ratio of actual farmers' yields to simulated yields and regarded as a kind of integrated index for agricultural technology:

$$Y_p = TC \times Y_a \quad (2)$$

The values of TC under the current climate conditions were relatively stable in the plain area and ranged 28 to 57% in the mountainous area (Fig. 3). We simulated wheat yields under the future climate conditions, assuming that the value of TC would be unchanged in each district.

4. Effect of Climate Change on Wheat Production in Adana

4.1 Input data

For predicting the effects of elevated CO_2 and the resulting climate on wheat production in Adana, one or two representative points were selected in each district of Adana (16 points in total). We used daily weather data for nine years from 1994 to 2003 at the representative points, which were the outputs of MRI model, for a base line analysis. Similarly we used outputs of MRI and CCSR models for 9 years in 2070's as pseudo warming climates with the atmospheric CO_2 concentration of 690 ppm.

The soil water content of root zone was estimated by SiBUC under the respective climates. The estimated soil water content *(W)* was converted into *FTSW* by the use of field capacity (W_{fc}) and permanent wilting point (W_{pw}):

$$FTSW=(W - W_{pw})/(W_{fc} - W_{pw}) \quad (3)$$

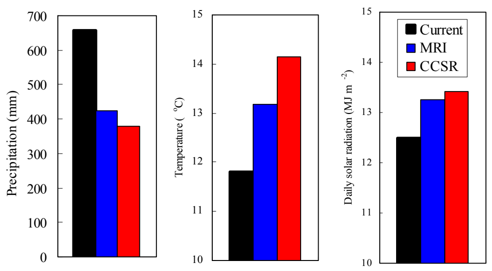

Fig. 4. Total precipitation, mean temperature and mean daily solar radiation during the growth period of wheat crops under the current, MRI and CCSR climates.

Precipitation was predicted to decrease by 234 and 278 mm on average over the 16 representative points for 9 years under MRI and CCSR climates, respectively, from the current level of 657 mm (Fig. 4). Similarly, average growth temperature would increase 1.4 and 2.3 ºC and average daily solar radiation would increase by 6.3 and 7.7%.

CO_2 concentration was set at the current (370 ppm) or a future level (690ppm) for simulating wheat yields under the future climates.

4.2 Effect of pseudo warming on attainable yields

Fig. 5 shows the effects simulated by SimWinc under the MRI and CCSR climates with or without an increase in CO_2 concentration on the relative change in wheat yield from the current. Without the CO_2 effect, wheat yields were expected to be decreased by MRI and CCSR climates in the plain area mainly due to decreases in precipitation, and to be increased by both climates in the mountainous area due to increases in temperature. At the simulation runs with the CO_2 effect, wheat yields in every districts were expected to be increased by global warming, excluding one district under the CCSR climate.

The average predicted yield was 4.03 t ha^{-1} in Adana Prefecture under the current climate. Reductions of 8.1 and 9.5% in average yield in Adana were predicted for MRI and CCSR climates without CO_2 effect, respectively. The predicted yield reduction of CCSR was larger than that of MRI, because precipitation in CCSR decreased from the current level more than that in MRI. When we included the CO_2 effect in simulation runs, average yields were predicted to increase by 13.5 and 11.9% for the two pseudo warming climates, respectively.

4.3 Probability analysis on effects of pseudo warming on wheat yields

Probability analyses were made on effects of pseudo warming and nearly doubling CO_2 on wheat yield for representative locations, by using simulation results for 9 years under the current and pseudo warming climates described previously. Fig. 6 gives the probability analysis by SimWinc at four representative locations.

At Adana city, the average predicted yield under the current climate was 4.99 t ha^{-1} with a coefficient of variation (CV%) of 7.0%. Decreases of 10.8 and 13.0% in yield were predicted for MRI and CCSR

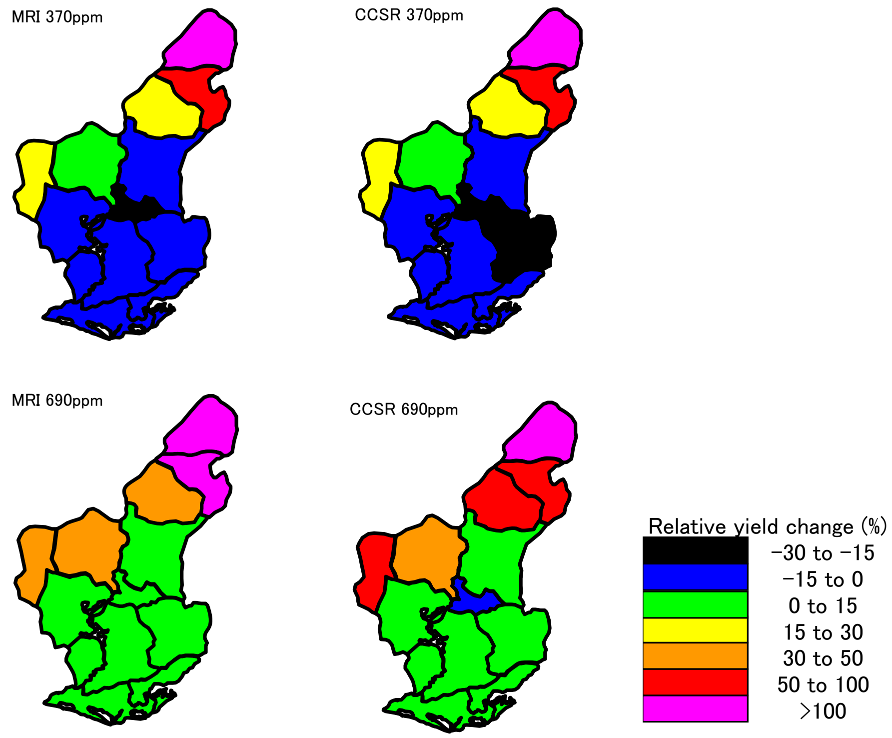

Fig. 5. Effects of climate change predicted by two GCMs with and without CO_2 fertilization effects on wheat yield in Adana (predicted by SimWinc).

climates, respectively, when we did not include the CO_2 effects. With CO_2 effects, increases of 10.2 and 7.5% were predicted. Predicted CV%'s were 10.9 and 12.5% under MRI and CCSR climates, respectively, irrespective of CO_2 concentration. Under the both pseudo warming climates, decreases in rainfall were predicted to cause yield reduction and to increase the variability of wheat yield. While the negative effects of global warming on average yield was expected to be compensated for by an increase in CO_2 concentration, yield variability would not be improved by that.

Similar results were obtained at other locations in the plain area, Yemişli and Sevinçli, although reduction in average yield was predicted in Sevinçli under CCSR climate even with CO_2 effects.

On the other hand, large improvement in average yield by pseudo warming was predicted at Kayarcık in the mountainous area due to increases in temperature. Also yield variability would decrease under the future climates. In the current study, a phenological parameter for a spring cultivar Adana99 was tuned to well explain the current phenology in each district, based on our field survey. Although farmers use winter cultivars in some districts in the mountainous area, such as Tufanbeyli, our simulation results may be reasonable even in those districts on the assumption that farmers would readily change their cultivars into spring types under the global warming climates.

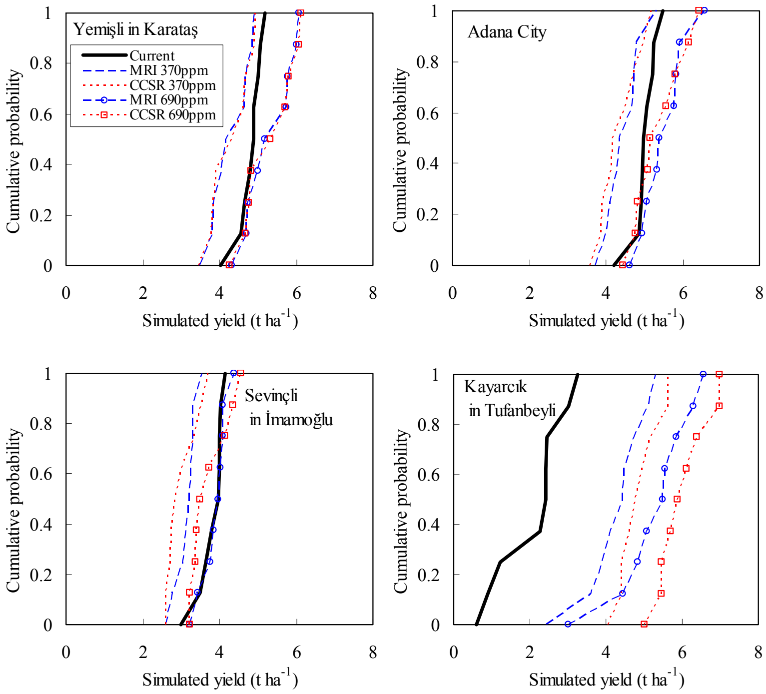

Fig. 6. Cumulative probability distributions for wheat yield at four locations in Adana under MRI and CCSR climates with and without CO_2 fertilization effects (predicted by SimWinc).

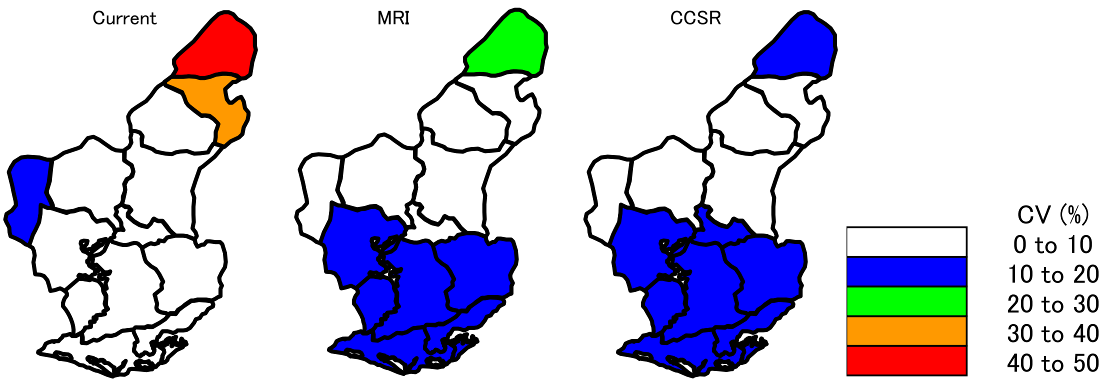

Fig. 7. Coefficients of variation in year-to-year change of wheat yield in Adana (predicted by SimWinc).

The same analysis was made for each district in Adana (Fig. 7). Similarly, the yield variability was predicted to increase in the plain area under the future climates, while to decrease in the mountainous area.

4.3 Rainfall and attainable yields

Simulated attainable yields under the current, MRI and CCSR climates without CO_2 effects were plotted against total precipitation during the growth period of wheat in Fig. 8. Although data were scattered in the figure, the maximum yield level attainable at an amount of total precipitation (a broken curve) seemed to be related with total precipitation. The maximum yield level was not related with precipitation above 500 mm, while it decreased with a decrease in precipitation below the value. Any yield data below the broken curve may be reduced by other factors, such as temperature and solar radiation.

A similar figure was made for Sağkaya in Ceylan, where precipitation was more important yield determinant (Fig. 9). Attainable yield was more clearly related with total precipitation during the growth period. This relationship shows that decreases in precipitation by global warming would reduce wheat yield in some drought-prone areas in Adana.

5. Conclusions

In conclusion, a decrease in precipitation by global warming would have a possibility to reduce and destabilize wheat yields in the plain area of Adana, although CO_2 fertilization effects will be able to partly compensate for the negative effect of global warming. In the mountainous area with severe winter, an increase in temperature would improve the wheat production under the future climates.

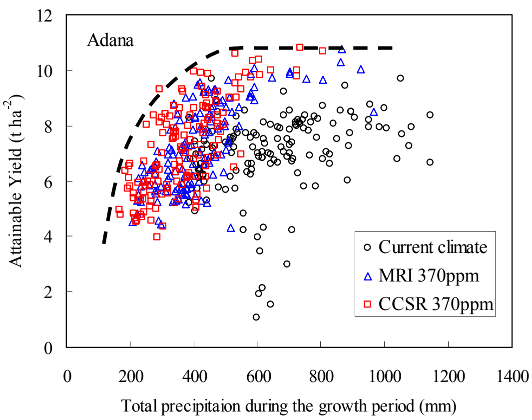

Fig. 8. Simulated attainable yield as a function of total precipitation during the growth period of wheat at 16 representative locations in Adana.

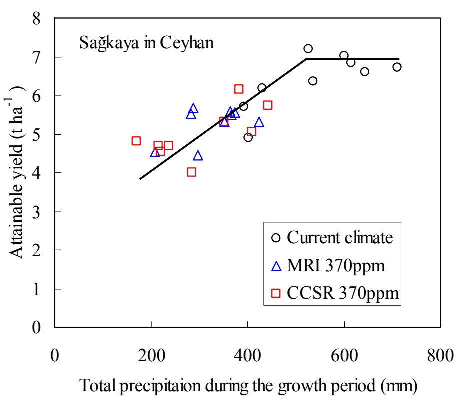

Fig. 9. Simulated attainable yield as a function of total precipitation during the growth period of wheat at Sağkaya in Ceyhan District.

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Actual Evapotranspiration and Potential Evapotranspiration of Maize Crop in Adana Region, Turkey

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1. Introduction

Actual evapotranspiration (*ET*, mm/day) and potential evapotranspiration (ET_p, mm/day) of maize crop under present crop, soil and micro- meteorological conditions have been determined as basic data to predict the impact of climate change on crop productivity. Both values have been calculated by using three micrometeorological methods of the energy balance flux ratio method (the EBFR method), the energy balance Bowen ratio method (the EBBR method) and the Penman-Monteith method (the PM method) for 88 days of July 29 to Oct. 24, 2004 (Odani *et al.*, 2005).

Transpiration (*T*, mm/day) of maize was obtained from the sap flow measurement during Aug. 7-16, 2004. Evaporation (*E*, mm/day) from soil surface was measured with the microlysimeter during Aug. 9-16, 2004 (Odani *et al.*, 2005). The quantity of latent heat (E_A, mm/day) transferred laterally due to advection in the space of furrow under maize canopy was measured during Aug. 8-15, 2004 (Odani *et al.*, 2006). Relationships between *ET* and *E*+*T*, and between $ET+E_A$ and *E*+*T* have been examined.

2. Calculation of the latent heat flux

First, the mean latent heat flux for 30 min. is calculated to obtain *ET* and ET_p.

2.1 The EBFR method

The EBFR method is used as the basic method to determine the latent heat flux. In this method, the latent heat flux is calculated as follows (Odani *et al.*, 2001):

① The latent heat flux (the water vapor flux; $F_{H_2O,f}$, kg s^{-1} m^{-2}) is calculated by the flux ratio method,

$$LF_{H_2O,\,f} = LH_s \frac{\rho_{w1}/\rho_1 - \rho_{w2}/\rho_2}{C_p(T_{d1} - T_{d2})}, \qquad (1)$$

where L(J/kg) is the latent heat of vaporization, H_s(W/m^2) the sensible heat flux measured by the eddy correlation method, ρ_w(kg/m^3) the water vapor density, ρ(kg/m^3) the dry air density, C_p(J K^{-1} kg^{-1}) the specific heat for constant pressure and ρ_w/ρ the mixing ratio. T_{d1} and T_{d2} temperatures at two heights z_1 and z_2, respectively. In the EBFR method, it is assumed that measured values of H_s are reliable.

In the flux ratio method, however, unreliable values of $F_{H_2O,f}$ are sometimes estimated for very small values of $|T_{d1}-T_{d2}|$.

② Values of Rn-G don't usually agree with those of $H_s+LF_{H_2O,f}$, where Rn(W/m^2) is net radiation and G(W/m^2) the soil heat flux.

③ Therefore, coefficients of p and q are introduced so that the energy balance equation hold good, and values of coefficients are determined by the method of least squares. Then the following a) and b) are assumed:

a)In the condition of relatively larger $|T_{d1}-T_{d2}|$ or $|H_s|$, latent heat fluxes, $LF_{H_2O,f}$, are estimated satisfactorily, and

b)Rn and G are overestimated or under- estimated by p and q times, respectively.

④New estimated values of the latent heat flux, $LF_{H_2O,ef}$, are calculated from the following equation instead of $LF_{H_2O,f}$ for all data,

$$LF_{H_2O,ef} = p \cdot Rn - q \cdot G - H_s \qquad (2)$$

2.2 The EBBR method

H_s was not measured during July 29 to Aug. 5 and Aug. 17 to Oct. 24. In addition, reliable values can be measured only in the restricted range of wind direction in the case of the instrument employed here to measure H_s. In the above period and the other range of wind direction, therefore, the latent heat flux, $LF_{H_2O,b}$, and the sensible heat flux, H_b, are calculated by the EBBR method with the next equations.

$$LF_{H_2O,b} = \frac{p \cdot Rn - q \cdot G}{(1+\beta)}, \qquad (3)$$

$$H_b = \beta LF_{H_2O,b}, \qquad (4)$$

$$\beta = \lambda \frac{T_{d1} - T_{d2}}{e_1 - e_2}, \qquad (5)$$

where β is the Bowen ratio, λ the psychrometric constant and e(hPa) water vapor pressure.

2.3 The PM method

In the EBBR method, reliable values of $LF_{H_2O,b}$ and H_b can't be obtained in the range of $-1.5< \beta <-0.5$, and it is often found out that the plus and minus signs of $LF_{H_2O,b}$ or H_b are inconsistent with those of e_1-e_2 or T_{d1}-T_{d2}. Such data can't be also adopted as the right value of the latent heat flux. In such cases, potential evapotranspiration calculated from the FAO Penman-Monteith equation is used to obtain ET and ET_p (Allen *et al.*, 1998).

The potential evapotranspiration (LEt_p, W/m^2) of Penman-Monteith is calculated from the next equation.

$$LEt_p = \frac{\Delta(p \cdot Rn - q \cdot G) + \rho_a C_p \frac{(e_s - e_a)}{r_a}}{(\Delta + \lambda)}, \qquad (6)$$

where (e_s-e_a) represents the vapor pressure deficit of the air, ρ_a is the mean air density, Δ represents the slope of the saturation vapor pressure temperature relationship and r_a is the aerodynamic resistance. The value of r_a is calculated from the next equation.

$$r_a = \frac{\ln\left[\frac{z_m - d}{z_{0m}}\right]\ln\left[\frac{z_h - d}{z_{0h}}\right]}{k^2 u_z}, \qquad (7)$$

where z_m is the height of wind measurements, z_h the height of humidity measurements, d the zero plane displacement height, z_{0m} the roughness length governing momentum transfer, z_{0h} the roughness length governing transfer of heat and vapor, k the von Karman's constant (0.41) and u_z wind speed at height z.

The value of r_a is given for a grass reference surface with a constant crop height of h_g=0.12m. Therefore, d, z_{0m} and z_{0h} are calculated from equations of $2/3h_g$, $0.123h_g$ and $0.1z_{0m}$, respectively. It is assumed that a grass is located at the height of $2/3h_m+0.123h_m$, where h_m is the crop height of maize. Therefore, z_m and z_h are reduced by $2/3h_m+0.123h_m$.

The actual latent heat flux is calculated from the relationship between LEt_p and adopted $LF_{H_2O,b}$ or $LF_{H_2O,ef}$.

**2.4 Calculation of latent and sensible heat trans-
ferred laterally due to advection**

The area of vertical cross section through which advection passed was supposed to be 0.6 × 0.7m². The quantities of latent or sensible heat transferred laterally due to advection in evaporation or sensible heat from soil surface were calculated from the difference of latent or sensible heat carried horizontally through the vertical cross section at two locations. The averaging time was 30 minutes. These values were divided by 0.7×14m², and corrected to values per unite area of soil surface. The quantities of latent and sensible heat transferred due to advection are represented in notations of F_{EA} and F_{HA} in W/m², respectively. The daily value in mm/day of F_{EA} is represented with E_A.

3. Measurements

3.1 Observation site

The observation was conducted at the research field of the Cukurova university in Adana. Maize was planted on June 28, 2004. Crop heights changed from 1.43m on July 29 to 3.25m on Sept. 4, and were almost constant after that. Irrigated water of 160mm, 102mm and 138mm was applied on July 28-29, Aug. 11-12 and Sept. 14-15, respectively.

3.2 The EBBR measurement system

Temperatures and the relative humidity at 2-3 heights were measured from July 29 to Oct. 24. During the same period, net radiation, the soil heat fluxes and the wind speed were measured with a net radiometer, heat flow meters at two locations in soil and a cup anemometer, respectively.

Table 1 Calculated results of actual and potential evapotranspiration (ET and ET_p, mm/day).

Date	ET	ET_p	Date	ET	ET_p	Date	ET	ET_p	Date	ET	ET_p	Date	ET	ET_p
7/29	5.03	5.76	8/16	5.39	5.44	9/03	5.17	5.12	9/21	4.41	4.49	10/09	2.81	3.57
7/30	6.05	6.53	8/17	5.17	5.10	9/04	5.10	5.08	9/22	4.35	4.45	10/10	3.02	3.45
7/31	5.88	6.38	8/18	6.21	6.14	9/05	5.21	5.27	9/23	3.78	4.16	10/11	3.22	3.49
8/01	4.90	5.37	8/19	6.14	5.92	9/06	6.10	6.56	9/24	4.33	4.30	10/12	3.17	3.59
8/02	6.21	7.34	8/20	6.17	5.86	9/07	5.85	5.79	9/25	3.94	4.29	10/13	2.73	3.34
8/03	5.55	6.30	8/21	5.78	5.56	9/08	5.52	5.33	9/26	3.90	4.19	10/14	2.73	3.10
8/04	5.81	6.22	8/22	5.50	5.49	9/09	4.58	5.32	9/27	3.71	3.99	10/15	2.89	3.28
8/05	5.69	6.45	8/23	4.72	4.61	9/10	4.32	4.58	9/28	3.79	4.20	10/16	2.75	2.99
8/06	5.15	5.64	8/24	5.37	5.36	9/11	5.27	6.12	9/29	3.90	4.23	10/17	2.92	3.45
8/07	4.87	5.09	8/25	5.57	5.84	9/12	6.33	8.21	9/30	3.54	3.85	10/18	2.83	3.30
8/08	4.79	5.06	8/26	5.54	5.91	9/13	5.37	5.87	10/01	3.76	3.89	10/19	2.61	3.28
8/09	5.18	5.61	8/27	5.49	5.55	9/14	4.58	5.00	10/02	3.54	4.18	10/20	2.25	2.93
8/10	4.35	4.65	8/28	5.21	5.16	9/15	4.89	5.15	10/03	3.19	3.31	10/21	2.49	3.66
8/11	3.93	4.74	8/29	4.62	4.81	9/16	4.63	4.84	10/04	3.88	4.47	10/22	2.65	3.01
8/12	5.94	5.51	8/30	5.05	5.21	9/17	4.52	4.53	10/05	4.30	5.39	10/23	2.67	3.49
8/13	6.68	6.18	8/31	5.06	5.24	9/18	5.07	5.12	10/06	2.76	3.43	10/24	2.72	3.28
8/14	6.26	5.61	9/01	4.89	5.03	9/19	4.98	4.87	10/07	2.49	2.83			
8/15	5.51	5.13	9/02	4.81	4.94	9/20	4.84	4.71	10/08	3.00	3.78			

3.3 The EBFR measurement system

The sensible heat flux (H_s) was measured by the eddy correlation method with a sonic anemometer during Aug. 6-16. The sampling time was 10 Hz, and the averaging time was 30 minutes. During the same period, the dry and wet bulb temperatures were measured by the self-made psychrometers with platinum resistance thermometers at three heights.

3.4 Measurements of wind speed, temperature and humidity in a furrow under maize canopy

Horizontal wind speed was measured with a hot-wire anemometer at the center of a furrow under maize canopy and the height of 0.3m over soil surface during Aug. 8-15. During the same period, the dry and wet bulb temperatures were measured by the self-made psychrometers with platinum resistance thermometers at two locations of the furrow and the same height as the hot-wire anemometer. The horizontal distance between two psychrometers was 14m. The anemometer was located in the middle of two psychrometers. The width of the furrow was 0.7m.

4. Results

4.1 Results of $p \cdot Rn$, $q \cdot G$, H and LF_{H2O}

Fig.1 shows fluctuations with time of $p \cdot Rn$, $q \cdot Q$, H and LF_{H2O} measured on Aug.13. Values of p and q were 0.905 and 1.28, respectively. H and LF_{H2O} are the sensible heat flux and the latent heat flux calculated with any of three methods.

As seen from this figure, most or almost energy of Rn was distributed to the latent heat flux. H was negative during 11:00-24:00. This sensible heat was used mostly or almost as the heat for vaporization. Such characteristics of the energy balance were seen on all days of July 29 to Oct. 24.

4.2 Calculated results of actual and potential evapotranspiration

Table 1 shows calculated results of actual evpotranspiration (ET) and

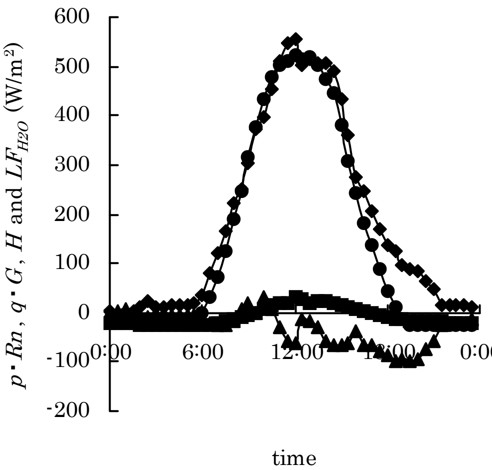


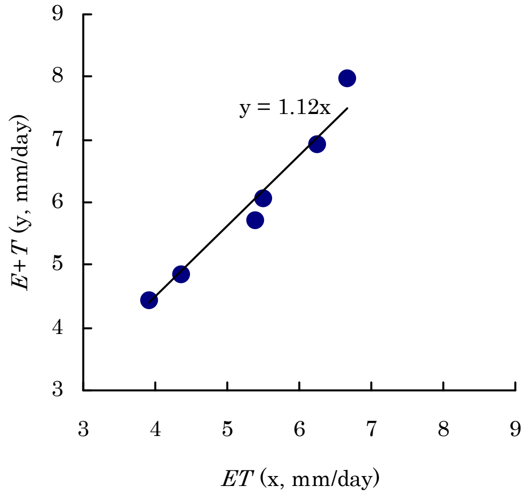
Fig. 1. Fluctuations with time of $p \cdot Rn$ (●), $q \cdot G$(■), H (▲), LF_{H2O}(◆) measured on Aug. 13, 2004.

potential evapo- transpiration (ET_p). Larger values of ET were obtained, when soil was wet and ET_p was large. Examples of the former were obtained on July 30 and Aug. 13, and examples of the latter were obtained on Aug. 2, Aug.13 and Sept. 12.

4.3 Relationship between ET and $E+T$

Fig.2 shows the relationship between ET and $E+T$. As seen from **Fig.2**, values of $E+T$ were larger than values of ET by 12%.

From the result of **Fig.2**, the next hypotheses will be made : ①Values of $E+T$ were overestimated, ②Values of ET were underestimated, and ③Part of evaporation from soil surface was transferred laterally due to advection in the space of furrow under maize canopy. Here, the hypothesis of ③ was examined.



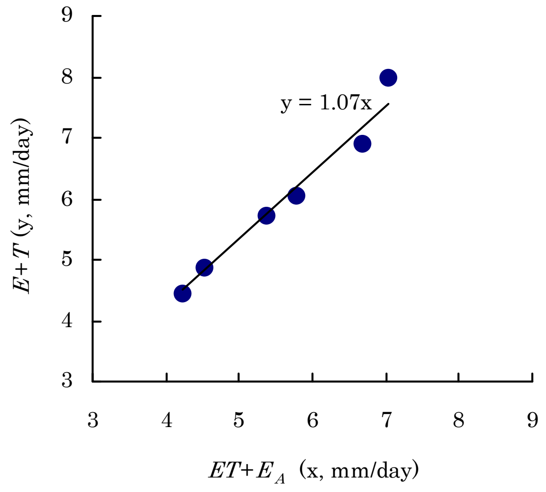


Fig.2. Relationship between *ET* and *E+T*.

Fig. 3. Relationship between $ET+E_A$ and *E+T*.

4.4 Results of F_{EA},and F_{HA}

On all measurement days, F_{HA} was negligibly small. F_{EA} was as large as *G* during the daytime, and was negligibly small during the nighttime.

4.5 Relationship between $ET+E_A$ and *E+T*

Fig.3 shows the relationship between $ET+E_A$ and *E+T*. As seen from **Fig.3**, values of *E+T* were larger than values of $ET+E_A$ by 7%.

5. Conclusion

Actual and potential evapotranspiration of maize crop were determined for 88 days of July 29 to Oct. 24, 2004. Mean actual evapotranspiration for 88 days was 4.52mm/day, and mean potential evapo-transpiration of Penman- Monteith was 4.83mm/day.

Actual evapotranspiration (*ET*, mm/day) was compared with the sum of transpiration (*T*, mm/day) obtained from the sap flow measurement and evaporation (*E*, mm/day) from soil surface measured with the microlysimeter. Values of *E+T* were larger than values of *ET* by 12%.

The quantity of water vapor (E_A, mm/day) transferred laterally due to advection in the space of furrow under maize canopy was estimated. *E+T* was larger than $ET+E_A$ by 7%.

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Separate estimation of transpiration and evaporation from a maize field

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1. Introduction

The impact of climate change on crop productivity will be predicted by using SWAP model. Understanding present water use condition is essential to utilize SWAP model adequately. Maize field was selected to investigate in this study during two growth seasons in 2003 and 2004. The intensive field observation was conducted at maize field near Adana from 14 to 28 August 2003 and from 6 to 16 August 2004. The objectives of our study are as follows,

1) Check the present farm irrigation method and the efficiency
2) Evapotranspiration with the Bowen ratio method as a standard approach for long period is improved by introducing the energy balance flux ratio method.
3) Separation of evapotranspiration into transpiration and soil evaporation with the sap flow measurements. Direct transpiration rate is available for considering crop productivity and stress response analysis.
4) Obtain the crop and miclo-meteorological parameter for SWAP model to predict the future change of the water balance and crop productivity following climate change.

Practical furrow irrigation has been applied every 13-15days. During our observation period, one cycle irrigation period was obtained. Root depth and profile was surveyed for evaluating application efficiency and consumptive use efficiency. Observed results and analysis of water use on maize field were reported for our intensive observation period in August 2003 and temporal data are also reported for August 2004 in this manuscript

2. Field observation

2.1 Site in 2003

The observation was conducted at commercial field (Sorakuri, ÖZEKİCİ farm), located 40km south from Adana and 100 km from the Mediterranean Sea. The size of the field size was about 10 ha and surrounded by another huge maize fields. Ground water table near this field was about 1.0m and soil was clay loam soil.

Maize (*Pioneer G-98*) were grown on furrows and distances between plants are about 20cm. The furrow has 40 cm width and the distance between two furrows was 70-75cm. Crop heights were 3-3.5m. The sowing date was 19 June 2003 and harvest date was 8 November 2003. Irrigated water was applied by furrow surface irrigation on 10 and 23 August. During the observation period, no rain was accounted.

2.2 Site in 2004

The observation was conducted at the research field for agricultural structures and irrigation department of Cukurova university in Adana. The soil of this site is classified as clay Mutlu soil series. Maize was grown almost same condition as we saw in 2003. Crop heights were changed from 1.6m to 2.7m within 12days. Irrigated water was applied by furrow surface irrigation on 11 and 12 August for 102mm.

2.3 Measurements

1) Transpiration

As an application for the estimation of transpiration in field conditions, the hourly variations of transpiration was estimated satisfactorily by using both methods at the same time without using predetermined calibration coefficient for the heat pulse method. (Takeuchi et al.1995) In this study, the heat pulse method and the stem balance method was applied on same stems.

Six sample plants (1.9-2.2cm in diameter, 309-347cm height) for monitoring sap flow were selected form 100 plants with measuring the diameter of each stem. Heat pulse probes were inserted at No.3 nods (23-31cm height) while the stem heat balance gauges were installed at No.4 nods (37-44cm height) for 2003 observation.

2) Evaporation

The microlysimeter technique allowed researchers make gravimetric measurements of daily evaporation under a crop canopy without drastically modifying the field and soil environment. Three microlysimeters, 0.2m long and 0.105m in diameter were installed midway between the rows, 2 rows apart from the sap flow measuring plot.

3) Evapotranspiration

Evapotranspiration was measured by Bowen ratio method and the energy balance flux ratio method (the EBFR method). In the EBFR method, the latent heat flux (evapotranspiration rate; F kg $s^{-1}m^{-2}$) is calculated by complementing the flux ratio equation (1) and energy balance equation (2).

$$LF=LH_s(\rho_{w1}/\rho_1-\rho_{w2}/\rho_2)/C_p(T_{d1}-T_{d2}) \qquad (1)$$

where L(J/kg) is the latent heat of vaporization, H_s(W/m^2) the sensible heat flux measured by the eddy correlation method, ρ (kg/m^3) the dry air density, ρ_w(kg/m^3) the water vapor density, C_p(JK^{-1}kg^{-1}) the specific heat for constant pressure and ρ_w/ρ the mixing ratio and T_{d1} and T_{d2} temperatures at two heights z_1 and z_2, respectively.

$$LF=p\cdot Rn-q\cdot G-H \qquad (2)$$

where Rn (W/m^2) is net radiation, G(W/m^2) the soil heat flux, and p, q are coefficients related to in-balance in energy balance equation.

The sonic anemometer was applied to measure the sensible heat flux and its sampling time was 10Hz, and the averaging time was 30 minutes. The dry and wet bulb temperature was measured at three heights, 3.375m(z_1), 3.7m, and 4.14m(z_2).

4) Additional measurements

Soil moisture was measured by ADR soil moisture sensor and SENTEK soil profile sensor. Root profile was surveyed and determined by root analyzer.

3. Results

3.1 Observations 2003

An example of obtained data is shown in Fig.1.

It was clear sky day on 16 August, air temperature on the canopy showed constant value from 11:00 to 17:00. In the afternoon, prevailing wind blew from the south seacoast constantly.

Sap flow rate measured by the stem heat balance method were shown higher than 100g h^{-1} at mid-noon, so combined approach with the heat pulse and the heat balance methods was applied to compute accurate sap flow rate. Daily sap flow rate was 741, 679, 784, 903, 770, 919g d^{-1} among 6 plants, while average value was 800g d^{-1}. These values are corresponding to 85 to 115% of average value.

Soil evaporation rate was reduced from 1.3 to 1.0 mm d^{-1} during first 3 days after irrigation, and then indicated 0.9 to 1.0 mm d^{-1} constantly. The ratio

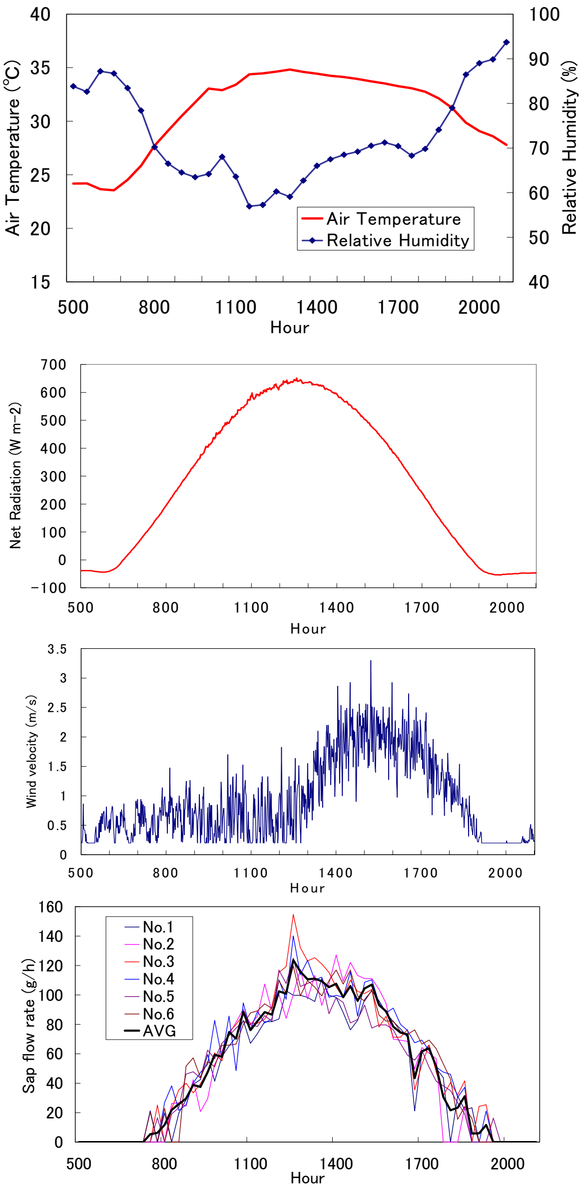

Fig. 1. Diurnal course of sap flow rate on 16 August with air temperature, relative humidity, net radiation and wind speed data. (Clear day)

between transpiration and evaporation was changed from 16.6% to 23%.

In Fig.2, evapotranspiration rate (ET) estimated by Bowen ratio method and EBFR method was compared with transpiration rate for two days as examples. In EBFR method, the flux is calculated in case that wind direction is agreed with allowable measuring direction for sonic anemometer in this system. On 19 August, similar curves were obtained between the Bowen ratio method and the EBFR method. On the contrary, the Bowen ratio method

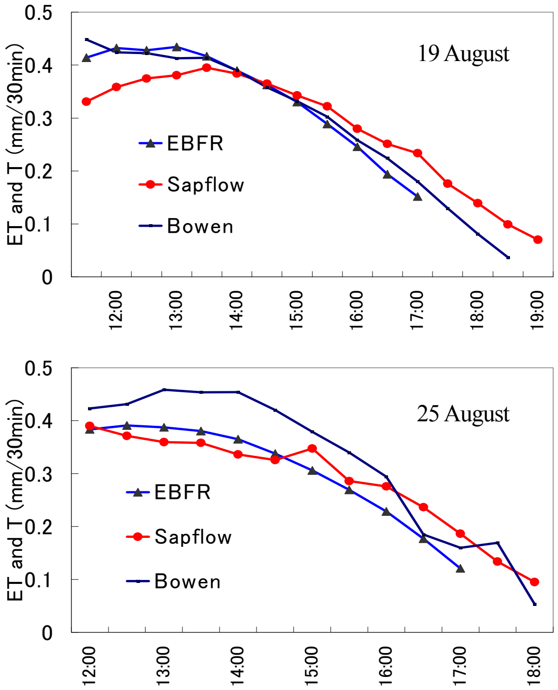

Fig. 2. Diurnal course of evapotranspiration :ET and sap flow rate :T on 19 and 25August

indicated greater that the EBFR method on 25 August. In this day, the sensible heat was estimated negative value in Bowen ratio method, while EBFR method with eddy correlation showed positive value. This discrepancy may come from the small difference between two wet and dry bulb temperature sensors. So, water use on maize field was analyzed below with transpiration by sap flow measurement and soil water evaporation by miclolysimeter in this study. In Fig.2, transpiration rate (sap flow:T) was also compared with EBFR method. Evaporation (E) was not considered in these figures, so E+T is greater than ET. This subject was investigated in 2004 whether vertical one dimension measurement is enough to capture all ET components.

The time lags between ET and T were also found on several days as shown in Fig.2. In Fig.3, the verification experiments for these time lags were conducted in August 2004. An enclosure with black screen (1.1 × 1.55 × 2.0m) was applied to make shadow effect for potted maize plants. This is the consideration of inside of maize canopy. Sap flow was measured with the stem heat balance method and transpiration was measured by mass loss method. A significant time lag between two curves was not obtained. So it is concluded that the time lag shown in Fig.3 was not related to water flow inside of plants as we saw on tree species. This will be come from complicated structure with tall maize canopies.

54 % of plant root was concentrated from 10 to 20

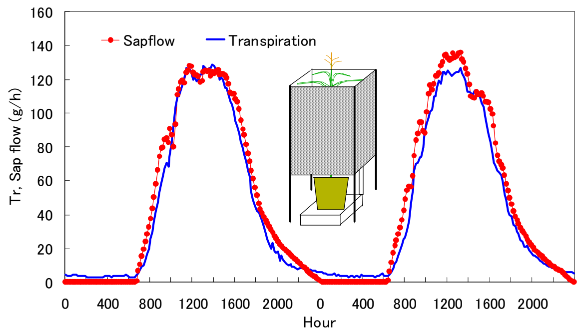

Fig. 3. Verification experiment for the time lag between transpiration and sap flow with potted maize (Pioneer 31 G-98)

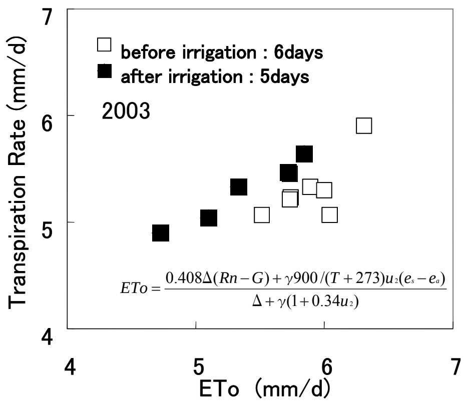

Fig. 4. Relationship between T and ETo,2003

cm from soil surface within 40cm furrow. Between furrow, root was not find significantly. The changes of soil moisture content near plant stem indicated significant stepped reduction in daytime within 20 cm soil layers from surface. It is also clarified that irrigated water penetrated immediately with passing cracks formed before irrigations.

The relationship between transpiration and reference evapotranpiration (ET_0) is indicated in Fig.5. Moderate water stress was shown within six days after the previous irrigation. After the irrigation on 23 August, transpiration was recovered and indicated liner relationship between T and ET_0. Before and after irrigation, the value of T/ET_0 was 0.906 and 0.978, respectively. The Kcb_{mid} for sweet corn is 1.10 and for field corn is 1.15. Our value was smaller than Kcb_{mid} although our plants were larger than normal plants.

Total water use amount between irrigation intervals was estimated 13.6 liter/plant, which is corresponded with 91mm/irrigation. On the contrary, irrigation water was applied with the depth of 100-200mm by soil sampling data. This is possible to conclude that maize were not suffered water stress condition and water saving will be achieved on farm basis and irrigation system bases.

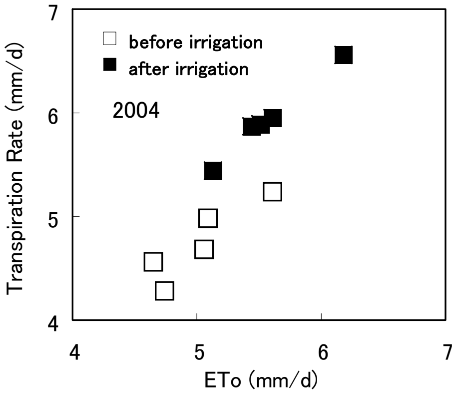

Fig. 5. Relationship between T and ETo,2004

3.2 Observations 2004

The relationship between transpiration and reference evapotranpiration (ET_0) is also indicated in Fig.5. Irrigation was conducted at 11:00 am on 12 August for observed area by furrow irrigation. Transpiration rate was dramatically increasing after irrigation. Before and after irrigation, the value of T/ET_0 was 0.944 and 1.066, respectively. Plants size and leaf area in Fig.4 were larger than in Fig.5. Plants height was changed from 205cm to 273cm within 7 days. The growth rate of plants in this period was higher than 10cm/day and increased after the irrigation significantly. The tendency of ET value during 2004 observation period was also higher than that in 2003. This may come from the structure of maize canopy that can absorb more energy and climatic condition.

In previous report and in Fig.4 and Fig.5, plant occupied ground area was employed as 75cm×20cm with considering seedling distances. However, actual condition of maize germination was not uniform and regular intervals. So, another plant occupied ground area was employed as 75cm×22.5cm. In this case, transpiration rate was decreased 87% of the value in previous ICCAP report. Soil water evaporation was measured by miclo-lysimeter. One lysimeter was installed between the rows and another one was installed between the maize stems on the furrow in 2004. Evaporation rate was calculated with considering shape of the furrow simply.

A diurnal course of transpiration, evaporation and evapotranspiration from Aug.7 to Aug.18 is shown in Fig.6. Furrow irrigation was executed on 13 August at observation site. Across the irrigation day, evapotranspiration rate was exceeded its potential value. This may be caused by stimulation of plant growth with the irrigated soil moisture. They grew 68cm within 8 days. Most of leaves were upward direction and it is well known that this shape is advantageous for collecting solar radiation.

It has rain in the morning on 12.Angust, soil water evaporation by miclo-lysimeter underestimated real evaporation rate. On the next day, the irrigation day on 13.Aug., ET+T was 2mm higher than ET. This is caused by the structure of the lysimeter. The bottom of lysimeter obstructed soil water flow to downward and this extra soil moisture caused additional evaporation as contrasted with natural soil condition.

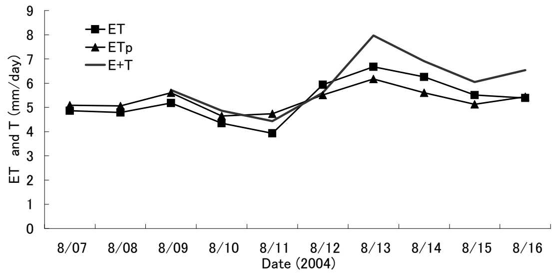

Fig. 6. Diurnal course of transpiration, evaporation and evapotranspiration (Re-analysis)

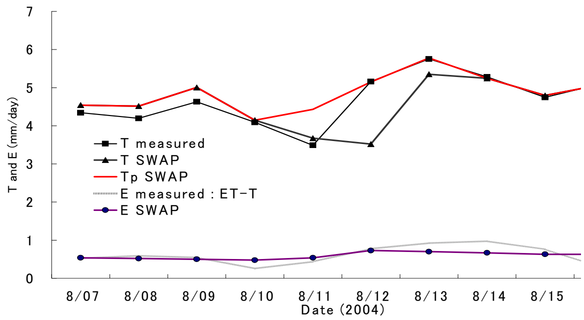

Fig.7. Estimated T and E by SWAP model

4. Estimated T and E by SWAP model

Transpiration rate and soil evaporation rate in Fig.1 was compared with both computed values by SWAP model. To obtain correct value of ET, meteorological data measured in the maize field was used. In case of meteorological data used in Adana weather station, computed evapotranspiration rate was smaller than the one with measured data in the field. Potential transpiration and soil evaporation computed by SWAP model were quite well agreed with measured value, while actual transpiration before irrigation were not good estimated. For investigating hydraulic property of the soil, computed results closed to the measured values.

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Simulation of Crop Productivity for Evaluating Climate Change Effects

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1. Introduction

The effect of climate change on the crop productivity is usually investigated with the experimental methods using a growth chamber or with the numerical methods using a crop model.

The objectives of this research are (1) to establish the crop parameters in a crop growth model for wheat and maize as main crops in the world based on the experimental data collected in Adana and (2) to evaluate the effects of elevated CO_2 concentration and risen air temperature on crop growth.

2. Materials and methods

The SWAP model which was developed in the Netherlands (van Dam *et al*., 1997) was used for the study. The model aims at simulating water, solute and heat transport in relation to plant growth at field scale level and for entire growing seasons. The SWAP model integrates soil-water balance and crop growth originally developed as the WOFOST model to describe daily phenological development and growth in response to environmental factors such as soils and climate, and crop management (Boogaard *et al.*, 1998). The model is eco-physiological process-based, simulating photosynthesis, evapotranspiration, and other major plant and soil processes. The major processes for crop growth are phenological development, CO_2-assimilation, respiration, partitioning of assimilates to the various organs, and dry matter formation.

The SWAP requires input data on soil, crop and climate for its calibration and validation in the different environments. Climate (solar radiation, maximum and minimum temperatures, relative humidity, wind speed and rainfall), soil (soil water retention and hydraulic functions) and crop management data (crop calendar, some growth parameters, irrigation etc.) were collected for the study location. The main parameters of the crop growth sub-model are temperature sum for the development rate of crop, specific leaf area, life span of leaves at optimum conditions, initial total crop dry weight, conversion of assimilates into biomass, fraction of dry matter increase partitioned to organs, maintenance respiration, reduction factor for senescence. Parameters for the crop growth model was decided with the crop growth measurement of two growing years for wheat and one growing year for maize.

The processes and relations incorporated in the WOFOST model are as follows: Using the absorbed radiation, which is absorbed by the canopy and is a function of incoming radiation and crop leaf area, and taking into account photosynthetic leaf characteristics the potential gross photosynthesis is calculated. The potential photosynthesis is reduced due to water and/or salinity stress, as quantified by the relative transpiration, and yields the actual gross photosynthesis. Part of the carbohydrates (CH_2O) produced are used to provide energy for the maintenance of the existing live biomass (maintenance respiration). The remaining carbohydrates are converted into structural matter. In this conversion, some of the weight is lost as growth respiration. The dry matter produced is partitioned among roots, leaves, stems and storage organs, using partitioning factors that are a function of the phonological development stage of the crop. The fraction partitioned to the leaves, determines leaf area development and hence the dynamics of light interception. The dry weights of the plant organs are obtained by integrating their growth rates over time. During the development of the crop, part of living biomass dies due to senescence. Some simulated crop growth processes are influenced by temperature, like for example the maximum rate of photosynthesis and the maintenance respiration. Other processes, like the partitioning of assimilates or decay of crop tissue, are steered by the phenological development stage (van Dam *et al.*, 1997).

The impacts of elevated CO_2 concentration and risen air temperature on crop growth and water balance components for wheat and second crop maize were examined using meteorological data of the Turkish Meteorological Station.

3. Results and discussions

Calculated and measured leaf area index (LAI) and biomass are compared in Fig. 1 for wheat in 2004/2005 and Fig. 2 for maize in 2004, respectively. The biomass values shown in these figures are total above-ground biomass. Although the discrepancy between calculated and measured values is recognized, estimation of crop growth with the SWAP model is satisfactory. The most sensitive parameters for crop growth simulation were found to be temperature sum for the development rate of crop, specific leaf area (i.e. the increase of the leaf area of the crop per kg weight increase of the living leaves) and initial crop total dry weight.

Since CO_2 is the fundamental parameter for crop growth prediction, it is supposed that use of only climatic data would cause the erroneous results. Thus, effects of elevated CO_2 concentration on plants should be imposed to the model simulations. Maize is one of C4 plants, and increases of CO_2 concentration are not so effective in crop growth unlike C3 plants. Although wheat is a C3 plant and elevated CO_2 concentration promotes photosynthesis, risen temperature may partially compensate it with stomatal closure. In fact, elevated atmospheric CO_2 concentration increases photosynthesis in C3 plants and reduces evapotranspiration in both C3 and C4 plants due to reduced stomatal conductance.

Since CO_2 concentration is supposed to increase up to doubling concentration under SRES A2 scenario (IPCC 2001) in 2070s, simulation was done using 2004/2005 meteorological data under doubling CO_2 concentration condition. In doing calculation, the percent change in acclimatized photosynthesis rate was assumed to be +27% and +4% for wheat and maize, respectively (Cure and Acock, 1986). As the result, it was found that biomass values under the doubling CO_2 condition are about 17% and 5% higher than the values under the current CO_2 condition both for wheat and maize, respectively.

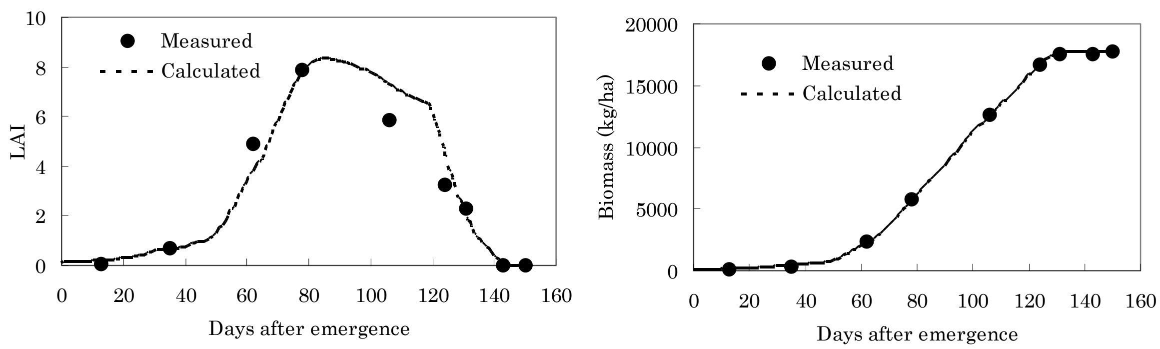

Fig. 1. Comparison between calculated LAI and biomass, and the measured ones of wheat.

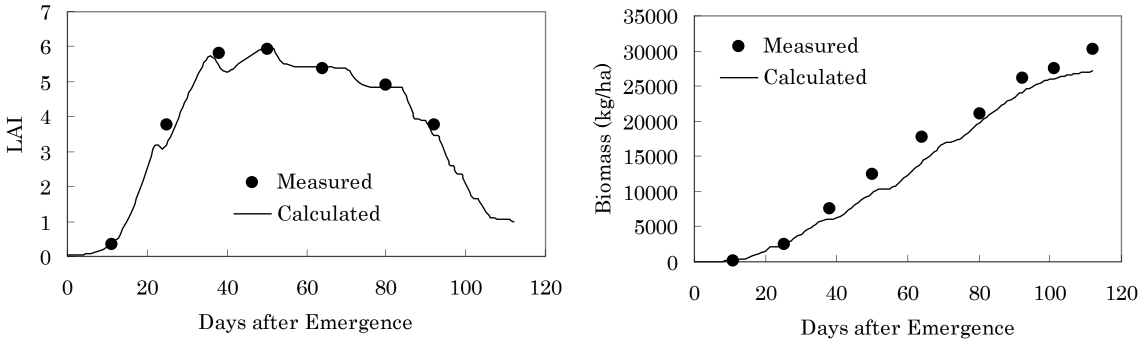

Fig. 2. Comparison between calculated LAI and biomass, and the measured ones of maize.

However, high temperatures accelerate the phenology of plants, resulting in quicker maturation. The shortened growth cycle, in turn, may reduce the yield potential of annual crops (Rosenzweig and Hillel 1998). Based on a range of several current climate models, the mean annual global surface temperature is projected to increase by 1.4 to 5.8 ℃ over the period of 1990 to 2100 (IPCC, 2001). In order to evaluate the positive effect of elevated CO_2 concentration and the negative effect of risen air temperature on crop yields, simulation was done by doubling CO_2 concentration and by increasing maximum and minimum temperature by 1, 3, 5 ℃ relative to the current condition.

Results of calculated yields as well as evapotranspiration (ET) are shown in Table 1 and Table 2 for wheat and maize, respectively. Increase of biomass due to doubling CO_2 concentration is about 15% and 6% for wheat as a C3 crop and maize as a C4 crop, respectively. On the other hand, ET does not similarly increase and even decreases for maize, probably due to temporal water stress resulted from active crop growth. Decrease of biomass and ET following temperature rise is clearly shown in the both tables which denote that temperature increase of 3 ℃ results in biomass decreases by 17% and 20%, respectively. ET decreases similarly as biomass does.

Thus, increased yields by doubling CO_2 concentration are counteracted by rise in temperature of 3 and 1 ℃, respectively for wheat and maize. More than 1 ℃ of temperature rise is estimated in 2070s when CO_2 concentration is supposed to increase up to doubling concentration, although much variations of temperature rise is recognized among models. Detailed description about temperature projection is given in the article "Prediction of Future Change of Water Demand Following Global Warming in the Cukurova Region, Turkey" by Yano *et al*. of this issue.

Reduction of ET due to stomatal closure is not considered in Table 1 and 2. Experimental findings indicating considerable decreases in actual ET due to stomata closure under elevated CO_2 concentration have received a wide recognition (e.g. Ainsworth and Long, 2005). Decreases in transpiration by 17% and 26%, respectively for wheat and maize have been reported by Cure and Acock (1986). Further decreased ET values are replaced with those in Table 1 and 2 as shown in **Table 3**. Thus, ET from wheat and maize further decreases by 54 and 111 mm by transpiration reduction.

Table 1 Effects of doubling CO_2 concentration ($2xCO_2$) and rise in air temperature (+T) on crop growth and ET for wheat without ET reduction

Factor	Biomass (ton/ha)	Grain yield (ton/ha)	Growth days	ET (mm)
Control	17.74	4.71	164	370.4
$2xCO_2$	21.67	5.74	162	371.4
+1 ℃	16.41	4.14	155	350.3
+3 ℃	13.21	3.96	141	310.4
+5 ℃	10.37	4.01	128	254.3

Table 2 Effects of doubling CO_2 concentration ($2xCO_2$) and rise in air temperature (+T) on crop growth and ET for maize without ET reduction

Factor	Biomass (ton/ha)	Grain yield (ton/ha)	Growth days	ET (mm)
Control	27.14	17.29	120	378.4
$2xCO_2$	28.85	17.98	120	359.0
+1 ℃	25.13	15.83	116	361.7
+3 ℃	21.71	13.14	110	335.2
+5 ℃	18.62	10.79	107	314.4

4. Conclusions

In this research, crop parameters in a detailed crop sub-model of the SWAP model were decided for wheat and maize using the field data of two growing years (2003/2004 and 2004/2005) for wheat and one growing year (2004) for maize in Adana. Consequently, the simulated values for LAI and biomass are in reasonable agreement with the measured data.

Then, the effects of elevated CO_2 concentration and risen air temperature on crop growth and evapotranspiration were separately evaluated using created meteorological data based on the observed data in 2004 and 2005.

Increase of biomass due to doubling CO_2 concentration is about 15% and 6% for wheat as a C3 crop and maize as a C4 crop, respectively. On the other hand, ET does not similarly increase and even decreases for maize. Decrease of biomass and ET following temperature rise is clearly shown that temperature increase of 3 ℃ results in biomass decrease for 17% and 20%, respectively. ET decreases similarly as biomass does.

Increased yields by doubling CO_2 concentration are counteracted by rise in temperature of 3 and 1 ℃, respectively for wheat and maize. More than 1 ℃ of temperature rise is estimated in 2070s when CO_2 concentration is supposed to increase up to doubling concentration, although much variations of temperature rise is recognized among the different models.

Acknowledgements

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Table 3 Effects of ET reduction on crop growth and ET for wheat and maize at doubling CO_2 concentration ($2xCO_2$)

Crop	Biomass (ton/ha)	Grain yield (ton/ha)	Growth days	ET (mm)
Wheat	22.06	6.15	162	317.8
Maize	28.44	17.74	120	248.2

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Prediction of Future Change of Water Demand Following Global Warming in the Cukurova Region, Turkey

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1. Introduction

It has been reported that the globally averaged surface temperature is projected to increase by 1.4 to 5.8 ℃ over the period of 1990 to 2100 (IPCC 2001). It is not likely that precipitation will have increased in arid regions and the effects of future climate change on irrigation and water resources may become of major concern. Although the raised temperature increases evaporative demand of the atmosphere, actual crop water use is dependent on growth response to temperature rise. The purpose of the research is to predict future change of water demand in the Mediterranean climate regions of Turkey by using the predicted climate change data, considering the effect of elevated CO_2 concentration and rise in temperature on crop growth.

2. Materials and methods

The GCM-based climate change data are available with seven climate models at the IPCC web-site (http://ipcc-ddc.cru.uea.ac.uk/). Among seven models, the CGCM2 model of Canadian Center for Climate Modeling and Analysis (CCCma) was selected, because the climate data are daily while those of other models are monthly. The predicted climate change data for the CGCM2 model are available for 4608 locations of the world which correspond to a grid distance of 412 km on the equator. Two kinds of the projected climate data of the regional climate model (RCM) with the grid distance of 25 km which were supplied by the climate subgroup were also used. The RCM data are based on a newly suggested method which uses reanalysis data as a boundary forcing of the RCM while a specially created boundary condition, in which projected changes of meteorological variables in the GCMs (MRI and CCSR/NIES) simulation are added on reanalysis data, is used for simulation (Sato *et al.*, in press).

Monthly water balance was first calculated for a double cropping pattern of wheat and second crop maize grown in Adana (37.00°N, 35.33°E) for a period of 10 years from 2070 to 2079 using the SWAP model developed in the Netherlands (van Dam *et al.*, 1997). The A2 scenario of the Special Report on Emission Scenarios (SRES) was used. This scenario depicts a very heterogeneous world. The underlying theme is that of strengthening regional cultural identities, with an emphasis on family values and local traditions, high population growth, and less concern for rapid economic development (IPCC, 2001).

3. Results and discussions

3.1. Projection of air temperature and precipitation

Variations of annual mean temperature and precipitation collected from four GCM-based models for 111 years from 1990 to 2100 in Adana are shown in **Fig. 1** as the difference from 1990 – 2004 mean. Four models are: CGCM2 model of Canadian Center for Climate Modeling and Analysis (CCCma), ECHAM4/OPYC3 model of Max Planck Institute für Meteorologie (MPIfM), CGCM2.2 model of Meteorological Research Institute (MRI) and AGCM + CCSR OGCM model of Center for Climate System Research and National Institute for Environmental Studies (CCSR/NIES). The MRI data are not available at the IPCC web-site. These data were computed for Adana using the projected values at the four nearest neighboring grid points using the inverse distance weighted method. Annual temperature increases gradually. According to the linear regression equation, averaged surface temperature is estimated to increase by 3.1-8.6 ℃ over the period of 1990 to 2100. Among the four models, the CCSR/NIES and MRI data denote the highest and lowest increase, respectively. Although annual precipitation denotes noticeable variations year

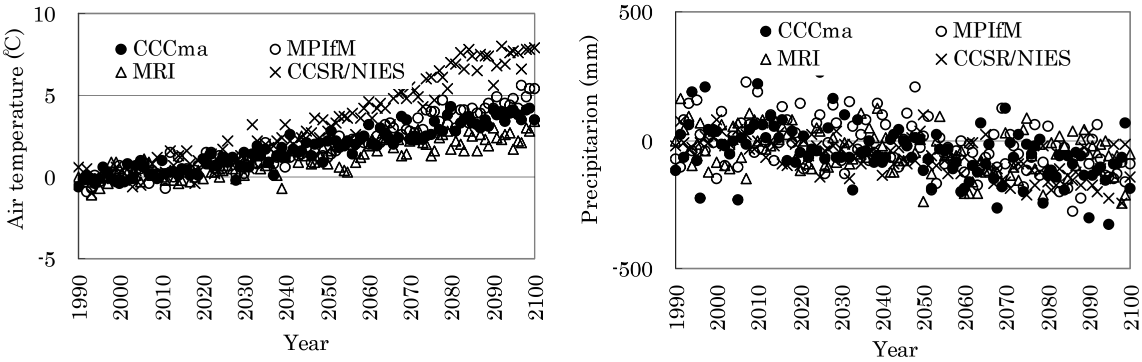

Fig. 1. Projections of air temperature and precipitation difference from 1990 – 2004 mean.

by year, it is not likely that it will have increased in the future.

A comparison of the predicted monthly temperature as well as precipitation with the CCCma GCM (hereafter referred as GCM) and MRI RCM (hereafter referred as MRI) models and observed ones for 10 years from 1994 in Adana is given in **Fig. 2**. Annual air temperature is 18.0, 18.2 and 19.2 ℃, respectively for the GCM, MRI and observed data. Although the GCM and MRI data show about same average values, annual pattern is different. Predicted air temperatures with the GCM data denote lower values than those with the observed one during spring and summer, while the MRI data show lower during summer and autumn. Also, the agreement between predicted and observed precipitation values is not reasonably well. Annual precipitation predicted with the models is 540, 526 and 662 mm, respectively for the GCM and MRI and observed data, and estimated values were underestimated when compared with observed one.

Monthly variations of potential evapo- transpiration from reference crop (ETref) to represent the evaporative demand of the atmosphere are shown in **Fig. 3**. ETref was calculated with the Penman-Monteith equation based on the GCM and RCM data and the observed data. Calculated potential ET from the different climate data shows the similar monthly variations with the air temperature variations. Since potential ET is the fundamental parameter for water demand prediction, it is supposed that direct use of the original GCM and MRI data would result in the erroneous results.

For the GCM data with large grid distance, the climatic scenarios for the future are sometimes created by superimposing the observed values to the change between the present and the future estimated values (Tao et al., 2003). The same procedure was used to create the future climate data using the GCM data. For the RCM data, predicted values were decided to use by correcting with the observed data for the current and future climate conditions.

Monthly air temperature and precipitation created for Adana are depicted in **Fig. 4**. It can be seen that created air temperatures and precipitation were modified in accordance with the discrepancy between the predicted values and the observed values in Fig.2. Projections of temperature rise over a time periods of 2070-2079 compared with 1994-2003 are 2.8 ℃, 1.4 ℃, 2.3 ℃ for GCM, MRI and CCSR/NIES RCM (hereafter referred as CCSR/NIES). Lower increase for MRI than those for GCM and CCSR/NIES is due to the process of data correction based on observed data. Projected mean annual precipitation during 2070-2079 compared with

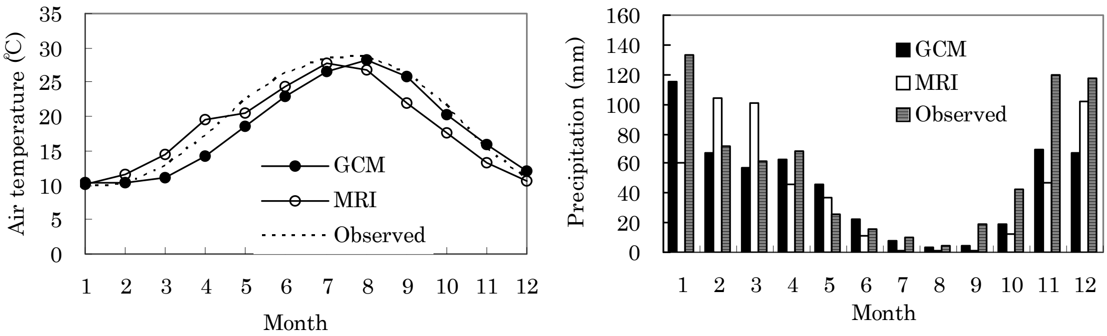

Fig. 2. Predicted air temperature and precipitation with the GCM, MRI and observed data.

1994-2003 would decrease by 56, 303, and 279 mm (equivalent to 11, 46 and 42% decrease) according to the GCM, MRI and CCSR/NIES models, respectively.

3.2. Water balance change due to global warming

The interactive effects of global warming and increasing CO_2 levels could especially impact agriculture, affecting water demand, growth and development of crops and ultimately impacting yield and food production.

Simulation models are a means to analyze the potential effects of climate change on crop growth, but testing model performance against measured data under such scenarios is essential for such an analysis to be meaningful. Before the water balance calculation for wheat and maize, crop growth was simulated using a detailed growth model of SWAP. It was parameterized with the crop growth measurement of two growing years for wheat and one growing year for maize. Detailed description about parameterization is given in the article "Simulation of crop productivity for evaluating climate change effects" by Yano *et al*. of this issue.

The average values and standard deviations of the water balance components for the periods of 10 years from 1994, and from 2070 together with biomass, grain yield and growing duration for wheat and second crop maize are given in **Table 1** and **Table 2**, respectively. Since CO_2 concentration in 2070s is estimated to increase up to doubling concentration under SRES A2 scenario, calculations were done for under doubling CO_2 concentration condition. In doing calculation, the percent change in acclimatized photosynthesis rate was assumed to be +27% and +4% for wheat and maize, respectively (Cure and Acock, 1986). It is well-known that actual ET decreases considerably due to stomata closure under elevated CO_2 concentration (e.g. Ainsworth and Long, 2005).

The percent change in transpiration decreases by 17% and 26%, respectively for wheat and maize was used for calculation for the period 2070-2079 (Cure and Acock, 1986).

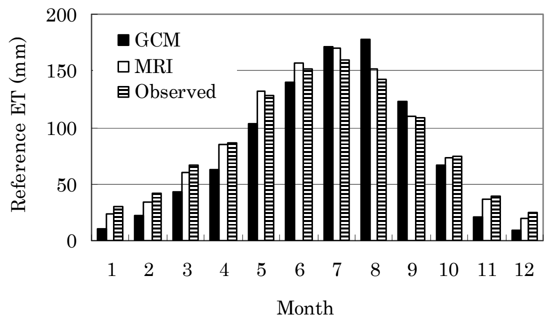

Fig. 3. Calculated reference ET from the GCM, MRI and observed data.

Comparison of calculated actual ET between the current climatic condition and the future for the GCM, MRI and CCSR/NIES data shows the decrease of 28%, 8% and 16%, respectively for wheat and 24%, 28% and 26%, respectively for maize, reflecting the different rises in air temperature in the future.

Future air temperature rise results in increase in evaporative demand of the atmosphere. However, decrease in actual ET for both wheat and maize shown in Tables 1 and 2 can be attributed to reduction of growing days and LAI due to temperature rise and transpiration reduction due to stomata closure regardless of increase in evaporative demand.

Irrigation water demand was estimated to increase in the future for wheat mainly due to decrease in precipitation. On the contrary, it was estimated to considerably decrease for maize, reflecting decrease of actual ET due to stomatal closure. The water balance components and crop growth under the assumption that there is no transpiration reduction even at elevated CO_2 concentration are shown in **Table 3** in which the GCM data was used for simulation. If there would be no reduction in transpiration at elevated CO_2 concentration, actual ET would increase by 32 and 79 mm for wheat and maize, respectively. As the result, irrigation for maize would increase by 73 mm (equivalent to 23% increase).

The duration of the regular crop-growing season for

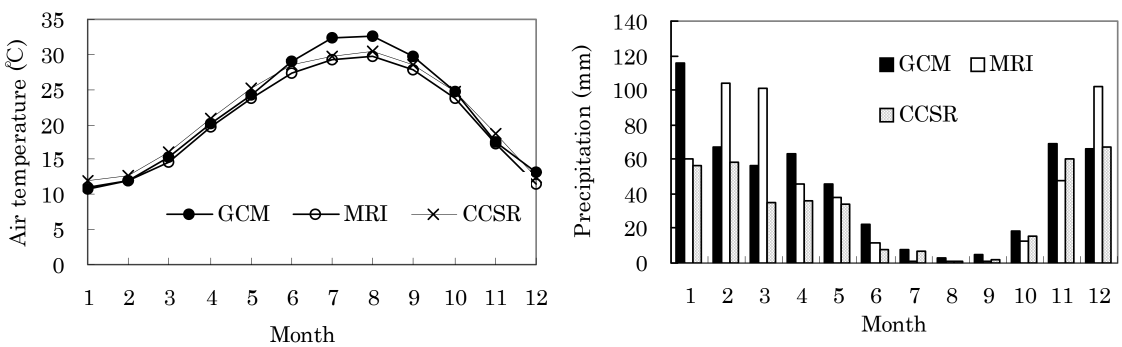

Fig. 4 . Comparison of projected air temperature and precipitation for 10 years from 2070.

wheat is 14, 7 and 11 days shorter in the future. This change is caused by the projected air temperature rise of 2.2, 1.6 and 2.4 ℃ for a growing period by the 2070s for GCM, MRI and CCSR/NIES. Duration of growth period for maize becomes shorter by 9 days for GCM and CCSR/NIES while only 3 days for MRI. Air temperature rise projected with the GCM, MRI and CCSR/NIES models was 3.5, 1.4 and 3.0 ℃ during growing period of maize, respectively. In other words, high temperatures accelerate the phenological development of plants, resulting in quicker maturation.

The predicted biomass and grain yield for wheat and maize in the 2070-2079 denote the complicated results to explain in accordance with the different photosynthesis rate and air temperature rise in the future. In case of wheat, biomass decreases for GCM, but increases for both of RCMs. Grain yield increases for all the models. Since rise in temperature for MRI is less than other two models, higher yields are expected to occur. However, biomass of more than 23 ton/ha may be too high. The reason why grain yield for all the models increase can not be explained well.

In case of maize, both biomass and grain yield decrease for GCM and CCSR/NIES, but increase for MRI because of less rise in temperature than those for GCM and CCSR/NIES.

As described earlier, original RCM data were corrected based on observed data. The difference between the current and future annual mean air temperature is 2.4 and 1.4 ℃ for the original and corrected MRI data and 3.6 and 2.3 ℃ for the CCSR/NIES data, respectively.
It seems that simulated results using the corrected RCM data would not reflect correctly the effect of air temperature on crop growth and water balance components. Therefore, although it is generally difficult to downscale GCM data with large grid point distance accurately to the study area, the approach to use the GCM data in this study to predict the future change in water demand must be appropriate under the present situation with less reliable RCM data.

4. Conclusions

Four kinds of GCM data published by four research organizations of CCCma, MPIfM, CCSR/NIES and MRI were downscaled for the study area with the projected data at the four nearest neighboring grid points using the inverse distance weighted method. Averaged surface temperature is estimated to increase by 3.1-8.6 ℃ over the period of 1990 to 2100. Among the four models, the CCSR/NIES and MRI data denote the highest and lowest increase, respectively. Although annual precipitation denotes noticeable variations year by year, it is not likely that it will have increased in the future.

The future climate scenario for GCM by CCCma was created based on the observed values and the change of predicted values between present and future, assuming that only change between the present and the future is correct. Two kinds of original RCM data based on CCSR/NIE and MRI GCM were corrected using observed data to avoid bias. Projected climate change data in 2070s when CO_2 concentration is estimated to

Table 1 Predictions of the combined effects of projected climate change with elevated air temperature and doubling CO_2 concentration with transpiration reduction due to stomata closure for wheat

Model	Period	Precipitation (mm)	ET (mm)	Irrigation (mm)	Biomass (ton/ha)	Grain yield (ton/ha)	Growth days
GCM	1994 - 2003	535.0 ± 186.3	349.2 ± 35.2	0 ± 0	17.5 ± 1.8	5.0 ± 0.9	198.5 ± 7.8
	2070 - 2079	503.6 ± 211.8	250.9 ± 32.1	16.6 ± 36.9	16.8 ± 2.0	5.8 ± 0.8	174.1 ± 6.6
MRI	1994 - 2003	597.9 ± 190.1	301.8 ± 30.1	24.8 ± 45.3	16.9 ± 1.7	4.5 ± 0.9	188.1 ± 5.8
	2070 - 2079	313.9 ± 82.5	276.6 ± 20.9	68.9 ± 56.8	23.3 ± 0.9	6.1 ± 1.3	181.3 ± 4.1
CCSR	2070 - 2079	308.0 ± 88.1	252.5 ± 26.7	79.2 ± 88.1	19.0 ± 2.1	5.6 ± 0.9	167.6 ± 4.5

Table 2 Predictions of the combined effects of projected climate change with elevated air temperature and doubling CO_2 concentration with transpiration reduction due to stomata closure for maize

Model	Period	Precipitation (mm)	ET (mm)	Irrigation (mm)	Biomass (ton/ha)	Grain yield (ton/ha)	Growth days
GCM	1994 - 2003	47.5 ± 23.8	414.1 ± 26.1	375.5 ± 51.7	27.3 ± 1.5	15.1 ± 1.3	115.9 ± 3.8
	2070 - 2079	24.9 ± 18.0	314.0 ± 23.7	318.4 ± 27.6	22.6 ± 1.6	11.4 ± 1.2	106.7 ± 0.7
MRI	1994 - 2003	9.8 ± 6.0	439.8 ± 5.8	423.1 ± 7.8	30.1 ± 1.0	16.4 ± 0.9	118.8 ± 2.9
	2070 - 2079	8.5 ± 8.0	317.6 ± 5.9	331.4 ± 36.0	31.0 ± 1.0	16.9 ± 0.8	115.8 ± 2.4
CCSR	2070 - 2079	10.7 ± 17.1	326.6 ± 5.2	328.2 ± 24.8	29.2 ± 0.8	15.5 ± 0.7	109.8 ± 1.3

Table 3 Predictions of the combined effects of projected climate change with elevated air temperature and doubling CO_2 concentration without transpiration reduction for wheat and maize using GCM

Crop	Period	Precipitation (mm)	ET (mm)	Irrigation (mm)	Biomass (ton/ha)	Grain yield (ton/ha)	Growth days
Wheat	2070 - 2079	503.6 ± 211.8	282.6 ± 24.4	16.6 ± 36.9	16.9 ± 2.0	4.4 ± 0.6	164.4 ± 6.0
Maize	2070 - 2079	24.9 ± 18.0	393.1 ± 33.9	391.0 ± 37.7	20.4 ± 1.4	10.4 ± 1.1	106.7 ± 0.7

reach doubling concentration were used for comparison with the current climate (1994-2003). Water balance components and crop growth were estimated using the SWAP model in which parameterization of the growth model for wheat and maize was done based on observed data.

Projections of temperature rise over the time period of 2070-2079 compared with 1994-2003 are 2.8 ℃, 1.4 ℃, 2.3 ℃ for CCCma GCM, MRI and CCSR/NIES RCM, respectively. Lower increase for MRI than those for GCM and CCSR/NIES is due to the process of data correction based on observed data. Projected mean annual precipitation during 2070-2079 compared with 1994-2003 would decrease by 56, 303, and 279 mm (equivalent to 11, 46 and 42% decrease) according to the GCM, MRI and CCSR/NIES models, respectively.

Comparison of calculated actual ET between the current climatic condition and the future for the GCM, MRI and CCSR/NIES data shows the decrease of 28%, 8% and 16%, respectively for wheat and 24%, 28% and 26%, respectively for maize, reflecting the different rise in air temperature in the future.

Future air temperature rise results in increase in evaporative demand of the atmosphere. However, decrease in actual ET for both wheat and maize can be attributed to reduction of growing days and LAI due to temperature rise and transpiration reduction due to stomata closure regardless of increase in evaporative demand.

Irrigation water demand was estimated to increase in the future for wheat mainly due to decrease in precipitation. On the contrary, it was estimated to considerably decrease for maize, reflecting decrease of actual ET due to stomatal closure. The water balance components and crop growth under the assumption that there is no transpiration reduction even at elevated CO_2 concentration using the GCM data show that if there would be no transpiration reduction at elevated CO_2 concentration, actual ET would increase by 32 and 79 mm for wheat and maize, respectively. As the result, irrigation for maize would increase by 73 mm (equivalent to 23% increase).

The duration of the regular crop-growing season for wheat is 14, 7 and 11 days shorter in the future. This change is caused by the projected air temperature rise of 2.2, 1.6 and 2.4 ℃ for a growing period by the 2070s for GCM, MRI and CCSR/NIES. Duration of growth period for maize becomes shorter by 9 days for GCM and CCSR/NIES while only 3 days for MRI. Air temperature rise projected with the GCM, MRI and CCSR/NIES models was 3.5, 1.4 and 3.0 ℃ during growing period of maize, respectively. In other words, high temperatures accelerate the phenological development of plants, resulting in quicker maturation.

The predicted biomass and grain yield for wheat and maize in the 2070-2079 denote the complicated results to explain in accordance with the different photosynthesis rate and air temperature rise in the future. In case of wheat, biomass decreases for GCM, but increases for both of RCMs. Grain yield increases for all the models. Since temperature rise for MRI is less than other two models, higher yields are expected to occur. However, biomass of more than 23 ton/ha may be too high. The reason why grain yield for all the models increases can not be explained well. In case of maize, both biomass and grain yield decrease for GCM and CCSR/NIES, but increases for MRI because of less rise in temperature than those for GCM and CCSR/NIES.

In this study, RCM data corrected based on observed values were used. The difference between the current and future annual mean air temperature is 2.4 and 1.4 ℃ for the original and corrected MRI data and 3.6 and 2.3 ℃ for the CCSR/NIES data, respectively. It seems that simulated results using the corrected RCM data would not reflect correctly the effect of air temperature on crop growth and water balance components.

Acknowledgement

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Combined Effects of Elevated Temperature and Carbon Dioxide Concentration on Growth and Water Use of Maize

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1. Introduction

Phenological responses of crop on micrometeorological variation should be quantitatively expressed to predict the effect of climate change on crop production. Evaluating influence of the global climate change on water use of crop is important for the irrigation planning. The objective of the present study was to evaluate the combined effects of elevated air temperature and carbon dioxide (CO_2) concentration on the growth and water use of maize.

2. Materials and methods

The experiment was conducted using three closed growth chambers at Biotron Institute of Kyushu University (E130° 14', N33° 38'), Japan in summer of 2004 and 2005. Air temperature and CO_2 concentration for a treatment were controlled as shown in Table 1. Chamber used for a treatment was different in 2004 and 2005. A set value of relative humidity was 70 % in all chambers. Sixteen Wagner pots with an area of 0.05 m^2 were placed in each chamber for measurements of growth rate and transpiration rate. Mixture of Andosols and Masa (sandy soil) (1:1 volume) was put into each pot with 10 g of chemical fertilizer (N-P-K; 16%-16%-16%) as basal dressing. Three seeds of maize (*Pioneer G-98*) were sown in each pot on June 11 in 2004 and June 13 in 2005, and seedlings were thinned to one plant five days after budding. For preventing soil surface evaporation, soil surface was covered with white plastic beads 10 days after sowing (DAS). Irrigation water was applied through a PVC tube of inner diameter 30 mm.

Crop height and the number of leaves were measured, and a pot was weighed few times a week. On 28, 45, 58 and 96 DAS in 2004, and 28, 42, 55 and 96 DAS in 2005, four plants were sampled from each treatment for measurements of dry matter weight and leaf area. Air temperature and humidity were measured every 10 minutes using a humidity and temperature logger (Sensor HA9630, Logger HA3631, NIHON SHINTECH Co., Ltd.), and solar radiation, R_s, was measured every 3 minutes with a pyranometer (LI-200SB, LI-COR, inc.) in each chamber.

Table 1 Meteorological condition for treatment.

Treatment	Air temperature (℃) day/night	CO_2 (ppm)
TLCL	28/22	350
TLCH	28/22	700
THCH	32/26	700

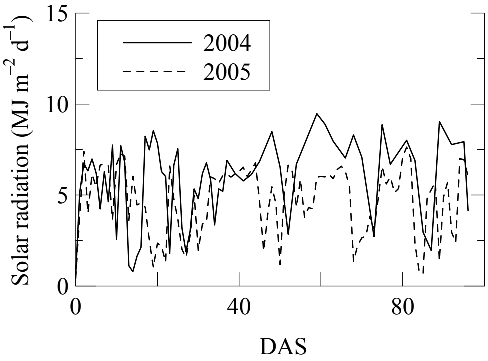

Fig. 1 Time courses of solar radiation.

3. Results and discussion

3.1 Crop growth

Figure 1 shows the time courses of solar radiation from the day of sowing in 2004 and 2005. Daily solar radiation in 2004 was larger than 2005, and total solar radiations during the experiment period (96 days) in 2004 and 2005 were 562 and 459 MJ m^{-2} ,respectively.

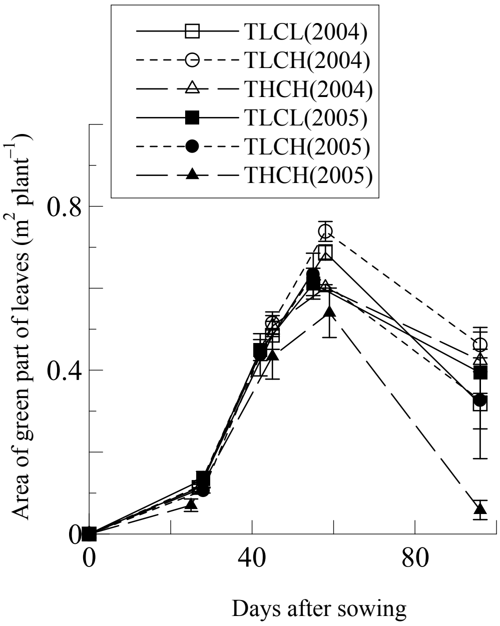

Fig. 2 Time courses of area of green leaves.

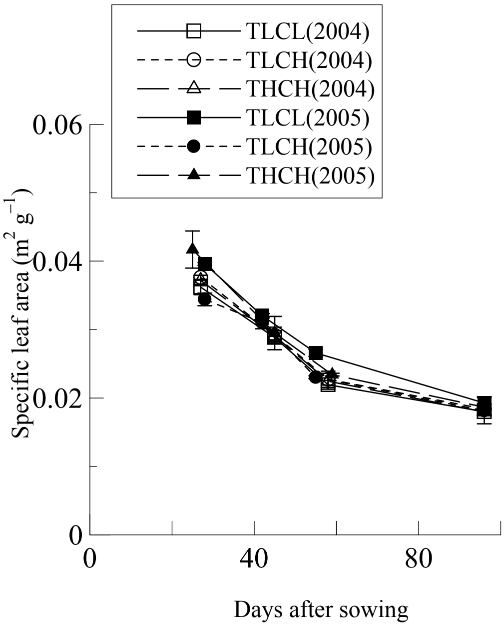

Fig. 3 Changes in specific leaf area.

Emergence of seedling and silking occurred on three and fifty-eight days after sowing for all treatments in both year.

Figure 2 shows the changes of the area of green leaves per a plant. There was no significant difference among treatments and years at the first and second samplings. The change in green leaf area changed depending on days after sowing rather than thermal time or solar radiation during this period although thermal time was different among treatments and solar radiation condition were different among years. At the third and last samplings, there were significant differences due to the effects of the growth environment.

The change of the specific leaf area was well expressed with time from the sowing except for TLCL in 2005 (Fig. 3).

Dry matter weight (DMW) of total leaves, including green, yellow and dead leaves, was highest in TLCH and lowest in THCH at the maturity stage (Fig. 4a). The difference in DMW of total leaves due to treatment was smaller than other organs. The change in dry matter weight of stem was highest in TLCH and lowest in TLCL at the maturity stage (Fig. 4b). DMW of stem was well expressed with a function of solar radiation cumulated from sowing except for TLCH at the third sampling. The change in dry matter weight of ear was lowest in THCH, and that in TLCH was almost equal with that in TLCL (Fig. 4c). DMW of ear was well expressed with a function of the cumulated solar radiation.

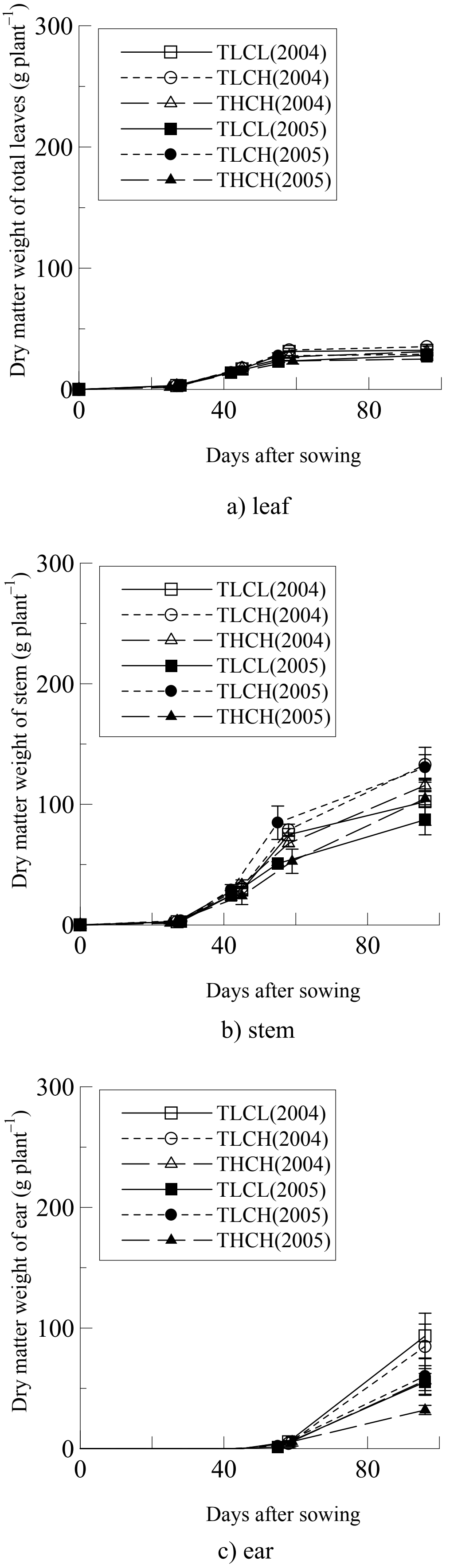

Fig. 4 Changes in biomass of organs.

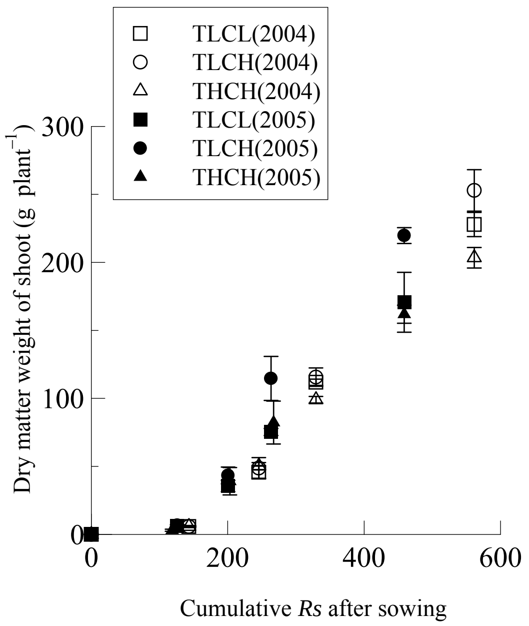

Fig. 5 Relationship between dry matter weight of shoot and cumulative shortwave radiation.

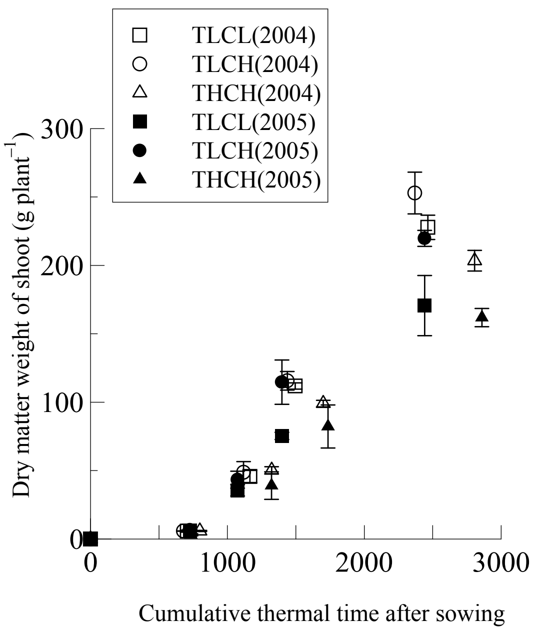

Fig. 6 Relationship between dry matter weight of shoot and cumulative thermal time.

Figure 5 shows the relationships between dry matter weight of shoot (leaves + stem + ear) and cumulative solar radiation from sowing (MJ m^{-2}). The difference in DMW among treatments was clearly illustrated at the last sampling. DMW of shoot at the maturity stage was highest in TLCL and lowest in THCH. DMW in 2004 was larger than that in 2005 for all treatments. This difference

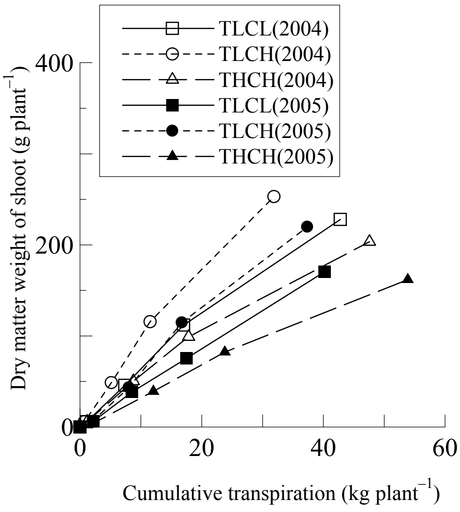

Fig. 7 Relationship between dry matter weight of shoot and transpiration.

was probably occurred because of the difference in total solar radiation during the growth period. The relationship for each treatment was expressed well than the relationship using the thermal time (℃ d) (Fig. 6).

3.2 Water use

Figure 7 shows the relationship between shoot biomass of sampled plant and transpiration cumulated from emergence to the sampling date for four sampling. The ratio of dry matter weight to cumulative transpiration at the last sampling corresponds to the water use efficiency during total growing period (WUE_t). The ratios of WUE_t in TLCH and THCH to TLCL were 1.5 and 0.8 for 2004, and were 1.4 and 0.7 for 2005.

The slopes of the line between two continuous data are equal to water use efficiency during the period (WUE_p). WUE_p was decreasing with the progress of growing stage. There was a tendency that WUE_p was highest in TLCH and lowest THCH during certain period.

The time courses of transpiration were affected by the growth progress. The variation of solar radiation and the difference of the growth environment also affected the change. The transpiration from a unit area of active leaf was obtained by dividing transpiration per a plant with green leaf area of a plant. The transpiration per unit leaf area in TLCH and THCH with high CO_2 concentration were smaller than TLCL with low CO_2 concentration because of decreased stomatal conductance.

Conclusions

The experiments for the combined effects of elevated air temperature and carbon dioxide (CO_2) on the growth and water use of maize in 2004 and 2005 reveal that:

- The rise in CO_2 concentration caused the increase in biomass of shoot especially in that of stem from the comparison treatments TLCL and TLCH.
- The increase in air temperature caused the reduction in biomass of shoot (leaf and ear).
- Water use efficiency increased due to the rise in CO_2 concentration, and decreased due to the increase in air temperature.

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The Integrated Assessment of the Impact of Climate Change on Lower Seyhan Irrigation Project

Irrigation and Drainage Sub-group
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1. Introduction

Many large-scale irrigation projects in the arid and semi-arid regions are now facing structural changes. Water management responsibilities are being transferred from governments to end-users; water distribution management is becoming more complicated by diversifying cropping patterns; and the predicted climate change may further bring constraints on water resource availability and management options. Therefore an assessment of the existing irrigation systems' capacity is important if existing irrigation systems were to adapt to social and climatic changes.

The Lower Seyhan Irrigation Project (LSIP) is one of the largest irrigation projects in Turkey, which extends to the delta plain of Seyhan river basin with a total irrigated area of 133,000 ha (**Fig.1**). Gravity irrigation is conducted with the water supply from the big reservoirs in the upper stream. However, climate change experiments project a decrease of precipitation in this region. The plain has potential drainage and salinity problems, which may deteriorate either with saltwater intrusion caused by sea level rise, or with a change of water use in the district.

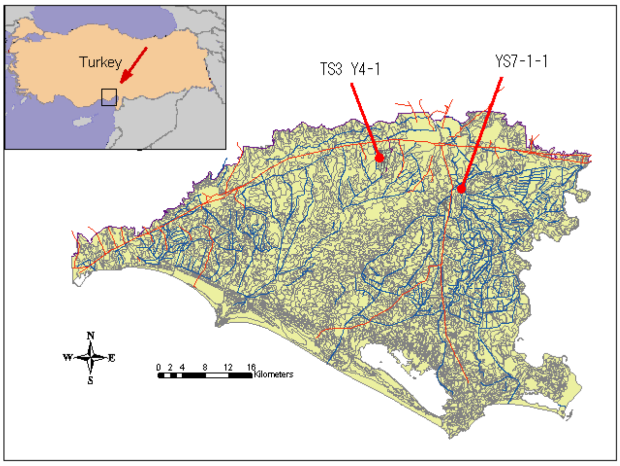


Fig. 1 Project area of the LSIP and situation of monitored canals.

The aim of the project "Impact of Climate Change on Agricultural Production System in Arid Areas," administered by the Research Institute for Humanity and Nature (RIHN) and the Scientific and Technical Research Council of Turkey (TÜBİTAK) is to analyze the systematic response of the agricultural production system towards climate change. The rapid advance in computational capacity and the introduction of GIS in recent years enabled us to integrate a wide variety of data with respect to space and time. We initiated the field work in 2002 with the ambition to collect and integrate as much data as possible and to analyze them with our newly developed model called the "Irrigation Management Performance Assessment Model" for simulating the systematic response of the whole LSIP to possible changes.

Our activity for the past five years can be classified into sub-activities below.

1) Preliminary questioning to Water Users Associations.
2) Collection of archive data related to irrigation.

3) Land use classification using remote sensing images.
4) Monitoring actual water budget of the tertiary canals in the LSIP.
5) Construction of Irrigation Management Performance Assessment Model and its validation for the small monitored area.
6) Field monitoring of salinity of soil and shallow water table in the coastal area.
7) Generation of social scenario of the LSIP in the 2070s
8) Simulation of land-use changes in the 2070s using pseudo-warming outputs and expected value-variance (E-V) model.
9) Simulation of crop growth and water budget of the whole delta using the IMPAM.

Hereafter the approach and main outcomes for each activity are explained.

2. Preliminary questioning

2.1 Visits to Water User Associations

In the summer of 2002, we tried to identify typical problems of the present system by visiting and questioning all water users associations (WUAs) in the LSIP. Although most previous research e.g. Scheumann (1997) and Cetin and Diker (2003) emphasized salinity and high water table as serious problems in the area, none of the WUAs have shown concern to those problems at the time. Instead, they were more concerned about the following four issues;

i) recent deficit of water during peak irrigation season,
ii) rehabilitation of canals,
iii) management and maintenance responsibility of drainage canals and
iv) collection of irrigation fee.

We have learned that the primary cause of low irrigation efficiency was due to degradation of canals. While responsibility of the management of irrigation facilities was transferred from DSI to the WUAs at the time of their establishment in 1993, main drainage canals remained to be DSI's property. This was probably due to the fact that the burden of maintenance of drainage canals was too heavy for newly established WUAs. Generally farmers don't pay attention or are not willing to pay for maintenance of drainage canals. It remains to be potential problem for the future because drainage is an indispensable part of the agricultural system in the LSIP.

2.2 Efficiency of WUA

Collection of irrigation fee determines sustainability of WUAs. Umetsu et al. (2006) addressed the relative efficiency of WUA management by suggesting alternative composite efficiency index. Data envelopment analysis was applied to compare efficiency levels with management-, engineering- and welfare-focused models. The analysis revealed that some WUAs were suffering from unfavorable management practices and there was a scope for major reorganization.

3. Collection of archive data related to irrigation

To make full use of the distributed model, we needed physical parameters with high resolution because the combined resolution of the different parameters would ultimately be determined by the dataset of the lowest resolution. In this sense, we were both fortunate and unfortunate in choosing the LSIP in terms of availability of data.

3.1 Soil

There was already an excellent soil database on GIS with high resolution established by the soil department of Çukurova University before the project was initiated. We were inspired of the high possibility of data integration when we first had a look at this database.

3.2 Meteorological data

As far as Lower Seyhan Plain is concerned, there are data from two automatic meteorological stations in Adana and Karataş available.

3.3 Irrigation intake

DSI keeps daily records of diversion from regulators to TS0 and YS0 and of direct intake from Seyhan Dam to main canals TS1 and YS1. But apart from that, even daily diversions to each main canal were not available in usable form. The method of

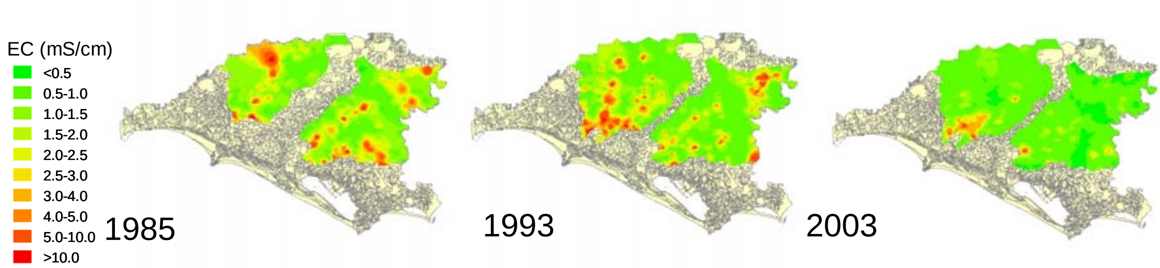


Fig. 2 Decadal change of salinity of shallow water table

building up seasonal irrigation demand was very simple, so if we had access to the cropping pattern with spatial reference, we could regenerate water demand in the past. Unfortunately, the cropping pattern record was only kept for the whole district scale. We strongly recommend DSI to be more cautious on data management, because they carry out very detailed buildup every year but not archiving those good records once they calculated the sums.

3.4 Shallow water table data

Since the 1980's, DSI has been measuring the monthly level and EC (once a year) of shallow water table (down to 4m from surface). The number of observation wells was 626 in the 1980's, and in the 1990's the number was increased to 1,134, covering nearly the entire command area of project phase I-III. The dataset of shallow water table has the highest spatial resolution of all water budget components so that the IMPAM used this data intensively for calibration of the model. When data from the 1980's, the 1990's and the 2000's were analyzed by Donma et al.(2006), it was found that EC of water table has been continuously decreasing in the most of parts as shown in Fig.2. On the other hand annual average depth of water table did not change so much.

3.5. Properties of irrigation and drainage facilities

Water flows in irrigation and drainage networks are much faster process compared to soil water movement and they can have large impacts on shallow water table fluctuations. Whereas soil hydraulic parameters have a dominant effect on water budget in a one dimensional crop water balance model, the influence of irrigation and drainage canal network density would become more dominant as we increase the calculation grid size. This networks density can be derived by the use of GIS and they can also reflect management and maintenance states. We digitized the canal networks and related properties.

4. Land use classification using remote sensing images.

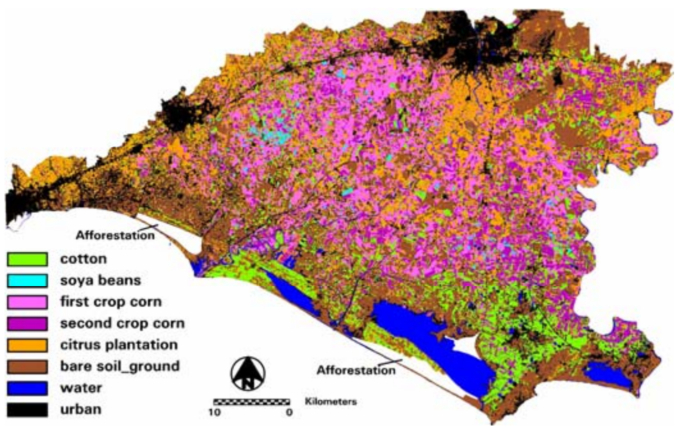


Fig. 3 Cropping pattern derived from Landsat image of August 2003.

As explained in the section 3.3, the cropping pattern for each plot should exist, but only the total cultivated area for each crop was obtainable. Since the cropping pattern would largely influence water use, an image analysis of past remote sensing data was carried out. Berberoğlu compared the Landsat image from year 2003 with the detailed cropping pattern record of a few WUAs, and succeeded in classifying major land use (Fig.3.) By following the same methodology land use in 1985 and 1993 were also classified.

5. Monitoring actual water budget of the tertiary canals in the LSIP

5.1 Irrigation method in the LSIP

Calculation of principle water demand for the LSIP is carried out in the simple manner. All WUAs use "DSI Sulamalarinda Bitki su Tutimleri ve Sulama Suyu Ihtiyaclar (1988)" for calculation of their irrigation water demands. A unit crop water demand multiplied by cultivation area is totaled for the whole command area to calculate water demand at the main canal inlet. They also consider transport loss (presently assumed as 0.8) and field application loss (presently assumed as 0.6). During irrigation season, each WUA strictly monitors water intake from the main conveyance canal to its responsible main canal to guarantee its water demand. After the transfer of operation from DSI to WUAs, there seemed to be a large inconsistency between their proposed irrigation demand before the season and their actual water intake during the season. From our impression there were several possible reasons for this.

i) WUAs were late to collect cropping plan from farmers.
ii) Some WUAs were not skillful in operating software for water demand calculation.
iii) Water loss due to deterioration of canals was not well considered.

After the intake, there is no more monitoring at the secondary or tertiary canal level. Water distribution technicians control water allocation by exchange of information via transceivers. They are capable of managing water distribution by this opportunistic method because there is enough water at a moment, but it will be very difficult if water resources become less available.

5.2 Monitoring of tertiary canals

Since there was no monitoring carried out in the past, water budget structure of the LSIP was unknown. We felt a need to monitor actual water use to provide answers to some important questions before modeling the whole system, such as ;

i) cause of low irrigation efficiency,
ii) irrigation rule of end users,
iii) actual irrigation efficiency of each land use, and
iv) relation between irrigation, drainage and fluctuation of shallow groundwater.

We chose two tertiary canals from the left and right banks of the Seyhan River (see Fig. 1) and started monitoring from the spring of 2004. YS7-1-1 in Gazi WUA on the left bank was a 'kanalet' type. Citrus and maize were mainly cultivated in the command area. TS3 Y4-1 was a concrete lined canal, which belonged to Yesilova WUA on the right bank. The main crops of this area were maize and watermelon.

During the course of measurement, we found out that farmers' actual irrigation practices were somewhat different from the rule established by DSI in the past. Firstly, water allocation within the tertiary canal was conducted on acquaintance base between farmers and they used mobile phones to communicate with each other. Secondly, distribution technicians were not strong controllers. Farmers preferred to take water from early morning and to continue until after dark. Therefore, distribution technicians were usually informed of water allocation after actual operation. Water demand tickets were not used for allocation planning, but rather used as a proof or a receipt, filled by technicians when they checked irrigation on site (Nagano et al. 2005).

If we only estimated water use from water demand tickets without measurements, we would have mistaken that water management was just being neatly carried out as principle. Instead, we found out that annual total of irrigation water intakes and drainage from unit area exceeded 2,500mm and 1,500mm, respectively in the upper part of the LSIP. We also found out that the majority of this large amount of irrigation intake was lost from the canal as leakage or was dropped to drainage as tail water.

6. Development of Irrigation Management Performance Assessment Model and its validation for the monitored area.

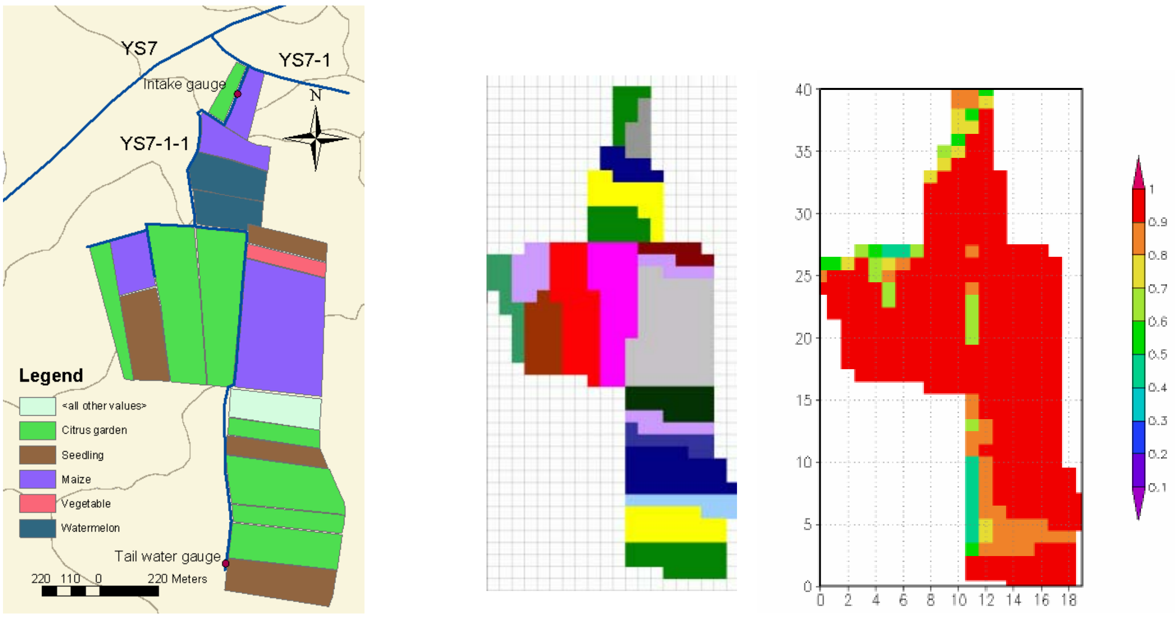
6.1 Irrigation Management Performance Assessment Model

One of the innovative parts of this project is the development of the "Irrigation Management Performance Assessment Model" (Hoshikawa et al., 2005). The IMPAM is a hydrological model specially developed for assessing performance of the irrigation system of a plot to district scale. As seen in the case of the LSIP, a large proportion of the water brought into an irrigation district moves much faster than Darcian flow i.e. flow in canal, leakage from canal recharging shallow water table, and drainage flow etc. Whereas most one-dimensional crop water balance models mainly focus on soil water balance, the IMPAM is one of the first to consider the spatial effect of an artificial water path. Another distinct character of the IMPAM is its ability to assess the effects of mixed land use. The neighboring plots have water budget interaction through water table. The IMPAM is a quasi-three-dimensional distributed model so that it can represent realistic land use.

6.2 Validation of the IMPAM at the tertiary canal level

The IMPAM was validated with observed water budget of YS7-1-1. Except for the saturated hydraulic conductivity which needed to be multiplied by ten, the model was able to represent actual water budget with actually measured soil physical parameters and with irrigation and drainage network densities (Nagano et al. 2006, Hoshikawa et al., 2006).

This trial also revealed that significant percentage of leakage from the irrigation canal was quickly drained through drainage canals that ran parallel to it. From the model, irrigation water that substantially infiltrated was estimated to be 800-1000mm. It means that the majority of water was lost as leakage during transport or as tail water from the end of the canal and from each end of the field. However, a good drainage network running adjacent to irrigation canals carried away excessive water quickly out of the area and avoided water logging. Therefore, low efficiency simply seemed to have resulted from poor control of



Disaggregation into grids Calculation of actual/ potential transpiration

Fig. 4 Land use in command area of YS7-1-1, disaggregation into grids, and the example of grid calculation by the IMPAM.

water in the canal.

7. Field monitoring of salinity of soil and shallow water table in the coastal area

Out of the 175,000ha originally planned for implementation of the LSIP, 133,000 ha is now reclaimed and receiving irrigation. The remaining area, called "phase IV area," is mainly lowland near the coast, and this area until very recently did not have proper irrigation or drainage facilities. The area was seriously affected by salinity in the past because of high water table and bad drainage.

We started to monitor the spatial distribution and temporal change of the shallow water table and soil salinity by field measurements and laboratory analysis in 2005. We set twelve new observation wells and fifty fields of different land use for regular monthly observation.

Kume et al.(2006) found that among the different land use in the Phase IV area, cotton field and bare land had relatively high soil salinity (Fig. 5) and for these two land uses, NDVI and soil salinity had high correlation. When Kume et al. (2007) compared salinity distribution of shallow water table measured in 1977 and the apparent salt affected areas through remote sensing in 1990 and 2005, they found that soil salinity had decreased from 1990 to 2005, but distribution pattern of salinity still was similar to that of water table in 1977.

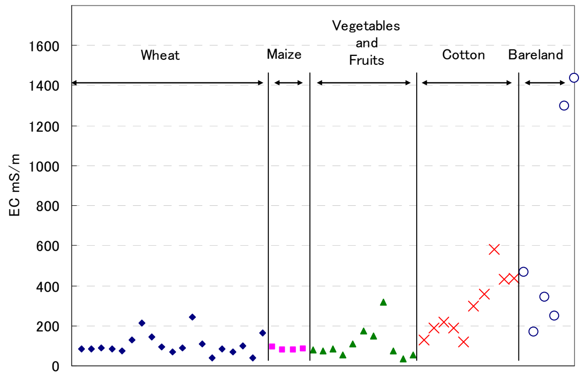


Fig.5 Relationship between land use and soil salinity

These results suggested that even in the coastal area, soil salinity has decreased with application of irrigation. Under this condition, farmers are shifting their cultivation from salt-tolerant cotton to the other varieties. However high water table still is problematic and without development of good drainage networks, the area may face even severer water logging with increase in irrigation. Another potential risk is increase in use of deep groundwater. The deep groundwater in the area has high risk of salt intrusion and this may bring devastating consequence.

8. Generation of social scenario of the LSIP in the 2070s

8.1 General setting of the scenario

The response of the irrigation system towards

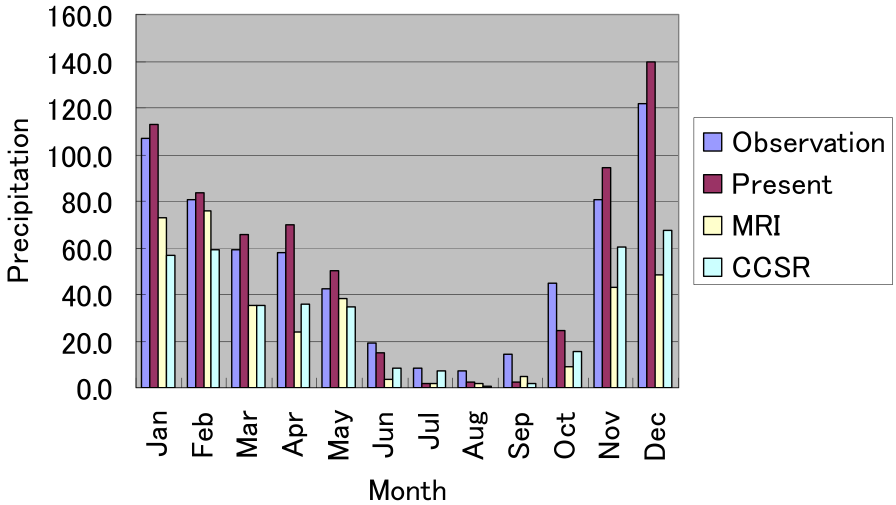


Fig. 6 Comparison of observed and projected precipitation in Adana

Table 1 Irrigation water requirement of major crops in LSIP

crop	(a) 1990s irrigation water requirement (mm/year)	MRI-GCM (b) 2070s irrigation water requirement (mm/year)	MRI-GCM (b)-(a) future increase in water requirement (mm/year)	CCSR-GCM (c) 2070s irrigation water requirement (mm/year)	CCSR-GCM (c)-(a) future increase in water requirement (mm/year)
fruit	762.1	848.6	86.4	778.8	16.6
citrus	661.4	749.0	87.6	724.4	63.0
maize	569.0	611.0	42.0	594.2	25.2
soybean	539.0	559.9	20.9	546.2	7.2
cotton	524.2	583.0	58.8	569.3	45.1
II maize	391.4	385.9	-5.5	380.3	-11.1
vegetables	229.2	302.0	72.8	289.2	60.0
melon	195.9	195.2	-0.7	239.6	43.7

Source: (a) Nuran Özgenç, Faruk Cenap Erdoğan. (1988) DSI irrigated crop water consumption and irrigation water requirement.
(b),(c) Estimated from the average precipitation decrease in 2070s from peud-warming experiment (Kimura et al., 2006). We used the same level of evapotranspiration in 2070s based on the results that the decrease in duration days trade offs the increase in precipitation increse by climate change.

climate change can vary with assumed socio-economical settings. Along with two scenarios for pseudo-climate output (MRI and CCSR), we assumed four sets of social scenarios. The four scenarios shown below correspond to general scenario assumed to integrate activities of all subgroups. For details, please refer to the paper "Generated social scenarios and basin conditions for the final integration" in this report.

Present: Same availability of water and same state of infrastructure as present.

Scenario 1: Passive and low investment scenario. The maintenance level of canal declines from present. Phase IV area would not be irrigated.

Scenario 2: Pro-active and high investment scenario. The maintenance level of canal improves from present. Phase IV area would be irrigated.

Scenario 3: Same setting as the scenario 2. Additionally, groundwater uptake occurs in the low lying area. On the whole LSIP average, 150mm of new groundwater use is assumed to occur.

8.2 Simulation of changes in land use in the 2070s

Using the available water calculated for the Seyhan and Çatalan reservoirs in the upstream with given pseudo climate and general social scenario of the basin , Umetsu et al. (2006) projected land use change in the 2070s using expected value-variance (E-V) model. As shown in Fig. 6, precipitation around Adana is projected to decrease significantly in the winter time according to the pseudo warming experiment. Table 1 shows the crop water demand in the 2070's according to climate change. The water demand would significantly increase for fruits because of water shortage in the early spring. Vegetables would have larger water demand for the same reason. Table 2 shows the assumed water use efficiency and cultivated area in the scenarios. Table 3 shows the result of simulation for the land use. Citrus would remain constant around 20% and in the case of scarce water supply, water melon would emerge. Watermelon is usually cultivated only once in five years to avoid replant failure. In order to take into account the crop rotation of watermelon, weighted average of watermelon (1 year) and maize (4 years) was used for the simulation.

9. Simulation of crop growth and water budget of the whole delta using the IMPAM

9.1 Setting of the Simulation

Dirichlet boundary conditions were used for the

Table 2 Water availability in the LSIP under the climate change and water development scenario

		Base	MRI-GCM			CCSR-GCM			
			Scenario 1 climate change with low water development	Scenario 2 climate change with high water development	Scenario 3 climate change with high water development with 150mm GW	Scenario 1 climate change with low water development	Scenario 2 climate change with high water development	Scenario 3 climate change with high water development with 150mm GW	
		2002	2070s	2070s	2070s	2070s	2070s	2070s	
(a)	conveyance efficiency	0.8	0.6	0.8	0.8	0.6	0.8	0.8	
(b)	application efficiency	0.6	0.6	0.7	0.7	0.6	0.7	0.7	
(c)=(a)x(b)	total efficiency	0.48	0.36	0.56	0.56	0.36	0.56	0.56	
(d)	actural water released for LSIP	1424	1523	1112	1112	1294	854	854	million m3
(e)=(d)x(c)	actural water available for LSII	683.5	548.1	622.7	622.7	465.8	478.5	478.5	million m3
(f)	total service area of LSIP	1,168,830.0	1,168,830	1,168,830	1,168,830	1,168,830	1,168,830	1,168,830	decare (da)
(g)=(e)/(f)	water availability per decare	585	469	533	683	398	409	559	m3/da (mm)
(h)	total service area with IV complete			1,450,980	1,450,980		1,450,980	1,450,980	decare (da)
(i)=(e)/(h)	water availability per decare with IV complete			429	579		330	480	m3/da (mm)

Source: (d) Water level for Scenario 1 and Scenario 2 was estimated by the Seyhan basin hydrology model (Tanaka et al. 2006).
Base water level is from DSI (2002) Briefing of WUA and Year 2002 Management Activity Report, DSI Region VI, Adana;
(f) from DSI (2003b) Transferred Irrigation Association Year 2002 Observation and Evaluation Report,
DSI Region VI, Lower Seyhan Irrigation Project, Operation and Maintenance Department.

Table 3 Simulated cropping pattern with climate and social scenario

Scenario	Base case	MRI-S1	MRI-S2	MRI-S3	CCSR-S1	CCSR-S2	CCSR-S3
Available water (mm)	585	469	429	579	398	330	480
Citrus	22.0	22.1	22.1	21.9	21.9	18.3	21.8
Cotton	59.3	24.0	15.1	48.3	4.3		26.0
Vegetables	7.0	4.4	3.6	6.4	3.0	3.2	4.7
Watermelon & Maize		41.3	51.7	12.9	64.0	78.5	38.8
Fruit	11.6	8.3	7.5	10.4	6.8		8.6
Gross revenue (YTL/da)	717.9	706.9	702.6	715.6	696.4	670.0	707.9
Shadow price of water		0.101	0.117	0.056	0.164	0.137	0.116
Idle water (mm)	23.5						

*The case of risk aversion parameter set as 0.01

northern and southern boundaries. Level of shallow water table at northern boundary that was along the foot of mountains was fixed at 5 m below the ground surface. The southern boundary that was on the coast was set to 0 m in simulations for the present climate and 0.8 m in the simulation for the projected climate. Neumann condition (zero flux) was assumed for eastern and western boundaries.

Soil type was set as homogenous silt for the whole delta As initial level of water table was unknown, five-year spin-up was conducted before calculation for 1994 – 2003 in each case.

Spatial resolution was 1000m x 1000m. Time step for crop growth and water management was 1-day. Other hydrological elements were calculated with 0.5 day time step.

9.2 Level of shallow water table

Level of shallow water table in simulations with projected climate data were all lower than that in the base run (Fig.7). Although higher sea water level (0.8 m) was given to the simulations with projected climate data, only water table within 3 km from the coast at most was affected. Water table was more sensitive to the degree of management. It is very apparent in comparison of four scenarios in Fig. 7. In general, the

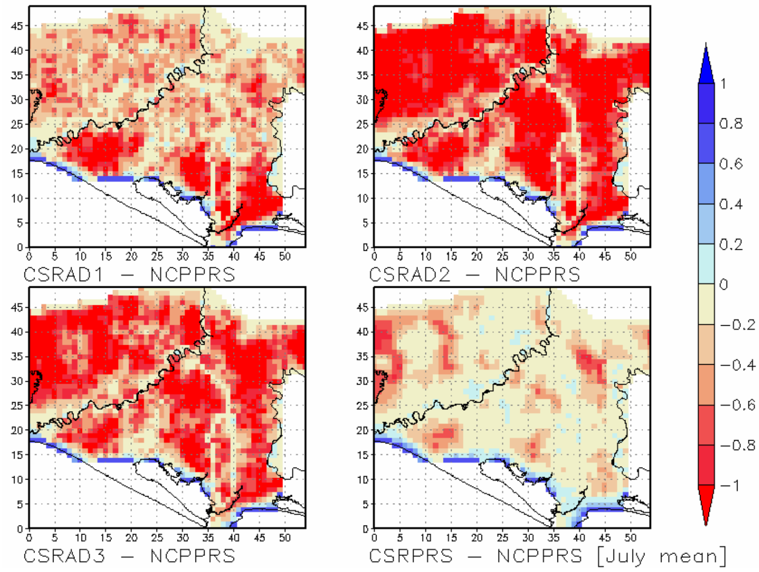


Fig.7 Comparison of water table level between present and different adaptation scenarios (The case of CCSR runs in july average, scenario 1: top left, scenario 2: top right, scenario 3: bottom left, present landuse: bottom right).

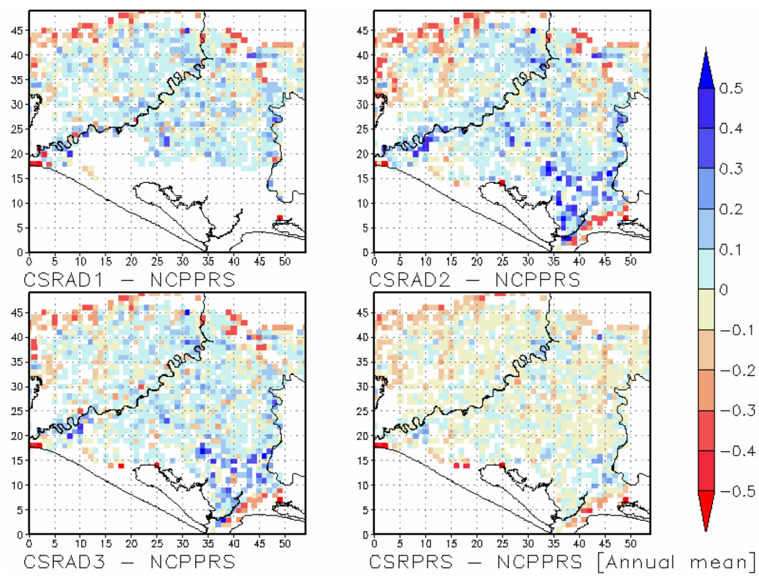


Fig.8 Comparison of the degree of water deficit (actual/potential transpiration) between present and different adaptation scenarios (The case of CCSR runs in annual mean, scenario 1: top left, scenario 2: top right, scenario 3: bottom left, present landuse: bottom right).

risk of higher water table seems less likely to happen due to projected decrease in precipitation and due to decrease in water supply. Water logging only partially occurred along the coast.

9.3 Crop growth

Due to increased evaporation demand of the air, plant transpirations for all scenarios were projected to increase. Therefore more irrigation water was applied to satisfy the need of plants. Significant water stress did not occur because cropping pattern was first determined with available water supply. Even for the case of present management with projected climate, the deficit did not occur. Root zone was kept wet as water table was not so far from the surface. It means that there is enough adaptive capacity for the LSIP towards climate change, if crops are to be chosen adequately with available water resource or application techniques are to be improved.

10. Conclusions

From the analysis of present situation, we have found the followings.

1) Irrigation water is excessively used in the present situation, due to degradation canals and due to low awareness of farmers or water users association for water saving. Water use efficiency is as low as 40%.
2) Salinity prone area has been decreasing in the LSIP for the last two decades mainly because of excessive irrigation and good drainage networks that carried away washed salts. However water table still remains to be high because of the leakage from the canal and the lower area still face the risk of water logging.
3) Water Users Associations in the LSIP is suffering from their difficult economic situation because the size of each WUA is too small.

From our projections with pseudo warming experiments and social scenarios, we have found the followings.

1) In the 2070s, precipitation in Adana is projected to decrease by 42-46% and this decrease would mainly occur in the winter time.
2) Even under this huge decrease of precipitation the reservoirs upstream would have enough capacity for irrigating the LSIP. With additional irrigation development in the upstream, available water decreases and land use must be planned accordingly.
3) There would be need for irrigation in the early spring to save tree crops and vegetables from drier winter.
4) Shallow water table in the LSIP is projected to lower in the 2070s, due to decrease of precipitation. Management of irrigation water and land use would have larger influence on shallow water table than climate change.
5) Land use would change with available water. With the projection of present revenue-water demand relation, cotton seems to become major crop in the less water deficit condition where as in the severe water deficit combination of water melon with maize would become the major crop. Citrus would have stable percentage unless severe water deficit (<350mm) occurs.
6) The coastal area may face higher water table due to sea level rise. This suggests the need of good drainage networks. Use of deep groundwater in the lower plain would increase the risk of salt water intrusion and resulting devastating situation.

As a system, the Lower Seyhan Irrigation Project at present seems to have large adaptive capacity towards climatic and social changes. To sustain its productivity, we strongly recommend farmers and water users association to improve water use efficiency by means of better maintenance of canals, better gate operation and employment of better application techniques. This would improve equity of water allocation, avoid high water table and conserve the soil in the long term. In the whole area and especially in the coastal zone, good management of subsurface drainage is vital for avoiding salinity problem and water logging. The use of deep groundwater should be avoided for its risk in salt contamination.

Acknowledgement

We are very grateful to 6th Regional district of State Hydraulic Works, Water Users Associations, especially the staff of Gazi and Yesilova Water User Association, and farmers in the LSIP for their cordial cooperation.

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Impact of the Irrigation Water Use on the Groundwater Environment and the Soil Salinity

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1. Introduction

Aside from the positive impact of irrigation on increasing crop production, in the downstream part of a river basin, irrigation can cause salinity to build up with the increasing depth of the groundwater. The visible influence of the groundwater environment on soil resulting from irrigation can only be observed at the advanced stages of salinity buildup, when expensive measures must be implemented. Irrigation also can cause upstream and downstream problems, such as water shortages downstream, drainage problems, and the drainage of contaminants. Thus, in order to prevent soil salinization, it is very important to assess the impact of irrigation on the groundwater environment in arid and semiarid regions.

This study was conducted in a large irrigation district that covers over 130,000 ha, in which soil salinization has occurred downstream. First, we studied the impact of irrigation water use on the groundwater environment. Then, we determined the effect of irrigation water use on soil salinization downstream. The specific objectives of this study were to determine the effects of irrigation water use on the fluctuations in groundwater depth and salinity, and then to assess the impact of the groundwater environment affected by irrigation on soil salinization.

2. Outline of the study area

This study is based on conducting field measurements in the delta of the Lower Seyhan Irrigation Project (LSIP) area located in the Seyhan basin, Turkey (Fig.1).

The highest elevation in the LSIP is about 30 m above sea level. The topography is flat and the altitude falls from Adana to the Mediterranean with dominant clayey Vertisols (Dinç et al., 1991).

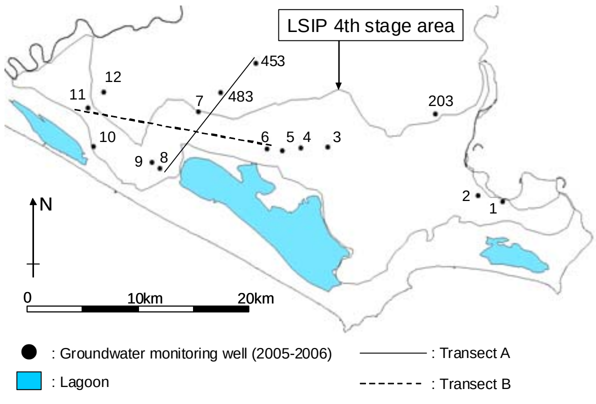

Fig.1. Status of area 4 of the LSIP

Table 1 Data used in this study

Year and area	Sample size	Measurement interval	Groundwater depth	Groundwater EC	Soil Salinity (ECe)
1977 (area 4)	156	August only		○	
1993-1994 (areas1-3)	572	Monthly	○	○	
2003-2004 (areas1-3)	572	Monthly	○	○	
2005-2006 (area 4)	15 (50*)	Monthly	○	○	○ (2005 July)

Symbol * shows a sample size of soil salinity (ECe) of July 2005

The construction of irrigation facilities started in the 1960s, and the district can be divided into four areas based on different stages of development. The installation of irrigation and drainage facilities in the first three areas has been completed, while the installation of the facilities in area 4 has just begun. Unlike the new developments in area 4, irrigation water leakage has increased with deterioration of the older irrigation facilities built in areas 1-3.

3. Materials and methods

First, we assessed the impact of irrigation water use and precipitation on the groundwater environment and then examined the effect of the groundwater environment on soil salinization. The irrigation and precipitation data were obtained from the State Hydraulic Works and General Directorate of Meteorology, respectively (Table 1). The soil salinity data, the electrical conductivity of saturated paste extracts (ECe), was measured in laboratory of Çukurova University.

Groundwater data for 2005-2006 were measured at 15 observation wells, including four wells located in area 3 (i.e., the area developed in stage 3), as shown in Fig.1. The groundwater observation wells for areas 1-3 covered the entire area.

To assess the impact of the groundwater environment affected by irrigation water on soil salinization, LANDSAT TM data for July 2005 was used to identify salt-affected fields. Salt-affected fields were identified and classified by established method (Kume et al., 2007) using the field measurement data and the soil map (Dinç et al., 1991).

4. Results and Discussion

4.1 Fluctuation of groundwater depth

The effect of irrigation water use on groundwater depth was analyzed for all four areas. Two peaks occurred in the fluctuations of the groundwater depths in areas 1-3 during 1993-1994 and 2003-2004 (Figs.2 and 3). The increase began in May and remained high until August with irrigation, and decreased from September to October in the absence of irrigation.

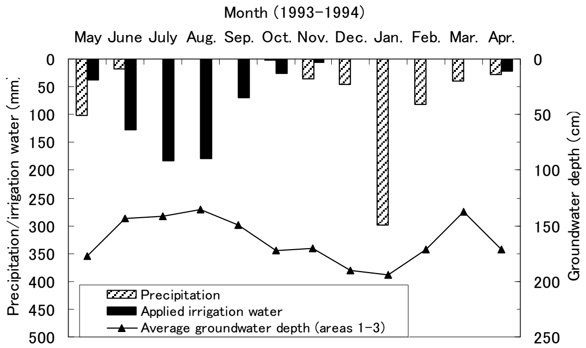

Fig.2. Fluctuation in the groundwater depth for areas 1-3 during 1993-1994

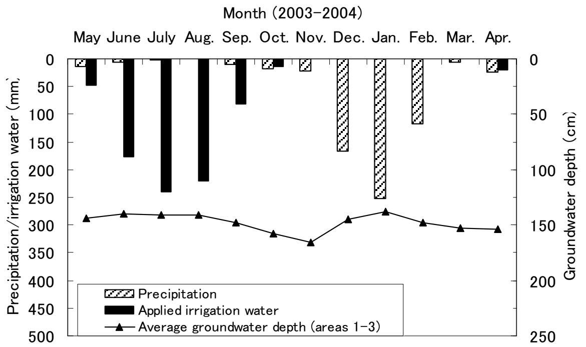

Fig.3. Fluctuation in the groundwater depth for areas 1-3 during 2003-2004

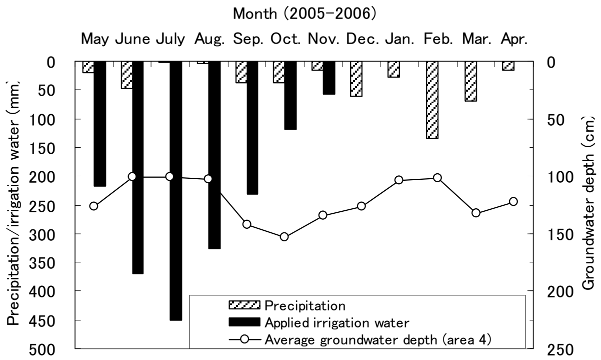

Fig.4. Fluctuation in the groundwater depth for area 4 during 2005-2006

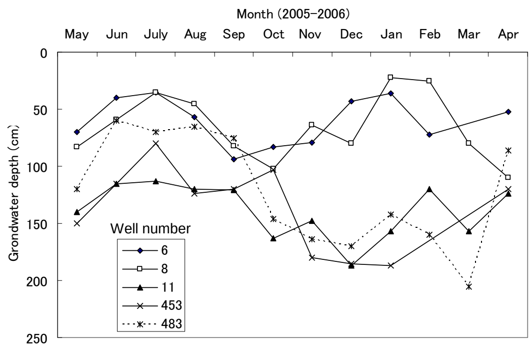

Fig.5. Fluctuation in the groundwater depth along transects A and B

Table 2 Descriptive statistics of groundwater EC

	Sample size	Average EC (dS m^{-1})	Standard deviation (dS m^{-1})	Maximum EC (dS m^{-1})	Minimum EC (dS m^{-1})
1977 (area 4)	156	46.8	40.6	276.0	1.2
1993-1994 (areas 1-3)	574	1.3	2.1	24.0	0.2
2003-2004 (areas 1-3)	574	0.8	0.8	12.0	0.1
2005-2006 (area 4)	15	12.4	19.6	78.6	0.5

An increase in the groundwater depth with precipitation occurred from November to March. Nevertheless, even with approximately 300 mm of precipitation, the groundwater depth decreased in January (1993-1994) for unknown reasons.

From these results, we found two peaks in the groundwater depth, which increased from May to August with irrigation, decreased from September to October, and increased from November to April with precipitation. The pattern of the fluctuation in the groundwater depth did not change with the elevation at different locations (data not shown). The average groundwater depth for 2003-2004 was shallower than for 1993-1994, which was likely attributed to the higher irrigation water use and increased leakage from decrepit irrigation facilities.

The same analysis conducted in area 4 during 2005-2006 revealed a similar fluctuation and pattern of groundwater depth as seen in areas 1-3. The two peaks resulted from the increase in irrigation water and precipitation (Fig.4). The average groundwater depth shown in Fig.4 includes data from wells 12, 203, 453, and 483 in area 3 representing irrigated and nonirrigated fields. In order to assess the effect of location and irrigation status on the fluctuation in the groundwater depth, we evaluated wells along two transects (A and B) shown in Fig.1, and plotted the fluctuation in groundwater depth individually (Fig.5).

Observation wells 6 and 8 were located in nonirrigated fields and wells 11, 453, and 483 were in irrigated fields. These results show clear groundwater fluctuation with the same two peaks seen in areas 1-3. Observation wells 6 and 8 were located in the lowest part of the district, and the groundwater depth remained quite shallow throughout the observation period.

4.2 Changes in groundwater salinity

The groundwater electrical conductivity (EC) in areas 1-3 dropped between 1993-1994 and 2003-2004, and in area 4 it dropped between 1977 and 2005-2006 (Table 2), most probably due to the development of drainage facilities and use of excess irrigation water. The standard deviation of the EC in area 4 during 2005-2006 was high. The large variation can be attributed to the construction of the main drainage canal, which is in the boundary between areas 3 and 4.

The groundwater flow and EC follows the slightly sloping terrain, with decreasing elevation from Adana to the Mediterranean coast along the LSIP area (Donma et al., 2004) (Fig.6). This result was likely due to the ease of access to irrigation water, the ease of drainage, and the convection of salt from upstream to downstream.

The scatterplots of the groundwater EC values for 15 observation wells from 1977 to 2005-2006 produced a linear relationship with R^2=0.61, as shown in Fig.7, in which the EC values for 1977 were estimated using the Kriging method (Delhomme, 1978) due to the lack of observation wells. The groundwater EC decreased in area 4, and was influenced by the distance from the drainage canal and type of land use, matching the high standard deviation of the groundwater EC for 2005-2006 (Table 2).

The Na+ and sodium adsorption ratio (SAR) showed a positive relationship with the groundwater EC (Figs.8 and 9), and were plotted on almost the same regression line in both 1977 and 2005-2006. High EC values, over 4.0 dS m^{-1}, were still observed at some spots in 2005-2006 in area 4 with an average SAR of 17.6 (a SAR of 13.0 equals an exchangeable sodium percentage (ESP) of 15.0) (Tanji, 1990; Ghassemi et al., 1995). The value for sodium-rich soil is over 15.0. Therefore, sodium most probably tends to accumulate on soil particles in the soils of area 4 due to the high SAR levels.

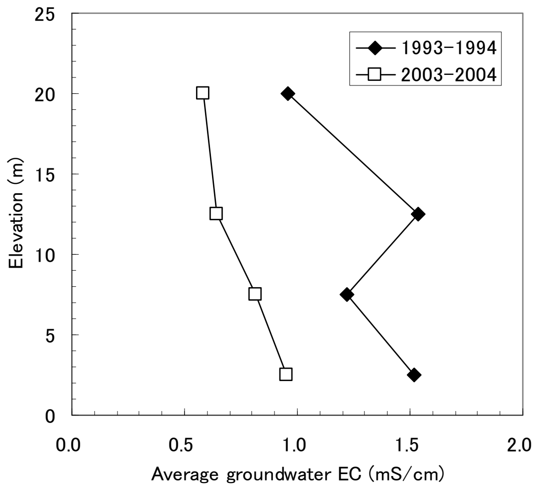

Fig.6. Groundwater EC classified according to the elevation of the monitoring wells

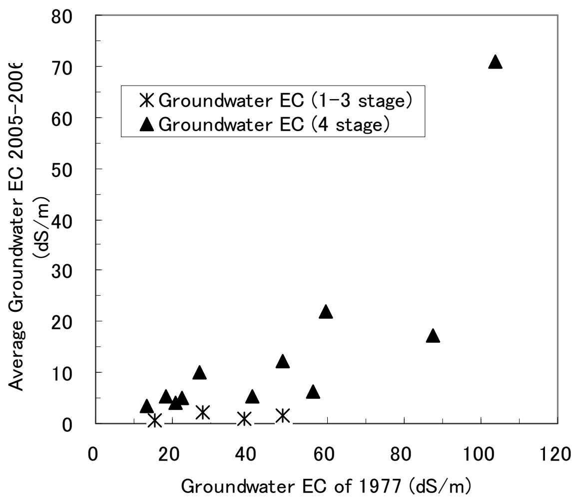

Fig.7. Relationship between groundwater EC in 1977 and 2005-2006

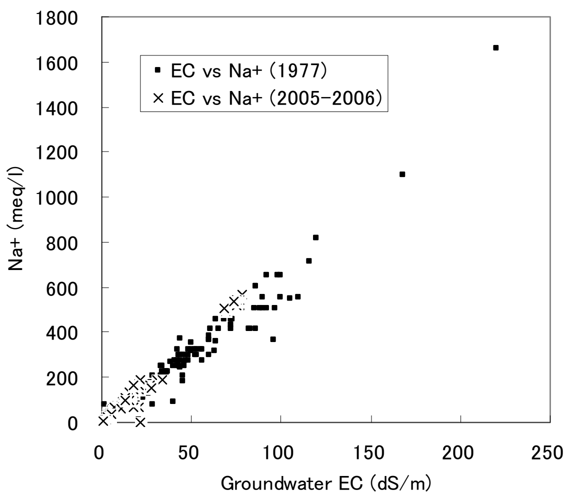

Fig.8. Relationship between groundwater EC and Na^+ for 1977 and 2005-2006

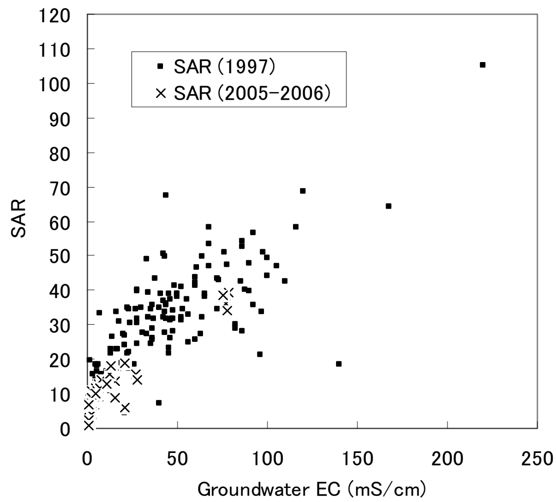

Fig.9. Relationship between groundwater EC and SAR for 1977 and 2005-2006

4.3 Spatial distribution of soil and groundwater salinity in area 4

Soil salinization occurs in area 4 due to the high groundwater depth and its high EC. Distribution map of the groundwater EC in area 4 in1977 was estimated by Kriging technique (Fig.10). The groundwater EC showed a linear relationship, that is, a similar pattern, from 1977 to 2005-2006 (Fig.7). Therefore, the distribution pattern of groundwater EC in 2005–2006 was similar to that in 1977.

Many plant species have been affected by ECe values above the threshold limit of 4.0 mS/m (US salinity laboratory staff, 1954), and ECe values above 7.7 dS m^{-1} is a threshold limit of cotton. Therefore, we classified salt affected fields in three classes, ECe<4.0 dS m^{-1}, 4.0 dS m^{-1}<ECe<7.7 dS m^{-1}, and 7.7 dS m^{-1}<ECe. The percentages of three salinity class in area 4 were 44%, 21%, and 35%, respectively. This result revealed that high soil salinity fields, more than 7.7 dS m^{-1}, still exist in area 4 (Fig.11), most probably due to the development of irrigation and drainage facilities.

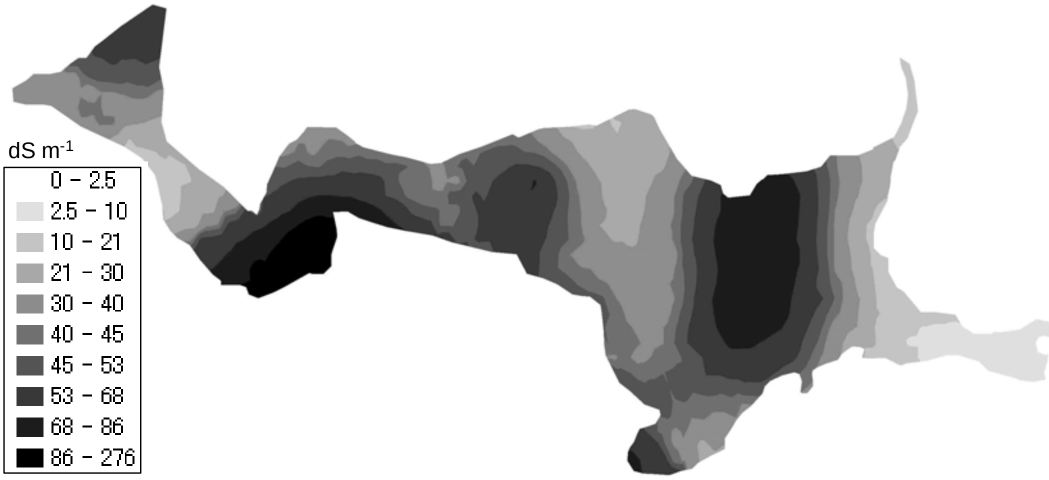

Fig.10. Distribution of the groundwater EC in area 4 in 1977

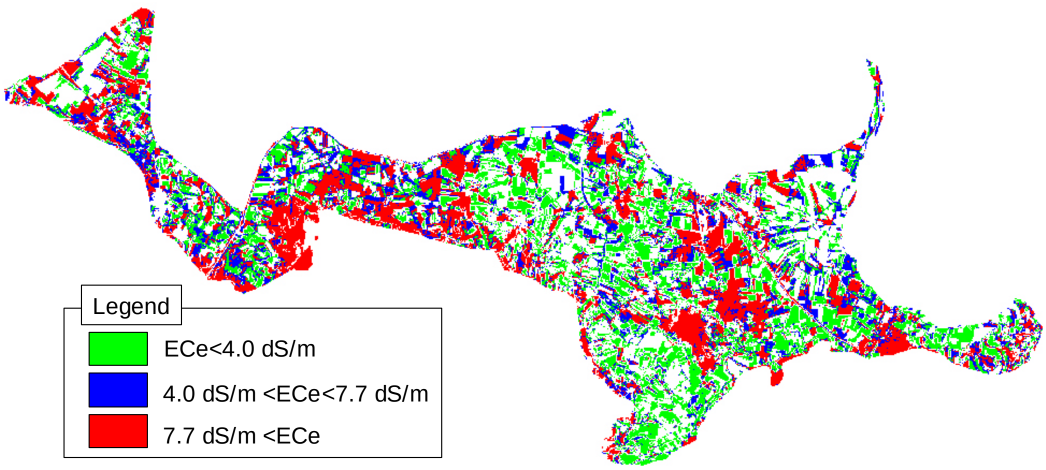

Fig.11. Estimated ECe in July 2005

Finally, we examined relationship between ECe of July 2005 and groundwater EC of 1977. The ECe data used here was measured at 50 point in area 4 in July 2005. The groundwater EC values, which agree with ECe of 50 points, were estimated by interpolated data using Kriging technique as shown in Fig.10. The scatter plots showed linear relationship between them (Fig.12). A comparison of the distributions also showed that salt-affected fields corresponded to high groundwater EC areas (compare Figs. 10 and 11).

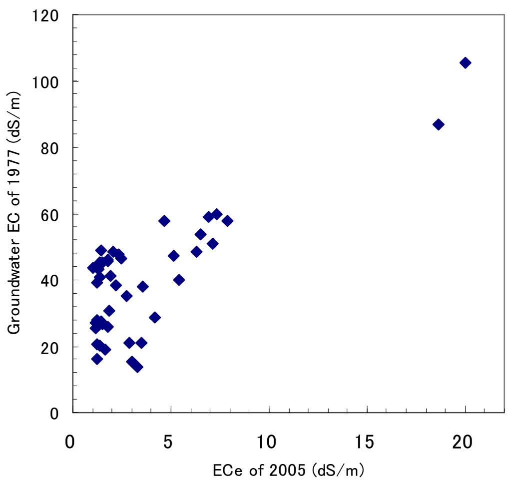

Fig.12. Relationship between ECe of 2005 and groundwater EC of 19777

5. Conclusion

First, we studied the impact of irrigation water use on groundwater fluctuation and second, analyzed the changes in groundwater EC and its quality. Third, we examined the impact of irrigation water use on soil salinization induced by the groundwater environment, which was affected by irrigation.

The fluctuations in the groundwater depths in all four areas had two peaks, one in the irrigation season and one in the rainy winter, irrespective of land use. The groundwater depth in 2003-2004 was higher than in 1993-1994 owing to decrepit irrigation facilities and excess irrigation water use. The groundwater EC decreased with time in areas 1-4. However, the standard deviation of the groundwater EC in area 4 was large because of the status of irrigation and location.

Salt-affected fields of 2005 corresponded to the area of high groundwater EC of 1977 in area 4. Although the salt-affected field of whole LSIP was reduced by excess use of irrigation water and drainage facilities, 35% of stage 4 is still affected by high salinity. Based on the EC, Na+, and SAR of the groundwater environment, we postulated that sodium accumulates on soil particles in the salt-affected fields.

Our study showed that irrigation water use upstream in the LSIP affects the fluctuation of groundwater depth downstream in the LSIP, which is area 4. Excess irrigation water use upstream reduces the groundwater depth downstream. Some fields in area 4 are below sea level and those areas were waterlogged, with insufficient drainage facilities. Therefore, irrigation water use in areas 1-3 in summer causes deterioration in the groundwater environment in area 4, and promotes soil salinization.

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Long-term Changes of Level and Salinity of Shallow Water Table in the Lower Seyhan Plain, Turkey

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1. Introduction

Lower Seyhan Irrigation Project (LSIP) is one of the largest irrigation projects in Turkey which extends on the delta plain of Seyhan river basin with a total planned area of 175,000 ha. With the water supply from the big reservoirs in the upper stream, gravity irrigation is conducted with water efficiency lower than 50%. Before the implementation of the project, wheat and cotton were cultivated with winter rainfall and residual soil water, respectively. When State Hydraulic Works (DSİ) started to implement the irrigation project in this area in the 1960s, the biggest challenge for the engineers was to deal with bad drainage and salinity problems widespread on the delta. Therefore implementation of irrigation was coupled with installation of subsurface drainage and construction of drainage canal networks.

By the 1980's, implementation of the project was complete in two thirds of the total surface area (133,000ha) and DSİ started monitoring of shallow water table level (monthly) and salinity (once a year), very intensively over the entire irrigated area.

Because DSİ only monitored water flow at main canal level and never monitored drainage flow in the past, shallow water table fluctuation and its salinity are the only spatially distributed, high resolution and continuous data which enables examination of the change in the water budget of the system over the long term.

In this study, we used the GIS to synchronize water table data with other features of the LSIP, such as remote sensed land use, canal properties and soil properties to find out their spatial influence on water budget. The data were compared at decadal interval to clarify the differences.

2. Long term changes in the irrigation environment

During the past 25 years, great changes occurred in the cropping pattern and the water management.

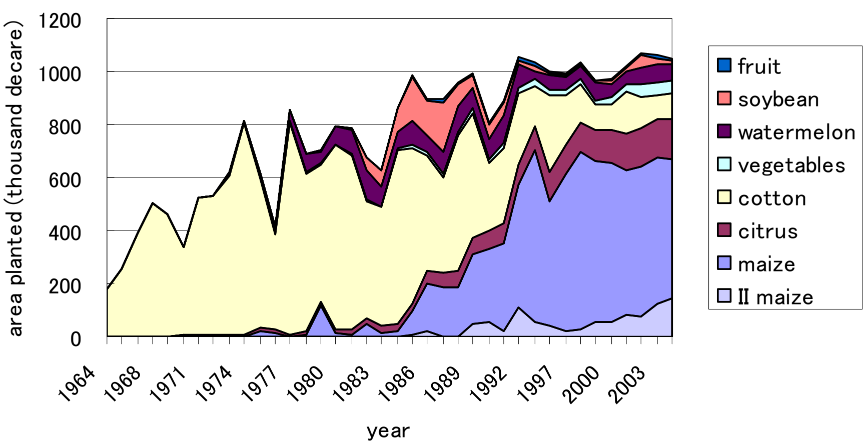

Fig. 1 Area planted for 8 major irrigated crops in Lower Seyhan Irrigation Project (1964-2004); Source: DSI. Year 2002 Yield Census Results for Areas Constructed, Operated and Reclaimed by DSI, various years.

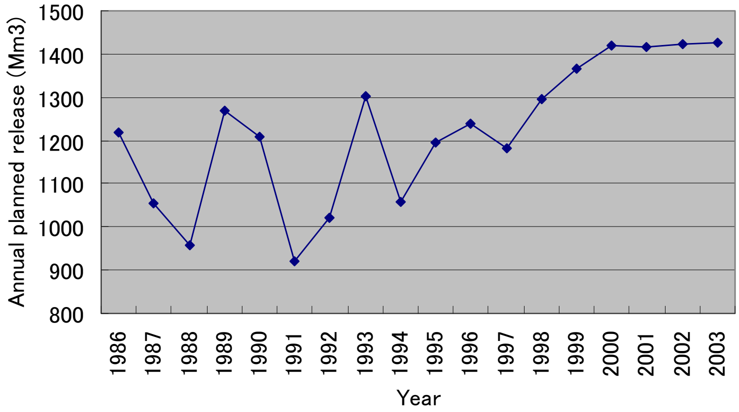

Fig. 2 Change in the planned water release to the LSIP.

Figure 1 illustrates the change in the cropping pattern in the LSIP. Until the 1990s, cotton was the major and dominant crop in the area. From mid 1980s, variety of crops started to increase and maize became the major crop by the mid 1990s. In the 2000s, cropping pattern has become somewhat stable with increased citrus area.

Figure 2 shows the change in the planned water release to the LSIP in the past two decades. The amount has been increasing with time, mainly due to shift in the cropping pattern and substantial increase in irrigated area in so called "phase IV" area near the coast where farm plots were not yet fully consolidated. Another significant change was the turn over of water management responsibility from DSİ to newly established water users associations (WUAs) in the mid 1990s. Due to degradation of canal, precipitation anomaly, conflicts between WUAs etc., the actual amount released nowadays seems far more than the planned value. Although consistent record on actually diverted water was not available, some data show that recent actual release is reaching nearly $2Gm^3$.

3. Material and method

3. 1 Topography and soil of the LSIP

The study area is the LSIP. Figure 3 shows the topography of the area. The delta is very flat, with maximum elevation of 40 meters above sea level in the north, with minimum ranging from zero in the south. The slope of the delta ranges between 0.1 and 1 %. The soil in the delta is alluvial which developed as deposits of the main rivers. Dominant soil in the delta is clayey loam to sandy or loamy clay.

3.2 The archive data used

For the hydrological record, cropping pattern, canal networks and shallow water table, we used archive data kept by DSİ. Precipitation record was obtained from State Meteorological Works (DMI), The depths of shallow water table observation wells were down to 4m from soil surface. Total number of observation wells was 626 in the 1980's, and the number was then increased to 1,134 in the 1990's, covering nearly entire command area of irrigated area.

Two sets of data from each decade (1984, 1985, 1992, 1993, 2002 and 2003) were chosen for analysis. After verifying that decadal change being much more significant than inter-annual variation, 3 sets of data (1985, 1993 and 2003) which could be compared with available satellite image were chosen for analysis. The wells which became immeasurable due to fall of water table beyond limit or by destruction were eliminated from analysis.

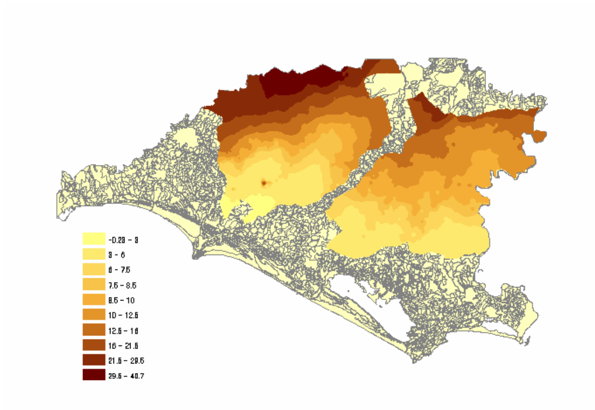

Fig 3 Topography of the irrigated area in the LSIP.

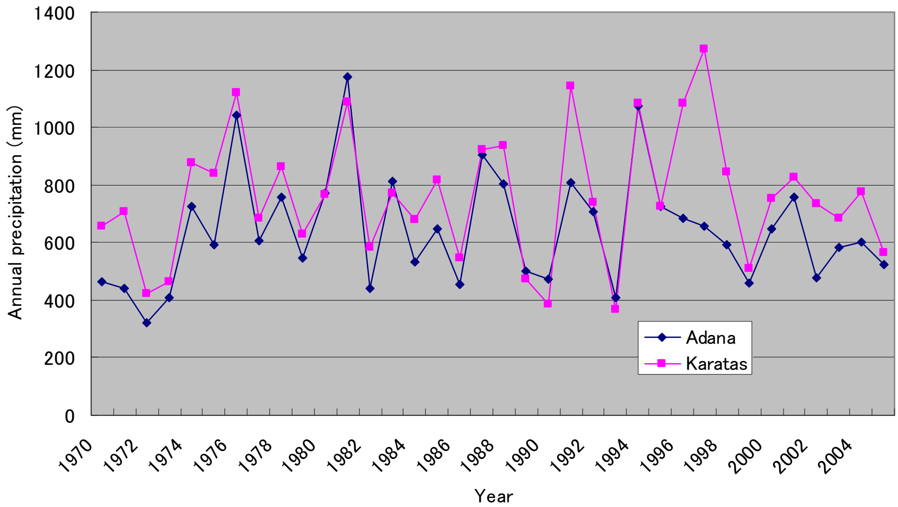

Fig.4 Precipitation in Adana and Karataş in the past 35 years

Figure 4 shows variation of precipitation in Adana and Karataş which are located at the northern and the southern edge of the delta, respectively. In the past 35 years no clear trend (increase or decrease) in precipitation was detected. The average precipitation of the two stations from October to next September was 660mm, 692mm and 569mm for 1984-1985, 1992-1993 and 2002-2003, respectively.

LANDSAT TM images for the summer of 1985, 1993 and 2003 were obtained and land use was classified using actual cropping pattern record as ground truth points. Boundary detection software (Definiens, Definiens co.) was used to detect farm plots. Compared to conventional method of classifying pixels, this improved the accuracy of land use classification. Figure 5 is one of the images obtained as the final products.

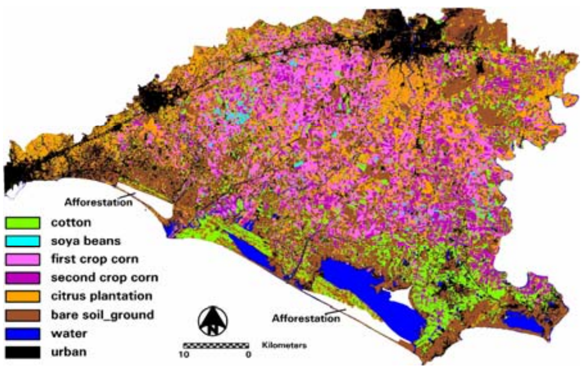

Fig. 5 Cropping pattern derived from Landsat image of August 2003.

3. Results and discussion

3.1 Effect of situation of drainage canal networks

To examine whether observation wells were located on representative locations, Euclidean distance between observation wells and nearest drainage canals were examined. The mean distances were 282m and 250m for the wells in 1980s and 1990s onwards, respectively. The distances seemed to be large enough for assuring the representative ness.

3.2 Shallow water table fluctuations.

Figure 6 compares average water table depth of different decades. There was no significant increase or decrease in water table depth observed in the past 20 years. Spatial distribution of minimum water depths observed in each area is shown in Fig. 7. Most of the area had relatively high water table, ranging between 50 and 100cm or between 100 and 150cm. The minimum depth did not show significant change over 20 years despite the increase in irrigation amount and possible degradation of subsurface drainages which were installed at the time of implementation of the project.

Figure 8 shows the months when minimum were observed in each well. Figure 9 shows the range of annual fluctuation. In 1985, minimum depth was observed either in mid summer (dominantly in cotton fields) or around January in the most of the area and the degree of fluctuation was quite large. In

1993, new peaks appeared in June-July (mainly in maize fields) and in November-December (mainly in harvested maize fields). In 2003, large area on the right bank had peak in winter and left bank had no clear peaks. The range of fluctuation was very narrow in this year. Water table fluctuation seems to have lost clear seasonal trend because of diversification of cropping pattern and substantial increase in irrigation.

3.3 Salinity distribution in shallow water table

Figures 10 shows change in electrical conductivity of shallow water table. In the LSIP, sodium ion dominantly contributes to EC thus measured value represents degree of salinity. Measurement was carried out during peak irrigation season (July). Although there may have been dilution effect by increased irrigation application, it is quite definite that salinity of shallow water table has been consistently decreasing over the years.

Salinity was severe when rain-fed cotton was cultivated before the implementation of the project. In that time, dry summer climate was the major driving force for bringing salt to soil surface. After the implementation, soil water flux in summer was also reversed to downward by irrigation. Recently the total applied water to the field exceeds 1500mm (precipitation and irrigation) and this has probably contributed to decrease of salinity. Irrigation water supplied from Seyhan dam has very low sodium content and the increase in its use would also work for decline in salinity. Without knowing the origin of salt, it is not appropriate to say that soil was leached out of soil profile in the last 20 years. However, at least it has been suppressed below the root zone with contributions from good network of the drainage system.

4. Conclusion

While many parts of the world suffer from increasing salinity problems associated with excessive irrigation, Lower Seyhan Plain seems to be a fortunate exception because

i) introduction of summer irrigation to winter rainfall Mediterranean Climate kept soil water flux always downward,
ii) although subsurface drainage must have deteriorated with time, there is no clear sign of water table becoming critically high, even with increased irrigation,
iii) good drainage networks quickly carry away surplus water and avoid water logging,
iv) irrigation water supplied from upstream has low salt content and there is no hazard for secondary salinization.

From this analysis it was found that land use clearly has influence on spatial distribution of water table. Water table seems to be kept high because of excessive irrigation and thus may decline in future if more efficient irrigation were carried out. For avoiding further salinity risk in the future, farmers in this area should primarily use river water and avoid groundwater uptake, especially near the coastal zone.

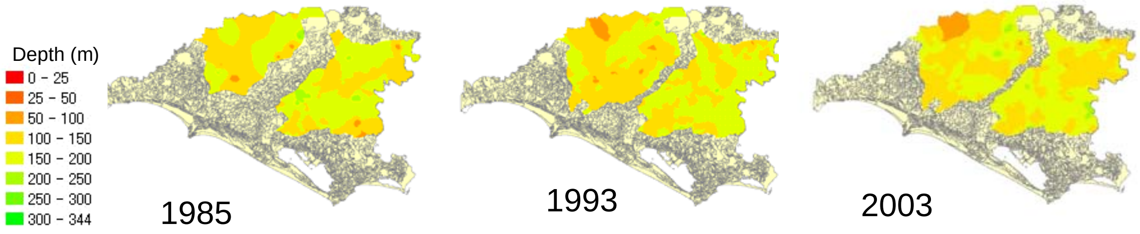

Fig.6 Annual average depth of shallow water table in the LSIP.

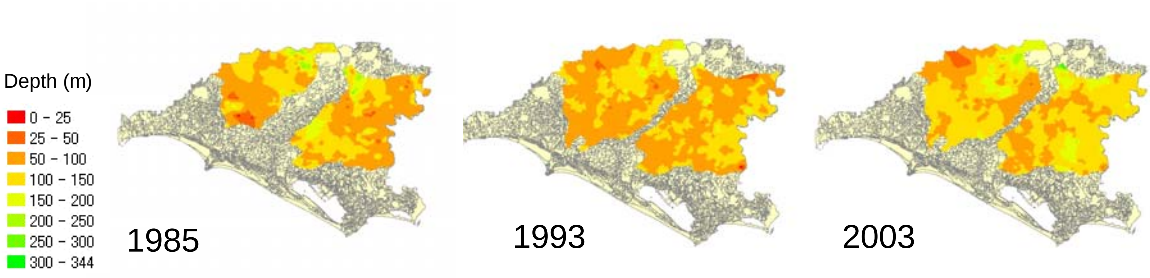

Fig.7 Annual minimum depth of shallow water table in the LSIP.

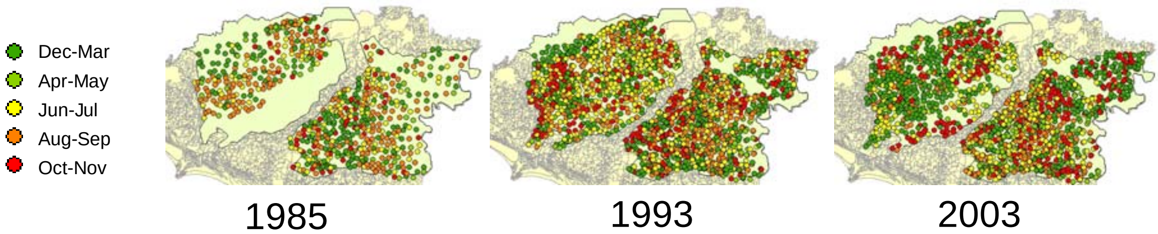

Fig. 8 Month for the occurrence of minimum depth.

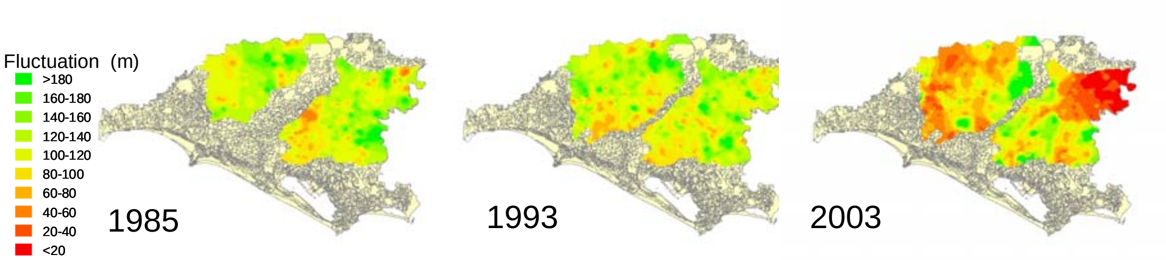

Fig.9 Annual fluctuation range of shallow water table in the LSIP.

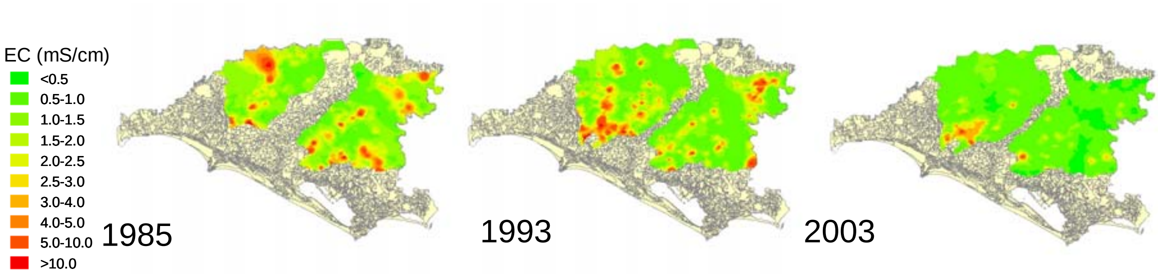

Fig. 10 Electrical conductivity of shallow water table in July in the LSIP.

Evaluation of Impact of Climate Changes on the Lower Seyhan Irrigation Project, Turkey

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1. Introduction

Agriculture strongly depends on water resources and climate conditions, and global warming will have increasing impacts on agriculture. This study hopes to quantitatively assess how global warming will affect irrigated agriculture in the 2070s by factoring projected future climate data into computational simulations of crop growth and hydrological structure in the Lower Seyhan Irrigation Project, Turkey. Simulations in this study are not seeking to predict the actual situation for the irrigated area, but are aimed at providing important information that should be considered regarding vulnerabilities in present irrigation management and determining how irrigated agriculture could adapt to a changing climate.

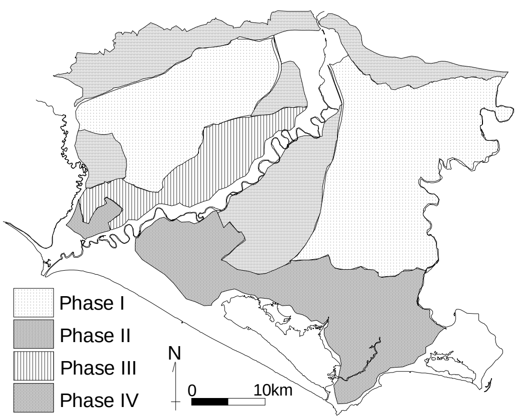
2. Study area

The Lower Seyhan Irrigation Project (LSIP) (Fig.1a) is located on the eastern Mediterranean coast of Turkey. Its construction began in 1960s. The project area of 175,000 ha was divided into four areas and construction for each area was conducted in each project phase. Project phases I – III (133,000 ha) were completed by 1985. The area phase IV that remains incomplete is located in the lowest part of the project area. Although it has no water allocation, irrigated agriculture is also practiced with surplus water from main canals of the completed areas.

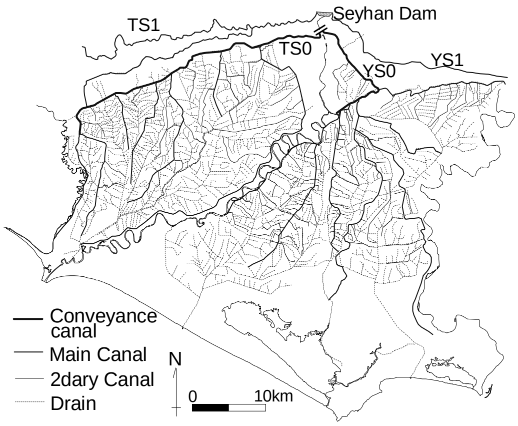
Average annual precipitation from 1994 to 2003 in this area was 744 mm (observed at Adana), with most of the precipitation falling during the winter months. According to the projection results by major General Circulation Models (GCMs), precipitation and river runoff in the Mediterranean Region including the Seyhan River Basin will decrease under warmer climates in the future. In response to the Mediterranean climate, farmers on the upstream side of the basin have been cultivating rain-fed winter wheat; however, in the command area of the LSIP, agricultural production is active mainly during the dry season from spring to autumn and uses a water supply from the Seyhan Reservoir, which stores runoff due to winter precipitation from upstream. As of 2005, winter wheat is cultivated in only 20% of the project area. Although cotton was a dominant summer crop in the LSIP before the 1980s, maize had replaced it by 2000 because of pest and disease problems and economic reasons. Cultivation of citrus has also been increasing gradually since the 1980s. In 2004, the cultivation areas of maize, cotton, citrus, vegetables, and watermelon comprised 45, 9, 13, 4, and 6% of the total area, respectively.

The irrigation canal system of the LSIP consists of two conveyance canals, main canals, secondary canals, and tertiary canals. The two conveyance canals (YS0 and TS0) are diverted at the Seyhan Regulator. All of the main canals branch off these two conveyance canals except for YS1 and TS1, which are diverted directly from the Seyhan Reservoir (Fig.1b). Annual amount of water diversion for the LSIP in 2000 is about $1.6\times10^9 m^3$. It is trending upward since 1990s because of a change of cropping pattern.

Groundwater level exists only 1 – 2 meters bellow the ground surface in most part of the LSIP. Some areas of the LSIP has severe problems of ill-drainage and salt accumulation induced by shallow water table (Cetin et al., 2003) although Turkish government have been carrying out intensive construction of drainage systems in the LSIP since 1960s (Sener, 1986). Several researches on salinity and water logging have been being conducted in the LSIP.



(a) Construction phase



(b) Irrigation and drainage systems

Fig. 1. Lower Seyhan Irrigation Project

3. Methods and materials

Climate data for 2070s derived from projection by climate models and assumed water and crop management in the area was fed to a numerical model that simulates hydrology and crop growth in irrigated agricultural areas. Impacts of climate changes were assessed through evaluation of results of the simulation.

The following two types of impact assessments were carried out in this strudy.

A) Impacts of climate changes on the current water and crop management

This was conducted for assessment of valunerability of the current water and crop management to climate changes as well as for evaluation of sensitivity of the irrigation and agricultural system of the LSIP to climate changes. All data and parameters except for climate data were set to the current situation.

B) Impacts of climate changes and assumed management

Agriculture in the Seyhan River basin may be obliged to change by climate changes. Decrease of precipitation may promote irrigation agriculture in the upper basin where rain-fed agriculture is conducted currently. The LSIP may also change crop and irrigation management to adapt to situations with less water availability. This assessment was conducted to assess impacts of climate changes and such assumed management changes on hydrological environment of the LSIP.

Datasets about water and crop management in the future were created according to the following three assumed basin change scenarios. Soil physics, geology and terrain were fixed.

3.1 Basin change scenarios

In processes to create the basin change scenarios, course of adaptation of the basin and the LSIP against climate changes was considered.

Adaptation scenario 1 (Ad.1)

It is assumed that the LSIP will adapt to climate changes without significant investment for water management. Management water requirement will increase because of deterioration of facilities as well as irrigation water demand at each field-lot will increase because of dryer climate. The LSIP will increase water withdrawal from the river to compensate the increased water requirement.

Incomplete project area (Phase IV) that is irrigated with surplus water from the completed area will be abandoned in this scenario.

Adaptation scenario 2 (Ad.2)

Although available water for the LSIP will decrease because of an irrigation development in the upstream in addition to decrease of run off, increase of irrigated area (completion of Phase IV) will be attained. Increase of management water requirement will be avoided through maintenance of irrigation facilities restricts.

Adaptaion scenario 3 (Ad.3)

While all farms depend on surface water in the scenarios 1 and 2, $0.17\times10^9 m^3$ (about 150mm for the irrigated area) of total water demand in the area is covered by well water in the scenario 3. In this study, it was assumed that well water is applied for 21,900 ha of orchards (citrus and other fruit-tree crops); 780mm in depth annually as much as the surface water irrigation.

3.2 Indices for the assessment

Ratio of actual transpiration (T_a) to potential transpiration (T_p) was used as an index for water stress and relative crop yield. In addition, changes in groundwater level was watched since water logging is one of the most important concern for the LSIP as mentioned above.

3.3 Model for the assessment

A grid-based distributed hydrological model IMPAM (Irrigation Management Performance Assessment Model) (Fig.2) was used in this study. IMPAM was developed by the authors for simulation of hydrology in irrigated agricultural areas. Its spatial scope is from command area of a tertiary canal up to command area of irrigation project. It calculates amount of irrigation water withdrawal to a subject area, precipitation, seepage from irrigation canals, drainage, evaporation from soil surface, transpiration from crops, etc that are major water balance components in irrigated agricultural areas. Soil moisture dynamics in saturated and unsaturated zones are calculated separately by 2-dimensional horizontal model and 1-dimensional vertical model respectively. Crop, irrigation, drainage, water delivery, well water withdrawal modules etc. are assembled on the quasi-three dimensional soil water dynamics model that consists of the 1-dimensional vertical and 2-dimensional horizontal models. All major factors and components in hydrological processes such as crop calendar and its spatial distribution, irrigation and drainage facility arrangement, topography, etc. are included within the spatial scope of the model. Major inputs of IMPAM are indicated in Figure 3. Hydrological processes that have to be described by this model are seepage from irrigation canals, groundwater flow to drainages, interaction between ground surface and groundwater (capillary rising and infiltration), soil surface evaporation, transpiration (soil moisture withdrawal by roots), and groundwater flow. Meteorology, irrigation schedule, landuse-crop spatial distribution, and the irrigation-drainage channels' spatial distribution database are the main input items of this module.

Resolution of horizontal grid can be set freely from ten meters up to about 1 km according to purpose of simulations.

Soil water dynamics

Horizontal water movement in saturated zone (temporal and spatial variation of groundwater levels) is expressed by the advection-dispersion equation (ADE) (Eq.1)

$$\frac{\partial h}{\partial t} = \frac{T}{S}\left(\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2}\right) + q_{ssh} \qquad (1)$$

where, h: head, T: transmissivity, S: coefficient of storage, qssh: sink/source flux for the horizontal model.

The sink/source term is calculated for each horizontal node by Eq.2.

$$q_{ssh} = q_{bot} + q_{drain} - q_{seepage} - q_{apl} + q_{well} \qquad (2)$$

where, q_{bot}: bottom flux of 1-dimensional vertical soil-water dynamics model (upward positive), q_{drain}: drainage, $q_{seepage}$: seepage from canal segments, q_{apl}: application loss at each farm-lot, q_{well}: well withdrawal.

Methodologies of calculations of vertical 1-dimensional water movement including matrix potential flux and root water extraction from soil are based on a theory used in SWAP (Soil Water Atmosphere Plant) model (Van Dan et al., 1997) although some parts are simplified. Soil water movement is calculated with the partial differential equation of Richards (Eq.3) for each horizontal node.

$$\frac{\partial \theta}{\partial t} = \frac{\partial\left[K(h)\left(\partial h / \partial z\right) + 1\right]}{\partial z} - q_{ssv} \qquad (3)$$

where, θ: volumetric coefficient of water content. $K(h)$: soil water conductivity [cm d^{-1}]given as a function of pressure head, q_{ssv}: sink/source term for the 1-dimensional model, that consists of root extraction and preferential flow.

Evaporation and transpiration

Transpiration and evaporation are calculated by two steps. Firstly transpiration without water stress, which is defined as "potential transpiration (T_p)", and potential evaporation are calculated by Penman-Monteith equation with climate data, minimum canopy resistance, leaf area index (LAI), and crop height. Then they are reduced by functions of soil moisture.

Soil surface evaporation is limited by unsaturated soil moisture conductivity.

Transpiration is given as sum of root water extraction S_a at each depth z (Eq.4):

$$T_a = \int_{-D_{root}}^{0} S_a(z) \tag{4}$$

where D_{root} is root depth. The S_a is the product of potential root water extraction S_p and a coefficient α that is a function of Feddes et al. (1978) (Eq.5, Fig.3).

$$S_a(z) = \alpha(z) \times S_p(z) \tag{5}$$

Although potential root water extraction at each depth should be determined by potential transpiration (total root water extraction) and ratio of root length density at each deoth to the total density, variation of the density with depth is oftern ignored (Van Dan, et al., 1997). IMPAM simply calculates the S_p assuming uniform density distribution (Eq.6).

$$S_p(z) = \frac{T_p}{D_{root}} \tag{6}$$

Cop growth

LAI, root depth and crop height that are used in the calculation of evaporation amd transpiration are calculated as a function of accumulated temperature for each farm plot.

Irrigation and seepage from canals

Irrigation schedule for each plot is given by table (day-plot-depth) or is calculated by the irrigation module that functions to keep soil water content not less than a threshold.

Losses in conveyance and delivery often occupy large parts of water balance in irrigated agricultural areas. IMPAM calculates spatial and temporal distribution of conveyance and delivery losses conceptually according to a time schedule of water delivery. Evaporation is ignored, and conveyance losses only consist of seepage loss in the model. The water delivery schedule is given as a table (canal segment-day) or is created by Water Distribution Module of the model.

Drainage

Drainage contains tree types of water: water directly discharged from irrigation canals (tail water), quick drainage of infiltration from the soil surface through cracks, and oozing from saturated zone. The oozing is calculated as a function of groundwater level, density and level of drain bottom.

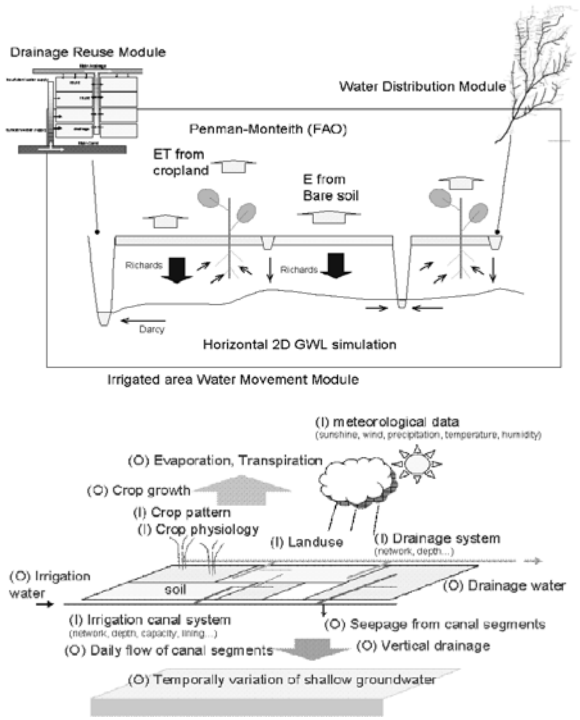


Fig.2. Concept and I/O of IMPAM

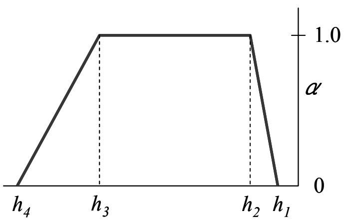


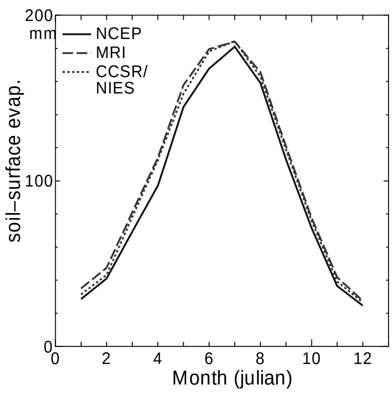
Fig.3. Function of Feddes

3.3 Data and parameters

3.3.1 Climate data

Climate data for 2070s that was used in this study was derived through RCM (Rregional Climate Model) downscaling of NCEP-reanalysis data with "Pseudo warming" method (Kimura and Kitoh, 2007). This method uses differential of climatology between present and future. Results of two GCMs (MRI-CGCM2 and CCSR/NIES-CGCM) were used to obtain the differential, and two datasets were generated. In the followings, the two climate datasets for 2070s will be called with name of the institutes that developed the GCMs: MRI and CCSR/NIES. The climate dataset delived through downscaling of NCEP-reanalysis data (called NCEP) was used for control runs.

Evaporation of MRI and CCSR/NIES is slightly larger than that of NCEP. Precipitation of MRI and CCSR is much less than that of NCEP during winter to spring (Fig.4).



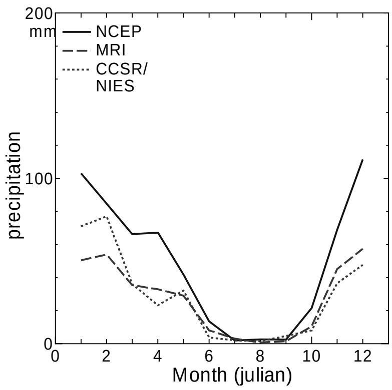


Fig.4. monthly precipitation and potential soil-surface evaporation (10-year average)
Soil-surface evaporation was calculated by Penman- Monteith equation

3.3.2 Water and crop management

Water and crop management depends on climate and the basin change scenarios that determine water requirement in the LSIP and available water resource. As two climate dataset and three basin change scenarios were used in this study, six water management and cropping patterns were assumed. Simulations were carried out with nine conbinations of climate and management dataset; one for control run (NCPPRS), two for impact assessment on the present management (MRIPRS and CSRPRS), six for climate and management changes (MRIAD1, MRIAD2, MRIAD3, CSRAD1, CSRAD2 and CSRAD3) (Table 1).

Crop pattern map for the base case (current situation) was rested of satellite data analysis by Dr. Suha Berberoglu and statistical data at 2002. Ratios of crop pattern under the adaptation scenarios 1, 2 and 3 under both the two projected climate (MRI and CCSR/NIES) based on results of economical analysis on relation between available water resource and farmers behavior by Umetsu et al. (2007) (Table 2). Amount of current water diversion to the LSIP and available water for the LSIP under the basin change scenarios scenarios that were used in Umetsu et al. (loc. cit.) was based on measurement by DSI and runoff-analysis by Fujihara et al (2007) respectively. Analysis of Fujihara et al. (loc. cit.) was besed on the same projeceted climate dataset as this study. Spatial cropping patterns (Fig.5) in assumed scenarios were made with a probability method based on the calculated crop ratios and spatial distribution pattern of crop in 2003 that was obtained through analysis of satelite data by Dr. Suha Berberoglu.

Nagano et al. (2005) reported amount of water supplied to a tertiary canal was tree times of net water requirement in the LSIP. As tertiary canals in the LSIP are lined or constructed with flumes, two-thirds of the water supply should mostly directly flow into drainage channels as tail water or infiltrate as application loss around an inlet of each farm-lot. Rotation irrigation is not practiced and water is supplied every canal throughout irrigation seasons. Ratio of delivery water requirement to the total should be quite large in the LSIP.

Based on Fujihara et al. (2007), Nagano et al.

(2005) and design conveyance efficiencies of the LSIP, parameters for water supply and delivery were set for present and assumed situations (Table 3).

Irrigation amount and schedule determined in the above processes were fed to IMPAM as a fixed schedule table.

The present command area in Table 3 does not contain Phase IV area (20,400ha was irrigated in this study). It was assumed that unit amount of net water requirement and application losses for phase IV are same as other areas. These water requirements for Phase IV area 0.23 x10^9 m^3 is covered by tail water (0.57×10^9 m^3) in Table 1 while tail water in Ad.1 (0.46×10^9 m^3) was wasted to the sea uselessly.

Table 1 Codes for combination of datasets for simulations

	Present	Adaptation 1		Adaptation 2		Adaptation 3	
	PRSN	AD1M	AD1C	AD2M	AD2C	AD3M	AD3C
NCP	NCPPRS						
MRI	MRIPRS	MRIAD1M		MRIAD2M		MRIAD3M	
CSR	CSRPRS		CSRAD1C		CSRAD2C		CSRAD3C

NCP, and CSR stand for NCEP and CCSR/NIES respectively

Crop and water management at the 2003

ADxM/ADxC: Crop and water management for each scenario under climate MRI / CSR.

Table 2. Ratio of crops for each scenario (unit: %)

	Present	Adaptation 1		Adaptation 2		Adaptation 3	
	PRSN	AD1M	AD1C	AD2M	AD2C	AD3M	AD3C
Maize	52	33	51	41	63	10	31
Wheat + Maize II	12	0	0	0	0	0	0
Cotton	9	24	4	15	0	48	26
Melon	7	8	13	10	16	3	8
Orchard	14	30	29	30	29	32	30
Soy	2	0	0	0	0	0	0
Vegetables	5	4	3	4	3	6	5

Table 3 Annual water supply and delivery parameters

	Present*	Ad.1		Ad.2		Ad.3	
	PRS	AD1M	AD1C	AD2M	AD2C	AD3M	AD3C
From the Seyhan R.	1.56×10^9 m^3	1.82×10^9 m^3	1.82×10^9 m^3	1.32×10^9 m^3	1.31×10^9 m^3	0.98×10^9 m^3	0.97×10^9 m^3
Well water						0.28×10^9 m^3	0.28×10^9 m^3
Irrigated area	93,500 ha	93,500 ha		113,900 ha		113,900 ha	
Irrigation (net)	0.50×10^9 m^3	0.59×10^9 m^3	0.59×10^9 m^3	0.70×10^9 m^3	0.69×10^9 m^3	0.66×10^9 m^3	0.61×10^9 m^3
Others							
Application losses	0.34×10^9 m^3	0.39×10^9 m^3	0.39×10^9 m^3	0.27×10^9 m^3	0.29×10^9 m^3	0.22×10^9 m^3	0.23×10^9 m^3
Conveyance losses	0.16×10^9 m^3	0.38×10^9 m^3		0.11×10^9 m^3		0.10×10^9 m^3	
Tail water	0.57×10^9 m^3	0.46×10^9 m^3		0.21×10^9 m^3		0.21×10^9 m^3	

* Net irrigation requirement (0.10×10^9 m^3), application losses (0.07×10^9 m^3) and conveyance losses (0.06×10^9 m^3) for Phase IV area is *not* included for PRS in this table.

3.3.3 Soil and geological parameters

Silt with saturated water conductivity 0.26 m $s^{-1}$was given for the whole area based on field measurements.

Transmissivity of groundwater was set to 4000m^2d^{-1} for the whole study area.

3.3.4 Other settings for calculation

Boundary conditions

Dirichlet boundary conditions were used for the northern and southern boundaries. Groundwater level at northern boundary that is along the foot of mountains was fixed about 5 m below the ground surface. That at southern boundary that is the coastline was 0 m in simulations with the present climate and 0.8 m in those with the projected climate. Neumann condition (zero flux) was assumed for eastern and western boundaries. As initial groundwater level is unknown, five-year spin-up was conducted before calculation for 1994 – 2003 in each case.

Resolutions

Spatial resolution was 1000m×1000m. Time step for crop growth and water management was 1-day. Other hydrological elements were calculated with 0.5 day time step.

4. Results and discussion

4.1 Control run

Temporal variation pattern of groundwater level and spatial distribution pattern of water logging areas (Fig.6) fairly agreed with observed ones.

Ratio of actual transpiration (T_a) to potential transpiration (T_p) was 0.7 – 1.0 in most of the area (Fig.7). Restriction of transpiration occurred mostly because water logging.

Through northern and southern boundaries, about 100mm/year ($1.8\times10^9 m^3$/year) of water was supplied constantly in the control run. It should be mostly recharge at the northern boundary where hydraulic gradient was much steeper.

4.2 Changed climate × present management

Groundwater level in MRIPRS and CSRPRS were lower than that in the control run (NCPPRS) especially in winter because of decreased precipitation (Fig.8). While CSRPRS showed more intensive fall of groundwater level in winter than MRIPRS, there was no significant difference between the two simulation results during and just after irrigation season (Fig.8). This suggests that decrease of precipitation affect groundwater level only in winter when irrigation with vast surplus is applied.

Although 0.8 m higher sea water level was given to the simulations with projected climate data, groundwater rise was seen within 3 km at most along the coastline.

Same amount of irrigation was applied in NCPPRS, MRIPRS and CSRPRS although the latter two cases have more potential evaporation and less precipitation. No significant difference in T_a/T_p ratio however was seen among the three cases.

4.3 Changed climate × assumed scenarios

4.3.1 Groundwater

AD1 simulations resulted lower groundwater level in project phase IV area (the lowest part of the area) and higher groundwater level in phase I – III areas (Fig.10a). Fall of groundwater level should be because of abandon of irrigation. Raise of groundwater level should be result of increase of seepage loss.

AD2 simulations showed fall of groundwater level throughout the area because of less seepage loss (Fig.10b).

Although application loss and conveyance loss of AD3 were less than those of AD2 and water requirement for each crop is common in AD2 and AD3, no significant difference in groundwater level was not seen between AD2 and AD3 (Fig.10a, b). Due to well water usage, AD3 had more total available water than AD2, and it had more high water requirement crops in ratio. Although water requirement for each crop was calculated based on evapo-transpiration, certain percentage of applied water infiltrated deeper zone inevitably in case of surface irrigation.

Inflow amounts at the boundaries were 150mm, 140mm and 170 mm in MRIPRS, MRIAD1 and MRIAD2 respectively while it was 100 mm in NCPPRS. As inflows may decrease in the future because of decrease of recharge in the upstream, actual groundwater levels may be lower than those projected in this study.

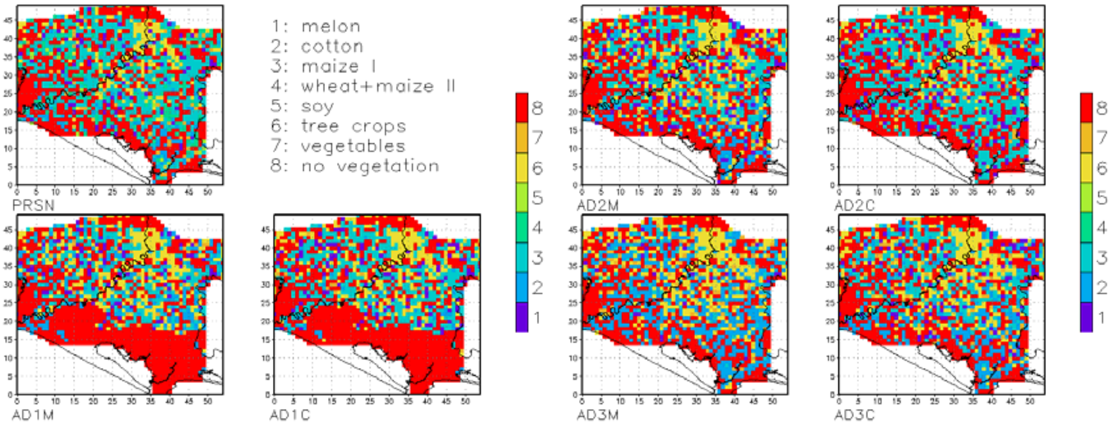
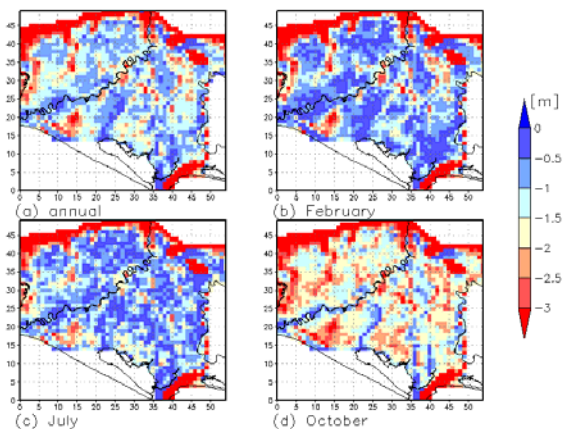


Fig. 5. Spatial distributions of crop patterns

Grid size: 1000m × 1000m



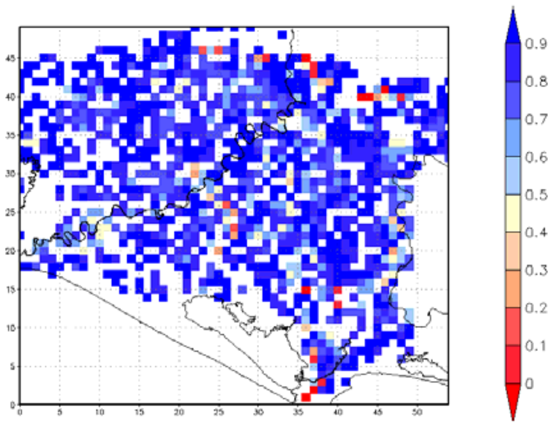
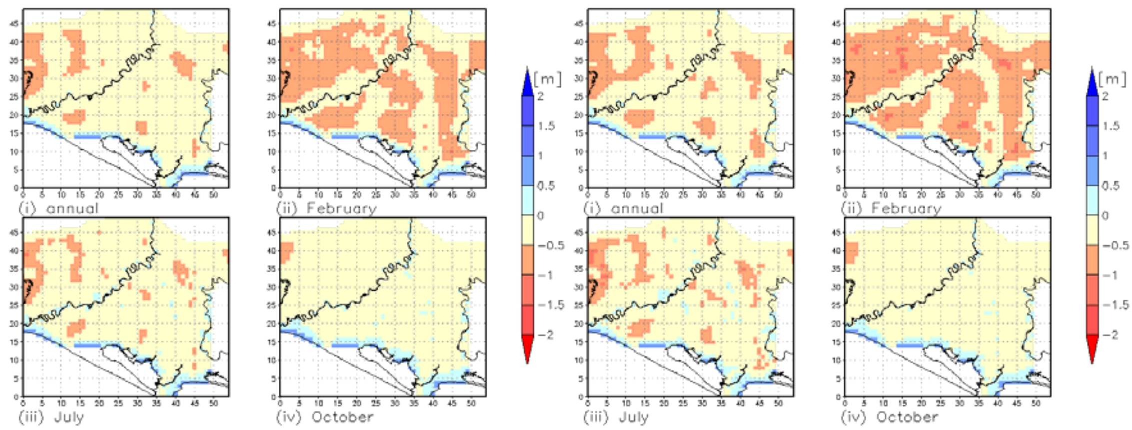


Fig. 6. Groundwater depth in NCPPRS

Fig. 7. Annual Ta/Tp in NCPPRS (10-year mean)



(a) MRIPRS – NCPPRS

(b) CSRPRS – NCPPRS

Fig. 8. Differential of groundwater level (annual mean and monthly mean of February, July and October) with the two climate dataset

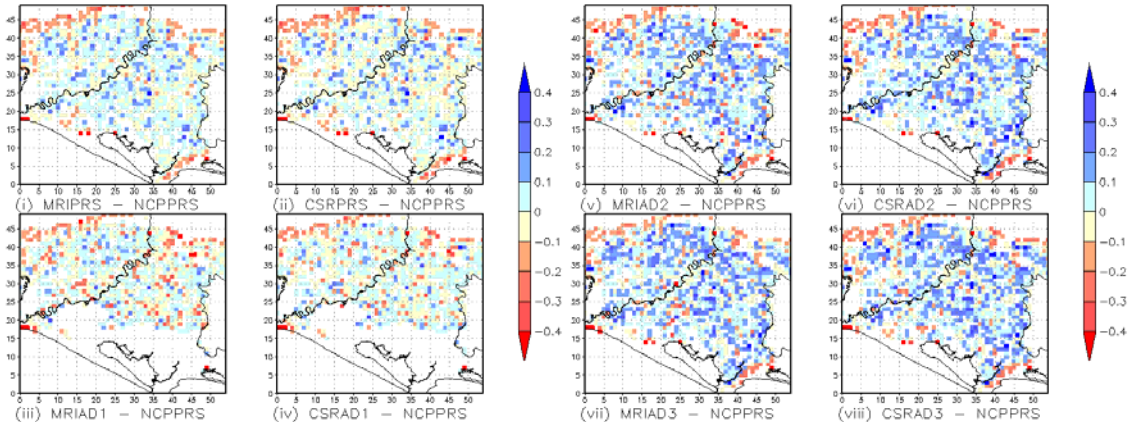
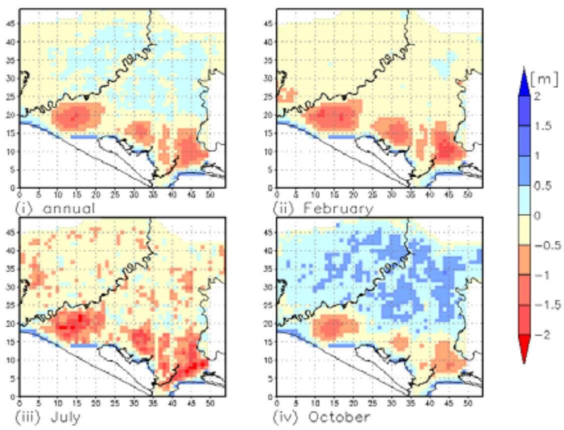
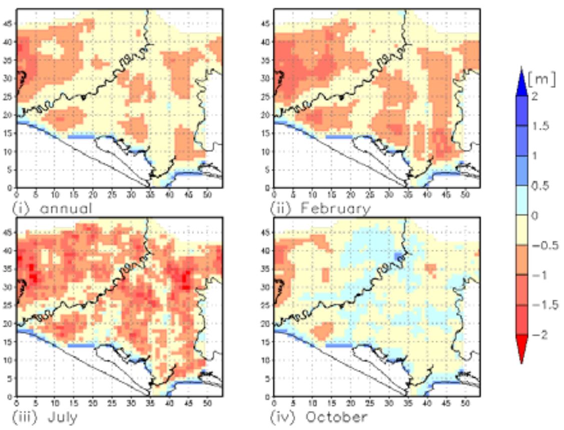


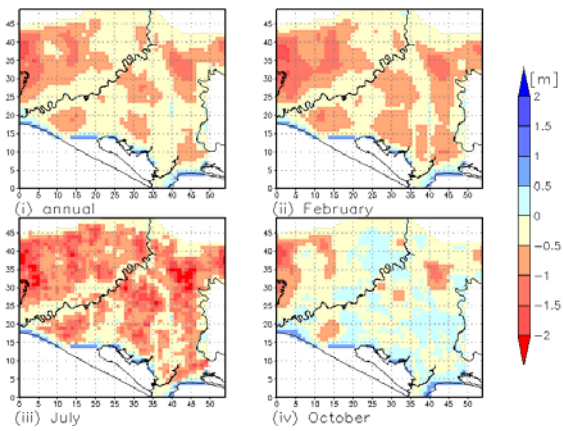
Fig. 9. Differential of annual mean of Ta/Tp ratio



(a) CSRAD1 – NCPPRS



(b) CSRAD2 – NCPPRS



(c) CSRAD3 – NCPPRS

Fig. 10. Differential of groundwater level (annual mean and monthly mean of February, July and October)

4.3.2 T_a/T_p ratio

No significant difference of T_a/T_p ratio (increase of water stress) was seen among the control run, AD1 and AD2 runs (Fig.9 iii - viii). As far as groundwater level is not changed much, soil moisture condition that determines T_a/T_p ratio is not changed drastically. Root zone was kept wet as water table was located near the ground surface in the LSIP. AD3 simulations resulted increase of T_a/T_p ratio because of fall of groundwater level.

5. Conclusions

Direct effect of global warming on hydrology in the LSIP may be not large enough to affect agricultural production in the LSIP. Effect of sea level rise might be limited within the range of a few kilometers from the coast line where there is little crop field. If changes in water and crop management are induced by global warming however, they might be much larger.

This study used two climate dataset derived from two GCMs. Simulations with the two datasets showed substantially same direction of hydrological changes in the LSIP.

Acknowledgement

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Climate Change and Alternative Cropping Patterns in Lower Seyhan Irrigation Project: A Regional Simulation Analysis with MRI-GCM and CSSR-GCM

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1. Introduction

Water scarcity is a major concern for agricultural production in arid areas where the amount of rainfall is limited. According to the IPCC climate change scenario, it is often indicated that the summer temperature increases and winter rainfall decreases in the Mediterranean region (IPCC, 2001). How agricultural sector, or farmers will adapt the changes in future water scarcity in face of global warming? One way is to change cropping patterns and make adjustment for available water resources. Another way might be to change farming practices by adjusting cultivation period, applying appropriate crop rotations and/or developing and adopting new varieties that are resilient to future climate variability. The recent development in climate change forecast using global circulation models and regional climate models (GCM and RCM) made it possible to provide more detailed information on future changes in regional precipitation, temperature and other climatic variables in face of global warming. The Lower Seyhan Irrigation Project in Adana was initiated by the Turkish government as one of the most important irrigation projects located in southern Turkey. There is a strong concern over the impacts of future climate changes on the agricultural production systems. Thus it is of great importance to provide farmers and government authorities with the information on future regional changes in climate and possible scenarios and policy implications for the future.

The purpose of this paper is to assess the regional impacts of climate change on agricultural production systems in Seyhan river basin in Turkey. We estimate the water availability in the 2070s using the regional precipitation data from pseudo warming experiment and assess the possible cropping pattern and the farmer welfare in Lower Seyhan Irrigation Project (LSIP). We use expected value-variance (E-V) model that is used to analyze risk. The model maximizes basinwide total gross revenue of agricultural production according to the risk aversion coefficient. Higher values of risk aversion coefficient indicate more risk aversion. The solution of the model will give proportion of cropping area in LSIP to be allocated to different crops to maximize gross revenue per unit area under different risk aversion levels. By estimating future water availability in the LSIP during the 2070s, the simulation was run with i) base case under current water use level, ii) low water development scenario, and iii) high water development scenario, and iii) high water development scenario with the possibility of groundwater use.

Organization of the paper is as follows. The first section reviews current water use and cropping patterns in Lower Seyhan Irrigation Project. The second section explains the method of analysis, scenarios and data set used in the simulation analysis. The third section presents the results of simulation analysis and the last section concludes the paper with some policy implications for the future climate changes in the region.

2. Water Use and Cropping Pattern in Lower Seyhan Irrigation Project

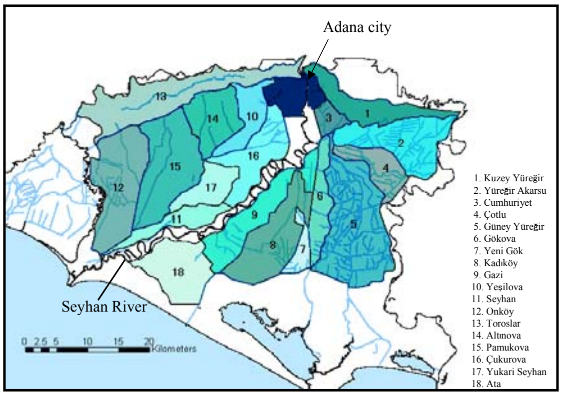

Figure 1. Lower Seyhan Irrigation Project and Water Users Associations

Lower Seyhan Irrigation Project (hereafter LSIP) is located in the south of Adana city stretching to the Mediterranean coast (Figure 1). Mediterranean climate prevails in the region with hot and dry summers and mild and rainy winters. The average annual rainfall is approximately 650mm and most precipitation occurs during the winter from November to March (Donma, 2004). The average temperature is 18 °C with max 45.6 °C and min –8.1 °C. The dominant irrigation technology is gravity irrigation.

For agricultural development in Turkey, three types of government intervention played an important role. Those are an access to credit facilities, price support policies, and the provision of irrigation infrastructure (Hale, 1981). The Lower Seyhan Irrigation Project in Adana was initiated by the Turkish government as one of the most important irrigation projects located in southern Turkey (Figure 1). The Government constructed The Seyhan Dam in 1956 for the purposes of irrigation, power generation and flood protection. The reservoir can store 1.2 billion cubic meters that supply irrigation water to LSIP. Construction of irrigation and drainage networks of Seyhan Plain has four stages. So far, area only up to stages I through III have completed and the area for stage IV at the down stream have left without concrete canal infrastructure. The completion of the stage IV is facing a problem of high water table, salinity and insufficient drainage. Until 1993 small-scale irrigation systems were transferred to water users at a pace of about 2,000 hectares per year. DSI (General Directorate of State Hydraulic Works) encouraged farmers to organize Irrigation Groups (IGs) or Water User Groups (WUGs) with limited responsibility for operation and maintenance. After 1994, large-scale irrigation systems including Lower Seyhan Irrigation Project (LSIP) started to be transferred to water users associations (Tekinel, 2001; Donma, 2004; Umetsu et al. 2005). Since then, water users associations have been playing an important role for water allocation at the secondary and tertiary canals and at the end-use in addition to DSI.

Figure 2 shows the area planted for eight major irrigated crops in LSIP during the period between 1964 and 2004. During the 1960s, after the construction of the Seyhan Dam in 1956, cotton production expanded very rapidly. However, since the early 1980s, other crops such as maize, soybean, melon (mostly watermelon) and citrus increased gradually. And during the early 1990s, the area planted by maize surpassed that of cotton. The completion of Ataturk Dam in the Southeastern Anatolia project in 1990 shifted the center of cotton production to the Harran plain. Since the early 2000s, the share of land allocated to high value crops such as citrus and vegetable production has been gradually increasing.

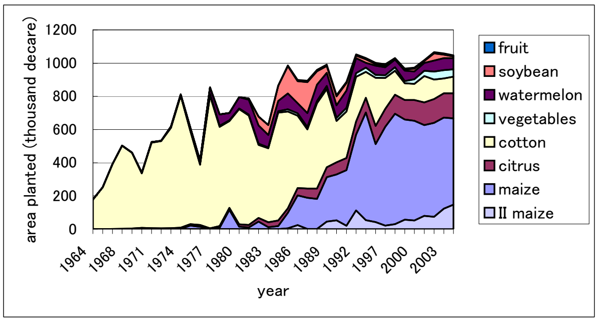

Figure 2. Area planted for 8 major irrigated crops in Lower Seyhan Irrigation Project (1964–2004); Source: DSI. Year 2002 Yield Census Results for Areas Constructed, Operated and Reclaimed by DSI. Verious years.

Table 1 shows the major agricultural crops in LSIP in 2002 cropping season. Irrigation season in Adana usually starts in April and ends in October or early November. When winter rainfall is not sufficient, spring wheat (November to May) is irrigated partially. The largest area was planted by maize (56.57%), followed by citrus (13.51%), cotton (7.36%), vegetables (6.30%), watermelon

Table 1. Major irrigated agricultural crops in LSIP in 2002

rank	area of production	%	production value	%	gross revenue	YTL/da
1	maize	56.57	citrus	38.90	strawberry	2,417
2	citrus	13.51	maize	33.43	citrus	1,180
3	cotton	7.36	watermelon	9.86	fruit tree	1,086
4	vegetables	6.30	vegetables	6.24	vineyard	875
5	watermelon	5.63	cotton	4.98	watermelon	718
6	soybean	4.38	soybean	1.40	greenhouse and II crop vegetable	640
	total	93.75	total	94.81	average	426
					average (2005 price)	707

Source: DSI (2003b) Transferred Irrigation Association Year 2002 Observation and Evaluation Report, DSI Region VI, Lower Seyhan Irrigation Project, Operation and Maintenance Department. II vegetables=second crop vegetabels.

(5.63%) and soybean (4.38%). In terms of production value, the highest value comes from citrus (38.90%), maize (33.43%), watermelon (9.86%), vegetables (6.24%), cotton (4.98%) and soybean (1.40%). Thus these major six crops covered 93.75% of total irrigated area and yielded 94.81% of total gross revenue of LSIP in 2002. Crops that yielded the highest gross revenue per decare[1] in 2002 are strawberry (2,417 YTL[2] / da) and citrus (1,180 YTL / da) followed by fruit tree (1,086 YTL / da) and vineyard (875 YTL / da).

Table 2 summarizes the result of Delphi forecast given by the staff members of 18 water users associations in LSIP in 2005. This method is typically used by the engineering sector to predict when the particular technology would be available in the future. Here Delphi forecast was used to obtain WUA staff members' view on the future cropping patterns in the year 2033. The column (a) shows the actual cropping pattern in LSIP reported in 2003. Maize acreage is 54.3% followed by citrus, cotton, watermelon and vegetables. The column (b) indicates the forecast of the cropping pattern of entire LSIP (Seyhan) in the year 2033. In

Table 2. Delphi forecast of cropping pattern in LSIP by WUA

	(a) Seyhan 2003 (observed)	(b) Seyhan 2033	(c) Seyhan by each WUA 2033	(d) Seyhan by WUA control	(e) Seyhan by WUA 10% water reduction	(f) Seyhan by WUA 20% water reduction
maize	53.3	40.6	42.6	31.9	26.3	21.3
citrus	14.2	21.3	23.9	26.4	25.9	27.2
cotton	8.7	10.9	9.0	9.0	12.9	14.4
watermelon	7.0	8.2	6.5	4.8	4.5	4.9
vegetables	4.8	6.2	7.8	8.8	8.0	5.3
onion	1.4	2.0	1.4	1.3	1.4	1.5
soybean	2.0	4.9	4.2	7.4	8.6	9.2
fruit	0.7	1.7	2.0	4.6	4.7	5.1
others	7.7	4.1	2.7	5.8	7.7	9.0
100%						
II maize	12.0	13.9	11.8	10.0	6.6	5.2
II vegetables	2.3	4.2	2.0	3.7	3.1	2.8

Source: Data in 2003 are from DSI (2004) Year 2003 Yield Census Results for Areas Constructed, Operated and Reclaimed by DSI. DSI Operation & Maintenance Department, Ankara.
Other information are from authors' interview survey (2005).
II maize = second crop maize; II vegetabels = second crop vegetables

1 decare (da) = 0.1 hectare

2 New Turkish Lira

this case, maize cultivation is reduced to 40.6% and citrus, cotton and watermelon increased. The column (c) shows the forecasts by WUA staff members for their WUA's own command area and then aggregated using land share parameters. Again maize area reduced and citrus area increased. Usually the decision of the cropping pattern is made by the individual farmers and then they are aggregated and reported to DSI by water users associations for planning water allocation for the next irrigation season. The column (d) shows the cropping pattern by assuming WUA has a full control of their command area. In this case, maize and watermelon decreased and citrus, vegetables and soybean expanded compared to 2003 cropping pattern. Additional questions were made in case of 10% and 20% irrigation water reduction case in column (e) and (f) respectively. In this case, maize cultivation is reduced to less than a half and citrus, cotton, soybean and fruit expanded. By the reduction of the water resources, farmers are more likely to choose high value crops such as citrus, vegetables and fruit.

3. Method and Data

3.1 *Method*

In order to estimate the optimal land resource allocated to various crops under different risky alternatives and constraint of water resources, expected value-variance (E-V) model was used. This model is used to analyze decision making in risky situations and it maximizes expected total return (or gross revenue) under different levels of variance of total return. In this model, expected return can be increased only at the expense of a larger variance of return. The optimal decision comes from the preferences on tradeoffs between expected return and variance of return. In other words, a risk-averse farmer will chose high expected return while choosing the low variance of return (Harwood et al., 1999). Using this E-V model, it is possible to analyze optimal decision making under risky situations. The specification of expected value-variance (E-V) model is as follows:

$$\text{Max } Z = \sum_j \bar{c}_j X_j - \Phi \sum_j \sum_k s_{jk} X_j X_k$$

$$\text{s.t} \quad \sum_j p_j X_j \le b \qquad (2)$$

$$\sum_j X_j = 1 \qquad (3)$$

$$\text{and} \quad X_j >= 0 \quad \text{for all } j,$$

where X_j is the proportion of land allotted to j^{th} crop, $\bar{c}_j$ is the mean gross revenue per decare for crop j, s_{jk} is the covariance of gross revenue between crop j and crop k, p_j is the water requirement per decare of j^{th} crop, and b is the maximum amount of water available per decare for irrigation and Φ is the risk aversion coefficient. Higher values of risk aversion coefficient indicate more risk aversion by decision makers. When Φ is equal to 0, the decision maker is risk neutral. The solution of the model will give proportion of the area to be allocated to different crops to maximize gross revenue per decare under different risk aversion levels. The equation (2) indicates that the amount of water used in the farm per decare is equal to or less than the total available water per decare for the entire LSIP.

3.2 *Scenarios*

For assessing the regional impacts of climate change on agricultural production systems in the 2070s, we used seven cases for simulation as shown in Table 3. Those include a base case, scenario 1, scenario 2 and scenario 3 using two types of climate change information given by MRI-GCM and CCSR-GCM, which we will describe later.

Table 3. Water availability in LSIP under the climate change and water development scenario

		Base	MRI-GCM			CCSR-GCM			
			Scenario 1 climate change with low water development	Scenario 2 climate change with high water development	Scenario 3 climate change with high water development with 150mm GW	Scenario 1 climate change with low water development	Scenario 2 climate change with high water development	Scenario 3 climate change with high water development with 150mm GW	
		2002	2070s	2070s	2070s	2070s	2070s	2070s	
(a)	conveyance efficiency	0.8	0.6	0.8	0.8	0.6	0.8	0.8	
(b)	application efficiency	0.6	0.6	0.7	0.7	0.6	0.7	0.7	
(c)=(a)x(b)	total efficiency	0.48	0.36	0.56	0.56	0.36	0.56	0.56	
(d)	actural water released for LSIP	1424	1523	1112	1112	1294	854	854	million m3
(e)=(d)x(c)	actural water available for LSIP	683.5	548.1	622.7	622.7	465.8	478.5	478.5	million m3
(f)	total service area of LSIP	1,168,830.0	1,168,830	1,168,830	1,168,830	1,168,830	1,168,830	1,168,830	decare (da)
(g)=(e)/(f)	water availability per decare	585	469	533	683	398	409	559	m3/da (mm)
(h)	total service area with IV complete			1,450,980	1,450,980		1,450,980	1,450,980	decare (da)
(i)=(e)/(h)	water availability per decare with IV complete			429	579		330	480	m3/da (mm)

Source: (d) Water level for Scenario 1 and Scenario 2 was estimated by the Seyhan basin hydrology model (Tanaka et al. 2006).
Base water level is from DSI (2002) Briefing of WUA and Year 2002 Management Activity Report, DSI Region VI, Adana;
(f) from DSI (2003b) Transferred Irrigation Association Year 2002 Observation and Evaluation Report,
DSI Region VI, Lower Seyhan Irrigation Project, Operation and Maintenance Department.

a) Base case

The current conveyance efficiency in LSIP and on-farm application efficiency under furrow irrigation systems are considered to be 0.8 and 0.6 respectively. Then it yields 0.48 as the overall irrigation water efficiency in LSIP. The total volume of water available for LSIP in 2002 was 1,424 million cubic meters. The total service area in 2002 was 1,168,830 decares (116,883 hectares) including irrigated area without canal infrastructure in Region IV. By dividing the actual amount of water available for LSIP by the total service area in LSIP, the annual water availability of 585 mm for the base case was estimated.

b) Scenario 1: Global warming under low water development

By the 2070s, no significant investment in water development, i.e. additional canal networks and dams, is made. In the upper and middle basin of Seyhan River, the entire wheat and barley area is converted to pasture. Also, forest area remains the same as present condition. In LSIP, the downstream of Seyhan river basin, the conveyance efficiency decreases from 0.8 to 0.6 due to no investment on canal maintenance. Then it yields 0.36 as the overall irrigation water efficiency in LSIP. The precipitation will decrease according to future climate change from pseudo warming experiment. The decrease in precipitation in the 2070s is reflected in the reduction of estimated potential water available for LSIP. The irrigated area remains the same as the base case with 469 mm annual water availability. The reduction of precipitation will also increase irrigation water requirement for each crop.

c) Scenario 2: Global warming under high water development and increased irrigated area

By the 2070s, significant investment in water development, i.e. canal networks and dams, is made. In the upper basin, barley remains as present. About 25% of winter wheat in the middle basin is now converted to the irrigated agricultural area where citrus is cultivated. In LSIP the conveyance efficiency remains 0.8 the same as base case with investment on canal maintenance, and the application efficiency increases to 0.7 by improving on-farm irrigation technology. Then it yields 0.56 as the overall irrigation water efficiency in LSIP. The precipitation will decrease according to pseudo warming experiment. The decrease in precipitation in the 2070s is reflected in potential water available for LSIP. The reduction of precipitation will also increase irrigation water requirement for each crop. The irrigation infrastructure in region IV of LSIP is now completed with complete canal networks and the total service area of LSIP expands to 1,450,980 decares (45,098 hectares) with 429 mm annual water availability.

d) Scenario 3: Global warming under high water development with 150 mm groundwater use

In addition to the significant investment in water development in scenario 2, additional 150 mm of groundwater use is now available. In LSIP the conveyance efficiency remains the same as scenario 2. The precipitation will decrease according to pseudo warming experiment. The irrigation infrastructure in region IV of LSIP is now completed with concrete canal networks with 579 mm annual water availability.

Similarly, the water availabilities for CCSR-GCM are 398 mm for scenario 1, 330 mm for scenario 2 and 480 mm for scenario 3 as shown in Table 3.

3.3 *Data*

In the simulation analysis, the following data set was used. (See Appendix 1 for the models and data sets for simulation analysis.) The RCM (Regional Climate Model) prepared for ICCAP[3] project (Kimura et al., 2006) provides various regional climate information in 2070s. For downscaling to Seyhan basin by RCM, the forcing data for the boundary condition of RCM are given by MRI-CGCM2 (Yukimoto et al., 2001; Kitoh et al., 2005) and CCSR-CGCM with T42 in wave truncation, which approximately corresponds to 2.5 degree (250 km grid) horizontal resolution[4]. Control run (1991-2000) of MRI-CGCM2 simulates the current climate condition, while global warming run (2071-2080) is performed based on A2 scenario in Special Report on Emission Scenarios (SRES) of IPCC (IPCC, 2001). Monthly precipitation in Seyhan river basin will decrease 10-40mm/month during cold season. Figure 3 shows the results of MRI and CCSR projections of precipitation in 2070s in Adana. The reduction of precipitation during winter and surface temperature are higher in CCSR although summer precipitations are higher in CCSR.

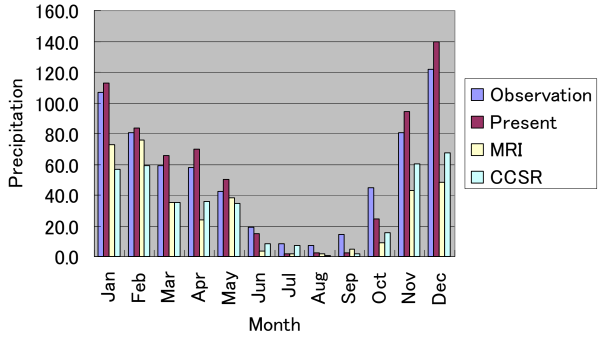

Fig. 3. Comparison of observed and projected precipitation in Adana

The potential total water availability at LSIP in the 2070s was estimated using SiBUC (Simple Biosphere including Urban Canopy) land surface model (Tanaka and Ikebuchi, 1994). This land surface model was designed to treat the land use condition (natural vegetation in forest area, cropland, urban area, water body) in detail including information on various irrigation schemes for different types of cropland in the entire Seyhan river basin. The SiBUC model utilizes the output of RCM. The RCM output includes seven meteorological components, i.e., precipitation, downward short-wave and long-wave radiation, wind speed, air temperature, specific humidity, and pressure. The simulation

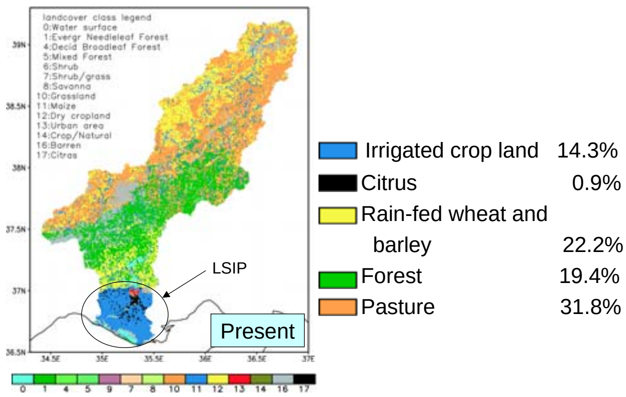

Figure 4. Present land use in Seyhan River basin

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3 The Research Project on Impact of Climate Changes on Agricultural Production System in Arid Areas.

4 MRI-CGCM2 and CCSR-CGCM are coupled general circulation models developed by Meteorological Research Institute, Japan Meteorological Agency, Tsukuba, Japan, and Center for Climate Science Research, Tokyo University, Tokyo respectively.

Table 4. Irrigation water requirement of major crops in LSIP

crop	(a) 1990s irrigation water requirement (mm/year)	MRI-GCM (b) 2070s irrigation water requirement (mm/year)	(b)-(a) future increase in water requirement (mm/year)	CCSR-GCM (c) 2070s irrigation water requirement (mm/year)	(c)-(a) future increase in water requirement (mm/year)
fruit	762.1	848.6	86.4	778.8	16.6
citrus	661.4	749.0	87.6	724.4	63.0
maize	569.0	611.0	42.0	594.2	25.2
soybean	539.0	559.9	20.9	546.2	7.2
cotton	524.2	583.0	58.8	569.3	45.1
II maize	391.4	385.9	−5.5	380.3	−11.1
vegetables	229.2	302.0	72.8	289.2	60.0
watermelon	195.9	195.2	−0.7	239.6	43.7

Source: (a) Nuran Özgenç, Faruk Cenap Erdoğan. (1988) DSI irrigated crop water consumption and irrigation water requirement.
(b),(c) Estimated from the average precipitation decrease in 2070s from peud-warming experiment (Kimura et al., 2006). We used the same level of evapotranspiration in 2070s based on the results that the decrease in duration days trade offs the increase in precipitation increse by climate change.

period for RCM is from 1994 to 2003 for the present climate condition. The future climate condition in the 2070s is simulated using pseudo warming experiment. The potential water available for LSIP was estimated using the data of inflow at Seyhan Dam, domestic water use, river maintenance flow, and irrigation water intake in the upper and middle basin. (For further information on SiBUC land surface model please see Tanaka et al. 2006.) Figure 4 indicates the present land use in Seyhan River basin. The total watershed area is 21,734 km^2 and the land cover class in upper and middle basin are dominated by rain-fed wheat and barley (22.2%), pasture (31.8%) and forest (19.4%).

The actual water released for LSIP in 2002 was obtained from the data reported in *Briefing of WUA and Year 2002 Management Activity Report* (DSI, 2002).

Eight major irrigated crops[5] in LSIP are chosen for the simulation analysis. Those are maize, citrus, cotton, vegetables, watermelon, soybean, fruit and 2nd crop maize (II maize). The first six crops covered about 94% in terms of area planted as well as the total gross revenue of production in LSIP during the 2002 cropping season as mentioned in the previous section (Table 1).

Table 4 indicates the current and future irrigation water requirement of major crops in LSIP. The information on current water requirement of crops (a) was obtained from *DSI irrigated crop water consumption and irrigation water requirement* (Özgenç and Erdoğan, 1988) that most of the WUAs follow when they estimate the total irrigation water required before the next cropping season. The highest water user is fruit (762 mm per annum) followed by citrus (661 mm per annum) and maize (569 mm per annum). The crop water requirement in the 2070s (b) was estimated using the average observed monthly rainfall data during 1970-2005 and the decrease of rainfall in the 2070s estimated by pseudo warming experiment (Kimura et al., 2006) as follows.

$$WR_i = \Sigma(U_i - r + \Delta) - K_i, \qquad (4)$$

where WR is the irrigation water requirement by crop i, U is monthly evapotranspiration of crop i (Özgenç and Erdoğan, 1988), r is the current monthly average rainfall (1970-2005), Δ is the

[5] Wheat is not included in this analysis because wheat is usually not an irrigated crop. The area cultivated by spring wheat in 2004 was about 21.9%. The second maize is usually cultivated after harvesting spring wheat.

monthly decrease in precipitation in the 2070s (Kimura et al., 2006), K_i is the maximum residual soil moisture for crop i (Özgenç and Erdoğan, 1988) at the beginning of the crop period in spring. We aggregated only the water deficit months and then subtracted the maximum residual soil moisture that soil can contain from the aggregate net water requirement. We used the same level of evapotranspiration in the 2070s based on the observation that the shortening growing period trade offs the increase in evapotranspiration by climate change. According to this estimation, the future increase in water requirement per annum is particularly high in citrus, fruit and vegetables by 87.6 mm, 86.4 mm, and 72.8 mm respectively for MRI-GCM. The future increase in water requirement for CCSR-GCM is less than the case for MRI-GCM due to the higher precipitation projection during the summer. Under the climate change with decreasing precipitation and rising temperature, it may be possible that the irrigation period may start earlier than the current irrigation period that normally stretches between April and October. However, this aspect was not considered in the analysis.

The gross revenue per decare from production of each crop in LSIP from 1996 to 2004 was obtained from the annual report of *Yield Census Results for Areas Constructed, Operated and Reclaimed by DSI* (DSI, 1997-2005)[6]. Because of limited information on production costs during this period, only gross revenue for each crop was used for simulation instead of net return. The value of gross revenue for each year was re-evaluated with 2005 price so that the high inflation during this period is taken into account. The real monetary value depreciated to one thirtieth during this period. Another concern was the gross revenue of watermelon. Watermelon is usually cultivated only once in five years in the same plot to avoid replant failure. Using the actual gross revenue may overestimate the gross revenue of watermelon in the long run. In order to take into account the actual crop rotation of watermelon, weighted average of watermelon (1 year) and maize (4 years) was used for simulation.

4. Simulation Results

4.1 *Results from MRI-GCM*

The amount of irrigation water available for LSIP in the 2070s is expected to decrease because of the decrease in precipitation by 5-90 mm in most of the months in Adana according to the pseudo warming experiment by ICCAP (Kimura et al., 2006). Given the availability of irrigation water in the 2070s from the SiBUC land surface model and future irrigation water requirement by crops, the simulation of E-V model was run with i) the base case under current water use level (585 mm per annum), ii) scenario 1 with the climate change case under low water development scenario (469 mm per annum), and iii) scenario 2 with the climate change case under high water development scenario when canal infrastructure in region IV at the downstream of Seyhan river is completed (429 mm per annum), iv) scenario 3 under high water development with 150 mm groundwater use (579 mm per annum).

Table 5-8 shows the simulation results of four cases. These tables indicate the land allocation to various crops in LSIP with risk aversion parameter (RAP) between 0 and 0.02. When RAP is 0, farmers do not avoid any risk. Higher the RAP, the risk averse attitude of farmers become stronger. Table 5 shows the base case under current water use level (585 mm water availability per annum). When farmers do not care any risk (when RAP=0), the area under citrus and vegetable is 82.3% and 17.7% of the total irrigated land of LSIP with average gross revenue of 1,981 YTL per decare. At the risk aversion level of 1%, area under citrus, cotton, vegetables and fruit is 22.0%, 59.3%, 7.0% and 11.6% respectively. This cropping pattern yielded average gross revenue of 718 YTL per decare at 2005 price. Considering that the actual gross revenue per decare was 707 YTL in 2002 at 2005 price (Table 1), the risk aversion level of farmers in LSIP may be close to 1%. In other words, farmers in LSIP will not likely to accept the

[6] Every year, water users associations report their cropping pattern, price, yield and gross revenue per decare for major crops to DSI. This data is aggregated to make a yield table for Seyhan (LSIP).

gross revenue per decare lower than 2002 level. Higher risk aversion parameter of 2% yielded low gross revenue per decare because high risk aversion means more reduction of gross revenue from the annual variability between study periods. In the base case under risk aversion level of 1% and 2%, water resources are still under utilized resulting in redundant or idle water resources of 23.5 mm/year and 75.0 mm/year respectively. This indicates that in these two cases, water is not the constraining factor to allocate land in the model.

Similarly Table 6 shows the simulation results of the climate change case under low water development scenario in 2070s (469 mm water availability per annum). This case may be considered the pure impact of climate change by giving other social conditions remain the same except for the upper basin vegetation change from wheat/barley to pasture and deterioration of canal systems. The reduction of water availability and the increase of water requirement of crops resulted in lowering cotton production (49.7%) which are relatively water intensive, and increasing watermelon production (41.4%) which is relatively high value and high income variability with less water intensity, at 1% risk aversion level. At lower risk aversion level between 0 and 0.05%, citrus and vegetable cultivation expanded. Compared to the base case at the same risk aversion level of 1%, the gross revenue per decare decreased from 718 YTL to 707 YTL (both at 2005 price). This may indicate the situation that in face of climate change in 2070s when farmers want to avoid yielding lower gross revenue per decare, they may have to take a higher risk. At 1% and less risk aversion level, water resources are no more idle and generating positive shadow prices for water.

Table 7 shows the simulation results of the climate change case under high water development scenario in 2070s (429 mm water availability per annum). In this case, not only because of the climate change but also the expansion of irrigated area in middle watershed of Seyhan River in addition to region IV at the downstream, the entire LSIP has to endure with the irrigation water level of 429 mm per annum. As a result, at risk aversion level of 1% watermelon further expanded to 51.7% while cotton (15.1%) and vegetable (3.6%) reduced the acreage. Under the water constraint and variability of gross revenue, farmers are more likely to choose high value added crops relative to water requirement such as watermelon, citrus, cotton, fruit and vegetables. This trend has a similarity with the earlier Delphi forecast by WUA

Table 5. Land allocation in LSIP under base case (MRI)
(585 mm water availability)

RAP	0	0.001	0.005	0.01	0.02
citrus	82.27	82.27	57.45	22.00	4.12
cotton			17.91	59.33	70.31
vegetables	17.73	17.73	1.97	7.04	9.41
watermelon			11.72		5.43
fruit			10.95	11.63	10.74
gross revenue (YTL/da	1981	1770	1022	718	547
shadow price of water	2.926	2.313	0.085		
idle water (mm)				23.51	74.96

RAP: Risk Aversion Parameter

Table 6. Land allocation in LSIP under low water development scenario1(MRI)
(469 mm water availability)

RAP	0	0.001	0.005	0.01	0.02
citrus	37.36	46.73	49.44	22.05	4.23
cotton				23.96	47.76
vegetables	62.64	14.04		4.36	7.48
watermelon		39.23	50.56	41.35	31.78
fruit				8.28	8.75
gross revenue (YTL/da	1413	1303	983	707	543
shadow price of water	2.829	2.472	0.617	0.101	0.083
idle water (mm)					

RAP: Risk Aversion Parameter

Table 7. Land allocation in LSIP under high water development scenario2 with region IV complete (MRI)
(429 mm water availability)

RAP	0	0.001	0.005	0.01	0.02
citrus	28.41	39.34	42.05	22.09	4.27
cotton				15.11	38.91
vegetables	71.59	14.93	0.89	3.60	6.73
watermelon		45.73	57.07	51.69	42.12
fruit				7.50	7.97
gross revenue (YTL/da	1300	1203	952	703	539
shadow price of water	2.829	2.529	0.902	0.117	0.116

RAP: Risk Aversion Parameter

Table 8. Land allocation in LSIP under high water development scenario3 with region IV complete and 150mm GW use (MRI)
(579 mm water availability)

RAP	0	0.001	0.005	0.01	0.02
citrus	61.97	67.07	57.59	21.94	4.12
cotton			0.68	48.29	70.31
vegetables	38.03	11.58	0.19	6.44	9.41
watermelon		21.35	32.04	12.90	5.43
fruit			9.49	10.43	10.74
gross revenue (YTL/da	1724	1567	1016	716	547
shadow price of water	2.829	2.316	0.087	0.056	
idle					8.105

RAP: Risk Aversion Parameter

staff members that preferred high value crops such

Table 9. Simulated cropping pattern of LSIP with MRI-GCM and CCSR-GCM

	2002	2070s MRI-GCM			2070s CCSR-GCM		
scenario	base	S-1	S-2	S-3	S-1	S-2	S-3
water availability (mm)	585	469	429	579	398	330	480
citrus	22.00	22.05	22.09	21.94	21.86	18.32	21.84
cotton	59.33	23.96	15.11	48.29	4.34		25.97
vegetables	7.04	4.36	3.60	6.44	2.98	3.17	4.74
watermelon (+maize)		41.35	51.69	12.90	64.03	78.51	38.82
fruit	11.63	8.28	7.50	10.43	6.80		8.64
gross revenue (YTL/da)	718	707	703	716	696	670	708
shadow price of water (YTL/m3)		0.101	0.117	0.056	0.164	0.796	0.116
idle water (mm)	23.51						

Risk aversion parameter = 1%

as citrus and vegetables. However this combination of crops will result in 703 YTL per decare, lower than the current (base) level of 718 YTL per decare at 2005 price.

Table 8 indicates the simulation results under high water development with 150 mm groundwater use. Because of additional groundwater is available, water availability in LSIP increased to 579 mm per annum. High water availability similar to base case allowed water intensive cotton production to expand (48.3%) and watermelon cultivation to decrease (12.9%). This combination of crops will result in annual gross revenue of 716 YTL per decare, which is similar to the base level of 718 YTL per decare at 2005 price.

The increasing shadow price of water by decreasing potential water availability in LSIP indicates the increasing scarcity of water resources in the future. At 1% risk aversion level, shadow price of water is 0.101 YTL/m3 under low water development case (469mm). The shadow price further increases to 0.117 YTL/m3 under high water development case (429mm).

4.2 *Comparison of MRI-GCM and CCSR-GCM*

Figure 9 shows the comparison of simulation results with various results with MRI-GCM and CCSR-GCM. Because CCSR projected precipitation decrease and surface temperature increase in Seyhan River basin, the potential water available for downstream LSIP is also 70-100 mm smaller with CCSR climate outputs. As a result, comparing to MRI cropping patters, CCSR cropping pattern is more dominated by watermelon which is water efficient in terms of gross revenue generated per unit of water. Because the scarcity of water is intensified in CCSR, the shadow price of water increased to 0.796 YTL/m3.

5. Conclusions

This paper tried to assess the regional impacts of climate change on agricultural production systems by estimating the potential water availability and crop irrigation water requirement in the 2070s and simulating the possible cropping pattern and the farmer welfare in Lower Seyhan Irrigation Project (LSIP) in Turkey. We used expected value-variance (E-V) model that is used to analyze risk. The model maximizes total gross revenue of agricultural production in entire LSIP according to the risk aversion coefficient. Under the water constraint and variability of gross revenue, farmers are more likely to choose high value added crops relative to crop water requirement such as watermelon, citrus, cotton, fruit and vegetables. However in the case of climate change case under high water development scenario this combination of crops will result in 701 YTL per decare, lower than the current level of 718 YTL per decare at 2005 price. Also the future increases in variability of rainfall may affect negatively to the farmer welfare by decreasing gross revenue per unit of land.

Comparison of MRI-GCM and CCSR-GCM

outputs indicated that the results of future climate change projections in 2070s are sensitive to the type of Global Climate Models adopted for the analysis. In our analysis, CCSR-GCM showed less precipitation and higher surface temperature that resulted in intensifying water scarcity in downstream irrigated areas compared to MRI-GCM. It should be noted that these two sets of information should be considered as a range of constraining factors and possible adjustment for the future when we take any policy measures.

The future investment should target more efficient use of water resources by various alternative options. First, incentive mechanism is required for introducing on-farm technology and water pricing systems that save water substantially if the expansion of the irrigated area is continuing at the upstream as well as downstream of the Seyhan River basin. The current practice of furrow irrigation system for major field crops needs to be transferred to more efficient on-farm water technology if the water scarcity is going to be intensified. Second, the role of WUA for efficient use of irrigation water may be quite important and there is a potential for saving water substantially by improving management and organization of WUAs (Umetsu et al. 2005).

The option of cultivating high gross revenue generating crops such as citrus, fruit and vegetables needs to allow risk of annual gross revenue variability. However, this option may cause environmental pressure on land and water resources in LSIP by introducing more intensive use of pesticides and fertilizers. These options should be assessed carefully for the sustainability of agricultural production systems such as environmentally acceptable crop rotations and agronomic adaptations to prevent crop failure.

This paper did not take into account the following issues due to data limitations. The impacts of heat damages due to the increase in air temperature and the increase in CO_2 concentration in the atmosphere in the future was not considered. If the information on the impact of heat damages and CO_2 concentration on the decrease and/or increase of yield of various crops is available, it may be possible to include these factors into the simulation analysis. Especially for the heat damage, there is a possibility that the threshold level may be more important. For example, the tree crops such as citrus and fruit are more sensitive to heat damages at the stage of flowering. Also future price changes for each crop were not considered. If the future price projections for all crops are available for the 2070s, it may be possible to take into account the effect of price factors into the analysis. However, the future prices are more prone to future market availability and conditions such as Turkey integration into the EU agricultural market, which requires further investigation.

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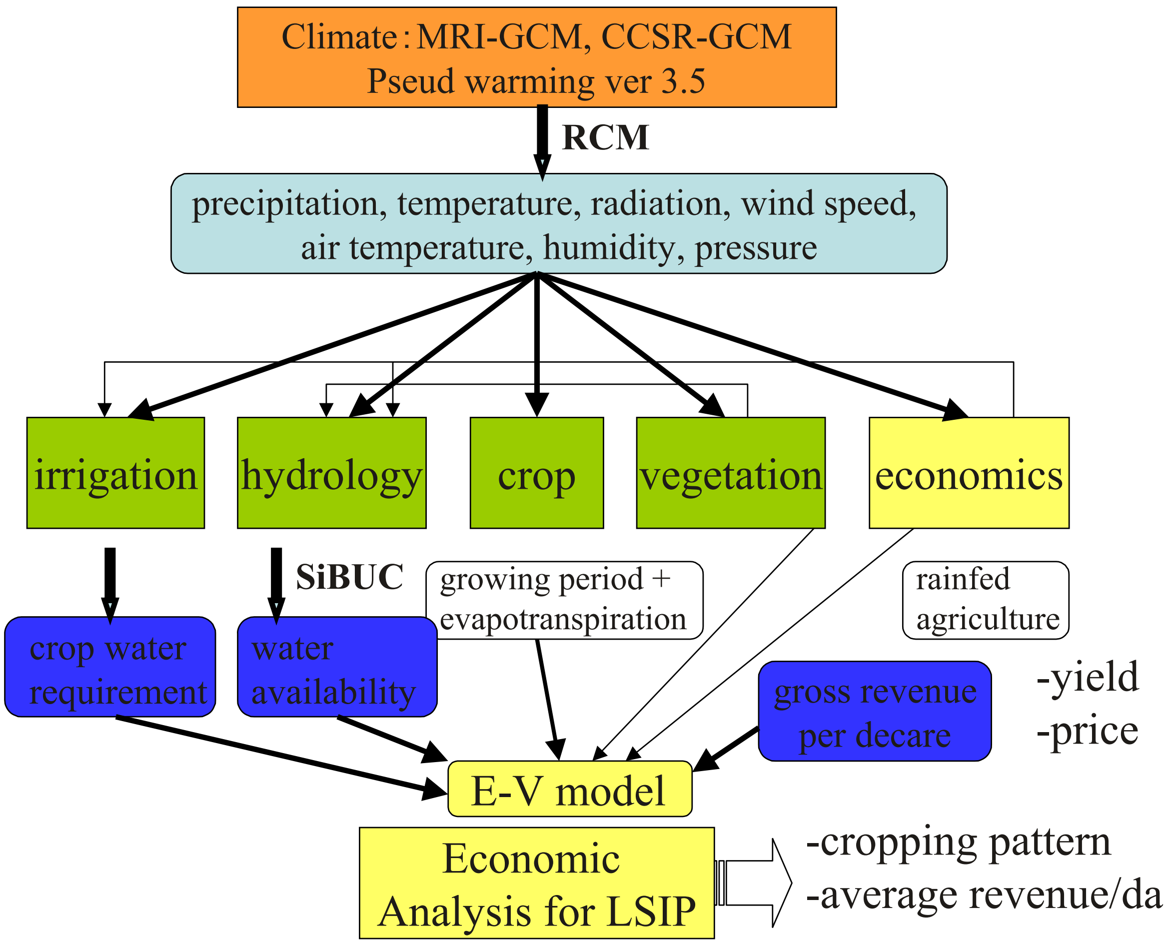
Appendix 1. Schematic diagram of models and data sets for simulation analysis



The Final Report of the Socio-economic Sub-group of the ICCAP Project

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1. Introduction

This is the final report of the research results of the socio-economic sub-group in the ICCAP project regarding the impacts of global warming to cropping pattern, land use and water use in Adana and Konya.

2. The Four Components of ICCAP's Socio-economic Study and Their Relationship

There are four components in the ICCAP's Socio-economic Study.

(1) An econometric and agro-climatological study of the impact of global warming and prices to wheat and barley production in Adana and Konya by H. Tsujii, and U. Gultekin.

(2) The new institutional economics analyses and an risk programming analysis of the use of commons such as water and land by farmers, and pastoralists under the condition of climatic change and institutional change in both irrigated and rain-fed areas of Turkey by Umetsu and Y. Asami.

(3) An economic analysis of the farm survey data regarding the interactions among farmers' perception of and responses to climatic changes, technological changes, and policy and institutional changes and their impacts to farmers' economy and agricultural sustainability by H. Tsujii, Y. Asami, M. Kusadokoro, T. Maru, O. Erkan, Ufuk Gultekin, C. Oguz, Kenan, Basen, Karayaci, Kan, Avci, Kemaletin Tasdan, Baran, Naciye

(4) A Country level input-output analysis of interrelations between agricultural sector productivity and climatic change by M. Kagatsume and Sanda.

The variables of these four components are related as shown by the following diagram.

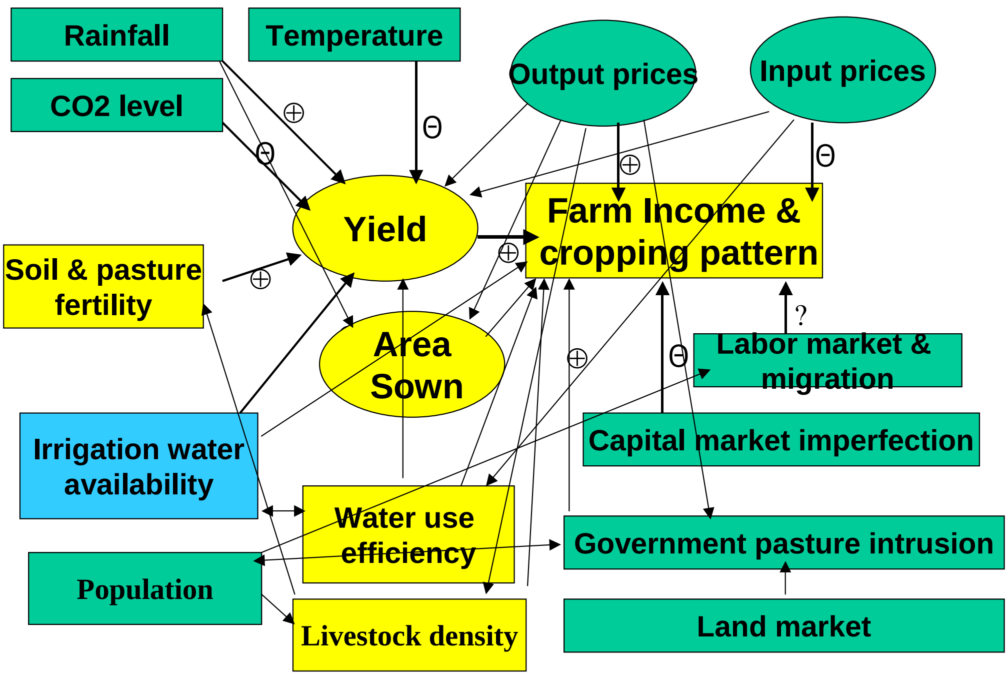

Fig1. Relationship among the Variables of the Four Components of Socio-economic Sub-group

3. Main Conclusions of the Socio-economic Research in ICCAP

Research methodology of the Socio-economic sub-group of ICCAP was described in two methodological and framework papers by H. Tsujii in The First Interim-report of the Socio-economic Sub-group of ICCAP published in 2005 (Tsujii, H., 2005a. & Tsujii, H., 2005b.).

In the rain-fed areas in Adana and Konya, an econometric study by Tsujii and Ufuk has found that the global warming under the case of no Turkey accession to the EU in 2070 will increase wheat and barley yields by 13% and 6% respectively, while it will decrease these yields in Konya by 18% and 17% respectively. This difference is probably caused by the fact that 2070 average temperature in Konya will increase by 21% of current climatic average temperature, while the same temperature in Adana will increase by only 14%, and that there are large differences in the characteristics of wheat and barley between Adana and Konya. The impacts projection of global warming to yields of wheat and barley include about +30% of yield increase by the increase of CO2 concentration, negative high temperature effects, and drought and soil moisture effects in 2070. The last two effects are found to be very large in Konya.

The impacts of global warming to area sown of wheat and barley in Adana and Konya in the case of no EU accession are all small negative percentages. Thus the total production of Adana wheat will increase by 10%, while the total production of Adana barley will reduce by 2% under global warming. But, the total wheat and barley production in Konya will decrease by large amounts of 18% and 18% respectively. This may imply a future decline of food security or wheat shortage in Turkey as Konya is a large and representative wheat producing area on the Anatolian Plateau in Turkey.

These reductions of wheat and barley production caused by global warming can be aggravated by the long run soil degradation perceived by most of the farmers surveyed in our farm surveys in Adana and Konya. Our analysis of farmers' perception showed clearly that degrading inherent soil fertility was caused by increasing use of chemical fertilizer and decreasing animal manure input in Adana and Konya. (Tsujii, Kusadokoro, Erkan, and Oguz.. 2005) Most of the surveyed farmers in Cesimilseville, Konya have told us that the inherent soil fertility of rain-fed wheat land has been degrading because of increasing chemical fertilizer application so that fallow frequency has increased form once in three years to every other year. The surveyed farmers told us and have shown us that the grass of vast national grazing land has deteriorated to the dominance of thorny grass because of overgrazing, and animals can not eat these thorny grass.

Many farm surveys, the analyses of the data collected, and some methodologies for economic analysis of the interactions among farmers' perception of and their responses to climatic changes, technological changes and policy and institutional changes have been conducted in the research projects of Hiroshi Tsujii conducted in Nigeria, Tanzania, Indonesia, and Japan using the farm questionnaires similar to the one used in Turkey. About 5 English papers by Tsujii and others have been published by, and have been accepted by international journals. (Chianu and Tsujii, 2006, Herianto and Tsujii, 2003)

From our farm surveys in Adana and Konya and from our risk programming analysis, it was found that global warming with less water availability in the future would be more beneficial to larger and land self-owned farmers in the irrigated area in Turkey as they can diversify the crops they grow to more profitable and less water demanding crops with their higher risk aversion capability comparing with smaller and tenant farmers. Comparing with these farmers, smaller tenant farmers in irrigated area and farmers in rain-fed area will suffer more from global warming as they do not have enough options to adapt their cropping patterns to global warming and enough capability to minimize risk they face during global warming.

In the irrigated area of Adana, Umetsu and others found the following results using their risk programming model. When water availability would decrease under global warming, the farmers in irrigated area would increase land use shares of higher priced commodities, so that they could use scarcer water more efficiently while at the same time minimizing risk of this diversification of their crops. Exactly speaking, the farmers with near real risk aversion behavior standard would increase the ratio of their land use for watermelon from zero percent in the base case when water is an idle resource to 11% in low water development scenario and 24% in high water development scenario, would decrease cotton land use ratios considerably, and would not change land use ratios of citrus, vegetables, and fruits very much in order for them to obtain desired level of gross revenue and at the same time to restrict risk at an acceptable level when water availability would be reduced by 1 to 5 percent when global warming would take place in 2070.

Erkan and others have recently written a long report summarizing the Turkish side farm survey results concerning farmers' perception about global warming and farmers' responses to global warming in Adana and Konya (Erkan, et al. 2007).

Cennet Oguz and Onur Erkan, Arzu Kan, and Ufuk Gultekin has done logit analysis of their specific farm survey data in order to measure the farmers' responses in their inputs use to weather changes in Konya, Turkey (Onur Erkan, Cennet Oguz, Arzu Kan, and Ufuk Gultekin. 2006.)

We have done farm surveys of about 500 farms in both Adana and Konya during 2002 and 2006 in both irrigated and rain-fed areas. We shall present the results of these farm surveys formally later. But here we like to comment on the results of this risk programming analysis from some results of our farm surveys. We can confirm that Turkish farmers do respond to crop prices and input prices as found in our farm surveys in the case of water melon, maize, cotton, and citrus in the irrigated area of Adana, and in the case of wheat in Adana. Kusadokoro found that farmers do try to averse risk. But they not only averse market risk as it was shown in the above risk response model analysis, but also they try very hard to averse the risk of yield damage caused by continuous planting of a single crop. As we will discuss in detail later, these risk aversion behaviors are closely related to the tenancy situations of the farmers concerned. Thus we think the risk programming model should be modified by taking the tenancy situations into account.

Kagatsume's IO analysis shows that the global warming increases productivity of forestry and fishery sectors greatly, while it increases productivities of grain, fruits, and livestock sectors moderately.

Kusadokoro has predicted the farmers' future cropping patterns under global warming using our farm survey data taking into farmers' tenure status, and analyzed the risk response behavior of farmers using district level time series crop data for Adana. He concludes that in Adana small tenants will be most severely affected by global warming since they have to change their cropping pattern of wheat and maize to vegetables that are very risky. Maze will not be an appropriate crop under global warming. He also found that risk response by farmers was very large.

Maru analyzed the relationship between global warming and feeding types, growth stages of livestock, milk yield, and growth of livestock in Adana.

Asami described the recent fast destruction of government pasture by its illegal conversion by farmers and its overgrazing and analyzed the effectiveness of new Pasture Law for the reduction of illegal government pasture conversion.

4. Main conclusions of an econometric and agro-climatological study of the interactions among production of wheat and barley, weather variables, prices of wheat and other major crops, and climatic change in Konya and Adana

Research methodology of the Socio-economic sub-group of ICCAP follows the two methodological memos by H. Tsujii written in 2003 and 2004(Tsujii, H., 2003 & Tsujii, H., 2004). An English interim-report of the socio-economic team was published and distributed in February 2005 (Tsujii, H. ed., 2005).

In the rain-fed areas in Adana and Konya, an econometric study by Tsujii and Ufuk has found that the global warming under the case of no Turkey accession to the EU in 2070 will increase wheat and barley yields by 13% and 6% respectively, while it will decrease these yields in Konya by 18% and 17% respectively. This difference is probably caused by the fact that 2070 average temperature in Konya will increase by 21% of current climatic temperature, while the same temperature in Adana will increase by only 14%.

The impacts of global warming to area sown of wheat and barley in Adana and Konya in the case of no EU accession are all small negative percentages. Thus the total production of Adana wheat will be increased by 10%, while the total production of Adana barley will be reduced by 2% under global warming. Wheat and barley yields in Konya will be decreased by 18% and 17% respectively under global warming in no EU accession case. The area sown of wheat and barley will decrease a little under global warming in 2070. Consequently the total wheat and barley production will decrease by large amounts of 18% and 18%. This may imply a future decline of food security or wheat shortage in Turkey as Konya is a large and representative wheat producing area in Turkey.

These reductions of wheat and barley production caused by global warming can be intensified by the long run soil degradation perceived by most of the farmers surveyed in our farm surveys in Adana and Konya. Most of the surveyed farmers in Cesimilseville, Konya have told us that the inherent soil fertility of rain-fed wheat land has been degrading because of increasing chemical fertilizer application so that fallow frequency has increased form once in three years to every other year. The surveyed farmers told us and have shown us that the grass of vast national grazing land has deteriorated to the dominance of thorny grass because of overgrazing, and animals can not eat these thorny grass.

Many farm surveys, the analyses of the data collected, and some methodologies for economic analysis of the interactions among farmers' perception of and their responses to climatic changes, technological changes and policy and institutional changes have been conducted in the research projects of Hiroshi Tsujii conducted in Nigeria, Tanzania, Indonesia, and Japan using the farm questionnaires similar to the one used in Turkey. About 5 English papers by Tsujii and others have been published by and have been accepted by international journals. (Chianu and Tsujii, 2006, Herianto and Tsujii, 2003)

4.1 The econometric and agro-climatological study of the impacts of global warming and price changes to wheat and barley in Konya and Adana.

The Tsujii and Ufuk econometric analysis, first estimated historical yield and area sown functions of wheat and barley in Adana and Konya, incorporating the effects of very high temperature, drought, soil moisture, and output prices. Secondly, combining the best estimated functions with the model bias adjusted projected monthly rainfall and temperature by the RCM of Dr. Kimura, and atmospheric CO2 concentration effects of global warming, yield, area sown, and total production of wheat and barley in Adana and Konya were predicted for 2070.

4.2 A result of the econometric analysis of the effects of very high temperature, drought, soil moisture, and output prices to wheat and barley production

This study follows the methodology used in the past econometric studies of H. Tsujii on the similar topic conducted for Japan and Thailand.
Here we show in the following figures the results of our econometric study of wheat and barley for Adana, and Konya, and the impacts of global warming to the production of these crops in Adana and Konya. The period of analysis is for 1951 to 1998, and the linear function is used for the analysis. The variable descriptions and the estimated yield and area sown functions for Adana and Konya are not shown here because of space problem.

4.3 An econometric and agro-climatological study of the interactions among production and prices of wheat, barley and other major crops, weather variables, and climatic change in Konya and Adana.

In this study Tsujii and Ufuk presented a result of their historical econometric analysis of the effects of the negative yield effect of high temperature (heat damage), drought, and output prices to wheat and barley production, and the evaluation of the impacts of heat damage, drought, output prices, and atmospheric CO2 concentration of global warming to these crops in Adana and Konya for 2070 utilizing the estimated yield and area sown functions for wheat and barley in these areas and the RCM climatic projection by Dr. Kimura. In the near future, we shall estimate models for other important crops in Adana and Konya, considering the interdependences between these crops, and analyze the impacts of global warming to the farmers' behavior concerning cropping pattern, land use and water use.

The global warming effects to yield (a+c), area sown (b), and total production of Adana wheat and barley (a+b+c) are shown in the following Tables for no EU accession case.

WHEAT ADANA YIELD	Coeff.	Var. Value	Yield 2070's	Estimated Yield 1993-2002	a (%)	c (%)	a+c (%)
CONSTANT	2624,62	1,00	2624,62				
Nominal price change	10,29	73,20	753,23				
DDmay(t)%20	-255,84	0,00	0,00				
DHDApril(t)162	-215,36	1,00	-215,36				
DHDMay(t)235	-580,26	1,00	-580,26				
			2582,23	**3162,49**	**-18,35**	**31**	**12,65**

WHEAT ADANA AREA SOWN	Coeff.	Var. Value	Area Sown 2070's	Estimated Area Sown 1993-2002	b (%)
CONSTANT	199932,10	1,00	199932,10		
Nominal price change	1531,91	73,20	112135,81		
CRSEP(t-1)OCT(t-1)	535,42	43,31	23189,04		
			335256,95	**345713,70**	**-3,02**

	a+b+c (%)
The Total Impact to Adana wheat production	**9,63**

Notes:

1. O=Y*AS, Of=(1+a)*(1+c)*Y*(1+b)*AS=(1+c)*(1+(a+b)+a*b)*Y*AS□(1+a+b+c)*Y*AS

Def.: Of=future producction. a=a rate of change in yield (Y) caused by weather changes of GW. b=a rate of change in area sown (AS) caused by GW. c=a rate of change in Y caused by CO2 concentration.

2. The values of real and relative prices and of nominal price change to be used for 2070's projection under the condition of no EU accsession are the averages of these corresponding price variables for the period of 1993 - 2002.

BARLEY ADANA YIELD	Coeff.	Var. Value	Yield 2070's	Estimated Yield 1993-2002	a (%)	c (%)	a+c (%)
CONSTANT	2106,94	1,00	2106,94				
Nominal price change	2,30	78,90	181,47				
DDMarch(t)35	-51,29	1,00	-51,29				
DHDApril(t)18,9	-83,83	1,00	-83,83				
DHDMay(t)23,4	-420,48	1,00	-420,48				
			1732,81	**2282,61**	**-24,09**	**30**	**5,91**

BARLEY ADANA AREA SOWN	Coeff.	Var. Value	Area Sown 2070's	Estimated Area Sown 1993-2002	b (%)
CONSTANT	-9912,30	1,00	-9912,30		
Real PriceBARLEY(t-1)	0,13	234646,10	30503,99		
CRJAN(t-1)OCT(t-1)	15,44	316,94	4893,56		
			25485,25	**27607,32**	**-7,69**

	a+b+c (%)
The Total Impact to Adana barley production	**- 1,8**

The global warming effects to yield (a+c) and area sown (b) of Konya wheat and barley are shown in the following Tables.

WHEAT KONYA YIELD	Coeff.	Var. Valu	Yield 2070's	Estimated Yield 1993-2002	a (%)	c (%)	a+c (%)
CONSTANT	1400,67	1,00	1400,67				
Nominal price change	5,07	73,20	371,27				
CROCT(t-1)MAY(t)	1,32	218,65	287,52				
DDApril(t) %20	-318,90	1,00	-318,90				
DHDApril(t)12,8	-205,46	1,00	-205,46				
DHDMay(t)16,3	-171,30	1,00	-171,30				
DHDJune(t)20,7	-267,22	1,00	-267,22				
			1096,59	**2130,70**	**-48,53**	**31**	**-17,53**

WHEAT KONYA AREA SOWN	Coeff.	Var. Valu	Area Sown 2070's	Estimated Area Sown 1993-2002	b (%)
CONSTANT	701373,66	1,00	701373,66		
relativePriceWB(t-1)	206883,04	1,20	248259,65		
CRJAN(t-1)FEB(t-1)	543,83	50,99	27729,79		
			977363,10	**982284,74**	**-0,50**

	a+b+c (%)
The Total Impact to Konya wheat production	**- 18,03**

BARLEY KONYA YIELD	Coeff.	Var. Value	Yield 2070's	Estimated Yield 1993-2002	a (%)	c (%)	a+c (%)
CONSTANT	1415,21	1,00	1415,21				
Nominal price change	4,91	78,90	387,48				
CROCT(t-1)JUN(t)	2,13	236,52	503,79				
DDApril(t) %15	-408,93	1,00	-408,93				
DHDApril(t)13,7	-312,07	1,00	-312,07				
DHDMay(t)16,3	-284,87	1,00	-284,87				
			1300,59	**2434,17**	**-46,57**	**30**	**-16,57**

BARLEY KONYA AREA SOWN	Coeff.	Var. Value	Area Sown 2070's	Estimated Area Sown 1993-2002	b (%)
CONSTANT	199257,53	1,00	199257,53		
RelativePriceBW(t-1)	305464,40	0,87	265754,03		
CRJAN(t-1)APR(t-1)	245,75	98,69	24253,46		
			489265,02	494841,18	-1,13

	a+b+c (%)
The Total Impact to Konya barley production	**- 17,70**

For EU accession case, similar global warming effects were calculated, but tables are not shown for saving the space. The two summary figures of these effects are shown just below.

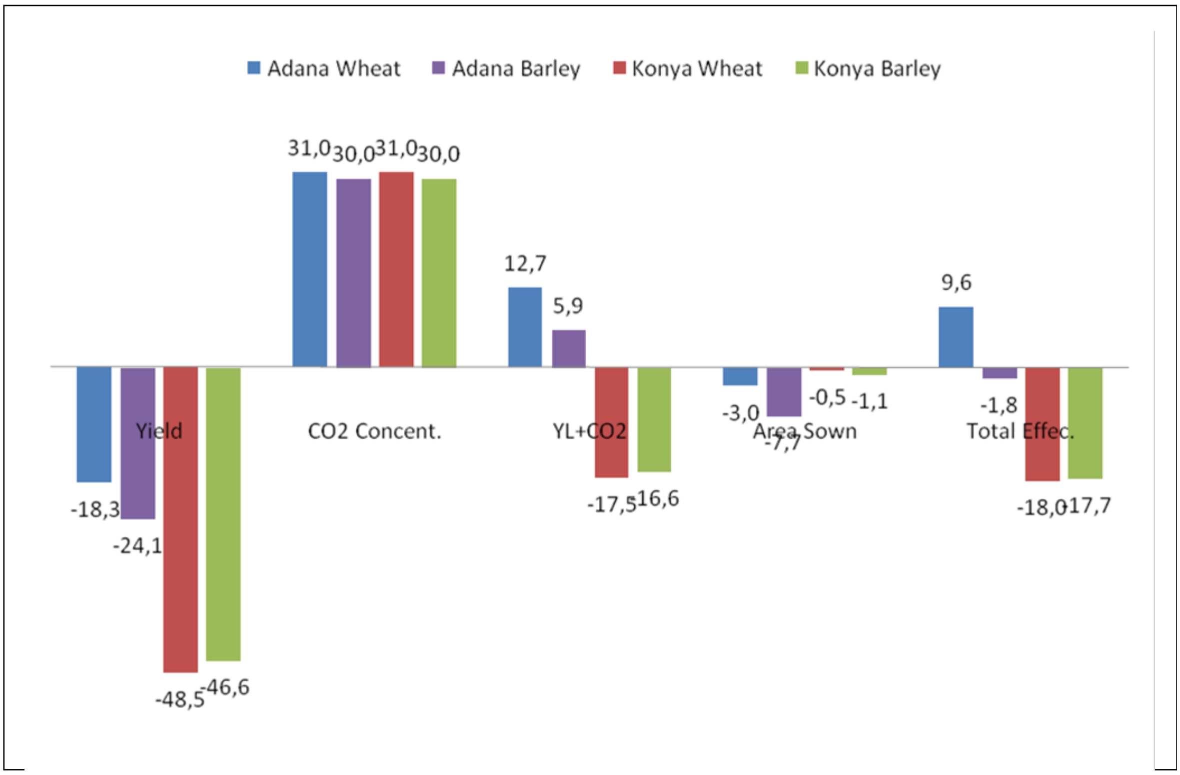

Fig2. Global Warming Impacts to Rainfed Wheat and Barley in Adana and Konya in No EU Accession Case

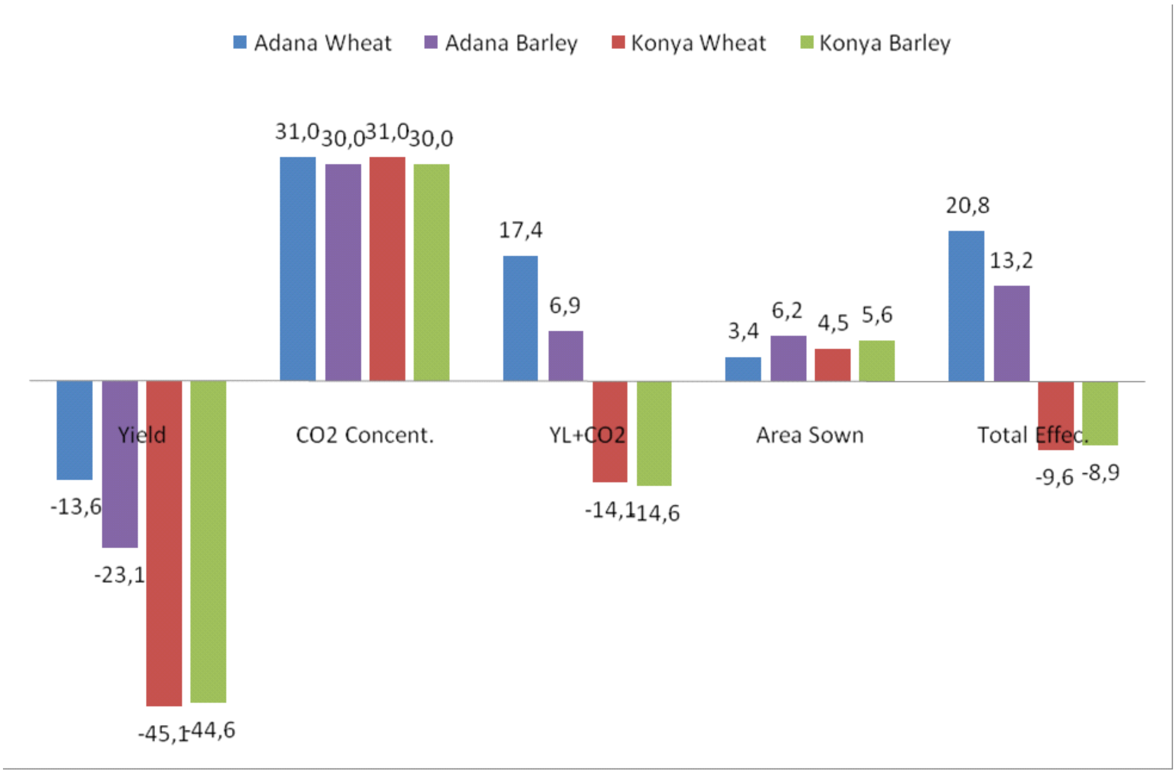

Fig3. Global Warming Impacts to Rainfed Wheat and Barley in Adana and Konya in EU Accession Case

5. Conclusion

The economic model predicts both yield effects and area sown effects of global warming in the decade starting in 2070 to wheat and barley in Adana and Konya. The yield effects were predicted by taking into account price effect, drought effect, high temperature effect, and CO2 concentration effect. The area sown effects were predicted by taking into account price effect and soil moisture effect. These predictions were made for two cases, i. e., no EU accession case and EU accession case. In the EU accession case prices used for prediction were assumed to be higher than no EU accession case by the current differences of protection between Turkey and the EU.

The economic model predictions show that wheat and barley production in warmer area, i. e., Adana will benefit from global warming, while wheat and barley production in colder area, i. e., Konya will reduce considerably as shown in Fig 1 and Fig 2.

This result is probably caused by the fact that RCM temperature predicted for 2070 will increase by 21% of the past long-run average in Konya, while the same ratio for Adana is only 14% and the differences of crop varieties between Adana and Konya. So adding the CO2 concentration effect, Adana wheat and barley yields will increase to some extents, while Konya wheat and barley yields will decrease considerably in both no EU accession and EU accession case under global warming. Area sown effects are all slightly negative in no EU accession case, while the same effects are all slightly positive in EU accession case.

Consequently, the global warming effects to the total production of wheat and barley in Adana are all positive except Adana barley production that is slightly negative in both no EU accession and EU accession cases as shown in Fig 1 and Fig 2. But the global warming effects to wheat and barley production in Konya are all considerably large negative in both no EU accession and EU accession cases. Konya is a large and representative wheat producing province on Anatolian Plateau, and this econometric result suggests fiture severe decline of Turkish wheat food security under global warming.

6. The new institutional economics analyses of the roles of the water users' associations (WUAs) and a risk programming analysis of farmers' choice of cropping patterns.

A survey of the water users' associations in Adana was done by Umetsu in 2003. Based on an application of frontier production function analysis, it was found that the efficiency of water users' associations in LSIP was compared with the emerging options. The analysis revealed that some WUAs are suffering from inefficient management practices and there is a scope for major reorganization.

A numerical optimization analysis of crop combination in Adana by maximizing the expected value of the total gross revenue of the crops grown minus covariance matrix of crops' revenue multiplied by risk aversion parameter of the farmers was done by Umetsu and others in 2005. Table 5-8 shows the simulation results of four cases. These tables indicate the land allocation to various crops in LSIP with risk aversion parameter (RAP) between 0 and 0.02. When RAP is 0, farmers do not avoid any risk. Higher the RAP, the risk averse attitude of farmers become stronger. Table 5 shows the base case under current water use level (585 mm water availability per annum). When farmers do not care any risk (when RAP=0), the area under citrus and vegetable is 82.3% and 17.7% of the total irrigated land of LSIP with average gross revenue of 1,981 YTL per decare. At the risk aversion level of 1%, area under citrus, cotton, vegetables and fruit is 22.0%, 59.3%, 7.0% and 11.6% respectively. This cropping pattern yielded average gross revenue of 718 YTL per decare at 2005 price. Considering that the actual gross revenue per decare was 707 YTL in 2002 at 2005 price (Table 1), the risk aversion level of farmers in LSIP may be close to 1%. In other words, farmers in LSIP will not likely to accept the gross revenue per decare lower than 2002 level. High risk aversion parameter of 2% yielded low gross revenue per decare because high risk aversion parameter means more reduction of gross revenue

Table 5. Land allocation in LSIP under base case (585 mm water availability)

RAP	0	0.001	0.005	0.01	0.02
citrus	82.27	82.27	57.45	22.00	4.12
cotton			17.91	59.33	70.31
vegetables	17.73	17.73	1.97	7.04	9.41
watermelon			11.72		5.43
fruit			10.95	11.63	10.74
gross revenue (YTL/da	1981	1770	1022	718	547
shadow price of water	2.926	2.313	0.085		
idle water (mm)				23.51	74.96

RAP: Risk Aversion Parameter

Table 6. Land allocation in LSIP under low water development scenario1 (580 mm water availability)

RAP	0	0.001	0.005	0.01	0.02
citrus	60.38	60.71	56.94	21.84	4.12
cotton				49.68	70.31
vegetables	39.62	37.14	0.32	6.63	9.41
watermelon		2.15	35.11	11.32	5.43
fruit			7.63	10.53	10.74
gross revenue (YTL/da	1704	1538	1014	716	547
shadow price of water	2.644	2.319	0.151	0.06	
idle water (mm)					23.48

RAP: Risk Aversion Parameter

Table 7. Land allocation in LSIP under high water development scenario2 (535 mm water availability)

RAP	0	0.001	0.005	0.01	0.02
citrus	50.98	52.34	55.71	21.86	4.13
cotton				38.57	65.00
vegetables	49.02	38.83	0.13	5.71	8.97
watermelon		8.84	42.60	24.32	11.64
fruit			1.56	9.54	10.27
gross revenue (YTL/da	1585	1433	1003	713	547
shadow price of water	2.644	2.382	0.333	0.083	0.022
idle water (mm)					

RAP: Risk Aversion Parameter

Table 8. Land allocation in LSIP under high water development scenario2 with region IV complete (431 mm water availability)

RAP	0	0.001	0.005	0.01	0.02
citrus	29.25	32.97	38.17	21.90	4.17
cotton				12.89	39.32
vegetables	70.75	42.73	3.56	3.58	6.84
watermelon		24.30	58.27	54.38	41.70
fruit				7.25	7.98
gross revenue (YTL/da	1310	1177	934	701	539
shadow price of water	2.644	2.529	1.031	0.137	0.129

RAP: Risk Aversion Parameter

from the annual variability between study periods. In the base case under risk aversion level of 1% and 2%, water resources are still under utilized resulting in redundant or idle water resources of 23.5 mm/year and 75 mm/year respectively. This means that in these cases, water is not the constraining factor to allocate land in the model.

Similarly Table 6 shows the simulation results of the climate change case under low water development scenario in the 2070s (580 mm water availability per annum). This case may be considered the pure impact of climate change by giving other social conditions remain the same. The reduction of water availability and the increase of water requirement of crops resulted in lowering citrus production (21.8%) and cotton production (49.7%) which are relatively water intensive, and increasing watermelon production (11.3%) which is relatively high value and high income variability with less water intensity, at 1% risk aversion level. At lower risk aversion level between 0 and 0.05%, vegetable cultivation expanded. Compared to the base case at the same risk aversion level of 1%, the gross revenue per decare decreased from 718 YTL to 716 YTL (both at 2005 price). This may indicate the situation that in face of climate change in the 2070s when farmers want to avoid yielding lower gross revenue per decare, they may have to take a higher risk. The impacts of climate change with other conditions remains the same is not very substantial. At 1% and less risk aversion level, water resources are no more idle resource generating positive shadow prices for water.

Table 7 shows the simulation results of the climate change case under high water development scenario in the 2070s (535 mm water availability per annum). In this case, not only because of the climate change but also the expansion of irrigated area in middle and upper watershed of Seyhan River, the potential water availability for LSIP is further reduced substantially compared to the previous two cases. As a result, at risk aversion level of 1% watermelon further expanded to 24.3% while cotton (38.6%) and vegetable (5.7%) reduced the acreage. When the canal infrastructure in region IV at the downstream is completed in the 2070s, the entire LSIP has to endure with the irrigation water level of 431 mm per annum (see Table 8). In this case, watermelon (54.4%), citrus (21.9%), cotton (12.9%), fruit (7.3%) and vegetables (3.6%) are cultivated. Under the water constraint and variability of gross revenue, farmers are more likely to choose high value added crops relative to water requirement such as watermelon, citrus, cotton, fruit and vegetables. This trend has a similarity with the earlier Delphi forecast by WUA staff members that preferred high value crops such as citrus and vegetables. However this combination of crops will result in 701 YTL per decare, lower than the current level of 718 YTL per decare at 2005 price.

The increasing shadow price of water by decreasing potential water availability in LSIP indicates the increasing scarcity of water resources in the future. At 1% risk aversion level, shadow price of water is 0.06 YTL/mm or 3.48 YTL per decare under low water development case (580mm). The shadow price further increases to 44.4 YTL per decare (535mm) under high water development case and 59 YTL/da (431mm) under high water development case with completed canal networks in region IV. Thisanalysis tried to assess the regional impacts of climate change on agricultural production systems by estimating the potential water availability and crop irrigation water requirement in the 2070s and simulating the possible cropping pattern and the farmer welfare in Lower Seyhan Irrigation Project (LSIP) in Turkey. We used expected value-variance (E-V) model that is used to analyze risk. The model maximizes total gross revenue of agricultural production in entire LSIP according to the risk aversion coefficient. Under the water constraint and variability of gross revenue, farmers are more likely to choose high value added crops relative to crop water requirement such as watermelon, citrus, cotton, fruit and vegetables. However in the case of climate change case under high water development scenario this combination of crops will result in 701 YTL per decare, lower than the current level of 718 YTL per decare at 2005 price. Also the future increases in variability of rainfall may affect negatively to the farmer welfare by decreasing gross revenue per unit of land.

Several hypothetical risk aversion levels of the farmers, and hypothetical irrigation water deficiency levels related with global warming were assumed, and hypothetical numerical calculation was conducted. Naturally it was found that risk aversion levels affected optimal crop combination. Irrigation water abundance was also found to be an important characteristic of Adana agriculture.

7. An economic analysis of the farm survey data regarding the interactions among farmers' perception of and responses to climatic changes, technological changes, and policy and institutional changes and the impacts of climatic change to farmers' behavior.

Farm surveys were conducted in Adana and Konya by Japanese and Turkish graduate students in 2002, 2003, 2004, and 2006. The collected data from earlier farm surveys were input and analyzed. Turkish Socio-economic sub-group in cooperation with Tsujii has done farm survey in Adana and Konya regarding farmers' perception of climatic change and their responses to the perception in 2005. As Japan side has done similar farm survey during last three years, both sides try to analyze the collected data and to integrate the result now. Three master theses using the results of the farm surveys were written by the Japanese students in February 2003, and another master thesis was written in February 2004.

Several methodologies for economic analysis of the interactions among farmers' perception of and their responses to climatic changes, technological changes and policy and institutional changes have been sought in the research projects of Hiroshi Tsujii conducted in Nigeria, Tanzania, Indonesia, and Japan using the farm questionnaire similar to the one used in Turkey. English papers by Tsujii and others have been published and were accepted by international journals.

Early this year Kusadokoro, Maru, Erkan, Gultekin, Tsujii and others have conducted farm survey in the following villages in Adana.

Irrigated Villages

- Geçitli (Yüreğir District; 26Households)
- Gerdan (Seyhan District; 25Households)

Rain-fed Villages

- Yeniyayla and Cihadiye (Yüreğir District; 28Households)
- Boztahta (Aladağ District; 27Households)

Tsujii, Cennet, Erkan, Kenan and others conducted farm survey of about 30 farms in Cesimilesevile(rainfed) and Arikoren(irrigated) in Konya, and we conducted farm survey of about 40 more farms in these villages and in Yaglibayat this year soon.

We shall summarize the results of our analysis of farm surveys data, based mainly on past Kusadokoro and Maru's papers. Based on the information collected from this survey, from earlier surveys of ours, and other sources Kusadokoro concluded as follows:

1. The dominance of cotton and wheat in Adana before 1975 had been changed, and wheat has become the dominant crop by the decline of cotton price and increasing shortage of cotton harvesting labor.
2. Thus in the rain-fed area of Adana wheat and cotton rotation had ceased and wheat monoculture was established and the inherent soil fertility has decreased. This decline has been compensated by modern inputs.
3. After 1990 in the rain-fed area of Adana shortage of grazing grass caused mainly by overgrazing and partially by illegal conversion of the government pasture land to crop land by farmers led wheat and barley rotation be adopted by the farmers there in which barley was fed to animals. This has enforced crop and livestock integration and the wheat and barley rotation contributed to soil fertility maintenance.
4. In the irrigated area in Adana, maize and citrus have become important as the factories for sweetening and citrus juice were established, and new maize varieties were introduced after cotton production had disappeared. Single cropping of wheat , maize, and other field crops became popular and was adopted by large owner farmers because they prefer better soil fertility conservation by half year fallow of the single cropping.
5. The double cropping of wheat and maize has become popular among tenant farmers in the irrigated area of Adana. This system is soil fertility depleting, but tenant farmers are not much concerned about this problem, and preferred this system because it has higher land productivity than the single cropping.

6. Citrus is planted widely in Adana. Since it is a perennial crop, tenant farmers cannot plant this crop as tenancy of irrigated land is annually contracted in Adana.

7. Vegetables, especially watermelon is very popular among tenants and small farmers in the irrigated area of Adana, because tenants can evade continuous cropping problem of vegetables by changing the rented land every year, and the vegetables have the highest land productivity among the crops discussed here.

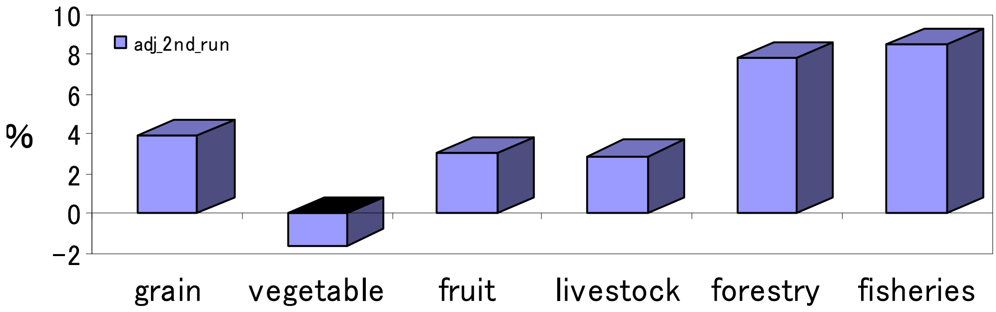

Fig4. Change of productivities between 2070s and current year.

8. Impact of climatic change to agricultural and national economy by the IO Analysis

In this research, the following analyses were carried out during 2004 and 2005.

(1). Generation of Agriculture based IO table in 3 time point (1985, 1990, 1996)

(2). Prediction of time series IO coefficients and output shares by RAS method and the Markov Transition Probability Matrix.

(3). Simulation on the effects of weather change on productivities.

(4). Simulation on the effects of climatic change on productivities.

(5). Simulation on the effects of the EU accession on production amount.

(1) to (3) were done in 2004. More or less good estimation result between the time series IO coefficients and weather variables were obtained.

Then changes in the productivities of major agricultural sectors in Turkey from now to 2070 are calculated using the predicted changes in the May rainfall and temperature in Konya and in May temperature and December rainfall in Adana from now to 2070 in Dr. Kimura's RCM calculatuion. The result of this simulation is shown in the next figure.

This figure shows that the productivity of forestry and fishery sectors increases most, while it of grain, fruits, and livestock sectors increases moderately as global warming will occur. This is may be because the products of last three sectors are produced under more protected condition than it in the forestry sector. The predicted increase of grain sector productivity in this study does not necessarily contradict with Tsujii & Gultekin's prediction in the Econ group study of decrease in wheat and barley production, because productivity and production are different concepts. The predicted decrease in the vegetable sector productivity can not be explained at the present time.

Then the effects of Turkey's accession to the EU are estimated for 2073, by estimating and using the Markov transition probability matrix based on 85 and 96 agricultural IO matrices, and adjusting production amount shares according to the EU's help to Turkey during pre-accession period and fishing quota following the ICCAT. Much sharper increases in the product shares for fruit and vegetable sectors, and much sharper decreases in the product shares for gtrain and livestock sectors comparing with the non-accession scenario were estimated for the period from now to 2073.

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The Features of Agriculture in Adana Prefecture
-From the Result of Farm Survey-

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1. Introduction

The report shows some results of the farm survey conducted in Adana prefecture. The aim is to clear the characteristics of agriculture and farm economy in Adana. One main feature of the agriculture is that the irrigated area and the rain-fed area are geographically separated, because the government constructed large irrigation system around lower Seyhan basin and lower Ceyhan basin. Hence, it is useful for our purpose to compare the agriculture and the farm economy between irrigated and rain-fed area.

We also conducted the same farm survey in Konya prefecture, which is located in Anatolia plateau. In the report, we use the data of Konya to clarify the features of agriculture in Adana.

2. Design of Farm Survey

The questionnaires used in the farm survey essentially consist two parts, although the details of each farm survey are somewhat different. One contains the questions about household characteristics, land tenure and cropping pattern, livestock activity, and sales and cost of agricultural activity. The purpose is to clear the features of agriculture and farm management of Adana and Konya. The other contains the questions related to the farmer's perception about climate change and other long-term changes and the change of farm management in long-term. In this report, we mainly use the first part of questionnaires.

The farm survey has been conducted four times in Adana and three times in Konya. The report uses the last three farm surveys for the analysis. The length of each farm survey was from one month to one and half month. In each farm survey, one or two irrigated villages and one to three rain-fed villages were selected from each prefecture. In Adana, the villages selected for the farm survey belongs to Seyhan, Yuregir, and Ceyhan district except one rain-fed village where belongs to the south part of Aladag district. Then, the data of rain-fed area of Adana does not represent the agriculture and farm economy of mountainous area of Adana, located in the northern part of Seyhan basin. Rather, the data represents the rain-fed agriculture and farm economy of suburbs of Adana city. In Konya, irrigated villages selected for the farm survey belongs to Cumra district, and rain-fed villages belongs to Sarayonu, Altinekin, and Karatay district.

Table 1 Number of villages and sample farmers

		2003		2004		2005	
		Village	Sample	Village	Sample	Village	Sample
Adana	RF	2	51	1	33	3	54
	IR	2	49	2	32	2	51
Konya	RF	2	43	1	32	-	-
	IR	2	41	1	34	-	-

Source: Farm survey, 2003, 2004, 2005 for Adana, 2003, 2004 for Konya.
RF means rain-fed area, and IR means irrigated area.

If possible, the random sampling method is desired to keep the representativeness of data. However, the random sampling method was not feasible because we could not get all household data in the selected villages required to select farmers randomly. Then, we randomly asked farmers at cafeteria of the village and adjusted the number of farmers to fit the farm size distribution of the village at the final stage of farm survey.

3. Land Property

First, we will see the structure of land property of the farmers. Table 2 shows the average land size per household for each ownership form. The total managed land of rain-fed (RF) area of Adana is the smallest in our classification (rain-fed area of Adana, irrigated (IR) area of Adana, rain-fed area of Konya, irrigated area of Konya), and the largest is rain-fed area of Konya.

Table 2 Average managed land size

Unit: da

		Owned	Rent-in	Shared	Other	Total
Adana	RF	50.35	11.18	6.13	0.84	68.51
		(73.49)	(16.33)	(8.95)	(1.23)	(100.00)
	IR	61.96	67.83	16.14	0.00	145.93
		(42.45)	(46.48)	(11.06)	(0.00)	(100.00)
Konya	RF	214.97	58.17	18.71	0.83	292.69
		(73.45)	(19.88)	(6.39)	(0.28)	(100.00)
	IR	137.91	54.37	2.97	1.83	197.08
		(69.97)	(27.59)	(1.51)	(0.93)	(100.00)

Source: Farm survey, 2003, 2004, 2005 for Adana, 2003, 2004 for Konya.
Figures in parentheses are the proportion of each tenure to the total land.

In both Adana and Konya, land rent market in irrigated area is more developed than that in rain-fed area. Especially, in irrigated area of Adana, the proportion of rent-in land to the total managed land is bigger than that of owned land. The difference between irrigated area and rain-fed area seems to be attributed to the difference of the planted crops (the detail will be discussed later). However, the development of land market in irrigated area of Adana is related to the historical aspect. The large landlord system had been prevailed in the area until 1950s. Some few landowners managed their land using hired labors. However, with the pervasion of agricultural machinery, the landlord system could not be maintained. The landowners rented-out their land to their hired labors and they moved to the city.

The typical land contract in both Adana and Konya is fixed rent contract and not share rent contract. Share rant contract only exists among relatives who share the land property. In general, the farmers using share contract are small farmers because the traditional succession system, that is the division of succession, continues to be exist in part. Then, share contract is utilized to put together the segmented plot to the person who manages the farms.

4. Choice of Cropping Pattern

Table 3 shows the cropping pattern that was expressed by the proportion of each crop to the managed land. The far right cell shows utilization rate of the managed land. Then, irrigated area of Adana utilizes intensively the agricultural land by the practice of double cropping, that the first crop is wheat, and the typical second crop is maize, groundnut, soybean, and more. In contrast, rain-fed area of Konya utilizes only 64% of the managed land. The area practices traditional fallowing system for keeping the soil fertility. But, rain-fed area of Adana does not conduct the fallowing system. The main reason is that the farmers need to utilize their agricultural land intensively for getting cash from agriculture because of the smallness of the managed land. However, it must be noted that the use of chemical fertilizer enabled the intensive use of the land in rain-fed area of Adana (this topic is discussed later).

The most prevailed crop in Adana and Konya is wheat except irrigated area of Adana. In rain-fed area of Adana, the other main crops are cotton and barley. Some farmers who have access to the irrigated land plant watermelon and other cash crops. In irrigated area of Adana, the most prevailed crop is maize, and the other main crops are wheat, tree crops (citrus), cotton, vegetables and watermelon. In rain-fed area of Konya, the other main crop is barley. In irrigated area of Konya, the other main crops are sugar beet, other field crops (dried bean), and maize.

Although wheat is prevailing in all areas, the role of wheat production on the farm economy is different between each area. In rain-fed area of Adana, the farmers secure the products for self-sufficiency, and after that, sell the surplus products. Barley is planted for feeding livestock, and not for eating and selling. The livestock farmers generally graze animals on the plot before barley puts forth ears. In contrast, the farmers in rain-fed area of Konya generally grow wheat for getting cash and not for eating. Barley is planted for eating in the area, although the residual of barley is used for feeding animals. The difference stems from the agronomic condition, market condition, and the volume of glazing land. The farmers in Adana plant spring wheat and the farmers in Konya plant winter wheat. The productivity of wheat is higher in Adana than that in Konya (Please see table 4). Then, the farmers in Konya give more priority to sell the products of wheat than to eat them. Grazing land in rain-fed area has decreased since 1960s and the farmers confront the lack of green feed. Then, the farmers in rain-fed area of Adana need to plant barley for feeding their livestock.

In irrigated area of both prefectures, the profitability of wheat is low compared to the other crops. Then, the economic incentive for planting wheat may be also low for the farmers in irrigated area. There are two main reasons that the farmers in irrigated area of Adana continue to plant wheat. One is that wheat is planted during winter season as the first crop of double cropping system with maize, groundnuts, and soybeans, which are planted during summer season. There is no choice other than wheat that can be planted in winter season. Second, because the double cropping system uses the land intensively, it is desired to rest the land every two years. In general, the farmers who conduct the double cropping system choose to plant only wheat to rest the plot during summer season after the year they operated the double cropping system. Third, farmers do not need great deal of labor force for the cultivation and the labor productivity of wheat is the highest in the available crops. Then, the farmers who confront the lack of labor force can easily choose to plant wheat. In irrigated area of Konya, sugar beet is the most profitable crop and the farmers contract with the public company buying the all products of sugar beet in the region. The contract forces the farmers to comply with the rotation system that restricts the planted area of sugar beet. The purpose of the contract is to stabilize the supply and price of sugar, and to keep the soil fertility of land. The farmers can plant sugar beet only once in every four years under the contract. In general, they rotate crops with wheat and sugar beet, since the alternative crops are limited in Konya.

In irrigated area of Adana, the high value crops are citrus and watermelon (please see table 4). However, the ratio of planting these crops is not so high. First, citrus and watermelon need great deal of labor force for the cultivation, and this results the low labor productivity of these crops despite the high land productivity. It is impossible to plant these crops for the farmers who confront the lack of owned labor force and does not have enough financial resource for hiring agricultural labor. In this area, the wage rate of agricultural labor is soaring because migrant labor from east part of Turkey is decreasing despite the high demand[1]. Second, the citrus farmers need to secure the land property in the long term, since citrus is perennial crop. The tenant farmers cannot plant citrus even if they want. As mentioned in section 2, there are many tenant farmers in irrigated area of Adana. This characteristic of land distribution is the main constraint on the advancement of citrus. Third, watermelon and some vegetables have severe replant failure. Especially, watermelon can be planted only once in every five years on the same plot. The farmers need to change the plot every year for continuing to plant watermelon. This is the main constraint for planting watermelon, and also the main reason that watermelon is the main cash crop for the tenant farmers.

The most prevailed crop in irrigated area of Adana is maize. The land productivity is middle-level in the available crops. However, as mentioned above, the area allocable to the more profitable crops than maize (citrus and water melon) is limited. Since maize does not need so much amount of labor force for the production, most of the farmers can plant maize with relatively little effort compared to other more profitable crops. Maize may be the best balanced crops in the alterative crops. Also, the product price of maize is relatively stable compared to the price of citrus and watermelon. Then, maize is the attractive crop for the farmers who want to avoid the risk. Furthermore, as mentioned above, maize can be planted as a second crop after wheat. The farmers can get cash income twice in a cropping season if they conduct the double cropping system, although the profitability of second maize is somewhat lower than that of first maize. Land-owing farmers generally are not willing to operate the double cropping system on the same plot because of the incentive land use. However, the tenant farmers have no any intensive to rest the rented plot, and also they can change their land every year if they need. The tenant farmers generally desire to get cash income more frequently from their rented land, and these farmers are willing to operate the double cropping system continuously.

[1] Recently, there is a movement that daily workers in the city emigrate to the irrigated area for getting jobs.

Table 3 Cropping pattern

%

		Wheat	Barley	Maize	Cotton	Sugar beet	Other field crops	Water melon	Vegetables	Tree crops	Total
Adana	RF	75.26	5.67	0.00	6.82	0.00	7.22	2.84	0.92	0.97	99.71
	IR	35.07	0.04	56.67	6.02	0.00	8.29	2.51	4.85	10.97	124.41
Konya	RF	39.68	18.12	0.00	0.00	0.11	5.84	0.00	0.00	0.35	64.10
	IR	50.04	4.36	12.16	0.00	12.59	18.21	0.52	0.70	0.03	98.62

Source: Farm survey, 2003, 2004, 2005 for Adana, 2003, 2004 for Konya

Table 4 The productivity of representative crops

Land Productivity[1] YTL/da

		Wheat[3]	Barley	Maize	Cotton	Sugar beet	Watermelon	Tree crops
Adana	RF	66.77	16.24	-	53.97	-	-	-
	IR	92.41	-	176.05	154.83	-	210.23	269.59
Konya	RF	40.38	80.94	-	-	-	-	-
	IR	103.05	70.63	139.22	-	313.65	-	-

Labor Productivity[2] YTL/day

		Wheat	Barley	Maize	Cotton	Sugar beet	Watermelon	Tree crops
Adana	RF	228.32	105.37	-	22.48	-	-	-
	IR	411.32	-	229.97	59.04	-	111.72	46.53
Konya	RF	105.54	186.58	-	-	-	-	-
	IR	227.91	167.85	207.86	-	105.44	-	-

Source: Farm survey, 2004 and 2005 for Adana, 2004 for Konya.

1) Land productivity = (Gross value of products - Cost of Seed, Fertilizer, Pesticide, Manure, and Water) / Land

2) Labor productivity = (Gross value of products - Cost of Seed, Fertilizer, Pesticide, Manure, and Water) / Labor

3) 2004 is the lean year for wheat in Adana because of the severe drought in March. Then the data of wheat in 2004 was not used to calculate productivity.

5. Production Method and Farm Management

The aim of this section is to clear the difference of production method and farm management in each area. For this purpose, we compare the input use for wheat production in each area. Although, because of the difference of agronomic condition and variety of wheat, the precise comparison of the production method cannot be allowed only by comparing input use for wheat production. However, it will disclose some features of the production method and farm management of each area.

Table 5 shows planted area, yield, and input use for wheat production. Each area has almost same planted area. In both of Adana and Konya prefecture, the yield of irrigated area is higher than that of rain-fed area. Also, in both of rain-fed and irrigated area, the yield is higher in Adana than Konya.

Table 5 Input use for wheat production

		Area	Yield	Input use per area				Input use per products			
				Fertilizer	Pesticide	Manure	Labor	Fertilizer	Pesticide	Manure	Labor
		da	kg/da	kg/da	YTL/da	kg/da	day/da	kg/100kg	YTL/100kg	kg/100kg	day/100kg
Adana	RF	60.51	347.28	67.59	3.940	81.98	0.495	20.95	1.195	21.26	0.153
	IR	60.91	426.60	51.93	3.912	72.73	0.361	14.62	1.003	18.18	0.116
Konya	RF	65.57	190.66	20.26	0.747	170.02	0.696	12.33	0.633	97.42	0.521
	IR	67.60	401.96	41.78	1.239	11.74	0.793	10.76	0.350	2.91	0.219

Source: Farm survey 2005 for Adana, 2004 for Konya

Input use per planted area shows that the farmers in Adana use more chemicals (fertilizer and pesticide) and less labor than the farmers in Konya. Then, it can be said that the farmers in Adana alternate chemical inputs for labor input and the farmers in Konya are opposite. Input use per products can be interpreted as what amount of each input is needed to get a certain amount of products. The farmers in rain-fed area of Adana need to use the most fertilizer in all areas to get 100kg of wheat products. In contrast, the farmers in rain-fed area of Konya use much amount of manure and labor force to get 100kg of wheat. This is adequate result because more labor input is needed for inputting manure than for chemical fertilizer.

Generally, farmers decide the amount of each input depending on the technology to which they have access and the price of product and each input. The relative price of labor to chemical fertilizer is 49.8 in rain-fed area of Adana, 54.6 in irrigated area of Adana, 44.5 in rain-fed area of Konya, and 47.4 in irrigated area of Konya. The relative price of labor in Adana is higher than that in Konya. Then, if we assume that both regions have same technology for wheat production, it is rational for the farmers in Adana to use less labor force and more chemical input compared to the farmers in Konya[2]. The high price of labor force in irrigated area of Adana may be the main reason that the farmers in the area save the labor force for wheat production. However, it seems there is another reason that the farmers in rain-fed area of Adana use much amount of chemicals.

As mentioned in section 3, the utilization rate of land in rain-fed area of Adana is nearly 100%, while that in rain-fed area of Konya is 64%. This may show that the farmers in rain-fed area of Adana utilize their land too intensively from the aspect of sustainable management. Then, they may be required to use much amount of fertilizer to get and keep the yield of wheat.

In rain-fed area of Adana, the crop rotation system of wheat and cotton had been prevailed until 1980s. The main reasons of the decline of this crop rotation were the increase of labor force for picking up cotton and the incidence of harmful insect. Furthermore, there was another reason for that. The productivity of cotton in rain-fed area was not so high even at that time unlike with irrigated area. In fact, the farmers needed to grow cotton to keep the yield of wheat. The diffusion of chemical fertilizer and new variety of wheat allowed the farmers to be released from the need of planting cotton. Recently, planting of sunflower is increasing in rain-fed area of Adana, because an oil-processing company constructed in the area buys all the products at high price. However, some farmers adopt the crop rotation system of wheat and sunflower for the purpose of keeping the yield of wheat. Both the past and the recent crop rotation support the view that the present land use in rain-fed area of Adana is not sustainable and the farmers need to use much fertilizer to keep the yield of wheat.

6. Animal Husbandry

In this section, we check animal husbandry of each area. Table 6 shows the number of livestock-keeping households and the ratio of those to all sample households by each livestock, and Table 7 does the number of each livestock. The farmers in rain-fed area of Adana keep cattle mainly. Goat is kept only in mountainous area. The farmers in irrigated area of Adana generally do not keep livestock except cattle for the purpose of stock and self-consumption of milk.

The farmers in Konya keep cattle and sheep. Especially in rain-fed area of Konya, nearly half of farmers keep sheep, and average number of sheep per sheep-keeping household is fairly large. This is because grazing animal is still prosperous in Konya. The ratio of livestock-keeping households in rain-fed area is lower than that in irrigated area in Konya. The reason for this is that farmers in rain-fed area in Konya tend to live in central city to get jobs in winter.

In both Adana and Konya, farmers in irrigated area keep larger number of cattle and smaller number of sheep and goat in average than those in rain-fed area. Sheep and goat need more grazing and therefore more labor force to keep than cattle. Hence, farmers in irrigated area tend to choose cattle which save labor force and land for grazing.

[2] It is needed to estimate production function of each region and test whether there is no structural difference in technology among each region for concluding the rationality of input use.

This is because of lower productivity of livestock production compared to crop production. Table 8 shows the labor productivity of animal husbandry. From this table and Table 4, it is observed that the labor productivity of animal husbandry is much lower than that of crop production.

With the introduction of irrigation since 1960s, land productivity of crop production increased. After 1980s, farmers started to cultivate various commercial crops that can achieve fairly high land productivity. As a result, farmers in irrigated area concentrate their management resources on crop production, and they stop to keep livestock or shift livestock to keep from sheep and goat to cattle for the sake of saving capital and labor force.

To see the detail in labor productivity, that in rain-fed area of Adana shows the best productivity. In rain-fed villages, especially near the city center of Adana, some of farmers managed intensive livestock farming. About Konya, labor productivity in rain-fed area is lower than that of irrigated area. This is because some of farmers in rain-fed area graze a lot of livestock, mainly sheep and goat, by themselves.

Table 6 Livestock keeping ratio

Unit: Household

		Cattle (%)	Sheep (%)	Goat (%)	Any livestock[1)] (%)
Adana	RF	74 (60.16)	21 (17.07)	5 (4.07)	88 (71.54)
	IR	27 (23.08)	3 (2.56)	1 (0.85)	27 (23.08)
	Total	101 (42.08)	24 (10.00)	6 (2.50)	115 (47.92)
Konya	RF	27 (36.00)	33 (44.00)	6 (8.00)	45 (60.00)
	IR	39 (52.00)	27 (36.00)	5 (6.67)	55 (73.33)
	Total	66 (44.00)	60 (40.00)	11 (7.33)	100 (66.67)

Source: Farm survey, 2003, 2004 and 2005 for Adana, 2003 and 2004 for Konya.
Figures in parentheses are the proportion to the numbers of sample households.
1) 'Any livestock' means the number of households that keep livestock.

Table 7 Number of livestock

Unit: Head

			Cattle[1)]	Sheep	Goat
Adana	RF	Number	313	524	201
		Average[2)] (CV[3)])	4.23 (0.65)	24.95 (0.69)	40.20 (0.65)
	IR	Number	152	33	20
		Average[2)] (CV[3)])	5.61 (1.11)	11.00 (1.50)	20.00 (-)
Konya	RF	Number	110	5245	96
		Average[2)] (CV[3)])	4.06 (0.88)	158.94 (1.04)	16.00 (0.52)
	IR	Number	265	1115	25
		Average[2)] (CV[3)])	6.78 (1.10)	41.30 (1.45)	5.00 (0.92)

Source: Farm survey, 2003, 2004 and 2005 for Adana, 2003 and 2004 for Konya.
1) Cattle number is adjusted according to feeding standard.
2) Average = Number of each livestock / Number of households that keep each livestock
3) CV shows coefficient of variation.

Table 8 Productivity of animal husbandry

Unit: YTL/day

		Labor productivity[1)] (CV[2)])
Adana	RF	11.318 (1.811)
	IR	5.570 (6.282)
Konya	RF	6.727 (5.057)
	IR	8.890 (1.903)

Source: Farm survey, 2004, 2005 for Adana, 2004 for Konya.
1) Labor productivity: See Note 2) in Table 4.
2) CV shows coefficient of variation.

7. Cash Income

In this section, we will see the structure of household income in each area. Table 9 shows the cash income from each activity (crop, livestock, off-farm, and pension). Here, the self-consumption of products for eating and feeding animals is not included in the cash income from crop and livestock activities, and then, it is possible that the calculation of cash income results in negative value[3].

The cash income from crop production in irrigated area is much higher than that in rain-fed area, even if we consider that the farmers in rain-fed area consume part of the products by themselves. The farmers in rain-fed area of Konya lose their cash by growing crops. The crop production of rain-fed area of Konya is not sustainable from the aspect of cash income though they are trying to keep soil fertility with the extensive use of land and heavy use of manure[4].

The cash income from livestock activity in rain-fed area is higher than that in irrigated area. When we see the average income, the profitability of livestock in rain-fed area of Adana is higher than that in rain-fed area of Konya. This reflects the difference in the management of livestock activity. In general, the management size of livestock activity is smaller in Adana than in Konya. However, a few farmers in Adana manage intensive livestock farming, especially in villages near the central city. These

[3] When we see the difference of productivity in each area, it is desired to concern the amount and value of self-consumption. However, calculating the value of self-consumption is difficult because the rain-fed area integrates crop activity and livestock activity. Quantifying the value of self-consumption under crop and livestock integration may require the estimation of multi-output cost function.

[4] From another aspect, the farmers may choose not to use their land intensively because they cannot get cash income from the crop production.

farmers achieve high profitability from livestock activity.

In rain-fed area of both prefectures, the main cash income sources of household are other income sources (off-farm and pension). In rain-fed area of Adana, nearly 60% of households engage in off-farm activity, but the rate of household getting pension is not high. As mentioned above, the selected villages in Adana are suburbs of the central city. Then, the young person in the villages can get a job in the city without migration to the city. Also, they have access to enough agricultural labor market in irrigated area during summer season because summer is agricultural off-season in rain-fed area. However, in the village belongs to Aladag district, depopulation is getting more strained because the village is far from the city and irrigated area.

In contradiction to the rain-fed area of Adana, only 32% of households in rain-fed area of Konya engage in off-farm activity, but more than 40% of household gets pension. The selected villages are located in mountain part and far from the central city. Then, the young members of household have to migrate to the city center for getting non-agricultural job. The pension system of Turkey is the voluntary reserve system and not the compulsory participation one. The result may show that, in rain-fed area of Konya, there are many farmers who feel the necessity to pay reserve for getting pension because of the low profitability of agriculture and lack of the opportunity for off-farm activity.

Table 9 Cash income from each activity

YTL

			Crop	Livestock	Agriculture Total	Off-farm	Pension	Other Total	Total Income
Adana	RF	Average	899.638	589.687	1,489.326	3,363.609	982.855	4,346.464	5,835.790
		CV[1]	0.532	0.450	0.345	0.149	0.213	0.121	0.134
	IR	Average	15,105.614	-222.086	14,883.528	2,781.571	1,098.812	3,880.383	18,763.911
		CV	0.153	-1.211	0.158	0.250	0.215	0.182	0.136
	Total	Average	7,781.645	196.428	7,978.073	3,081.644	1,039.030	4,120.673	12,098.746
		CV	0.159	0.969	0.156	0.137	0.151	0.106	0.113
Konya	RF	Average	-332.186	218.246	-113.940	1,329.755	1,582.501	2,912.256	2,798.316
		CV	-1.345	1.445	-4.832	0.308	0.168	0.187	0.272
	IR	Average	10,633.189	-118.665	10,514.524	1,017.892	690.602	1,708.494	12,223.018
		CV	0.141	-4.544	0.171	0.295	0.264	0.200	0.151
	Total	Average	5,321.836	44.526	5,366.362	1,168.950	1,122.616	2,291.566	7,657.928
		CV	0.176	7.106	0.199	0.215	0.146	0.140	0.144

Source: Farm survey in 2003, 2004, 2005 for Adana, 2003, 2004 for Konya.
1) CV shows coefficient of variation.

Table 10 The rate of household engaging to the other income sources

		Off-farm	Pension	Total
Adana	RF	59.5%	20.7%	69.0%
	IR	40.4%	21.1%	56.0%
Konya	RF	31.7%	41.3%	60.3%
	IR	25.8%	19.7%	42.4%

Source: Farm survey in 2003, 2004, 2005 for Adana 2003, 2004 for Konya

8. Conclusion

We summarize the features of agriculture and farm economy in Adana.

Rain-fed area of Adana: Monoculture of wheat has been formed since the decline of the crop rotation system of wheat and cotton. Wheat is only a product that farmers can get cash income though the income is not enough. Because of the small farm size, the farmers need to intensively utilize their land. The monoculture of wheat and the intensive land utilization cause heavy usage of chemical fertilizer and pesticide for wheat production in the area though the amount of input may be rational. Some farmers feel that the monoculture depending on chemicals is not sustainable. Then, the way that enables the farmers to cast off the monoculture of wheat is needed. The crop rotation of wheat and sunflower may be favoring because the demand for oil in Turkey is expected to increase, at least for next several years. However, the farmers need off-farm income to keep their livelihoods. Unless some crops planted during summer season are introduced in the area, that means no construction of irrigation system, the crop production is not able to keep the livelihoods of household and the rural economy.

Irrigated area of Adana: The farmers enjoy the highest productivity of crop production in the surveyed area and have wide array of alternative crops. Also, unlike the irrigated area of Konya, there are no any institutional or political regulations that restrict the choice of crop to the farmers. However, there are two main factors that constrain the farmers' choice of crop. First is labor constraint, which comes from high labor requirement of the cash crops (citrus and watermelon) and decrease of the labor supply from east part of Turkey. Second is the heterogeneity of land distribution that partly stems from the historical landlord system. Because of these constraints, citrus and watermelon are not planted so much despite the high land productivity. Under present circumstance, maize and other field crops (mainly, groundnut and soybean) sustain the agriculture because the farmers can easily plant and get decent cash income. The existence of profitable field crops is a necessary condition for keeping the present population of independent farmers. The significant decrease of profitability of maize and other field crops without any relaxation of labor and land constraints may make some marginal farmers, especially small tenant farmers to exit from farm management. It depends on the social and political choice whether that movement is preferable for Adana and Turkey.

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An econometric and agro-climatological study of the impacts of global warming and prices to production of rain-fed wheat and barley in Konya and Adana.

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1. Main conclusions of an econometric and agro-climatological study of the interactions among production of wheat and barley, weather variables, prices of wheat and other major crops, and climatic change in Konya and Adana

Research methodology of the Socio-economic sub-group of ICCAP follows the two methodological memos by H. Tsujii written in 2003 and 2004(Tsujii, H., 2003 & Tsujii, H., 2004). An English interim-report of the socio-economic team was published and distributed in February 2005 (Tsujii, H. ed., 2005).

In the rain-fed areas in Adana and Konya, an econometric study by Tsujii and Ufuk has found that the global warming under the case of no Turkey accession to the EU in 2070 will increase wheat and barley yields by 13% and 6% respectively, while it will decrease these yields in Konya by 18% and 17% respectively. This difference is probably caused by the fact that 2070 average temperature in Konya will increase by 21% of current climatic temperature, while the same temperature in Adana will increase by only 14%.

The impacts of global warming to area sown of wheat and barley in Adana and Konya in the case of no EU accession are all small negative percentages. Thus the total production of Adana wheat will be increased by 10%, while the total production of Adana barley will be reduced by 2% under global warming. Wheat and barley yields in Konya will be decreased by 18% and 17% respectively under global warming in no EU accession case. The area sown of wheat and barley will decrease a little under global warming in 2070. Consequently the total wheat and barley production will decrease by large amounts of 18% and 18%. This may imply a future decline of food security or wheat shortage in Turkey as Konya is a large and representative wheat producing area in Turkey.

These reductions of wheat and barley production caused by global warming can be intensified by the long run soil degradation perceived by most of the farmers surveyed in our farm surveys in Adana and Konya. Most of the surveyed farmers in Cesimilseville, Konya have told us that the inherent soil fertility of rain-fed wheat land has been degrading because of increasing chemical fertilizer application so that fallow frequency has increased form once in three years to every other year. The surveyed farmers told us and have shown us that the grass of vast national grazing land has deteriorated to the dominance of thorny grass because of overgrazing, and animals can not eat these thorny grass.

Many farm surveys, the analyses of the data collected, and some methodologies for economic analysis of the interactions among farmers' perception of and their responses to climatic changes, technological changes and policy and institutional changes have been conducted in the research projects of Hiroshi Tsujii conducted in Nigeria, Tanzania, Indonesia, and Japan using the farm questionnaires similar to the one used in Turkey. About 10 English papers by Tsujii and others have been published by and have been accepted by international journals. (Chianu and Tsujii, 2006, Herianto and Tsujii, 2003)

2. The econometric and agro-climatological study of the impacts of global warming and price changes to wheat and barley in Konya and Adana.

This Tsujii and Ufuk econometric analysis, first estimated historical yield and area sown functions of wheat and barley in Adana and Konya, incorporating the effects of very high temperature, drought, soil moisture, and output prices. Secondly, combining the best estimated functions with the model bias adjusted projected monthly rainfall and temperature by the RCM of Dr. Kimura, and atmospheric CO2 concentration effects of global warming, yield, area sown, and total production of wheat and barley in Adana and Konya were predicted for 2070.

2.1 A result of the econometric analysis of the effects of very high temperature, drought, soil moisture, and output prices to wheat and barley production

This study follows the methodology used in the past econometric studies of H. Tsujii on the similar topic conducted for Japan and Thailand. Here we show in the following figures the results of our econometric study of wheat and barley for Adana, and Konya, and the impacts of global warming to the production of these crops in Adana and Konya. The period of analysis is for 1951 to 1998, and the linear function is used for the analysis. The variable description and for the wheat yield function for Adana is shown in Table 1 just below.

Table 1. Description of the Variables for the Wheat Yield Function for Adana

NPC	:	Nominal Price Change
DDMA(t)20	:	Drought Effect in May in year (t) (1 if rainfall <= 20%, 0, otherwise)
DHDAA(t)16.2	:	Heat damage in April in year (t) (1 if temperature >= 16.2 ^{o}C, 0, otherwise)
DHDMA(t)23.5	:	Heat damage in May in year (t) (1 if temperature >= 23.5 ^{o}C, 0, otherwise)

The estimated Adana wheat yield function is shown in the following table.

Table 2. The Estimated Wheat Yield Function for Adana

	R^2= 0.279	AR^2= 0.205	DW= 0.808
Variables	**Coefficients**	**t-value**	**Significance**
CONSTANT	2624.62	6.93	0.00
NPC	10.29	3.23	0.00
DDMA(t)20	-255.84	-1.61	0.26
DHDAA(t)16.2	-215.36	-0.63	0.53
DHDMA(t)23.5	-580.26	-0.77	0.44

The variable description and the estimated wheat area sown function for Adana are shown in Table 3 and 4.

Table 3. Description of the Variables for Wheat Area Sown in Adana

NPC(t-1)/(t-2)	Nominal farm gate price Change from year (t-1) to year (t-2)
CRSEP(t-1)OCT(t-1)	Cumulative monthly rainfall from September in year (t-1) to October in year (t-1)

Table 4 The Estimated Wheat Area Sown Function for Adana

	R^2= 0.467	AR^2= 0.441	DW= 1.058
Variables	**Coefficient**	**t-value**	**Significant**
CONSTANT	199932.10	10.19	0.00
NPC(t-1)/(t-2)	1531.91	5.24	0.00
CRSEP(t-1)OCT(t-1)	535.42	2.12	0.04

The variable description and estimated functions of barley yield and area sown for Adana are presented in Table 5-8 below.

Table 5 Description of the Variables for the Barley Yield Function for Adana

NPC	:	Nominal Price Change
DDMA(t)35	:	Drought Effect in March in year (t) (1 if rainfall <= 35%, 0, otherwise)
DHDAA(t)18.9	:	Heat damage in April in year (t) (1 if temperature >= 18.9 ^{o}C, 0, otherwise)
DHDMA(t)23.4	:	Heat damage in May in year (t) (1 if temperature >= 23.4 ^{o}C, 0, otherwise)

Table 6 The Estimated Barley Yield Function for Adana

	R^2= 0.190	AR^2= 0.107	DW= 1.239
Variables	**Coefficient**	**t-value**	**Significant**
CONSTANT	2106.94	28.94	0.00
NPC	2.30	2.06	0.05
DDMA(t)35	-51.29	-0.47	0.64
DHDAA(t)18.9	-83.83	-0.48	0.64
DHDMA(t)23.4	-420.48	-1.45	0.15

Table 7 Description of the Variables for Barley Area Sown in Adana

RPBARLEY(t-1)	Real Farm Gate Price for Barley deflated by Whole Sale Price Index, 1938=100
CRJAN(t-1)OCT(t-1)	Cumulative monthly rainfall from January in year (t-1) to October in year (t-1)

Table 8 The Estimated Barley Area Sown Function for Adana

	R^2= 0.208	AR^2= 0.170	DW= 0.347
Variables	**Coefficient**	**t-value**	**Significant**
CONSTANT	-9912.30	-0.84	0.41
RPBARLEY(t-1)	0.13	3.18	0.00
CRJAN(t-1)OCT(t-1)	15.44	1.11	0.28

The estimated results of Konya wheat and barley yild and aera sown functions are shown in Table 9-16.

Table 9 Description of the Variables for the Wheat Yield Function for Konya

NPC	:	Nominal Price Change
CROCT(t-1)MAY(t)	:	Cumulative monthly rainfall from October in year (t-1) to May in year (t)
DDAK(t)20	:	Drought Effect in April in year (t) (1 if rainfall <= 20%, 0, otherwise)
DHDAK(t)12.8	:	Heat damage in April in year (t) (1 if temperature >= 12.8 ^{o}C, 0, otherwise)
DHDMK(t)16.3	:	Heat damage in May in year (t) (1 if temperature >= 16.3 ^{o}C, 0, otherwise)
DHDJK(t)20.7	:	Heat damage in June in year (t) (1 if temperature >= 20.7 ^{o}C, 0, otherwise)

Table 10 The Estimated Wheat Yield Function for Konya

	R^2= 0.579	AR^2= 0.511	DW= 1.120
Variables	**Coefficient**	**t-value**	**Significant**
CONSTANT	1400.67	4.98	0.00
NPC	5.07	3.33	0.00
CROCT(t-1)MAY(t)	1.32	1.61	0.12
DDAK(t)20	-318.90	-2.62	0.01
DHDAK(t)12.8	-205.46	-1.48	0.15
DHDMK(t)16.3	-171.30	-1.59	0.12
DHDJK(t)20.7	-267.22	-2.13	0.04

Table 11 Description of the Variables for Wheat Area Sown in Konya

RPWB(t-1)	Relative farm gate price between wheat and barley in year (t-1)
CRJAN(t-1)FEB(t-1)	Cumulative monthly rainfall from January in year (t-1) to February in year (t-1)

Table 12 The Estimated Wheat Area Sown Function for Konya

	R^2= 0.144	AR^2= 0.102	DW= 0.464
Variables	**Coefficient**	**t-value**	**Significant**
CONSTANT	701373.66	5.60	0.00
RPWB(t-1)	206883.04	2.01	0.05
CRJAN(t-1)FEB(t-1)	543.83	1.31	0.20

Table 13. Description of the Variables for Barley Yield Function for Konya

NPC	Nominal Price Change
CROCT(t-1)JUN(t)	Cumulative monthly rainfall from October in year (t-1) to June in year (t)
DDAK(t)15	Dummy for drought in April, year (t) (1 if rainfall <= 15%, 0, otherwise)
DHDAK(t)13.7	Dummy for heat damage in April, year (t) (1 if temperature >= 13.7 ^{o}C, 0, otherwise)
DHDMK(t)16.3	Dummy for heat damage in May, year (t) (1 if temperature >= 16.3 ^{o}C, 0, otherwise)

Table 14. The Estimated Barley Yield function for Konya

	R^2= 0.595	AR^2= 0.542	DW= 1.349
Variables	**Coefficient**	**t-value**	**Significant**
CONSTANT	1415.21	4.14	0.00
NPC	4.91	3.67	0.00
CROCT(t-1)JUN(t)	2.13	2.22	0.03
DDAK(t)15	-408.93	-2.81	0.01
DHDAK(t)13.7	-312.07	-1.11	0.27
DHDMK(t)16.3	-284.87	-2.32	0.03

Table 15. Description of the Variables for Barley Area Sown in Konya

RPBW(t-1)	Relative farm gate price between barley and wheat in year (t-1)
CRJAN(t-1)APR(t-1)	Cumulative monthly rainfall from January in year (t-1) to April in year (t-1)

Table 16. The Estimated Function for Barley Area Sown in Konya

	R^2= 0.117	AR^2= 0.074	DW= 0.279
Variables	**Coefficient**	**t-value**	**Significant**
CONSTANT	199257.53	1.60	0.12
RPBW(t-1)	305464.40	2.30	0.03
CRJAN(t-1)APR(t-1)	245.75	0.66	0.52

The global warming effects to yield (a+c), area sown (b), and total production of Adana wheat and barley (a+b+c) are shown in the following Tables for no EU accession case.

WHEAT ADANA YIELD	Coeff.	Var. Value	Yield 2070's	Estimated Yield 1993-2002	a (%)	c (%)	a+c (%)
CONSTANT	2624,62	1,00	2624,62				
Nominal price change	10,29	73,20	753,23				
DDmay(t)%20	-255,84	0,00	0,00				
DHDApril(t)162	-215,36	1,00	-215,36				
DHDMay(t)235	-580,26	1,00	-580,26				
			2582,23	**3162,49**	**-18,35**	**31**	**12,65**

WHEAT ADANA AREA SOWN	Coeff.	Var. Value	Area Sown 2070's	Estimated Area Sown 1993-2002	b (%)
CONSTANT	199932,10	1,00	199932,10		
Nominal price change	1531,91	73,20	112135,81		
CRSEP(t-1)OCT(t-1)	535,42	43,31	23189,04		
			335256,95	**345713,70**	**-3,02**

	a+b+c (%)
The Total Impact to Adana wheat production	**9,63**

Notes:

1. O=Y*AS, Of=(1+a)*(1+c)*Y*(1+b)*AS=(1+c)*(1+(a+b)+a*b)*Y*AS≒(1+a+b+c)*Y*AS

Def.: Of=future producction. a=a rate of change in yield (Y) caused by weather changes of GW. b=a rate of change in area sown (AS) caused by GW. c=a rate of change in Y caused by CO2 concentration.

2. The values of real and relative prices and of nominal price change to be used for 2070's projection under the condition of no EU accsession are the averages of these corresponding price variables for the period of 1993 - 2002.

BARLEY ADANA YIELD	Coeff.	Var. Value	Yield 2070's	Estimated Yield 1993-2002	a (%)	c (%)	a+c (%)
CONSTANT	2106,94	1,00	2106,94				
Nominal price change	2,30	78,90	181,47				
DDMarch(t)35	-51,29	1,00	-51,29				
DHDApril(t)18,9	-83,83	1,00	-83,83				
DHDMay(t)23,4	-420,48	1,00	-420,48				
			1732,81	**2282,61**	**-24,09**	**30**	**5,91**

BARLEY ADANA AREA SOWN	Coeff.	Var. Value	Area Sown 2070's	Estimated Area Sown 1993-2002	b (%)
CONSTANT	-9912,30	1,00	-9912,30		
Real PriceBARLEY(t-1)	0,13	234646,10	30503,99		
CRJAN(t-1)OCT(t-1)	15,44	316,94	4893,56		
			25485,25	**27607,32**	**-7,69**

	a+b+c (%)
The Total Impact to Adana barley production	- **1,8**

The global warming effects to yield (a+c) and area sown (b) of Konya wheat and barley are shown in the following Tables.

WHEAT KONYA YIELD	Coeff.	Var. Value	Yield 2070's	Estimated Yield 1993-2002	a (%)	c (%)	a+c (%)
CONSTANT	1400,67	1,00	1400,67				
Nominal price change	5,07	73,20	371,27				
CROCT(t-1)MAY(t)	1,32	218,65	287,52				
DDApril(t) %20	-318,90	1,00	-318,90				
DHDApril(t)12,8	-205,46	1,00	-205,46				
DHDMay(t)16,3	-171,30	1,00	-171,30				
DHDJune(t)20,7	-267,22	1,00	-267,22				
			1096,59	**2130,70**	**-48,53**	**31**	**-17,53**

WHEAT KONYA AREA SOWN	Coeff.	Var. Value	Area Sown 2070's	Estimated Area Sown 1993-2002	b (%)
CONSTANT	701373,66	1,00	701373,66		
relativePriceWB(t-1)	206883,04	1,20	248259,65		
CRJAN(t-1)FEB(t-1)	543,83	50,99	27729,79		
			977363,10	**982284,74**	**-0,50**

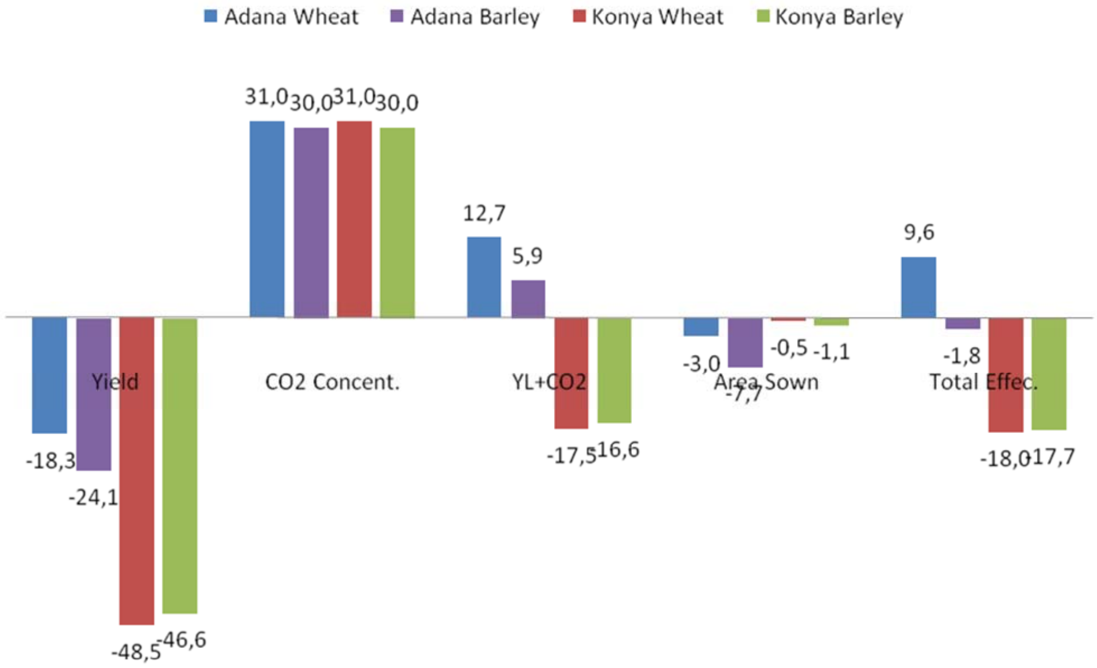
	a+b+c (%)
The Total Impact to Konya wheat production	**- 18,03**

BARLEY KONYA YIELD	Coeff.	Var. Value	Yield 2070's	Estimated Yield 1993-2002	a (%)	c (%)	a+c (%)
CONSTANT	1415,21	1,00	1415,21				
Nominal price change	4,91	78,90	387,48				
CROCT(t-1)JUN(t)	2,13	236,52	503,79				
DDApril(t) %15	-408,93	1,00	-408,93				
DHDApril(t)13,7	-312,07	1,00	-312,07				
DHDMay(t)16,3	-284,87	1,00	-284,87				
			1300,59	**2434,17**	**-46,57**	**30**	**-16,57**

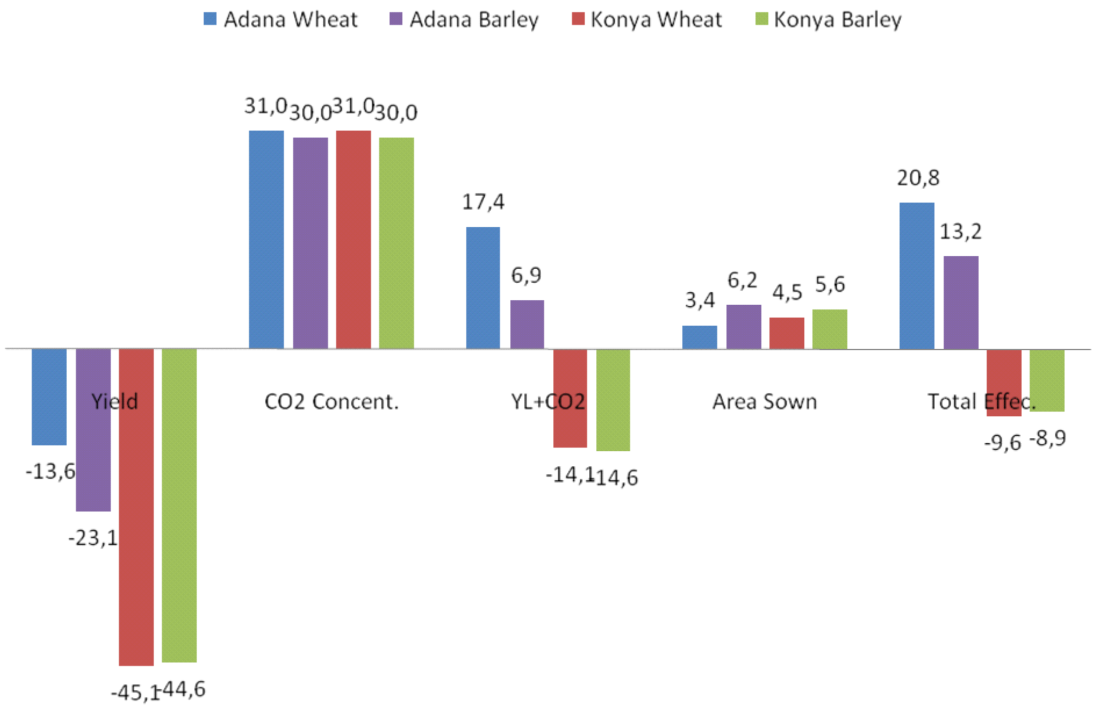
BARLEY KONYA AREA SOWN	Coeff.	Var. Value	Area Sown 2070's	Estimated Area Sown 1993-2002	b (%)
CONSTANT	199257,53	1,00	199257,53		
RelativePriceBW(t-1)	305464,40	0,87	265754,03		
CRJAN(t-1)APR(t-1)	245,75	98,69	24253,46		
			489265,02	494841,18	-1,13

	a+b+c (%)
The Total Impact to Konya barley production	**- 17,70**

For EU accession case, similar global warming effects were calculated, but tables are not shown for saving the space. The summary figures of these effects are shown just below.



Global Warming Impacts to Rainfed Wheat and Barley in Adana and Konya in No EU Accession Case



Global Warming Impacts to Rainfed Wheat and Barley in Adana and Konya in EU Accession Case

3. Conclusion

The economic model predicts both yield effects and area sown effects of global warming in the decade starting in 2070 to wheat and barley in Adana and Konya. The yield effects were predicted by taking into account price effect, drought effect, high temperature effect, and CO2 concentration effect. The area sown effects were predicted by taking into account price effect and soil moisture effect. These predictions were made for two cases, i. e., no EU accession case and EU accession case. In the EU accession case prices used for prediction were assumed to be higher than no EU accession case by the current differences of protection between Turkey and the EU.

The economic model predictions show that wheat and barley production in warmer area, i. e., Adana will benefit from global warming, while wheat and barley production in colder area, i. e., Konya will reduce considerably as shown in Fig 1 and Fig 2.

This result is probably caused by the fact that RCM temperature predicted for 2070 will increase by 21% of the past long-run average in Konya, while the same ratio for Adana is only 14% and the differences of crop varieties between Adana and Konya. So adding the CO2 concentration effect, Adana wheat and barley yields will increase to some extents, while Konya wheat and barley yields will decrease considerably in both no EU accession and EU accession case under global warming. Area sown effects are all slightly negative in no EU accession case, while the same effects are all slightly positive in EU accession case.

Consequently, the global warming effects to the total production of wheat and barley in Adana are all positive except Adana barley production that is slightly negative in both no EU accession and EU accession cases as shown in Fig 1 and Fig 2. But the global warming effects to wheat and barley production in Konya are all considerably large negative in both no EU accession and EU accession cases. Konya is a large and representative wheat producing province on Anatolian Plateau, and this econometric result suggests fiture severe decline of Turkish wheat food security under global warming.

Acknowledgements

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The Change of the Weather Risk by Global Warming and the Impact on the Yield of Wheat in Adana, Turkey

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1. Introduction

The researchers of agricultural economics have tried to estimate the impact of weather factors on the yield and the profitability of crops using econometric way. Climate change or global warming changes directly the background of crops. Then, farmers will correspond to the change of the background of crops: for example, changing the date of sowing and changing the amount of fertilizer. Hence, to estimate the impact of climate change on the yield and the profitability of crops, it is important to consider the farmers' responses to climate change. Estimating the reduced form function which assumes the profit maximizing farmers (yield response function, profit function and etc.) is useful to capture the response of farmers to the exogenous factors that affect the growth of crops and the profitability. Kaufmann and Snell (1997) and Sgerson and Dixon (1999) estimated the yield response function and the profit function respectively to quantify the impact of farmers' responses to the climate change on the yield or the profitability of crops.

Global warming affects not only the average weather condition but also the variance. If weather condition becomes risk factors for farmers and the farmers have risk averse utility functions, the change of variance will affect the average productivity of crops through the responses of the farmers to the change of weather risk. Then, the farmer's response to the change of the weather risk by climate change is comprised in the part of the farmers' responses to the climate change. However, the above researches which estimated the reduced form function did not consider the change of the weather risk.

The aim of the report is to conjecture the yield of wheat in Adana under climate change with the consideration of the farmers' responses to the change of the weather risk by global warming. For this purpose, the report introduces the reduced-form yield response function that is derived from the expected utility maximization theory under weather uncertainty. Then, the function is estimated using wheat production data of district in Adana, Turkey.

2. The Model

Assume a farmer who grows wheat on his or her plot. We assume that the production technology has constant returns to scale and multiplicative weather risk. Then, the production function of wheat is expressed as

$$y = Leg(x, h),$$

where, y is production amount of wheat, L is the size of plot, x is the amount of fertilizer, h is a vector of exogenous factors, and e is the weather risk which the farmer confronts. Weather risk is assumed to obey the cumulative distribution function $F(e)$ between closed interval $[a, b]$. Then, if the farmer is risk averse, his or her problem which maximizes the expected utility can be expressed as

$$\max_x \int_a^b U\left[pLeg(x,h) - rLx\right] \mathrm{d}F(e),$$

where, $U[\cdot]$ is the von Neumann and Morgenstern utility function, p is the price of wheat products, and r is the price of fertilizer.

Pope and Chavas (1994) proved that, if the technology has multiplicative risk, the cost function $C(\bar{q}, r, h)$ which minimizes the cost of the subjective expected yield $\bar{q}$ and is coherent with the expected utility theory can be defined. Hence, the above problem which maximize expected utility can be rewritten as

$$\max_{\bar{q}} = \int_a^b U\left[pLe\bar{q} - LC(\bar{q}, r, h)\right] \mathrm{d}F(e).$$

In this problem, the farmer chooses the optimal expected yield of wheat which maximizes his or her expected utility. Then, the optimal expected yield is defined by $\bar{q}^{*}\left(p, r, h, \bar{e}, \sigma^2\right)$, where, $\bar{e}$ is the expected value of the weather risk and σ^2 is the variance of the weather risk[1]. The actual yield that the farmer can gain depends on the realization of the weather risk. The relationship $\bar{e}q = e\bar{q}^{*}$ consists between the actual yield and the optimal expected yield, because the technology of wheat has multiplicative weather risk. Hence, the reduced-form yield response function of wheat can be expressed as

$$q = \frac{e}{\bar{e}}\bar{q}^{*}\left(p, r, L, h, \bar{e}, \sigma^2\right).$$

Taking the logarithm of the both side of the equation and assuming the Cobb-Douglas function for the optimal expected yield function, the reduced-form yield response function is rewritten as

$$\begin{aligned} \ln q = \alpha_0 + \alpha_p \ln p + \alpha_r \ln r + \alpha_l \ln L + \\ \beta' \ln h + (\gamma - 1)\ln \bar{e} + \eta \ln \sigma^2 + \ln e. \end{aligned} \quad (1)$$

Estimating this yield response function, we can quantify the effect of farmers' responses to weather risk on the yield of wheat[2].

3. Data and Empirical Strategy

As mentioned above, the main aim of this paper is to clear how the farmers adapt to the change of the weather risk and how the adaptation affect the yield of wheat in Adana. For this purpose, the wheat production data at district level in Adana is utilized for the estimation of the yield response function (eq:1). However, some strategies are needed to estimate the yield response function.

The data consists the production data of wheat from 1991 to 2003. The main variety of wheat planted in Adana is spring wheat. But, in the northern part and mountain area of Adana, winter wheat is the main variety. Because of this, it is not appropriate to estimate the yield response function using together the data of the district where the spring wheat is grown and the district where the winter wheat is grown. Then, the districts where winter wheat is grown are eliminated from the estimation[3].

The empirical model introduced above allows only one source of risk. Hence, we need to define the duration when the weather condition is the risk factor for the wheat producing farmers in Adana. The farm survey conducted in 2004 clarified that the weather condition from March to May is the main source of weather risk in Adana (Kusadokoro and Asami (2005)). Then, we assume that the risk source for the wheat farmers in Adana is only the weather condition of March to May.

There are several kind of weather conditions: for example, temperature, precipitation, isolation duration, and etc. Then, it is needed to combine the several weather conditions for estimating the yield function. In this paper, Aridity index developed by Oury (1965) is used for this purpose. Aridity index is defined by

$$W = R / 1.07^{T}.$$

W is the aridity index, R is the total monthly precipitation (mm), and T is the average monthly temperature (□). Hence, the index quotes higher value, if the precipitation becomes higher and the temperature becomes lower. Then, small value of the index shows that the level of aridity is high. We define the weather risk as the average value of the aridity index of March to May.

The weather risk was defined. Then, the expected value and the variance of weather risk must be calculated to estimate the yield response function. The paper adopts the adaptive expectation approach, that was used by Chavas and Holt (1990) and others, to calculate the expected value and the variance. The expected value and the variance are defined as follows:

$$\bar{e}_t = E(e_t) = E(e_t - e_{t-1}) + e_{t-1}, \text{ and}$$

$$\sigma_t = \operatorname{var}(e_t) = \sum_{j=1}^{3} w_j \left[e_{t-1} - E_{t-1}(e_{t-1})\right]^2.$$

w_j shows the weight value: from w_1, the value is

[1] More precisely, the optimal expected yield depends on the more higher moment of weather risk distribution. However, the report eliminates the moments higher than second order for simplification.

[2] I conducted comparative statics of the optimal expecred yield function and analyzed how the risk averse farmers response to the change of weather risk and other exogenous factors (product price, fertilizer price, and etc.) The results are not discussed in the report due to space limitation.

[3] Finally, we used the data of 12 districts for the estimation.

0.5, 0.33, and 0.17, respectively.

Table 1 shows the definition of independent variables that explain the yield of wheat in Adana. Aridity index for November and December are chosen as the other exogenous factors which affect the yield of wheat in Adana. The reason is that the weather condition of this season determines the early growth of wheat. Then, the weather condition of this season may be crucial for the yield of wheat.

4. Result of the Estimation

Table 2 shows the result of the estimation of the yield response function (eq:1). The data used here consist cross sectional and time series data (i.e. panel data). Then, it is needed to test whether there is fixed effect or not. The *F* test rejected the null hypothesis that there is no fixed effect. Hence, fixed effect model and random effect model were estimated and Housman test was conducted to examine which of the models is appropriate. The test chose the fixed effect model.

Firstly, we will see the effect of the weather risk on the yield of wheat. The coefficient of the expected value of the weather risk was positive and statistically enough at 1% level. This means that, if the farmer has the expectation that the aridity index between March to May becomes high (i.e. high precipitation and low temperature), the farmer chooses higher yield. The coefficient of the variance of the weather risk was minus and statistically enough at 5% level. This means that, if the farmer has the expectation that the variability of aridity index between March to May becomes high, the farmer chooses lower yield.

Next, we will see the effect of the other independent variables on the yield. The coefficient of the price of wheat price was minus and statistically enough at 10%. This result is odd under the world of certainty. However, when there is risk for the production, high price of products means that the variability of profit is also high. Hence, it is possible that the risk averse farmer chooses to decrease the yield when the price of products increases.

5. The Effect of Global Warming

In this section, we simulate the yield of wheat under climate change using the coefficients of the yield response function and pseudo warming data which projected the climate condition of 2070s'.

Generally, the change of risk refers to the situation that only the variability of risk varies with the mean value is held to be constant. Then, for the purpose of quantifying the farmers' response to the change of weather risk, it is appropriate to conduct the sensitivity analysis. However, because global warming affects not only the variance of the weather risk, but also the mean value, the sensitivity analysis cannot say rich suggestion about the effect of global warming on the yield of wheat in Adana. The paper simulates the yield of wheat with the coefficients of weather risk (expectation value and variance) and the yield without the coefficients of weather risk, and then, compares these simulated yields. The former shows the yield that the risk averse farmer can achieve with the farmer' response to the weather risk, and the later shows the yield that the farmer can get, if there is no weather risk.

Table 3 shows the aridity index calculated from pseudo warming data. The result shows that the weather condition of Adana will be parched by global warming. Standard deviation of the weather risk (March to May) decreases by global warming.

Table1 The definition of independent variables

Variables	Definition
WPRICE	Price of wheat products
FPRICE	Price of fertilizer
WAREA	Area for wheat per population in rural area
AR11	Aridity index for November
AR12	Aridity index for December
EAR0305	Expected value of the weather risk
VAR0305	Variance of the weather risk

Table 2 The result of the estimation

	Fixed effect model	
	Coefficient	CF of variation
WPRICE	-0.607	0.141 ***
FPRICE	-0.211	0.14
WAREA	0.029	0.075
AR11	-0.02	0.015
AR12	0.049	0.023 **
EAR0305	1.104	0.055 ***
VAR0305	-0.038	0.019 **
Constant	14.876	1.824 ***
F test = 7.18 (0.000)[1)]		
Hausman test = 23.51 (0.001)[1)]		

*** shows statisticaly enough at 1%,
** at 5%, and * at 10%.
1) The figure in the parentheses shows p valu

Table 3 Aridity index under pseudo warming

		Controll run	Global warming
Nov.	Mean	25.4	14.93
	SD	15.41	10.94
	CV	60.68%	73.24%
Dec.	Mean	103.14	37.72
	SD	83.34	35.21
	CV	80.81%	93.34%
Mar. to May	Mean	50.97	31.92
	SD	25.12	21.37
	CV	49.29%	69.10%

Then, the degree of weather risk the wheat producing farmer in Adana confronts will decrease, but the relative degree will increase.

Table 4 shows the result of the simulation of yield of wheat. (A) shows the estimated yield with the coefficients of weather risk, and (B) shows the estimated yield without the coefficients of weather risk. (C) is the difference of the yield with weather risk and the yield without weather risk. Then, the value reflects the amount of yield that the risk averse farmers lose because of the existence of the weather risk.

The result shows that the yield of wheat will decrease by global warming. The main reason of the decrease is the aridification of Adana region. The effect of the weather risk on the yield will decreases by global warming because of the decrease of the weather risk.

6. Result

The paper quantifies the effect of the farmers' responses to the change of weather risk and simulated the yield of wheat in Adana under global warming. The result shows that the yield of wheat will decrease by global warming, even if we consider the existence of weather risk and the farmers' response to it. It must be noted that the paper did not consider the effect of CO_2 concentration.

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Table 4 Estimated yield of wheat with pseudo warming

Unit:kg/ha

		Station data	Control run	Global Warming
Estimated yield	with weather risk(A)	3864	4062	3699
	witout weather risk(B)	4610	4931	4444
Effect of Weather risk	Absolute value(C=B−A)	746	869	745
	Proportion(D=100*C/B)	16.18%	17.62%	16.76%

The Effect of Irrigation on the Adoption of Crop-Livestock Multiple-Farming and the Livestock Keeping

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1. Introduction

In the traditional agriculture, farmers manage crop production and animal husbandry multiply. There are several merits in multiple production. First, as a accumulation measure of more liquid assets compared to land. Secondly, it plays a important role of diversification of risk. Thirdly, economies of scope from utilizing crop residue for livestock feeding, livestock excreta for fertilizing land, and livestock itself for tilling land.

However, in areas where introduction of irrigation has been progressed, animal husbandry has been declined and farm production shifted to crops. The introduction of irrigation may have changed environment of crop production, and also affected animal husbandry through allocation of labor and capital.

Then, changes caused by the introduction of irrigation will be grasped and sorted out according to the farm survey, and factors of decision of the adoption of crop-livestock multiple-farming and the livestock keeping will be analyzed.

Data used in this report was obtained in farm survey conducted in Adana region from January to March in 2006. In this report, sample households for analysis are farmers who produce only crops and those who manage crop-livestock multiple-farming. Sample villages of this survey are as follows:

Irrigated Villages
- Geçitli (Yüreğir District)
- Gerdan (Seyhan District)

Rain-fed Villages
- Yeniyayla and Cihadiye (Yüreğir District)
- Boztahta (Aladağ District)

2. Decision of the Adoption of Crop-Livestock Multiple-Farming and the Livestock Keeping

2.1 Situation of Surveyed Areas

The lower part of Seyhan river, running through Adana prefecture, is a Çukurova plain with fertile soil, where irrigation is well introduced. The middle part of Seyhan river is a hilly area goes to the upper plateau, where irrigation is not well introduced.

In irrigated area, production of wheat and cotton had been prosperous since before the introduction of irrigation. But in recent years, cotton production declined because of the declining of immigrant labor from east part of Turkey, and production of maize, citrus and vegetables has been increasing instead of cotton. About animal husbandry, in general a few cattle are kept and fed in drylot.

In rain-fed area, mainly wheat and barley is planted and farmers make their living by combining animal husbandry with production of these crops. In general, sheep and Goat are mainly grazed in piedmont and cattle are also kept in other area.

2.2 The Difference in Decision Whether or Not to Keep Livestock

In farm survey, the following question was asked to farmers: whether keeping livestock or not, purpose when keeping livestock, and reason when not keeping livestock. The results are shown in Table from 1 to 3.

Table 1 Whether Keeping Livestock or Not

(Unit: Number of Household)

	Irrigated Area		Rain-fed Area	
		%		%
Keep	10	19.6	36	72.0
Kept in the past	10	19.6	11	22.0
Not keep	31	60.8	3	6.0
Total	51	100.0	50	100.0

Source: Farm Survey in 2006

From Table 1, only 20% of respondents keep livestock in irrigated area, on the other hand 72% of respondents keep livestock in rain-fed area.

Table 2 Purpose of Keeping Livestock

(Unit: Number of Answer)

Purpose	Irrigated Area	%	Rain-fed Area	%
As a stock of capital	3	17.6	8	11.0
For economic security of household	5	29.4	16	21.9
For home consumption	5	29.4	25	34.2
To sell livestock at the festival season	0	0.0	7	9.6
To sell milk, hair, and other by-products	4	23.5	17	23.3
Total	17	100.0	73	100.0

Source: Farm Survey in 2006
Note: Multiple answer is possible.

Table 2 shows purpose of keeping livestock when farmers answered that they keep livestock. In irrigated area, animal husbandry is placed not as the main measure to make their living by itself, but as means to avoid risk and to get products for home consumption. In rain-fed area, animal husbandry is considered equally as means of 'avoidance of risk and stabilization in household', 'home consumption' and 'income'.

Table 3. Reason for Not Keeping Livestock

(Unit: Number of Answer)

	Reason	Irrigated Area	%	Rain-fed Area	%
Kept in the past	No space or barn	2	16.7	2	15.4
	Lack of capital	2	16.7	1	7.7
	Lack of labor	5	41.7	8	61.5
	Costs too much	0	0.0	1	7.7
	Low profitability	1	8.3	0	0.0
	Lack of knowledge	1	8.3	0	0.0
	Living in city	0	0.0	0	0.0
	Don't want to keep	1	8.3	1	7.7
	Total	12	100.0	13	100.0
Not keep	No space or barn	5	12.5	0	0.0
	Lack of capital	2	5.0	0	0.0
	Lack of labor	10	25.0	1	33.3
	Costs too much	3	7.5	0	0.0
	Low profitability	6	15.0	0	0.0
	Lack of knowledge	6	15.0	0	0.0
	Living in city	5	12.5	2	66.7
	Don't want to keep	3	7.5	0	0.0
	Total	40	100.0	3	100.0

Source: Farm Survey in 2006
Note: Multiple answer is possible.

The reasons for not keeping livestock is shown in Table 3. In irrigated area, farmers who have experiences of keeping livestock cite 'lack of capital' and 'lack of labor' as reasons for not keeping livestock. Farmers who don't have experiences of keeping livestock wonder profitability in addition to lack of labor. In rain-fed area, most farmers keep livestock or have experiences. The reason for stop keeping livestock most farmers who kept livestock in the past cite is 'lack of labor'.

Putting it all together, in irrigated area, some farmers manage animal husbandry for the purpose of 'avoidance of risk and stabilization in household' and 'home consumption', and most farmers do not manage animal husbandry in consideration of low profitability and its requirement for much labor. On the other hand, most farmers manage animal husbandry according to three purpose: 'avoidance of risk and stabilization in household', 'home consumption' and 'income', and farmers who do not keep livestock cite 'lack of labor' as the main reason for not keeping livestock.

From the above, it can be said that the difference between in irrigated area and in rain-fed area is the point that farmers decide whether they keep livestock or not according to the judgement on profitability, and the common reason for not keeping livestock is that farmers consider availability of labor.

Next, based on these results, 'labor productivity' and 'land productivity' will be checked.

Table 4 Labor Productivity and Land Productivity in Surveyed Area

		Productivity	Crop Production	Livestock Production
Irrigated Area	Keeping Livestock	Labor	27.845	-0.550
		Land	193.426	
	Not Keeping Livestock	Labor	113.128	
		Land	196.005	
Rain-fed Area	Keeping Livestock	Labor	136.161	1.332
		Land	66.244	
	Not Keeping Livestock	Labor	42.603	
		Land	48.448	

Source: Farm Survey in 2006
Note: Labor Productivity (Unit: YTL/day) is defined as
[(Production Value - Input Goods Cost) / Labor Amount].
Land Productivity (Unit: YTL/da) is defined as
[(Production Value - Input Goods Cost) / Land Size].

From the Table 4, it can be seen that the land productivity in irrigated area is from three to four times higher than those in rain-fed area and that there is a big difference in the labor productivity between crop production and animal husbandry. From this result, it can be thought that agriculture in irrigated area concentrates on crop production because of higher productivity of crop production than that in rain-fed area.

2.3 The Background of the Decision

Here, the background of difference in decision is considered.

There is some constraints in condition of cultivation in the traditional agriculture and therefore farmers grow grains in extensive way. However, introduction of irrigation and accompanying technological progress ease condition of cultivation, and production of commercial crops become prosperous and productivity improves. Consequently, a disparity in productivity between crop production and animal husbandry enhances, resulting in changes in capital allocation between crop production and animal husbandry.

Animal husbandry requires a lot of labor constantly. In the extensive agriculture, animal husbandry is useful to utilize household labor. However, in the area where animal husbandry is not so prosperous compared to crop production, like surveyed area, labor market does not develop enoughly. On the other hand, commercial crops production needs a lot of labor only in particular period like planting and harvesting. Effective management of agriculture can be achieved by combinating production items and hiring labor. Additionally, profitability growth in crop production increases household income, and leads to a rise in oppotunity cost of family labor. Consequently, changes in labor allocation between crop production and animal husbandry occur.

From the above, it is presumable that the differences in productivity and profitability cause changes of capital and labor allocation between crop production and livestock production, resulting in a transition from the traditional crop-livestock multiple-farming to commercial crops-forcused production.

3. Factor Analysis of Adoption of Crop-Livestock Multiple-Farming and Livestock Keeping

3.1 Tobit Model - Variables and Hypotheses

Here, farctors which affect farmers' decision whether they adopt crop-livestock multiple-farming or not is analyzed with econometric approach. In this analysis, Tobit model is used with adjusted number of managed livestock as a dependent variable. Each independent variable and its theoritical ground are mentioned below.

a) Household Size

Animal husbandry does not have labor market and only family labor is utilized. Therefore, number of household member can be constraint. If the number of family labor is limited, farmers may accord crop production that has high labor productivity priority over animal husbandry. If there are a lot of members, farmers can utilize surplus labor efficiently.

b) Education Level of Household Head

In case education level of household heads are high, it can be judged that they have high management ability. They can manage crop-livestock multiple-farming in consideration of efficient allocation of labor and risk.

c) Self-Owned Land Size

In rain-fed area, land marked is fragile. Even in irrigated area, land market is not perfedt because there exist constraints in some crops. Under this situation, it can be thought that farmers with large self-owned land shift the emphases on capital allocations from animal husbandry to crop production. Technical disparity in profitability between irrigated area and rain-fed area must be considered.

3.2 Estimation Result

Table 5 shows the estimation result of Tobit model on decision how many livestock to keep.

Table 5 Estimation result of Tobit Model on Decision How Many Livestock to Keep

Number of observations: 101, Log of likelihood: -168.495			
Variables	Coefficients	t-statistic	p-value
Household size	1.378	3.96	0.000
Education level of household head	1.369	1.77	0.080
Self-owned land size	-0.218	-2.67	0.009
Irrigation dummy	-8.311	-5.06	0.000
Constant	-4.516	-1.85	0.067

Source: Farm Survey in 2006

Note: Livestock number is adjusted according to feeding standard.

a) Household Size: Positively Significant

Shortage of the number of household member results in difficulty of keeping livestock. That is, there is a labor constraint. Adversely, farmers utilize surplus labor efficiently in case of lots of household members.

b) Education Level of Household Head: Positively Significant

The higher education level of household head, the more the head manage crop-livestock multiple-farming in consideration of efficient allocation of labor and risk.

c) Self-Owned Land Size: Negatively Significant

Farmers with large self-owned land shift the emphases on capital allocations from animal husbandry to crop production. To the contrary, farmers with small self-owned land manage crop-livestock multiple-farming for the reason that they can not produce crops stably.

d) Irrigation Dummy: Negatively Significant

In this variable, effects of preference structure and home consumption except technical profitability are to be included in this variable. This means that there exist disadvantage to animal husbandry according to the introduction of irrigation.

From the above result, it is confirmed that the decision of adoption of crop-livestock multiple-farming is affected by availability of labor and land. If the self-owned land sizes are large, farmers center management on crop production and they shift the emphases on labor capital allocations from animal husbandry to crop production. Under the condition, they allocate surplus family labor to animal husbandry in case of lots of available household member. Also, if management ability of household head is high, the head adopt crop-livestock multiple-farming in consideration of avoidance of risk.

4. Conclusion

The introduction of irrigation raised productivity of crop production, and farmers changed allocation of capital and labor between crop production and animal husbandry. Consequently agricultural system shifted from the traditional crop-livestock multiple-farming to the commercial crop production. Animal husbandry is adopted by farmers who do not have enough capital to manage crop production stably, or farmers who have enough household labor for animal husbandry after allocating household labor crop production.

Acknowledgement

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Impacts of Climate Change and the EU Accession on Turkish Rural Industries by the Input-Output model and Markov-Transition Matrix

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1. Introduction

The purpose of this paper is to discuss about impacts of climate change and the EU accession on Turkish rural industries For this purpose, the following analyses are carried out in each section.

(1) Generation of Agriculture based IO table in 2 time points (1985 and 1996)

(2) Prediction of Input coefficient and Production amount share by RAS method and the Markov Transition Probability Matrix.

(3) Simulation on the effects of Climate Change on productivities.

(4) Simulation on the effects of the EU accession on production amounts

(5) Finding and some implications

2. Generation of Agriculture based IO table in 2 time points (1985 and 1996)

Original Input-Output tables have been published for the year 1985, 1990 and 1996 by Turkish Government. Those are tables of the competing import type and the commodity based type. The 1985 and 1990 tables contain 64 industry sectors, 7 final demand sectors and 7 value added sectors and 1996 table contains 98 industry sectors, 7 final demand sectors and 7 value added sectors. The unit of all tables is million Turkish Lira.

In this paper, actually there are 3 IO tables in 1985, 1990 and 1996. and so, 3 kinds of transition process can be estimated. However, our prediction period is so long time as 70 years to year 2070. To save the estimation loss in repeated multiplication process, here the relation between the two IO tables in 1980 and 1996 is used.

By aggregating non-rural sectors as much as possible, these tables were reduced to the smaller size of 24 industry sectors, 6 final demand sectors and 4 value added sectors and they were converted to the Agriculture based IO tables. These tables are shown in Table 1, Table2 and Table3. In the following, due to the space limitations, only the rural sectors (i.e. 6 sectors from grain to fisheries) are indicated explicitly and non-rural sectors (i.e. 18 sectors from coal/oil to administration) are indicated implicitly by the notation **** in the corresponding rows and columns.

3. Prediction of Input coefficient by RAS method

1). Industry Structure Analysis

The following orthodox manipulations of the Input-Output Analysis are applied to these Agriculture-based IO tables.

$$A X + F = X \quad \text{............ (1)}$$

$$X = (I - A)^{-1} F \quad \text{......... (2)}$$

Here, A: input coefficient matrix

F: final demand column vector

X: output column vector

I: unit matrix

And matrix $(I - A)^{-1}$ is known as the Leontief's Inverse matrix B, which shows the production inducement multiplier matrix. i.e. the matrix of the induced increase in the production derived from the unit increase of the final demand sector.

Table 1 Agriculture Based Input Output Tabl;e (1985) (unit: billion Turkish Lira, 1985)

		Intermediate Demand Sector								Final Demand Sector							Total Production
		Grain	Vegetable	Fruits	Livestock	Forestry	Fisheries	****	Intermediate Demand Total	Private Consumption	Public Consumption	Private Investment	****	Export	Final Demand Total	(-)Import	
Intermediate Input Sector	Grain	1465	0	0	7122	0	0	****	20556	4834	96	0	****	689	4799	-948	24407
	Vegetable	0	33	0	0	0	0	****	565	6658	25	0	****	76	7126	-24	7667
	Fruits	0	0	379	0	0	0	****	2154	11608	49	0	****	686	12784	-71	14867
	Livestock	12	399	130	0	0	0	****	5993	16055	62	11	****	670	16817	-475	22335
	Forestry	0	0	0	0	0	0	****	2699	601	164	0	****	97	869	-440	3128
	Fisheries	0	0	0	0	0	0	****	112	1560	0	0	****	117	1672	-8	1777
	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****
	Intermediate Input Total	9225	2284	1726	10699	489	286	****	242327	221979	29808	23169	####	59180	368546	-78935	531938
Value Added	Tax	-1800	-104	257	105	28	4	****	14080								
	Depreciation	369	129	317	108	15	16	****	15961								
	Wage	2740	844	592	539	820	179	****	59881								
	Profits	13873	4514	11974	10883	1777	1291	****	199688								
	Value added Total	15181	5383	13140	11636	2639	1491	****	289611								
Total Products		24407	7667	14867	22335	3128	1777	****	531938								

("****" shows the sectors omitted to list)

Table 2 Agriculture Based Input Output Table (1996) (unit: billion Turkish Lira, 1996)

		Intermediate Demand Sector								Final Demand Sector							Total Production
		Grain	Vegetable	Fruits	Livestock	Forestry	Fisheries	****	Intermediate Demand Total	Private Consumption	Public Consumption	Private Investment	****	Export	Final Demand Total	(-)Import	
Intermediate Input Sector	Grain	97251	0	0	289980	472	0	****	886723	231000	25410	0	****	73441	418655	-128576	1176803
	Vegetable	0	2171	0	0	0	143	****	34256	318000	6590	0	****	8141	334304	-3245	365314
	Fruits	0	0	25127	0	0	46	****	93278	554000	12883	0	****	73118	673231	-9661	756848
	Livestock	470	15609	5071	41118	22	0	****	235783	478000	504	5569	****	8455	640598	-17866	858515
	Forestry	0	1300	0	0	1481	22	****	85686	18845	1306	0	****	350	20503	-11819	94370
	Fisheries	0	265	0	0	0	672	****	9418	89888	22	0	****	1972	92494	-135	101777
	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****	**** ****
	Intermediate Input Total	444000	102000	93655	448245	12956	23924	****	11752352	9840000	1711286	3130000	****	3650000	19966954	-4133894	27585412
Value Added	Tax	-97000	-5615	13866	8583	2477	900	****	586262								
	Depreciation	25767	9034	22136	13764	401	690	****	837440								
	Wage	104000	32059	22514	41927	24943	8018	****	3234567								
	Profits	701000	228000	604674	345994	53590	68242	****	11174788								
	Value added Total	733000	263000	663192	410269	81413	77852	****	15833059								
Total Products		1176803	365314	756848	858515	94370	101777	****	27585412								

("****" shows the sectors omitted to list)

$$\begin{bmatrix} r_1 & 0 & 0 & 0 \\ 0 & r_2 & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & r_n \end{bmatrix}^{m} \bullet \begin{bmatrix} a_{11} & \cdots & \cdots & a_{1n} \\ \vdots & a_{22} & & \vdots \\ \vdots & & \ddots & \vdots \\ a_{n1} & \cdots & \cdots & a_{nn} \end{bmatrix}_{t=T} \bullet \begin{bmatrix} s_1 & 0 & 0 & 0 \\ 0 & s_2 & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & s_n \end{bmatrix}^{m} = \begin{bmatrix} a'_{11} & \cdots & \cdots & a'_{1n} \\ \vdots & a'_{22} & & \vdots \\ \vdots & & \ddots & \vdots \\ a'_{n1} & \cdots & \cdots & a'_{nn} \end{bmatrix}_{t=T+m}$$

Fig.1 Formula of RAS method

Table 3 Estimation of Input Coefficient Function

Grain

Variables	Coeff	t-value	p-value
const.	-5320.633	-5.90	0.010
RainK	0.268	1.70	0.189
TempK	6.527	2.34	0.101
RainA	-0.038	-0.30	0.786
TempA	-9.018	-2.24	0.111
DMdt	-25.913	-5.90	0.010
DM93	2.499	0.59	0.598
DM94	-2.186	-0.31	0.775
DM99	2.190	0.54	0.624
DM01	-7.015	-1.31	0.282
year	2.741	6.06	0.009

R^2(adj)= 0.791 DW= 1.807

Vegetable

Variables	Coeff	t-value	p-value
const.	-1266.381	-16.16	0.001
RainK	0.014	1.04	0.374
TempK	0.076	0.31	0.774
RainA	-0.019	-1.71	0.185
TempA	0.091	0.26	0.811
DMdt	-2.284	-5.99	0.009
DM93	-0.939	-2.54	0.085
DM94	0.267	0.44	0.690
DM99	-0.395	-1.13	0.340
DM01	0.149	0.32	0.770
year	0.649	16.52	0.000

R^2(adj)= 0.983 DW= 1.997

Fruit

Variables	Coeff	t-value	p-value
const.	-1059.882	-6.87	0.006
RainK	0.042	1.57	0.215
TempK	1.194	2.51	0.087
RainA	-0.006	-0.27	0.806
TempA	-1.636	-2.38	0.098
DMdt	-5.778	-7.69	0.005
DM93	0.584	0.80	0.481
DM94	-0.356	-0.30	0.786
DM99	0.150	0.22	0.841
DM01	-1.427	-1.56	0.217
year	0.548	7.08	0.006

R^2(adj)= 0.863 DW= 1.863

Livestock Product

Variables	Coeff	t-value	p-value
const.	-1408.864	-5.87	0.010
RainK	0.059	1.41	0.253
TempK	2.000	2.70	0.074
RainA	-0.001	-0.03	0.976
TempA	-2.805	-2.62	0.079
DMdt	-7.673	-6.57	0.007
DM93	1.458	1.29	0.288
DM94	-0.729	-0.39	0.722
DM99	0.190	0.18	0.871
DM01	-2.636	-1.85	0.162
year	0.749	6.23	0.008

R^2(adj)= 0.829 DW= 2.008

Forestry

Variables	Coeff	t-value	p-value
const.	-89.595	-0.78	0.494
RainK	0.033	1.65	0.197
TempK	0.869	2.44	0.093
RainA	-0.003	-0.19	0.862
TempA	-1.223	-2.38	0.098
DMdt	-3.103	-5.52	0.012
DM93	0.473	0.87	0.449
DM94	-0.276	-0.31	0.778
DM99	0.296	0.57	0.606
DM01	-0.973	-1.42	0.251
year	0.059	1.02	0.381

R^2(adj)= 0.892 DW= 1.878

Fisheries

Variables	Coeff	t-value	p-value
const.	-9328.142	-3.54	0.038
RainK	0.770	1.67	0.193
TempK	19.237	2.37	0.099
RainA	-0.064	-0.17	0.874
TempA	-27.104	-2.31	0.104
DMdt	-66.717	-5.21	0.014
DM93	9.687	0.78	0.492
DM94	-7.405	-0.36	0.741
DM99	7.884	0.67	0.550
DM01	-21.098	-1.35	0.270
year	4.850	3.68	0.035

R^2(adj)= 0.734 DW= 1.863

2) Estimation of R (substitution change coefficient) & S (processing degree change coefficient),

In order to predict the Input Coefficient matrix, the following relation are utilized. Here, matrix A is the original input coefficient matrix at base year T and matrix A' is the coefficient matrix at predicted year T+m.

By solving the above relation of the RAS method, matrix R and S are derived. Here, matrix R is row wise correction matrix of the original input coefficient matrix A and it indicates the substitution change effect matrix. Similarly, matrix S is column wise correction matrix of A and it indicate the processing degree change effects matrix. In other word, the elements ri of matrix R show the increase rate of intermediate demand for sector i by every sector. The elements si of matrix S show the increase rate of intermediate input in sector i from every sector. Thus, the sectors with combination of ri bigger than one and si smaller than one can be considered as the growing sectors while the sectors with combination of ri less than one and si bigger than one can be considered as the declining sectors.

3) Prediction of Input Coefficient and Impact of Climate Factors on Agricultural Productivities.,

By multiplying R and S to the Input Coefficient Matrix in the base year, time series of the input Coefficient Matrix are obtained. The reverse of input coefficient indicates productivity or efficiency of input in each sector. Then, the following regression equation are estimated to investigate impacts of climate factors on agricultural productivity.

$$a_j = a_{(\Sigma i)j} = f(Prec, Temp, DM, \ldots)$$

Here, aj; Input Coefficient in Sector j
Prec; Precipitation in Konya, Adana
Temp; Temperature in Konnya, Adana
DM; dummy variable corresponding to

difference in data source, abnormal weather, etc

Table 3 shows the results of this regression analysis. According to the major statistical criteria such as adjusted determination coefficient, Durbin Watson ratio and t-value, considerably good results are shown for all of rural industries. Among error terms, serial correlation were not observed and most of coefficient estimates are statistically significant.

4. Impacts of Climate Change on Productivities

By using the results of RAS method on the Input-Output tables, and the current and predicted climate conditions in the 3.5th run of GCM and the CCSR/NIES-GCM, the impacts of global warming and decreasing trend of rainfall on Turkish rural industries were calculated.

In this calculation, the rainfall and the temperatures in May in the case of Konya and the temperatures in May and the rainfall in December in the case of Adana were used as the analysis by Tsuji & Ufuk suggested that those factors affected the productions substantially.

The changes in productivities of the 6 rural industries due to 1% increase in rainfall and temperature are estimated for each of Konya and Adana in the first place.(Figure [2])

And then, the changes in the productivities between 2070s and current year were calculated (Figure [3]). Here, the productivities in 2070s were derived from the rainfall and temperature in 2070 predicted by the simulated results of the 3.5th run of GCM and the CCSR/NIES-GCM.

Those implications were derived from the combination of the "rural industries based Input-Output table" related information and the results of the 3.5th run of GCM and the CCSR/NIES-GCM,.

As shown in the Figure [2], the impacts of climate change on productivities in the rural industries are summarized in the following way. The increase of rain in May in both Konya and Adana does not affect any rural sectors so much but the temperature increase in Konya will affects all of rural sectors positively while the temperature increase in Adana will affect all rural sectors except vegetable negatively. The reasons for these results are explained as follows.

As the climate in Konya is very cold, the increase of the temperature affects the growth of the productivity positively. But in Adana the climate is already relatively warm enough and so, additional increase of temperature may cause the heat damage and give negative impact on the growth of productivity.

And the relative impacts in percentage are very small in vegetables and rather big in grain, forestry and fisheries.

It is considered that as for vegetables, they have already been grown by the capital intensive and efficient methods and so, the climate change does not affect so much.

Under the 3.5th run of GCM and the CCSR/NIES-GCM, as for the total impacts of climate change on productivity in each rural industry, the forestry and fisheries sectors are most negatively affected. Also, grain, fruits and livestock sectors are negatively affected although the effects are less than the former 2 sectors. Only vegetable sector is seldom affected by the climate change. The reason for these seems to be that the negative effects of temperature increase in Adana dominate the effects of other factors except vegetables which are not affected significantly. As a whole, the predicted negative effects under the CCSR/NIES-GCM are more significant than under the 3.5th run of GCM

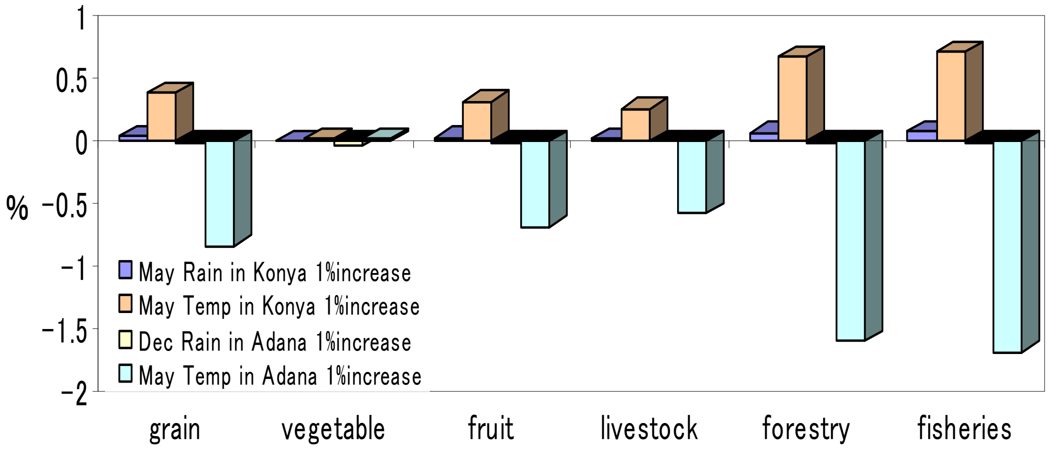

Fig. 2 Impacts of Climate Change on Productivities

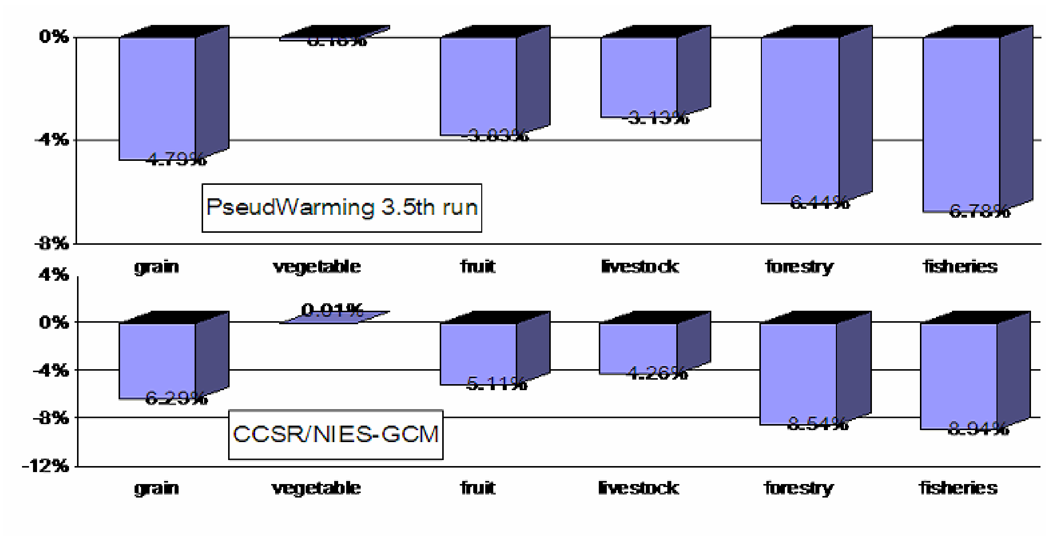

Fig.3 Change of productivities between 2070s and current year.

5. Impacts of the EU accession on Production Amount Shares

Based on the total production column vectors ([X86] and [X96]) in the input output tables in basis year (1986) and comparison year (1996) shown in the first section of this paper, the Markov transition probability matrix can be estimated in the following way. First of all, total production column vector in comparison year can be shown as multiplication of a matrix and total production column vector in base year. In the next stage, this matrix can be expressed by the multiplication of the diagonal matrix and Markov transition probability matrix.

In this process, it is necessary to adjust the original Matrix by dividing the elements by the row's (i.e. row wise) sum. By substituting the corresponding values estimated in the IO tables into total production column vectors in two time point, the diagonal matrix whose non-zero elements are sum of the elements in each row are calculated. In this case, the non-zero diagonal elements are so called the "production amount shares" in each industry, which are supposed to be the function of repetition number of prediction.

By multiplying Markov transition matrix in the center position of this relation formula for m times, total production column vector in m periods future can be estimated.

This relation can be expressed in the matrix formula of Figure 4 and the estimated results of the Markov transition probability matrix is shown in Table 4.

In the equation of Figure 4, the vector in the left hand side [X_{t+m}] shows the column vector of total productions amounts for 6 rural sectors in comparison year t+m, and the vector [X_t] in right hand side shows the column vector of total productions amounts for 6 rural sectors in base year t, in this case 1985.

$$\left[X_{t_{0+m}}\right] = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & & \vdots \\ \vdots & & \ddots & \vdots \\ r_{n1} & \cdots & \cdots & r_{nn} \end{bmatrix} \bullet \left[X_{t_0}\right]$$

$$= \left[A_{ii}(m)\right] \bullet \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & & \vdots \\ \vdots & & \ddots & \vdots \\ p_{n1} & \cdots & \cdots & p_{nn} \end{bmatrix}^m \bullet \left[X_{t_0}\right]$$

Where $p_{ij} = r_{ij} / a_{ii}$

$$a_{ii} = \sum_{j=1}^{n} r_{ij}$$

$, \quad a_{ij} = 0 \quad (\text{for } i \neq j)$

r_{ij} : Element of the relation matrix between X_{t_0} and X_{t_1}.

m : Repetition number of forecasting.

Fig.4 Formula if Markov Transition Matrix

By following the procedure expressed in Figure 4, the elements of the matrix [r_{ij}] satisfying this identity formula can be obtained.

As the Markov transition matrix is probability matrix, the elements have to be adjusted by dividing each elements of the matrix with the sum of the corresponding row. In order to satisfy the identity formula in Figure 4 and to predict the total production amount in each time period [X_{t+m}], the diagonal matrix which has sum of elements in each row as its non-zero elements is multiplied from left hand side together with the production amount shares matrix [A(m)] to the column vector [X_t] for the number of prediction.

By the above procedure, under the assumption that original structural relation between 1985 and 1996 is hold in the future, given the column vector of total production in one time point, the corresponding column vector of total production in 11 years ahead can be obtained by the first multiplication.

By repeating this process for 7 times from 1996 on, the situations in 2070s are forecasted. The result of this simulation run is used as the baseline case for analysis on the effects of the EU accession in this paper.

1) Timing of the EU Accession for Turkey

According to the paper "Turkey and the EU Budget –Prospects and Issues－" by Dervis [7], Turkey is assumed to join the EU in 2015. The reason for this is that the effects of Turkey accession on EU budget is so large that it should be after the 2014 when the Turkish current budget plan is completed.

Also, as the EU budget is reviewed every six years, it is expected that the year when Turkey is integrated into the EU budget entirely is, at earliest case, some year between 2018 and 2024.

Accordingly, here in this simulation, the earliest case for Turkey to join the EU is considered. Based on the above assumption, the accession year for Turkey to join the EU is set at 2015. In this simulation, calculation is carried out every 11 years. So, the period from 2007 to 2018 is defined as the "pre-accession period" i.e. the period for preparation to join and adaptation to the EU budget. Then the period after 2018 is defined as the "period for Turkey to join the EU entirely".

Table 4 Markov Transition Probability Matrix

Sector (t_1) / Sector (t_0)	grain	vegetable	fruit	livestock	forestry	fisheries
grain	0.7767	0.0629	0.0393	0.0856	0.0262	0.0094
vegetable	0.0099	0.9526	0.0080	0.0224	0.0054	0.0016
fruit	0.0118	0.0099	0.9471	0.0061	0.0250	0
livestock	0.0425	0.0212	0.0022	0.8930	0.0391	0.0020
forestry	0.0120	0	0.0259	0.0041	0.9580	0
fisheries	0.0067	0.0004	0	0.0130	0	0.9799

2) Effects in the "Pre-Accession period"

In the "pre-accession period", there are 3 assistance from the EU. Those are i) PHARE for democratization, ii) ISPA for infrastructure and iii) SAPARD for agricultural structure adjustment.(cf. "Turkey and the EU Budget"). Among those, what affects agriculture directly is SAPARD. The important assistant items of SAPRD are i) improvement of processing and marketing of farm products, ii) investment in farm management, iii) repair of rural regional infrastructure and iv)diversification of economic activities (secure of off farm income). Judging from these items, the following two items are taken into account and based on these items, the "production amount shares" are adjusted as the scenarios for the simulations.

(a)The repair of rural infrastructure will expand the irrigated farmland, which contribute to the increase of fruits and vegetable production and the mixed farming of grain and livestock sector. In the non-irrigated areas, it is expected that the grain monocultures increase and the livestock industry production decreases.

(b) shift to the farm crop diversification and the cash crop will contribute the expansion of fruits and vegetables.

3) Assumed Changes in the EU Accession

As for the assumed changes in the EU accession, the information described in "Structural Change and Market Opening in Turkish Agriculture" (Erol H.Chakmak [8]) and the "ICCAP Scenario Families "impacts are applied.

In the paper by Chakmak, the change in one year after the EU accession of Turkey assumed in 2005 is simulated by applying the non-linear optimization model, i.e. PMP model. In this paper, following the EU accession, 5 conditions are assumed such as i) application of CAP, ii) abolition of current agricultural policy in Turkey, iii) continuation of current population growth (the annual rate of 1.5 – 2.0%), iv) increase of irrigated farmland, and v) price adjustment due to the adaptation to the EU common market. As the results of this simulation, it is pointed out that wheat, oilseed and livestock products will decrease and also barley, beans, timber, vegetable, fruits, nuts will increase. Based on characteristics of these changes, the following situation is suggested. i.e. (a) a little decrease of grain sector, (b) big expansion of vegetables, (c) increase of fruits, (d) sharp reduction of livestock products and (e) a little increase of forestry.

In addition, as the other change due to the EU accession, there is the application of "fish resources managements". It was disclosed that Turkey had exceeded the fishing quota of ICCAT in 2005 and so, it is not satisfying the international standard. However, due to the strict application of international rules following the EU accession, (f) a little reduction of fishery sector is also suggested. These tendencies in the above 6 sectors are taken into account in our simulation analysis and these are reflected in the values of the "production amount shares" as shown in Table 5.

Table 5 Production Amount Shares

Production Amount Share	2007-2018 Pre-Accession	2018-2073 EU Fully Accession
53.4	54.8	48.1
44.6	46.9	53.5
51.6	54.2	54.2
40.3	41.3	36.3
25.1	25.1	30.1
46.2	46.2	41.6

As shown in Figure 5, in the case of baseline simulation under the assumption that Turkey keeps the current situation without joining the EU, the relative production shares for fruit and fishery sectors will increase and those for livestock and forestry sectors will decrease constantly until 2073 while those for the grain and vegetable sectors will expand until 2030 or so but begin to decrease after 2030.

As shown in Figure [6], in the case of the EU accession scenario simulation, again, the production shares for fruit sector will increase and those for livestock sector will decrease constantly until 2073 but more sharply than the baseline case. Those for grain sector will show the similar pattern to the baseline case where the production share will expand for some years and then begin to decline after 2018. However in this case, the production share for vegetable sector will keep expanding until 2073, which is different from the baseline case. Those for fishery sector will increase until 2029 but begin to decline after 2040, which is also different from the baseline case. Those for forestry sector will decline for some years and then begin to increase slightly after 2018, which is also different from the baseline case.

Figure 7 shows the comparison of the simulated prediction results between the two scenarios for each sector. The above mentioned implications can be confirmed in these Figures.

Finally, Figure 8 shows the increased rate of production amount for each sector in the EU accession scenario case compared to the baseline scenario case. It can be observed that all sectors will increase their production amounts in absolute term but the increased rate of each sector is not the same with each other. Vegetable sector shows the biggest increase rate. Forestry and fruit sectors are second and third biggest respectively. Fisheries sector shows the smallest increased rate, followed by livestock and grain sectors in this order from the lowest rate.

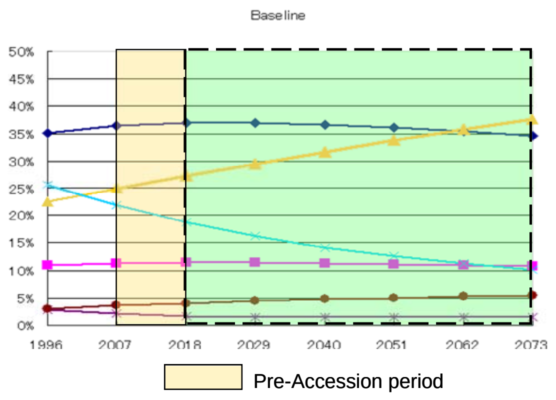

Fig.5 Prediction under the Baseline scenario

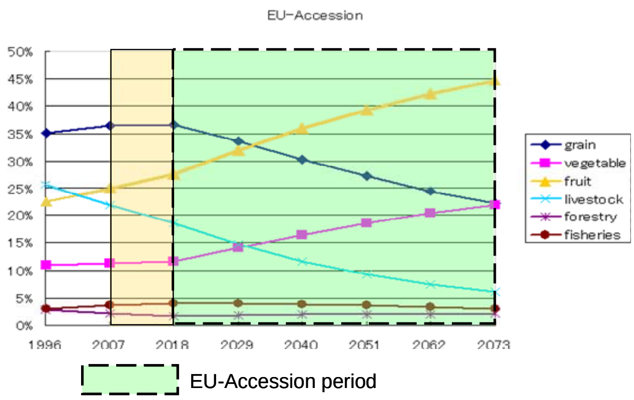

Fig.6 Prediction under the EC accession scenario

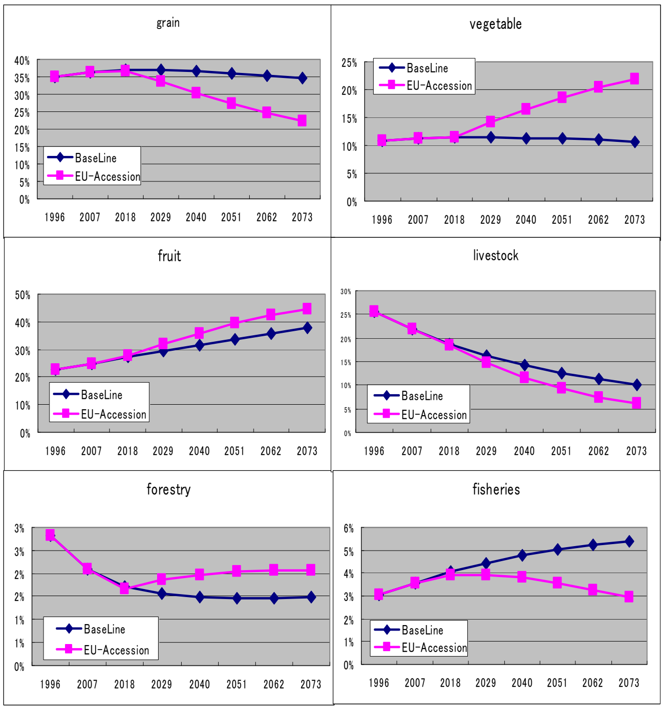

Fig.7 Compaison of production amount shares in each sector between the EU accession scenario and baseline scenario

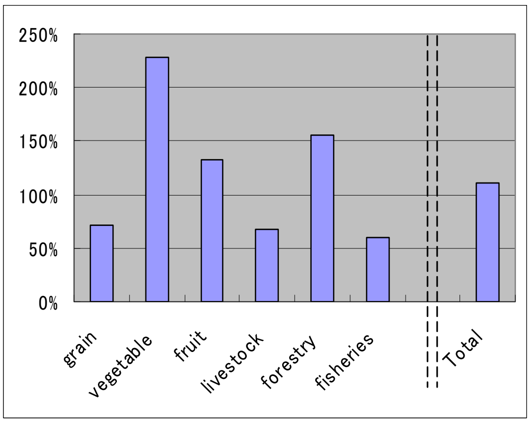

Fig.8 Changes of production amounts in the EU accession

6. Findings and Some Implications

From the above estimation and prediction results, as for impacts of climate change and the EU accession on Turkish rural industries, the following points are observed.

For the marginal effects of each climate change on the productivities, the following points are confirmed.

i) the increase of rain in May in both Konya and Adana does not affect the productivities in any rural sectors so much but the temperature increase in Konya will affects all of rural sectors positively while the temperature increase in Adana will affect all rural sectors except vegetable negatively.

ii) the relative impacts in percentage terms are very small in vegetables and rather big in grain, forestry and fisheries.

iii) as for total impacts of climate change on productivity in each rural industry, the forestry and fishery sectors will be affected positively and significantly while grain, fruit and live stock sectors will be affected positively but less significantly. Only vegetable sector will be affected negatively.

From the prediction results for impacts of the EU accession on the relative production amount, the following points are confirmed.

i) in the case of baseline simulation, the production shares for fruit and fishery sectors will increase and those for livestock and forestry sectors will decrease constantly until 2073 while those for the grain and vegetable sectors will expand until 2030 but begin to decrease after 2030.

ii) in the case of the EU accession scenario simulation, the production shares for fruit sector will increase and those for livestock sector will decrease constantly until 2073 but more sharply than the baseline case. Those for grain sector will show the similar pattern to the baseline case where the production share will expand for some years and then begin to decline after 2018.

iii) the production share for vegetable, fishery and forestry sector showed the different pattern from those in the baseline case.

iv) finally, as for the increased rate of production amount for each sector in the EU accession scenario case compared to the baseline scenario case, all sectors will increase their production amounts in absolute term but the increased rate of each sector is not the same with each other . Vegetable sector shows the biggest increase rate. Forestry and fruit sectors are second and third biggest respectively. Fisheries sector shows the smallest increased rate, followed by livestock and grain sectors in this order from the lowest rate.

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The Conservation of Government Pasture Land and the Role of Pasture Law in Turkey

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1. Destruction of Government Pasture

Government pasture which covers about 100% of total pasture in Turkey has been fundamental resource to graze animals for more than one hundred years. Before 1950, almost 50% of the country was covered by government pasture, so that there was abundant size of pasture resource that could satisfy the demand of animal products of those days. However, the size of government pasture has decreased sharply and the number of animals has increased since 1950. The former was caused by the conversion of government pasture to crop land which could satisfy more demand of cereals, and the latter was caused by augment of the demand of animal products, with growth of population. This contradiction has drawn the destruction of government pasture, which embraces two serious problems, that is the excessive conversion of government pasture and the overgrazing.

1) Excessive Conversion of Government Pasture to Other Use

It is necessary to convert government pasture to other use in order to meet the population growth. In fact, the large amount of government pasture has been converted under the direction of the government. The problem is the degree of conversion progression. The appropriate conversion that keeps government pasture satisfying the demand of animal products will be acceptable. But, under the current circumstance that the demand of animal products increase rapidly, the excessive conversion of government pasture makes matters worse.

In fact, there has been fast decrease of government pasture and fast increases of agricultural land and other uses since 1950 as shown in Figure 1[1)]. The fast decrease of government pasture is connected with the excessive conversion of it. If the government pasture had been converted under the strict management of government, the pasture could have been converted appropriately. In actual fact, however, vast size of the pasture has been converted by farmers for the use of their private cropland without any permission of the government. This unlawful conversion defined as the intrusion, that is called as 'pasture attack (mera fecavozj), has caused the excessive conversion.

2) Overgrazing

The contradiction between decrease of government pasture and increase of number of animals brought about overgrazing. Overgrazing has caused grass quality of the government pasture worse. According to the results of shepherds interviews in Konya province, the plant cover ratio of total government pasture was 75% before 1980, but now this ratio has reduced to only 25%. Especially about 20% in the botanical composition of the government pasture are thorny (dikenli of), and animals can not eat them at all. Good grasses on the government pasture is not enough to sustain animals as many as before. This serious deterioration of the government pasture started since about 1980. The speed of decline in the size of the good quality grass pasture increased during the last two decades.

2. Factors in Causing Destruction of Government Pasture

1) Causing Factors of Excessive Conversion of Pasture

The excessive conversion of pasture is caused by the improper institutional arrangements of land management. Especially the inefficient execution of the land registry law is the main causing factor. First we will state the land registry system in Turkey and then illustrate the problems of the system that has brought about the excessive conversion.

1-1) Land Registry System in Turkey

All lands in Turkey are currently required to be registered as either private ownership or government ownership based on cadastral survey according to the land registry law (law no. 2644). Private ownership of land is indemnified by the title deed which is called 'tapu'. Before 1922, that is Ottoman Turkse empire days, land ownership was not clearly defined. Some parts were possessed by sultans, some were traditionally cultivated by peasants, and vast uncultivated land were used freely as common pasture by pastoralists. At the founding time of the state in 1923, huge uncultivated common pasture was taken by government. Thereafter, because of population growth and immigration, there has been strong social need to convert vast uncultivated government pasture to privately cultivated land. Government authorized the farmer who had reclaimed a certain area of cropland from the government pasture by himself and hold on to the area for long enough years such as 20 years to take possession of the area. Both the continuously cultivated land and the newly reclaimed land were obliged to be registered with 'tapu' according to the current land registry law of Turkey. But, in fact, issuing 'tapu' was very difficult work.

1-2) Transaction Cost and Inefficient Execution of the Land Registry Law

The cadastral office is in charge of issuing 'tapu' and indemnifying the legal ownership of the land in question to the owner under the control of director of state cadastral bureau. Land with 'tapu' must be demarcated strictly by the 'tapu' officials who actually came to check the ownership. But quite lots of expense are inevitable for the demarcation, because the cadastral officials should come to each plot, get the exact evidences of the ownership to the plot in question, and measure the plot. There are seldom formal written evidences for the plot in question, so that it is often very difficult to prove the ownership of the plot by the person who claims to own the plot.

These expenses for demarcation and registration of land are the transaction costs. The reason of difficulties in issuing 'tapu' is that the transaction costs of establishing private ownership of land are too high. Due to high transaction cost, the current land registry law is not executed efficiently. Only 70% of whole land of Turkey has been registered with 'tapu' until now. The other 30% of land is still unregistered with 'tapu'. A number of farmers who possess land without 'tapu' were interviewed in our field surveys in Adana and Konya province during the last few years. The unregistered land is called as customary land (zilyet). Holders of the customary land have faced such severe problems as difficulties in disposal by sale, in inheritance, and in mortgaging during the past few decades.

1-3) Pasture Attack and Excessive Conversion of Government Pasture

The difficulty of lawful demarcation is linked to the facility of unlawful border transgression. It is very difficult for the government to monitor and restrict each unjust farmer who appropriates the government pasture unlawfully, because of the extremely high transaction cost to do so. Therefore, the government pasture has been attacked under the current land registry law as fallows.

Government pasture has been always allowed to be used only for common grazing. But it is said that unjust farmers had started to attack pastures or to intrude government pastures in 1950-60's. That was the time when farmers were able to expand their cultivated land more easily by technological improvement such as switch from animal draft to tractor draft. This unlawful intrusion started to decrease since 1980's, because deterioration of the government pasture became too severe. However, 30~40% of the total government pasture was already unlawfully converted to private crop land in Turkey by then. Many cases of pasture attack found in field survey of Konya and Adana give evidences to high transaction cost for preventing intrusions[2)]. Unlawful pasture attack resulted in the excessive conversion and fast decrease of the government pasture.

2) Causing Factors of Overgrazing

The overgrazing is considered to be caused by (1) tragedy of commons, and (2) excessive conversion of government pasture.

The first factor is what we call tragedy of commons[3)] . The government pastures are being allocated among animal-grazing villages in Turkey. In other words, there is the village common pasture that belongs to government property, that is to say village government pasture, in every animal-raising village. The village government pasture is the village common pool resource that any member of village can have accesses to nonexclusively. As the demand of animal products increased, individual member of village were motivated to add more number of animals to herds on the village government pasture. The overgrazing is caused by the fact that size of the government pasture is limited compared with the increasing population of animals. Each individuals try to use as much grass as possible to increase his income directly. Animals added non-exclusively to the total herds by him and others deteriorates the grasses on the village government pasture. Every individuals are suffered from the deterioration of pasture relatively less than the gain from additional animals, so that they will continue to add animals to graze over the total optimum number of animals on the pasture. Each individual does not stop continuing to add animals, because his activities are not rewarded individually to him, but only externalized to the other users. Ultimately the grass on the village government pasture will be destroyed.

Second, the excessive conversion of the government pasture has also induced overgrazing problems. Decrease in size of the government pasture makes shepherds face the problem of grass shortage. Thus they could not help to start bringing their animals to the government pasture much earlier than the optimum season. They had to start grazing their animals just after snow melt (around 15 Feb). But this date is too early for the grass to grow appropriately. Once growing points of grass has been eaten by the animals, grass loses the power to grow well. This early grazing also deteriorates the quantity and quality of grass.

The overgrazing based on tragedy of commons and excessive conversion of pasture has caused severe degradation of government pasture. In addition, decrease of precipitation of last two decades has accelerated the speed of degradation. According to the results of the village elders interviews in Konya province, the speed of degradation of the government pasture increased along with the decrease of rainfall on pasture for the last two decades. There must be the strong causality between the government pasture degradation and the precipitation decrease.

3. Enactment of the Pasture Law

The excessive conversion based on pasture attack and the overgrazing of the government pasture have severely decreased both quantity and quality of grass on it during the past four decades. These problems were caused by inefficient institutional arrangements under the current land registry law system. The government introduced new institutional arrangements in order to restore and conserve the government pasture with the enactment of pasture law (law no.4342) in February 1998. Under the new arrangements the following objectives were sought.

(1) To delineate the border between private cropland and the government pasture.

(2) To confiscate the intruded government pasture area.

(3) To implement the project for improving grass quality on pasture. Subsidized fertilizer and grass seeds are often provided to shepherds and farmers.

(4) To assign use right of demarcated government pasture to the authority of village community.

(1), (2) are executed as follows. Extension service workers and cadastral officials are jointly in charge of attaining these objectives. First, the boundary stones are placed on the border between the government pasture and private crop land based on the cadastral map (kadastral pafta). The farmers who admit the stoned border must voluntarily limit their crop land up to the stoned one. But in many cases farmers object the stoned border and continue to occupy the intruded area. Therefore, second, the heads of villages are obliged to investigate the intrusion according to the stoned border. If he finds it, he must report to the extension workers regarding location of the doubtful area. Third, a survey map (tecavus krokisi) of the doubtful area is drawn by an actual survey. Fourth, in the case where the fact of intrusion is proved, the intruder are warned by the government. Unless he will returned the intruded area to the government in 4years from the warning, he is supposed to be sentenced 2-3 months' imprisonment. Though the law was enacted, however, still only a small portion of the illegally intruded area of the government pasture has been delineated or confiscated (see table 1).

(3) and (4) are performed such as the following two cases. One case is Karakislakci village of Adana Province. The village government pasture consists of 500da summer pasture (Yayla) and 1,000da hilly pasture (1da = 0.1ha). Those pastures belong to the government land, but the use right is assigned to the village according to the pasture law. The pastures are divided into some plots and only one plot is permitted to be used for grazing in one season. If a plot is used in this season, the plot is forbidden to be used in a few years. This system is what we call the rotational grazing for sustainability of pasture. Because administration of the village is remitted to the board of village which consists of the head and 4 elected staffs, the usage of the village government pasture was also decided by the committee. The committee forces shepherds to use the pasture

Table 1 Execution of Pasture Law

	Confiscatior	(ha)	Delineation	(ha)		Confiscatior	(ha)	Delineation	(ha)
Province	Done	Targeted	Done	Targeted	Province	Done	Targeted	Done	Targeted
ADANA	0%	5,640	32%	33,851	KONYA	1%	379,357	3%	314,563
ADIYAMAN		0		0	KUTAHYA	0%	12,850	1%	11,948
AFYON		0	0%	695	MALATYA	18%	48,620	34%	161,111
AGRI	0%	2,553	74%	13,106	MANISA	30%	3,130	6%	14,897
AMASYA		0		0	K..MARAS	1%	145,318	26%	172,814
ANKARA	0%	12,736	0%	26,665	MARDIN	0%	12,965	13%	18,264
ANTALYA	0%	4,635	0%	1,389	MUGLA	0%	1,388	39%	7,035
ARTVIN	100%	16,144	100%	3,868	MUS	2%	59,794	24%	74,301
AYDIN	0%	9,471	0%	18,911	NEVSEHIR	16%	21,576	3%	168,735
BALIKESIR	0%	52,976	0%	47,761	NIGDE	0%	27,757	10%	24,122
BILECIK	11%	1,528	11%	1,535	ORDU	100%	32,382	100%	45,443
BINGOL		0		0	RIZE	98%	4,788	97%	40,730
BITLIS	0%	14,073	0%	51,949	SAKARYA		0		0
BOLU	0%	2,856	0%	8,960	SAMSUN	0%	8,382	0%	103
BURDUR	0%	6,977	0%	7,726	SIIRT		0	5%	637,787
BURSA	0%	12,885	11%	14,979	SINOP		0	0%	2,270
CANAKKAL	38%	4,737	15%	19,920	SIVAS	7%	40,403	100%	20,768
CANKIRI	0%	31,326	0%	67,947	TEKIRDAG	0%	32,996	0%	33,541
CORUM	0%	13,941	0%	30,359	TOKAT	5%	23,807	0%	3,749
DENIZLI	0%	4,263	0%	6,645	TRABZON	76%	2,460	95%	37,839
DIYARBAKI	0%	36,798		0	TUNCELI	0%	15,429	0%	5,569
EDIRNE	0%	55,100	0%	5,382	S.URFA		0		0
ELAZIG	0%	20,612	0%	20,612	USAK	0%	48,466	100%	2,246
ERZINCAN	0%	31,320	100%	2,816	VAN	67%	185,792	61%	412,936
ERZURUM	24%	31,274	0%	144,438	YOZGAT	0%	71,052	1%	116,015
ESKISEHIR	0%	62,582	0%	49,688	ZONGULDA	2%	142	43%	870
GAZIANTE	0%	12,128	0%	44,232	AKSARAY	0%	1,470	0%	144,884
GIRESUN	100%	247	63%	47,560	BAYBURT	0%	19,096	0%	20,106
GUMUSHA	60%	48,677	73%	59,264	KARAMAN	0%	51,127	0%	62,233
HAKKARI		0	100%	830	KIRIKKALE	0%	3,836	0%	8,950
HATAY	0%	3,896	0%	8,258	BATMAN	0%	13,310	2%	10,134
ISPARTA	0%	14,277	0%	13,955	SIRNAK	0%	13,089	0%	13,205
ICEL	100%	162	52%	58,179	BARTIN	0%	239	6%	1,854
ISTANBUL	0%	3,297	0%	1,644	ARDAHAN	0%	13,298	0%	16,465
IZMIR	0%	26,538	0%	12,366	IGDIR	59%	3,832	47%	8,290
KARS	0%	16,561	1%	32,786	YALOVA	0%	844	0%	791
KASTAMO	9%	5,597	31%	1,584	KARABUK	6%	889	55%	1,662
KAYSERI	9%	39,430	22%	84,148	KILIS	0%	6,698	0%	11,993
KIRKLARE	0%	1,815	4%	30,411	OSMANIYE	2%	2,381	2%	2,381
KIRSEHIR	0%	45,508	0%	14,149	DUZCE	0%	1,899	0%	1,889
KOCAELI	0%	226	0%	714	TURKEY	13%	1,963,643	20%	3,621,773

based on the Rotational grazing. Another case is Dagdibi village of Adana Province. The village government pasture of 5,000~6,000da is also controlled under rotational grazing for grass sustainability. In addition, according to the government project based on World Bank's fund, fertilizers were spread on the pasture in last year and grass seeds are planed to be spread on the pasture in this year. According to the interviews of the village head, increase of grass yield can be recognized distinctly in this summer. But this project of pasture rehabilitation is just the special case. The projects and assignment of use right of government pasture to village, that is (3) and (4), are related to coping with overgrazing, but the concrete cases of (3) and (4) are still very few. On the contrary, places of border stone and confiscation, that is (1) and (2), which can cope well with excessive conversion based on pasture attack, are currently mainly being executed. We will henceforth focus on the pasture attack related issues of (1) and (2).

4. Issues of Confiscation under the Pasture Law

The pasture law is enacted in order to solve the pasture attack problems caused by inefficient institutional arrangements under the current land registry law. If so, is the pasture law intrinsically the efficient one to conserve and restore the government pasture? We need to examine the efficiency of institutional arrangement of the pasture law.

We consider that the special institutional aspect of the pasture law is the confiscation that government dispossess the attacked pasture compulsorily. It is because the confiscation is contrary to the interest of pasture attacker, so that it makes the institutional arrangement more difficult and more inefficient. We establish the following 3 issues that are linked to the confiscation and examine theoretically them in following sections. .

(1) Choice between confiscation and reparation

There are two ways for coping with the unlawful intrusion. One is confiscation and another is reparation by the intruder. The trouble of adversely possessed land is often resolved by reparation instead of confiscation, when confiscation costs monetarily and time-consumingly more than reparation. We need to examine whether the government's confiscation is more efficient than reparation.

(2) Cost and benefit of confiscation

Transaction cost such as place of border stones, actual survey, judicial procedure, or exercise of police power must be also bore when the confiscation is executed. The benefit from restoration of government pasture can be gotten instead. We must investigate whether benefit covers cost efficiently on the case of confiscation.

(3) The factors that affect the execution of confiscation

Even though Turkish government started to try to confiscate the intruded area, only a small portion of intruded government pasture has been restored. In fact, the confiscation can not be executed perfectly. We must investigate the factors that affect the execution of confiscation.

5. Theoretical Framework for Analysis of the Pasture Law

The raison d'etre of law is assessed by both equity and efficiency. If judicial judgment were one sided, principle of equity would be collapsed and social order would break down. If judicial judgment caused waste resource, principle of efficiency would be collapsed and society could not be sustainable. These are the reasons why the importance of equity and efficiency is emphasized. Equity is the domain that hitherto jurisprudence mainly dealt with. But efficiency is the domain that jurisprudence does not dealt deeply in but economics is strong in. The judicial judgment based on the law must be equal to the most efficient agreement that is socially acceptable after exhaustive negotiations among privies. The most efficient agreement is driven from the courthouse's arbitration that the one maximizes his utility subject to the constraint that the other has already maximized his utility. This concept of the most efficient agreement is equal to Pareto optimality that is also sought in Economics. This is the reason why there are spheres that economics can take an active part in jurisprudence. Interdisciplinary studies between jurisprudence and economics has been often applied to analysis of law in the last decade, which is called as Economics and Law[4)].

The above mentioned issues of confiscation can be investigated with the simple model that is originated by the author based on economics and law. There are two encountered parties, namely the pasture attacker who has intruded unlawfully the government pasture and the government who tries to confiscate the intruded area. The confiscation brings about the conflict between them. Basically the attacker is to blame, because he intruded the state demesne. But the fault is partly laid to the government's charge, for the government's inefficient institutional arrangement has caused the pasture attack. If an attacker has occupied the area of government pasture for long enough years, he must be allowed to acquire the area in problem by prescription. The problem is the case that the attacker claims his ownership without any evidences. In the case, both sides claim the ownership and are brought into conflict. The conflict should be mediated under the third party that is independent from both parties. The typical third party is the courthouse. Actually there are so many cases that farmer institutes a suit against government about ownership of his occupied crop land in question. If we could collect adequate number of the precedents for pasture confiscation suits, we could provide strong evidence to our theoretical analysis. But, because of difficulties of collecting official judicial documents in Turkey, first we focus on theoretical studies in this paper.

We can investigate the efficiency of confiscation by assuming that the conflict is resolved based on the judicial judgment. Let p ($0 \leq p \leq 1$) be the attacker's probability assessment of winning a suit. Let q ($0 \leq q \leq 1$) be the government's probability assessment of winning a suit

Different attacker has different p and different government officer in charge has different q. Let P be the attacker's total probability assessment of winning a suit that is representative of all attackers' assessments. Let Q be the government's total probability assessment of wining a suit that is representative of all officers' assessments. The judicial judgment arbitrates the conflict based on Pareto optimality, because it is the only one agreement that can be concluded between two parties in the most efficient institutional arrangement. The courthouse ought to judge the agreement in the way that P is equal to $1-Q$ and Q is equal to $1-P$ on the basis of Pareto optimality. Pareto optimality is realized on the point that the attackers maximizes their total expected value based on P subject to the constraint that the government officers have already maximized their total expected value based on Q. Suppose the judicial judgment is P^* (=$1-Q^*$) and Q^*(=$1-P^*$). All attackers and government officers are obliged to agree on the point of the courthouse's P^* and $1-P^*$ (, that is Q^* and $1-Q^*$).

6. Efficiency of Confiscation under the Pasture Law

First, issues of (1) choice between confiscation and reparation and (2) cost and benefit of confiscation will be examined in this section. Now suppose that the value of the intruded area for the pasture attacker is V which creates return of harvests. On the judicial judgment, P^* becomes equal to $1-Q^*$ and Q^* becomes equal to $1-P^*$ in order to conclude agreement between the attacker's party and the government's party. In that case, P^* represents $1-Q^*$, so that Q^* is not needed to be referred. Transaction cost TC such as judicial cost is required in order to conclude the agreement. Basically the party who lose a suit must bear the transaction cost.

6-1) Confiscation or reparation

If government gives up the idea of confiscation and makes attacker pay indemnity in compensation for occupation of intruded area, the agreement between two parties can also be reached by reparation rule. There are actually a few such cases in Turkey. Let the indemnity be X. The total expected value of the attacker and the government under reparation rule is respectively therefore,

A (Attacker) : $E(A) = P\,V + (1-P)(V-X) - (1-P)TC$ (1)

G (Government) : $E(G) = (1-Q) * 0 + Q\,X - (1-Q)TC$ (2)

On the judicial judgment, (1) and (2) become

A (Attacker) : $E^*(A) = P^*\,V + (1-P^*)(V-X) - (1-P^*)TC$ (3)

G (Government) : $E^*(G) = P^* * 0 + (1-P^*)\,X - P^*TC$ (4)

The social welfare that fulfills the condition of Pareto optimality is summation of expression (3) and (4). That is

$E^*(A) + E^*(G) = V - TC$ (5)

(5) is the frontier line on which both parties can agree under the judicial arbitration, regardless of P^*(or Q^*) and X. If the social welfare is positive, that is $V > TC$, the agreement of both parties can be concluded under the reparation rules, irrespective of the courthouse judgment P^* and indemnity X. This is called as Coase Theorem[5)].

The reparation rule could be efficient under only this condition.

But the reparation is exceptional instance and there is no case interviewed in our field surveys in Adana and Konya province. Government pasture is prohibited strictly by the government from being used as crop land. The government will accept the reparation rules only in the case that the attacker uses the intruded area as pasture. But it is impossible to make the attacker use it as pasture, because pasture is of no value for him. So far as both parties will not make a compromise with each other, the transaction cost under reparation is prohibitive, that is $V < TC$. Therefore, the reparation rule is concluded to be inefficient institutional arrangement, so that the other confiscation rule must be adopted by the government.

6-2) Cost and Benefit of Confiscation

The confiscation is now tried to be executed by police power under the pasture law. If attacker does not return the intruded area to the government, the area is compelled to be confiscated and the attacker is supposed to be amerced in the sum of ***M*** in which negative value of imprisonment is included. But he may be allowed to acquire the occupied area of government pasture by prescription, in the case of long years occupation. The conflict between both parties is caused by the case that the attacker claims his ownership without any evidences.

Let ***P*** be the attacker's total probability assessment of wining a suit that the intruded area can be held out on by the attacker. Let ***Q*** be the government's total probability assessment of winning a suit that the intruded area can be retrieved by the government. In the case that the area can be confiscated, the attacker can gain nothing but penalty. Suppose that government is given ***M*** intact and that both parties evaluate the area at ***V***. Transaction cost ***TC*** such as judicial cost must be bore by the party who lose a suit.

The total expected value of the attacker and the government under confiscation rule is respectively therefore,

A (Attacker) : $E(A) = P\ V + (1-P)(-M) - (1-P)TC$ (6)

G (Government) : $E(G) = (1-Q) * 0 + Q(V+M) - (1-Q)TC$ (7)

On the judicial judgment, (6) and (7) become

A (Attacker) : $E^*(A) = P^*\ V + (1-P^*)(-M) - (1-P^*)TC$ (8)

G (Government) : $E^*(G) = P^* * 0 + (1-P^*)(V+M) - P^*TC$ (9)

The social welfare that fulfills the condition of Pareto optimality is summation of expression (8) and (9). That is

$E^*(A) + E^*(G) = V - TC$ (10)

(10) is also the frontier line on which both parties can agree under the judicial arbitration, regardless of ***P*(or Q*)*** and ***M***. If the social welfare is positive, that is ***V*** > ***TC,*** the agreement of both parties can be concluded under the confiscation rules, irrespective of the courthouse judgment ***P**** and amercement ***M***. This is also understood as Coase Theorem. As the frontier of land has been vanishing and the size of unreclaimed land has been decreasing, the value of government pasture has been increasing. So far as the benefit of the retrieved government pasture area is expected to be higher than the transaction cost necessary for confiscating processes, the confiscation rule is concluded to be the efficient institutional arrangement. Judging by the interview of local government in Konya, we can say Turkish government has decided to execute the new pasture law progressively.

7. Social Agreement on Confiscation under the Pasture Law

Finally, issues of (3), namely the factors that affect execution of confiscation will be examined in this section.

Under the confiscation rule, both attacker and government can agree on the frontier line, that is to say expression (10) regardless of ***P****, because Pareto optimality is fulfilled. Next thing of judicial judgment to do is decision of social agreement ***P***** that both parties accept. ***P***** stands for the degree of the confiscation that actually can be executed. The courthouse gives the ruling in the way that the attacker win a suit in ***P***** *100 %. As ***P***** is larger, the judgment case favorable to the attacker is more. As ***P***** is smaller, the judgment case favorable to the government is more.

According to Nash-bargained solution, the attacker and the government jointly choose the social agreement ***P***** to maximize the product of their expected value ***E*(A)*** and ***E*(G)***, subject to their Pareto optimality. The product is a kind of acceptable social utility. That is

$$\text{Max } E^*(A) * E^*(G)$$

$$= \text{Max } (P^*\ V + (1-P^*)(-M) - (1-P^*)TC) * (P^* * 0 + (1-P^*)(V+M) - P^*TC) \quad (11)$$

$$\text{s.t. } E^*(A) + E^*(G) = V - TC \quad (12)$$

The necessary condition of this social agreement ***P***** is

$$P^{**} = (V+2M+TC)/2(V+M+TC) \quad (13)$$

The courthouse arbitrates both parties according to this ***P***** and the attacker is obliged to return the intruded area in the possibility of ***P***** *100 %.

There are three factors that interact to affect the degree of confiscation execution ***P*****, that is the evaluation of the intruded area ***V***, amercement ***M***, and transaction cost such as judicial cost ***TC***. In order to investigate the influence of ***V***, ***M***, and ***TC*** on ***P*****, provided the other factors remain unchanged, ***P***** is differentiated by each variable as follows.

$$dP^{**}/dV = -2M/(2V+2M+2TC)^2 < 0 \quad (14)$$

$$dP^{**}/dTC = --2M/(2V+2M+2TC)^2 < 0 \quad (15)$$

$$dP^{**}/dM = (2V+2TC)/(2V+2M+2TC)^2 > 0 \quad (16)$$

These are concluded as following. First, the degree of confiscation execution ***P***** is proportional to the incremental land value of the intruded area ***V***. The higher the intruded area is evaluated, the more progressively the confiscation will be executed. At the present, the frontier of land has been vanishing and both the government and the public has started to revaluate the government pasture. In fact, the Turkish government is going forward the confiscation and the attackers cannot help fulfilling the pasture law policy.

Second, on the contrast, the lower the intruded area is evaluated, the more difficultly the confiscation will be executed. If less precipitation reduces the marginal productivity of the intruded area, it will result in decreasing the evaluation of the area and reducing the attacker's agricultural income. The attacker will strongly insist on continuing to occupy the area in problem in order to keep his total agricultural farm income level. Decrease of precipitation affects the confiscation execution negatively.

Third, the degree of confiscation execution ***P***** is inversely proportional to the incremental amercement ***M***. It is futile to fine the attacker heavily in order to promote the confiscation, because the attacker resists the avaricious government policy and is not willing to compromise easily. Heavy punishment can not reduce cases of lawless act.

Forth, the more transaction cost ***TC*** the attacker incurs, the more progressively the confiscation will be executed. Compared with the case of government, it is more burdensome for individual attacker to bear the transaction cost such as judicial cost. The attacker may favorite to fulfill the government order rather than suffering from the complicated formalities in courthouse.

8. Concluding Remark

The government pasture has been drastically destroyed since 1950, due to the excessive conversion of the pasture to other use and the overgrazing. The most serious factor in causing fast destruction of the government pasture is the unlawful intrusion, that is what we call pasture attack. Pasture attack was the results of inefficient institutional arrangement under the land registry law, so that Turkish government newly enacted the pasture law in 1998 in order to resolve the institutional inefficiency. According to the pasture law, the intruded area of the government pasture is now tried to be confiscated by the government.

We theoretically examined the efficiency of the new pasture law in this paper. Judging from the present situation that both Turkish government and the public reevaluates the value of government pasture, the confiscation rule is considered to be intrinsically efficient device rather than any other rules at the present. However, on the case that the crop productivity of the intruded area is decreased by some reasons such as climate change, the confiscation will be executed more difficultly. It is because the attacker will insist on continuing to occupy the area in problem in order to keep his income level.

＜Note＞

1) On the contrast, the government forest has been conserved carefully under rigorous application of the law of forest (law no.6838). 99% of forest belongs to state treasury and lumbering is completely controlled by the government. The border of forest is being firmly fenced against intrusion.

2) We introduce two typical cases of pasture attack. One is the case of Kilicli village in Adana. There is hilly area where trees grow sparsely and animals are grazed on the underbrush of there in the village. 'Tapu' officials came to this village in 1960's and agricultural land was registered with 'tapu' at that time. But, compared with the size of hilly area at that time, it has reduced strongly without notice. The size that used to be 4,000da (1da=0.1ha) 20 years ago has reduced to 2,000~3,000da by pasture attack until now.

Another case is Buyukbrnak village in Konya. In this village many farmers attacked the government pasture unlawfully, even though they know the fact of intrusion. The agricultural land is 22,000da in area. The area of pasture is 21,026.00509da which is divided among 31plots. 397.733da of whom used to be intruded and 200da was returned to the government. In other words, 5% of pasture was intruded and 3% of pasture are still unlawfully occupied by unjust farmers.

3) According to the original sentences by G.Hardin, tragedy of commons is described as fallowing.

Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit – in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. (Hardin(1968) , The Tragedy of Commons, Science 162, p1244)

4) See Miceli,T.(1997), "Economics of the Law : Torts,

Contracts, Property, Litigation", Oxford.

5) The Coase theorem is defined in Miceli,T.(1997) , p9 as following.

The Coase theorem says that if transaction costs are low enough to permit bargaining between the parties to an externality, and if property rights are well defined, then the initial assignment of rights will not affect the ultimate allocation of resources, which will be efficient.

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Effect of Global Warming on the Secondary Factors Affecting Water Use Efficiency and Irrigation Management

Israel Sub-Group

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Abstract

The major factor affecting crop production in semi-arid environment is certainly water availability. However, according to Liebig's law of the minimum, agricultural productivity is controlled only by one or two environmental properties that are the scarcest resource. When water is available crop growth is affected by the secondary factors. Therefore, quantitative estimate of environmental properties such as temperature, CO2 concentration in the air , salinity relative humidity and dew formation can be useful to determine optimal growth conditions.
In this presentation we describe experimental and theoretical results that were obtained during the years of ICCAP project. Productivity data , evapotraspiration and photosynthetic rates (PN) were collected in the Chukuva basin Turkey. Nine different summer and winter crop, orchards and natural habitats were studied using unique measuring systems and analyzed from a biophysical and economical points of view.

Temperature effect: The steep decline in PN with temperature above 24-25 °C for winter wheat or 34-36 for summer crops means that small increases in ambient temperature can then lead to significant decreases in net CO2 uptake ability and it indicate that irrigation then may lead to only small enhancements in net CO2 uptake.

Relative Humidity (RH) and Dew formation: Contrary to expectations, photosynthesis in the early morning hours was not linked to transpiration (or weakly linked). This weak link resulted from the presence of dew on the leaves which caused a temporary reduction in leaf to air VPD followed by increased stomatal conductance and improved water use efficiency (WUE).

Salinity: Agroproductivity of the saline soils in the Chukurova basin is reduced to half the productivity of the non-saline soils but the optimal temperature remain the same.

Climate model: The outputs of the global climate model HadCM3 was adjusted to the specific research locations, we generated projections for 2070-2100 temperatures and precipitations for two climate change scenarios. These data were used to support the economic analysis.

Economic analysis: Net revenues from wheat become negative under the severe scenario (A2), but may increase under the moderate one (B2), depending on the fertility of the soils. By contrast, under both scenarios cotton evinces a considerable decrease in yield, resulting in significant economic losses.

Interactive effects: Increase of CO2 concentration in the air increased NP and transpiration rates but the NP was reduced under low relative humidity at all plants species. Low RH increased the transpiration rates and hence reduced WUE. Contrarily, dew formation on the leaves increased

NP but reduced transpiration rate to result in improved WUE.

Concluding remarks This study was aimed to predict the effect of climate change on natural and managed vegetation and contribute to strategy to conserve them. It's unique approach was that with the appropriate field instrumentation it provided increased understandings of the complex interactions between crops and their environment. For example elevated CO2 humidity, and temperature changes. From the standpoint of irrigation management the consequenses are that we established a tool to control the crops environment even under global warming. Undoubtedly the models for predicting effect of climate change are constantly modified as knowledge increases but this study with the understanding of the interactive effects was a step to minimize the economic damage of global warming. Goal: Investigation of crop factors that are influenced by global warming

Reasearch objectives

A. Global warming effect on biomass production and water requirements.(BGU)

1. Quantification and development of models to predict the effect of extreme GCC scenarios on biomass production

B. Socio-Economic impact of GCC. (HU)

2. Assessment of Damage and Adaptability to Regional Climate Change.
3. To determine how farming would change with the expected changes in precipitation patterns.

C. Regional climate change (TAU)

4. Analysis of the global warming models over the Mediterranean.
5. Daily classification of synoptic systems for 1948-2000 including : change of seasons,

I Effect of Global Warming on the Secondary Factors Affecting Water Use Efficiency and Irrigation Management

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Goal: Investigation of crop factors that are influenced by global warming

1. Irrigation as a Major Factor Affecting Crop Production.
2.Water Use Efficiency:
3.The Secondary Factors Affecting Productivity.

1.1 Introduction

The Chukurova basin provides a good case study for analyzing the impact of global climate change on a regional basis. The predicted increase in temperature by 2-4˚C and the expected decrease in precipitation by 30% may adversely affect crops productivity and water availability by the year 2050. Computer crop models and intensive field measurements in the Chukurova basin in Turkey, the Negev Desert and the Jordan River basin in Israel were used to evaluate possible yield changes caused by climate change including the beneficial effect of increasing CO2 levels on crop growth. Results showed that wheat yield may increase by 20-25% for respective increase of 2˚C and 4˚C. But, the associated increase in water consumption is 18% and 40% and the water cost for increased productivity may be too high. (Fig.1).There is no need to emphasize the importance of irrigation and water availability as the major factor for agricultural production but availability of water resources is not necessarily affected by global warming because water resource are unlimited especially if one considers sea water desalination technology which may be improved to a point of feasibility. Thus water availability is only a problem of "money" as opposed to the secondary factors which are uncontrollable and depend on climate variations / change. In our study the selected non-conventional factors affecting irrigation policy were temperature , salinity, relative humidity and dew formation.

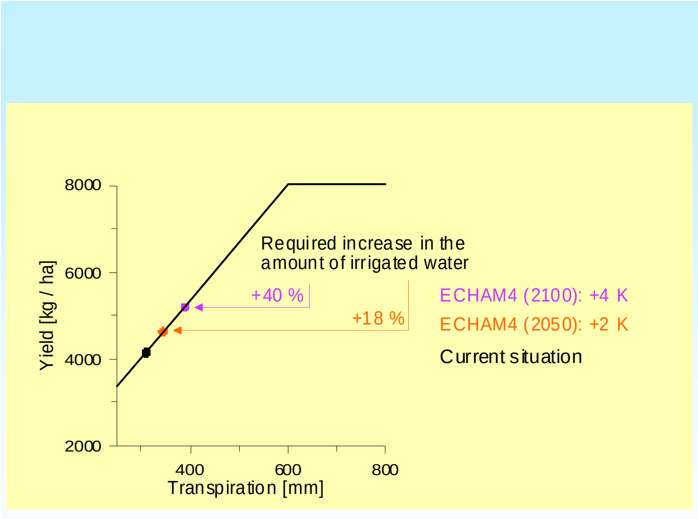

Fig. 1. Preliminary results from ECHAM4 climate change scenarios Simulated effects for wheat production

1.2 Methodology

Study region: Study sites (37o04´-36o46´N, 35o20´-35o25´E) are located in the Çukurova region, a southern Mediterranean region of Turkey, at an altitude 6 to 150 m above sea level. A typical Mediterranean climate prevails in the study region with the long term mean annual temperature18.7 oC (Minimum and maximum air temperatures are -8.1 oC in January and 45.6 oC in August), 647 mm precipitation, 1320 mm potential evapotranspiration and incident PAR of 284 MJ m-2.. About 87% of precipitation falls during the winter (November to May). Maximum incident PAR occurs in August (415 MJ m-2 month-1) and the minimum in December (141 MJ m-2 month-1).

he surface soils (0-30 cm) with different proportions of sand, silt, and clay fractions in the study locations were predominantly fine-textured soils. The soils of the wheat sites displayed a wide range of variation with respect to field capacity and permanent wilting point which corresponded to -0.03 MPa and -1.5 MPa, respectively, in matric potential. Soil dry bulk densities ranged between 1.22 and 1.35 g cm-3. The soils had no salinity problem, and total soluble salt contents were under 0.1%. Soils of the study sites had slightly alkaline pH values of 7.5 to 7.7 and were determined to be poor in soil organic matter (1.18 to 2.37 %).

Measurements: The coupled dynamics of net photosynthetic rate (PN), transpiration rate (ET), water use efficiency (WUE), light use efficiency (LUE), stomatal conductance (gs), photosynthetically active radiation (PAR), air temperature (T), relative humidity (RH), and atmospheric CO2 concentration (Catm) were quantified at five rainfed wheat sites with the same stages of development (midflowering) along south-to-north and east-to-west transects for eight days in April.

For measuring various environmental and plant parameters the PM-48M Photosynthesis Monitor (PhyTech Ltd., Israel) was used (Fig. 2A).

The system contains: four self-clamping leaf chambers LC-4A(Fig 2B) which successively close for two minutes for monitoring CO2 exchange of leaves, infrared CO2 analyzer and a built-in data logger. The monitor also has eight inputs for additional sensors.

The additional sensors used in the current experiment included:

- PIR-1 Photosynthesis Radiation Sensor
- ATH-2 Air Temperature and Humidity Sensor
- Four SMS-2 Soil Moisture Sensors
- SF-4M Sap Flow Relative Rate Sensor

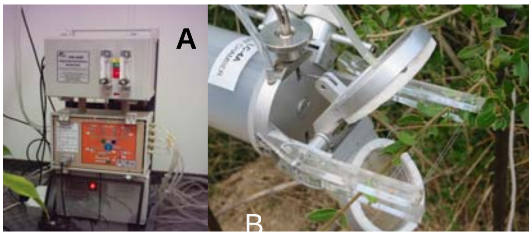

Fig. 2. The PM-48M Photosynthesis Monitor (Fig. 2A).and the self-clamping leaf chambers LC-4A(Fig 2B)

Photosynthesis data from four leaf chambers as well as data from the 8 additional sensors were automatically recorded every 30 minutes around-the-clock. Soil temperature was recorded at two points of the soil profile every 30 seconds using two CR10XTCR thermocouples (Fig. 3), attached to CR10X Measurement and Control Module (Campbell Scientific Inc., USA).

Crops: Summer measurements were taken throughout 24 hours taken from June 16 to June 22,2003.. The plants were: forty days old Cotton (Gossypium hirsutum) and Soybean (Glycine max), mature Maize (Zea mays) representing field crops. Lemon (Citrus limon,) representing perennial groves. Three typical Mediterranean trees were tested on the Taurus mountains (Turkey): Pine (Pinus pinea), Pistachio (Pistacia terebinthus) and Oak (Phyllyrea media). From April 9 to 16 of 2005 measurements of photosynthesis and transpiration rates of wheat leaves (Triticum aestivum L.) were carried out automatically at 30 min intervals.

Statistical considerations : We analyzed the standard deviation of three leaf chambers per plant while the forth chamber was used to measure soil respiration. Ambient CO2 was detected with four probes including the probe attached to soil respiration. The dimensionless data are average of actual values from three dew affected plants with three replications such that each data point represent a population of 9 samples Average standard deviation of the normalized values was 0.13 for both photosynthesis and transpiration.

Fig. 3. a) thermocouples; b)datalogger; c) digital thermometer.

1.3 Key results

Effect of dew and relative humidity

The measured dew point temperature and associated climatic conditions are given in table 1. According to Table 1 dew was formed in four nights each for a different crop (Cotton, Soybean and Corn). In the early morning hours of the 16,17,18,and 19 of June the canopy temperature was below the dew point temperature of the surrounding air and leaves were covered with dew. It was formed between 3:30 and 5:30 am. (Local time) whereas dew formation was not detected on the mornings of 20 and 21st of June when leaf temperature was slightly higher than the dew point temperature.

The results in Fig.1a display the lag time between peak photosynthesis and peak transpiration

Table 1. measured dew point temperature and associated climatic conditions

Date	Occurrence Time	Crop	Dew point Temperature	Leaf temperature	Air temperature	Relative Humidity (%)
16/6/03	3:30	Cotton	20.2	20.0	21.3	93.2
17/6/03	4:00	Cotton	21.1	19.8	21.7	96.2
18/6/03	5:30	Corn	20.4	20.1	21.5	93.3
19/6/03	5:30	Soybean	20.9	20.6	21.7	95.4
20/6/03	5:30	Lemon	20.6	20.8	21.4	95
21/6/03	5:30	Oak, Pine&Pistachio	20.4	20.7	22.9	85.6

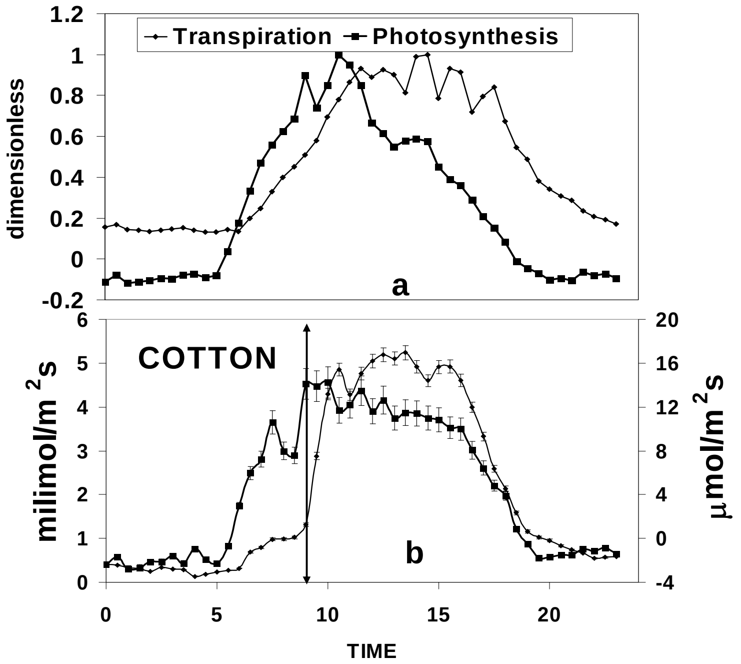

Fig. 4. The effect of dew formation on the diurnal course of photosynthesis and transpiration. (a) Normalized values for the three dew affected plants. (b) Example of actual data of photosynthesis in the right ordinate and transpiration in the left ordinate for cotton. In both displays maximum photosynthesis preceded maximum transpiration due to the combined effect of wide stomatal aperture under dew formation and high CO2 gradient at sun rise. The double arrows line indicates 9:00 am at which the largest difference and ratio between photosynthesis and transpiration was obtained. It thus indicates the time of maximum WUE.

of the dew affected crops (3 crops with 3 replications n=9, 1 standard deviation, s.d. = 0.13). From Fig.4a , maximum photosynthetic rates were measured several hours earlier than maximum transpiration rate. Fig 4b shows the same trend with actual fluxes of H_2O and CO_2 .

Separated, early peaks of photosynthesis and late peaks of transpiration are contrary to expectations because the pathway for diffusion of CO_2 into leaves is similar to the pathway for diffusion of H_2O out of leaves. Both are linearly affected by stomatal conductance and solar radiation. Thus the two processes are expected to be in phase.13-14. In Fig 4 however, photosynthesis in the early morning hours was weakly linked to transpiration or not linked at all.

We argue here, and later demonstrate it experimentally that, thanks to the dew, this weak linkage is an inherent part of strategy aimed at maximizing water use efficiency (WUE) which is most important in habitats where water supply is limited.

The practical consequences of the above relate to irrigation methodology and irrigation timing. It implies that production of "artificial dew" by sprinkling a crop shortly before sunrise may improve water use efficiency and crop productivity as shown in Table 2

We now turn to the question of how much can the "artificial dew" improve the productivity and WUE in dry environments. . In particular, in Table 2 and figure 5 we examined the concept of photosynthetic WUE .

Table 2 The effect of dew on CO_2 and H_2O uptake

Dew	gr. CO2 m^{-2} (leaf) h^{-1}		
	Corn	Cotton	Soybean
Production with dew	3.2	2.2	2.2
Production without dew	1.4	1.7	1.2
	gr. H2O m^{-2} (leaf) h^{-1}		
Production with dew	116.9	112.3	103.5
Production without dew	151.2	291.6	227.5

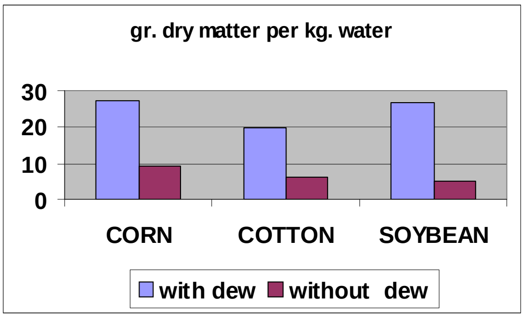

Fig. 5. The effect of due on water use efficiency of three crops

The average CO2 assimilation by wet leaves was 80% larger than dry leaves. The maximal assimilation rate was that of corn which amounted to 3.2 g CO_2m-2 hr-1 (about the potential production rate of C4 plants[17]) whereas dry leaves produced only 1.4 g CO_2m-2 hr-1 , a ratio of more than 2:1 wet:dry leaves assimilation under the same environmental conditions. In terms of WUE the results are even more convincing. Average transpiration of wet plants (covered with dew) was111 compare to 223 g H2Om^{-2} hr^{-1} transpiration from dry plants. The combination of high photosynthetic rate and low transpiration of dew affected leaves led to average WUE of 24.6 compare to 6.6 gr. CO_2 per kg. water for unaffected plants. Thus the synergistic contribution of dew or the artificial sprinkling to WUE was clearly demonstrated.

Effet of temperature

Net CO2 uptake rates (PN) were measured under relatively moderate climatic conditions in Cukurove basin Turkey (Fig 6).

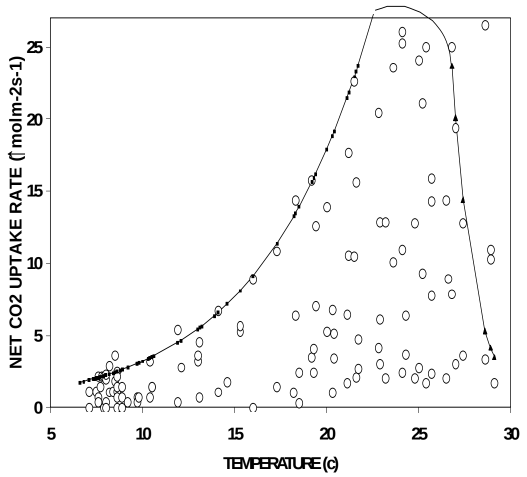

Fig.6 Temperature dependence of the net CO2 uptake rate, PN . under fresh water application.

The range of temperatures was from 7-10 C in the morning to maximum 26-28 C in the afternoon.. The Pn maximized to 27 micromolemm-2s-1 for the fresh water water. The peak was obtained at about 23-24°C. The consequences in term of irrigation policy are providing a furthere support for early morning sprinkling while irrigation during high temperatures times may be ineffective in terms of biomass production. The consequences are summarized below:

- The steep decline in PN with temperature above 24 °C for these wheat species may suggest that small increases in ambient temperature due to global warming can then lead to significant decreases in net CO2 uptake ability
- It indicate that irrigation then may lead to only small enhancements in net CO2 uptake.
- Irrigation method and timing that is cooling the canopy may be more effective.

Effect of salinity

The higher temperatures and lower relative humidity in the field led to a rapid response to salinity. The range of temperatures was from 7-10 C in the morning to maximum 26-28 C in the afternoon.. The Pn maximized to 27 micromolem/m2s for the fresh water and only 12 for the saline water (Fig.7). The peak was obtained at about the same tempersture 23-24. When looking at the data after several measuring days we could not say any thing about the tepmerature -Pn relationships . This may happen very often in our studies because there were many incidents that could not be controlled and we could not explain (For example water shortage , cloudiness etc.) but the envelope which integrates all optimal cases is complying with the known theories of van't hoff and

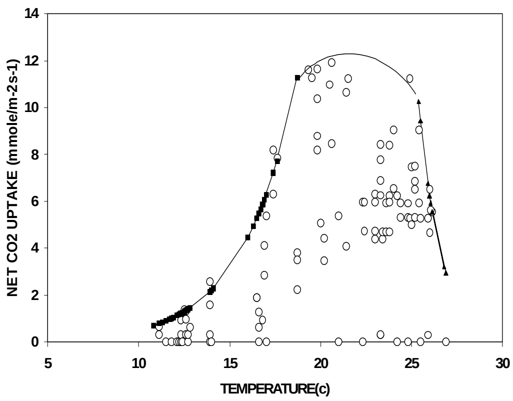

Fig.7 Temperature dependence of the net CO_2 uptake rate, P_N .of wheat on saline soil neat Karatash at the Chukurova basin. Turkey

Arrhenious model.

The envelopes for the rising portions were analyzed using Arrhenius equation (Eq1), and the envelopes for the falling portions were analyzed using enzymes inactivation equation (Eq 2 and 3);

Rate=Be-A/RT (1)

where B is a constant, A is the apparent activation energy [kJ mol-1], R is the gas constant (8.314 J mol-1 K-1), and T is the absolute temperature [K]. Using an Arrhenius plot [lnPN vs. 1/T], A, which represents the minimum energy for the reaction, was estimated for both species.

Above the optimum temperature, PN values declined with increasing temperature, presumably representing inactivation (or deactivation; Bernacchi et al. 2002, Sharkey 2005) of the catalytic properties of the enzymes involved. The decline in rate with increasing temperature was assumed to be proportional to the rate:

d(Rate)/dT=–C×Rate (2)

where C represents the relative fraction of inactivated molecules per unit increase in temperature. Reorganizing Eq. 2 and integrating leads to:

Rate=De-CT (3)

where D is a constant of integration that incorporates the particular units used. Eq. 3 was used to fit the upper envelopes of PN above the optimal temperatures.

Parameter values are summarized in Table 1.

Table 3. Parameters for equations describing the upper envelopes of the responses of net CO2 uptake to temperature for saline and non-saline conditions. Rising portions (below the optimal temperature) were described by Eq. 1 and falling portions (above the optimal temperature) were described by Eq. 3.

1.4 Concluding remarks:

Conditions	*A*	ln *B*	*C*	ln *D*
	[kJ mol-1]		[K]	
Saline (3dS/m)	240	101.7	0.83	250
Non saline (1dS/m)	118.4	51.2	0.83	252

How to apply the results for irrigation management?

In arid lands such as Israel irrigation is often given on a daily basis. The systems are permanent (not moving) and daily drip irrigation is applied. The system has had its revolutionary impact on agricultural productivity. However, it removed from the plant the natural effect of rain that was provided by sprinkling. That created conditions of "artificial rain" . Moreover, when sprinkling applied early in the morning it created an environment of dew formation and thus help improving WUE.

Thus with the above resultswe now have the tools to re-examine the following questions : What is the best time of the day to apply water ? What is the suitable irrigation method ?

What can we do in order to address the problems created by the response of the secondary factors to global warming ?

Ⅱ Effects of changing water availability on agricultural profits: The Israeli test case

Mordechai Shechter, David haim, Iddo Kan and Naomi Zeitouni; University of Haifa

2.1 Objectives and Methodology

The objective of this part of the research is to evaluate how the benefits of the winter agricultural production in Israel as a test case for Cukurova basin would vary with the expected changes in climatic variables in the EM.

A field-level economic model was developed, where variations in a single climate variable, annual precipitations, were considered. Given the annual precipitations, the model calculates the annual amount of irrigation water required for maximizing the field's net profits. Three winter crops were selected to represent three types of crop-groups: wheat for field crops, processing tomato for vegetables, and vetch (leguminous plant Vicia) for fodders. Profits associated with these crop-groups were considered with respect to climate conditions in the north, center and south regions of Israel. The effect of climate change on the net profit was evaluated by running the model according to various scenarios of annual recipitations.

Rainfall Gamma-distribution functions were used to describe present and future rainfall patters. Forecasts for future rainfall-distribution patterns were based on the assumption that the trend of changes in the distribution-functions found in the past for the years 1931-60 and 1961-90) will continue in the future; the estimated new distribution functions that estimated that the average rainfall will decline relative to that of 1960-1990 in 2020, 2050 and 2100 by 1.5%, 3% and 6%, respectively.

2.2 Key Results

The simulations are presented in Fig.8 .They indicate a future decline in net-benefits relative to the latter part of the twentieth century. The conditions in the past (1945-1975) have increased winter-crops profitability, but then (since 1975) there is a steady reduction. The most sensitive region is the South of Israel with a reduction of 35% in net profits in 2100 relative to 1975. The most sensitive crop-group is field crops. Although most of the effect is seen in the semi-arid southern region, some reduced profitability is detected in the Center and the North of the country as well. Concomitantly, risks for annual economic losses increase because of the larger variability in rainfall events.

The continuation of this study is within the

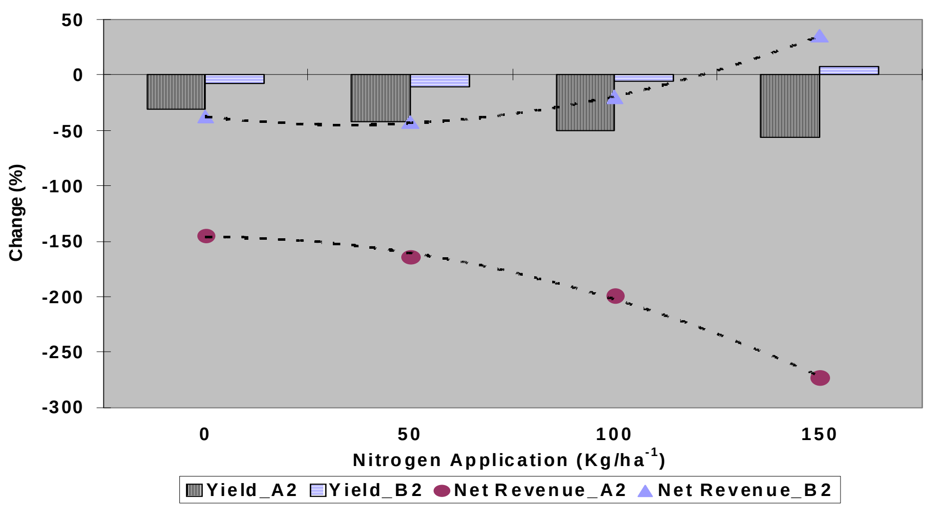

Fig. 8. Yield & net revenue changes (%) in wheat production according to A2 and B2 scenarios.

framework of socioeconomic determinants and consequences of water and land use. The aforementioned analysis focuses on the effect of one climate factor (precipitation) on a part of the agricultural activity (winter production) by a field level model in which there is only one adaptation tool (water application). The intention is to extend this model during 2006 along various directions. First, land allocation among crops as a decision variable and an additional adaptation tool will be incorporated; this requires the development of a regional scale optimization model, and application of a calibration procedure. Second, to account for the effect of variations in additional climatic and adaptation factors (e.g.temperatures and fertilizers), the appropriate response functions will be estimated.Third, summer crops will be incorporated into the model. To this end surface water constraints will be considered, where these will also be affected by climate conditions.

Ⅲ Climate analysis: regional atmospheric processes

P. Alpert, C. Price and S. Krichak – Tel Aviv U niversity

3.1 Introduction

The main goals of the research in the framework of ICCAP have been:

− To identify observed trends in climate variables over the Eastern Mediterranean.

− To evaluate the ability of climate models to capture the observed trends.

− To analyze predicted trends and compare to the observed ones. − To estimate model errors due to land-use changes over selected global regions and study the implications to the Eastern Mediterranean.

− To find out the optimal configurations of the applied regional climate model MM5 for the region.

− To perform coarse resolution dynamical downscaling for the Eastern Mediterranean using NCEP re-analyses as well as two different climate models (ECHAM4 and HadCM3) and two different scenarios (A2 and B2). − To analyse the respective results.

The characteristic behavior of global warming , may result in changes in intensity, location and frequency of occurrence of many if not all climatic parameters. Thus, it is important to pay attention to changes in synoptic disturbance characteristics -- not only to changes in the mean conditions.

3.2 Key Results

Trends in tropospheric temperatures over the EM: We analyzed 850 mb summer temperature trends over the EM from reanalysis data. A long term warming trend of 0.013 K/year was found over a 55 year period. There is an increase of both "hot" and "cool" days. The summer maximum temperature increase is 3 times greater than the increase in minimum temperatures. The increase of extended hot periods in summer was associated with severe impacts e.g. on agriculture (Saaroni et al. 2003).

Additional primary result is a significant increase in the means higher probability for flooding due to active Red-Sea trough situations.

The RCM simulations with the RegCM3 model of TAU demonstrated its ability to represent important elements of the eastern Mediterranean climate. The simulation results demonstrated a tendency for a temperature increase, precipitation decrease as well as increase in the frequency of occurrence of the extreme events in the EM according to the IPCC GHG emission scenarios A2 and B2 .

Climate Change and IPCC Assessments

Mostafa Jafari
Islamic Republic of Iran Meteorological Organization
IPCC/AR4 Lead Author

Climate change is one of the most serious environmental issues that we face today. The impacts of climate change could have far-reaching and unpredictable environmental, social, and economic consequences.

The world has taken major strides towards meeting the challenge of climate change - moving on from scientific analysis, to public concern, to developing and implementing an international Convention. There is, however, still a long way to go: first, in achieving a better understanding of the global climate system; second, in taking decisive and early action to reduce greenhouse gas emissions; third in ensuring a broad public support for both mitigation and adaptation efforts.

Human societies have long been subject to disruption by climate change. In the past, most of these variations have reflected natural phenomena, from fluctuations in levels of solar radiation to periodic eruptions of volcanoes. But in future most climate change is likely to result from human actions.

The main increased greenhouse gases (GHG s) are chiefly carbon dioxide, methane and nitrous oxide. Since the beginning of the industrial revolution the atmospheric concentration of carbon dioxide has increased exponentially from about 280 parts per million (ppm) in 1800 to about 380 ppm today and there have been similar increases for methane and nitrous oxide. The Intergovernmental Panel on Climate Change (IPCC) has projected that by 21 00 atmospheric concentrations of carbon dioxide could have reached between 540 ppm and 970 ppm and that, as a result, global surface temperature could rise by between 1.4 ° C and 5.8 ° C.

In 1990 the IPCC issued its First Assessment Report, which confirmed that the threat of climate change was real. The Second World Climate Conference, later that year, called for the creation of a global treaty. The Intergovernmental Negotiating Committee (INC) first met in 1991 and its government representatives adopted the United Nations Framework Convention on Climate Change (UNCED) 1992. At the Rio de Janeiro United Nations Conference on Environment and Development (UNCED or Earth Summit) of June 1992, the new Convention was opened for signature. It entered into force on 21 March 1994. Ten years later, the Convention had been joined by 188 States and the European Community. In December 1997, representatives of 160 nations met in Kyoto, Japan, in an attempt to produce a new and improved treaty on climate change. Major differences occurred between industrialized and still developing countries. The Kyoto Protocol was adopted at the 3rd session of the Conference of the Parties (COP3) to the UNFCCC held in Kyoto, Japan, in December 1997. The Kyoto Protocol required industrialized nations to reduce their emissions of carbon dioxide, methane, nitrous oxide, hydro fluorocarbons, sulfur dioxides, and per fluorocarbons below 1990 levels by 2012. The requirements would be different for each country and would have to begin by 2008 and be met by 2012. There would be no requirements for the developing nations. Whether or not to sign and ratify the treaty was left up to the discretion of each individual country. The Protocol introduces 3 market mechanisms, namely the Kyoto Mechanisms. Annex I Parties would be able to achieve their emission reduction (or remove by sinks) targets cost-effectively, by using these mechanisms: 1- **Joint Implementation (JI)**; 2- **Clean Development Mechanism (CDM)** and 3- **International Emissions Trading**. In June 2002, the 15 member nations of the European Union formally signed the Kyoto Protocol. The ratification by the 15 EU countries was a major step toward making the 1997 treaty effective. Before the EU ratified the protocol, the vast majority of countries that had ratified were developing countries. With the withdrawal of the United States, responsible for 36.1According to the modified information on date of 13 December 2006, status of ratification for Kyoto Protocol is as follow: from list of 173 countries total of 84 have signature, 169 have ratification, acceptance, accession or approval status which cover 61.6The organization that provided the research for the Kyoto Protocol was the Intergovernmental Panel on Climate Change (IPCC). Recognizing the problem of potential global climate change, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) established the IPCC in 1988 to: (i) assess available scientific information on climate change, (ii) assess the environmental and socio-economic impacts of climate change, and (iii) formulate response strategies options for adaptation and mitigation. The IPCC does not carry out research nor does it monitor climate related data or other relevant parameters. It bases its assessment mainly on peer reviewed and published scientific/technical literature. It is open to all members of the UN and WMO. In 2001 the IPCC released a report, ”Climate Change, 2001”. Using the latest climatic and atmospheric scientific research available, the report predicted that global mean surface temperatures on earth would increase by 2.5-10.4 ° F (1.5-5.9 ° C) by the year 2100, unless greenhouse gas emissions were reduced well below current levels. The IPCC has three Working Groups and a Task Force: Working Group 1: **The Physical Science Basis**; Working Group 2: **Impacts, Adaptation and Vulnerability**; Working Group 3: **Mitigation of Climate Change**; and The Task Force on National Greenhouse Gas Inventories is responsible for the IPCC National Greenhouse Gas Inventories Programme.

The First IPCC Assessment Report was completed in 1990. The Second Assessment Report, in 1995, and the Third Assessment Report (TAR), was completed in 2001. At its Eighteenth Session in September 2001 the Panel decided to continue to prepare comprehensive assessment reports. At further sessions the Panel agreed that the Fourth Assessment Report would be completed in 2007. Around 500 lead authors, supported by hundreds of other contributors, are involved in drafting the IPCC 4th Assessment Report. Review is an essential element in the preparation of IPCC Reports to ensure that they represent the latest scientific, technical and socio-economic findings and are as comprehensive as possible. In early April 2006, the second draft of Working Group 1 ’ s contributions to AR4 was circulated for review - a process still in progress. Furthermore, governments and experts have received the second drafts of Working Group 2 and Working Group 3, which delivered in May and July 2006 respectively. The Report of Working Group 1 finalized in 2 February 2007. The Working Group 2 Report will be completed in early April 2007, the Working Group 3 Report in early May 2007 and the Synthesis Report by mid-November 2007. In order to ensure a better treatment and coordination of matters that are dealt with in more than one working group called cross cutting themes will be used. The following concept papers and guidance notes on cross cutting themes were prepared: Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on Addressing Uncertainties; Uncertainty and risk concept paper; Integration of Mitigation and Adaptation in 2 parts; Article 2 of the UNFCCC and key vulnerabilities; Sustainable Development; Regional Integration; Water and Technology. Outline for the IPCC Working Groups I, II and III Contributions to the Fourth Assessment Report (AR4) “ CLIMATE CHANGE 2007 ” are presented.

At its 22nd in 2004 the Panel decided to prepare an AR4 Synthesis Report (SYR).

Here, there are a few general comments that could be considered in future work.

1- During our work on preparation of AR4 we faced with very scare references -base upon publication of research results- in the Central Asia and Middle East. It needs with help of developed countries and international and regional agencies this gap partly or full will fill. Without complete set of data and information from all part of earth it wouldn ' t be possible to have precise and correct climate projection for the world.

2- ICCAP project area very well cover different ecosystem like grassland, forest, cropland or water ecosystem and urban areas. According to its name that is " Impact of Climate Change on Agricultural Production System in the Arid Areas " it can abbreviate ICCAP-SAA and some more complementary information from arid and semi-arid zone could be collected.

3- Information that is available or would be provided in Caspian Zone could give good indication as supplementary information to interpret data gathered in ICCAP project for climate change impact on different ecosystem specially forest and sea or cropland and human being.

4- Synergies and the mainstreaming of the issues of climate change with other programmes dealing with development and environment would considerably enhance the efficiency of planned activities.

5- Climate change has been recognized drought and water deficiency as a major environmental issue that involves several stakeholders. Desertification is a truly global phenomenon with serious economic and social implications.

6- Synergy and link between different UN conventions with common and sharing objectives are essential. Most important issues are biodiversity and drought that can be formulated according to the related conventions UNCCD and UNCBD.

7- Water scarcity is very important and effective issue in worldwide scales, but it is in critical condition in Middle East and Central Asia.

8- Cooperation to propose small-scale CDM projects could provide good tools to support developing countries for emission reduction and increase sink. Afforestation and Reforestation CDM (A/R CDM) project activities could be used as much as possible and feasible. In addition to small-scale A/R CDM projects new CDM projects on water can be define and could be considered in future cooperation.

9- Plant ecophysiological studies to understand climate change effect on different ecosystems namely forest, rangeland, desert and croplands are important.

The recent Stern Review of the Economics of Climate Change, led by former World Bank Chief Economist Sir Nicholas Stern for the UK Department of the Treasury, received a lot of attention. Without any criticizing the summery of conclusions from its review is brought here.

Appendix I

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(in alphabetical order of family name)

Appendix II

Publication List of ICCAP

Papers reviewed (refereed)

【Climate】

Aoki, I., Y. Kurosaki, R. Osada, T. Sato, and F. Kimura 2005: Dust storms generated by mesoscale cold fronts in the Tarim Basin, Northwest China, *Geophy, Res, Lett*, 32-3, L06807 10.1029/2004GL021776.

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Iizumi, T., Y. Hayashi, and F. Kimura 2006: Influence of global warming on rice production in Japan in years with a hot summer and cool summer, accepted by *Journal of Agricultural Meteorology*.

* Iizumi, T., Y. Hayashi, and F. Kimura 2007: Influence on rice production in Japan from cool and hot summers after global warming, *J, Agric, Meteor*., 63. (in press)

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Appendix III

List of ICCAP Publications: Reports and Proceedings

No. Title

1. Proceedings of the Kick-off Workshop for ICCAP. Çukurova University, Adana, Turkey. July, 2002

2. Proceedings of the International Workshop for ICCAP. Kyodai-Kaikan, Kyoto, Japan. January, 2003

3. The Interim Report of ICCAP. March, 2004

4. Proceedings of the International Workshop for ICCAP. Cappadocia, Turkey. November, 2004

5. The First Interim Report of the Socio-Economic Sub-group of ICCAP. "An Economic and Institutional Analysis of the Impacts of Climatic Change on Agriculture and Farm Economy n Eastern Mediterranean and Central Anatoria Regions in Turkey". February, 2005

6. Proceedings of the International Workshop for ICCAP. RIHN, Kyoto, Japan. February, 2005

7. The Progress Report of ICCAP. April, 2005

8. Proceedings of the International Workshop for ICCAP. RIHN, Kyoto, Japan. March, 2006

9. The Advance Report of ICCAP. May, 2006

10. The Final Report of ICCAP. March, 2007 (this volume)

11. ICCAP Project Turkish Group Final Reports. March 2007

12. ICCAP PROJESİ TÜRK GRUBU SONUÇ RAPORLARI. March 2007 (in Turkish)

13. The Final Report of the Socio-economic Sub-group of the ICCAP. "An Economic and Institutional Analysis of the Impacts of Climatic Change on Agriculture and Farm Economy in Eastern Mediterranean and Central Anatolia Regions in Turkey". March, 2007

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