Overview of the Progress of ICCAP 2005-2006
Innovated Cross-disciplinary Approach to Impact Assessment of Climate Changes on Agricultural Production System in Arid Areas

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1. Introduction - Research topics of ICCAP

The research project ICCAP - Impact of Climate Changes on Agricultural Production System in Arid Areas - is an on-going project of RIHN (Research institute for Humanity and Nature) launched in 2002, to analyze the relationship between climate and agricultural system. It is being implemented as an international joint project in cooperation with TÜBİTAK (The Scientific and Technical 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 paper, the project framework is re-outlined and the progresses since the commencement of the project, mainly achieved in the Japanese fiscal year 2005-2006, and further necessary works are overviewed, focusing on its challenging aspect on developing the methodology, 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 of ICCAP

2.1 Scope of the project

As the world population grows and the demand for food increases, agriculture in arid areas is required to enhance its productivity, while its development is severely restricted by less water resources. 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 with irretrievable changes in the regional hydrological cycle. The changes in agricultural land and water management practices pose serious threats to the sustainability of agriculture itself.

Moreover, future global climate change may 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. What measures are required to sustain productivity in such an environment?

2.2 Consideration of agricultural "wisdom" through projecting impacts

Agricultural production is intricately related to its surrounding natural elements and phenomena, such as soils, crops, and fauna and flora as well as meteorological, hydrological, geographical and geological conditions of the region. Any change in these conditions, which may result from global

climate change, inevitably affects the dynamics of the agricultural ecosystem. This aspect has been the focal point of conventional assessment of climate change impacts on agriculture.

However, agriculture 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. This reaction is a fundamental characteristic of agriculture. Then now, is the conventional 'wisdom' of 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**.

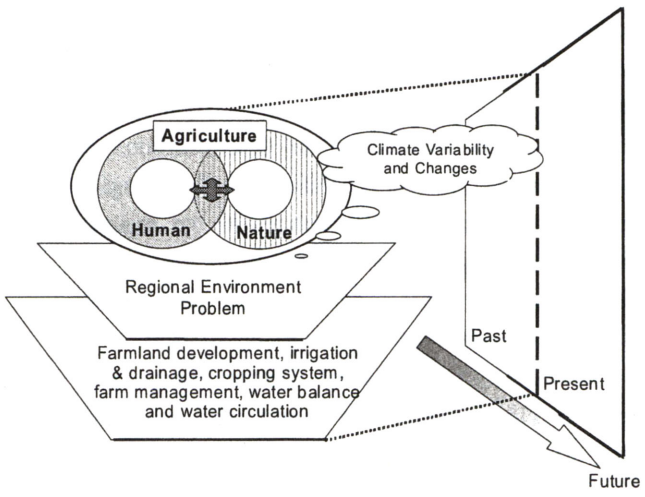

Fig. 1 Scope and framework of the research

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.

2.2 Main objectives of ICCAP

Main objectives are itemized as four points below, in the research plan.

a) To examine and diagnose the structure of land and water management in agricultural production system in arid areas, especially to evaluate quantitatively the relationship between cropping system and hydrological cycle and water balance in farmland and region.

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

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

d) To assess the vulnerability of agricultural production system and to suggest possible and effective measures for enhancing sustainability of agriculture, through integrated impact and adaptation assessment of climate changes.

2.3 Methodology and case study area

The research of this project is being implemented in the arid and semi-arid areas in the east coast of the Mediterranean Sea, including the Seyhan River basin in Turkey as a main case study area. Firstly, a comprehensive assessment of the basic structure of agricultural production system is carried out with special reference to regional climate, land and water use, cropping pattern and irrigation system. Then, it attempts 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 prediction with higher resolution is critical to precise impact assessment. Furthermore, impacts on the regional water resources, irrigation and drainage system, natural vegetation, growth of crops, farm management and cropping patterns as well as the effect on the food production and marketing will be taken into account. Also feedback of agricultural production systems on regional climate will be considered. The project aims at providing suggestions for regional policies and monitoring systems as well as accumulating information that

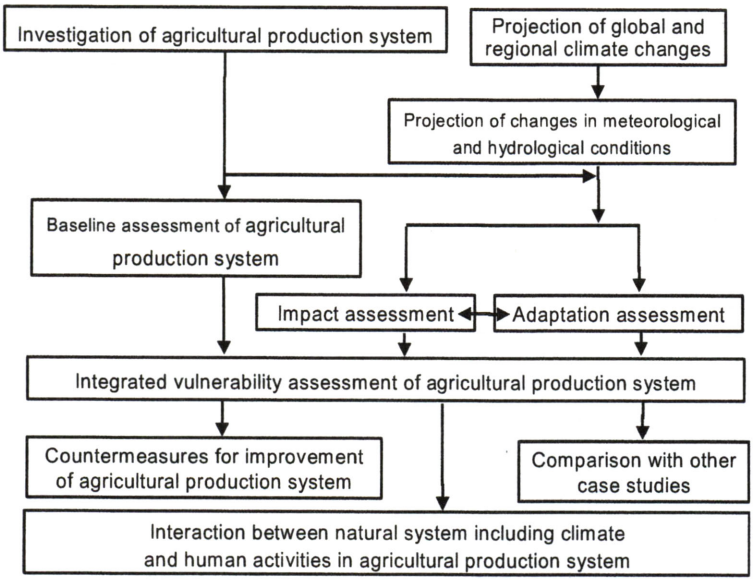

Fig. 2 The planned research procedure flow

will assist to analyze relationship between climate/natural systems and human activities. The research procedures are shown in **Fig. 2**.

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.

The Seyhan River Basin, which area is about 25,000km^2, is 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 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.

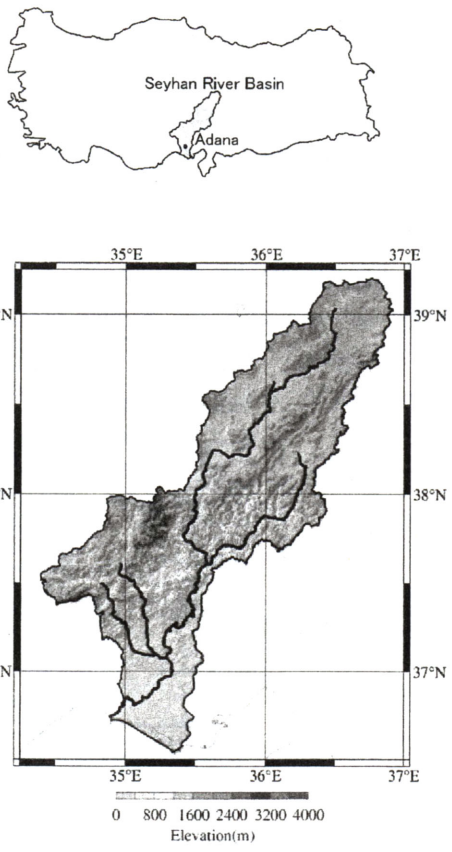

Fig. 3 The study basin – the Sehan River Basin, Turkey

The research works in Turkey are carried out in cooperation with TÜBİTAK, as the international joint project. In the future, the project study area can be expanded to other regions in arid and semi-arid areas.

3. Present Progress and Outcomes of the Project

3.1 Brief overview of the outcomes

Based on the 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 possible climate changes of the basin in the 2070s is projected 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.

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:

a. The climate change scenarios for the 2070s of the basin have been generated, with which impacts of climate changes on basin hydrology and agriculture could be assessed and discussed.
b. The projection of future climate by the GCMs and RCM has still much uncertainty, while measures for improvement are developed and applied during the model development stage.
c. 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.

The analyses on particular aspect provide some interesting findings and verified the general estimation on this issue. The major points are listed below, while the details are reported in the following chapters or sub-group reports:

d. In the basin in the 2070s, air temperature will increase by one to two degree in Centigrade in winter, and monthly precipitation will decrease by 5 to 10 mm, at maximum 30mm.
e. The conventional rain-fed wheat depends on rainfall in winter from November to May.
f. Wheat production may have some damages caused by higher temperature and lack of rainfall. Higher temperature might make growing period shorter and less fertility

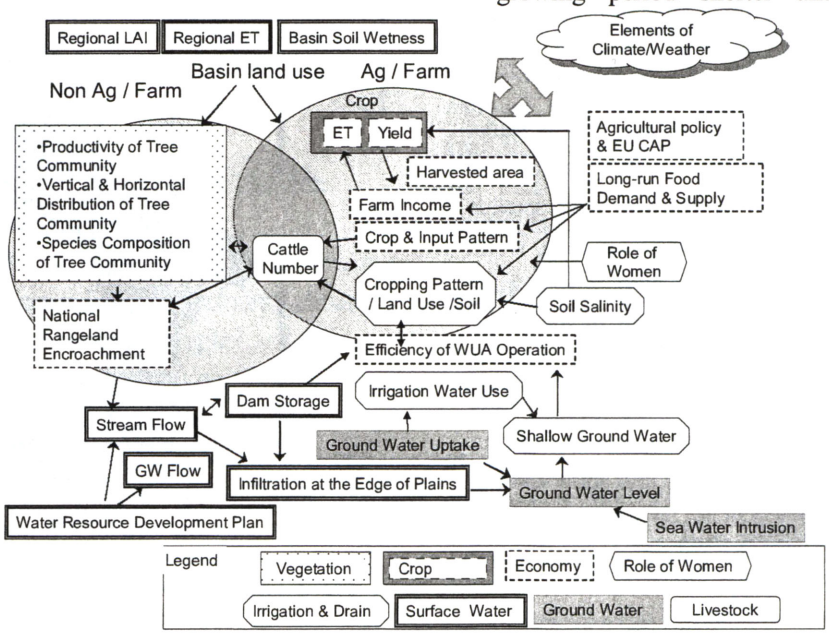

Fig. 4 Framework for assessment of climate change impacts on agriculture production system

resulting in reduction of vegetation growth and yield, while higher concentration of CO_2 could enhance photosynthesis of crops with higher vegetation production.

g. Available water resources for irrigation will be decreased by less rainfall and snow in winter and earlier snow-melt in spring with higher temperature.

h. Irrigation water requirements in summer will be increased with higher temperature resulting in much water consumption.

i. Sea-level rise will cause ill drainage in the lower region in the delta, while seawater intrusion into ground water will be very limited because of less permeability of geological profiles.

j. The possible natural vegetation will be shifted: steppe, deciduous broadleaf trees, and savanna will expand and semi-alpine evergreen trees will shrink in area.

k. Land use and cropping pattern may change, for example, spring-wheat may come up to north and higher land.

l. Other impacts on pest and disease and changes in livestock reproduction system can be predicted.

3.2 Brief summary of the present findings

a. Climate

The MRI-CGCM2 of Metrology Research Institute, Japan projects that average temperature will increase by 2.3℃ in southern part of Turkey in the 2070s with global warming experiment and annual precipitation will decrease from 470mm to 360mm. The method to downscale the outputs of GCM with RCM and re-analyzed meteorological data like of NCEP or ECMWF is developed. **Fig.5** shows the projection example of the temperature of August in the 2070s. Analysis of the archived meteorological station data proves the trend of temperature increase and precipitation decrease in the past.

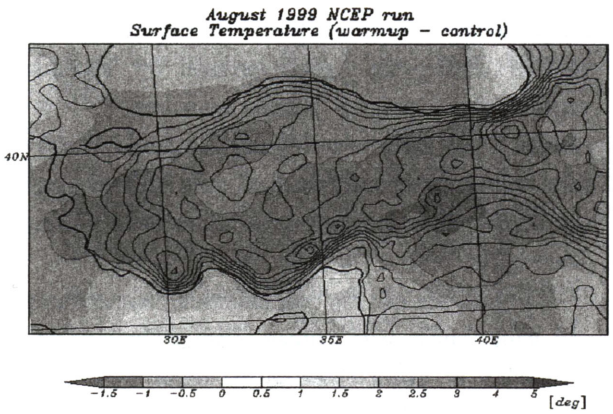

Fig. 5 Predicted changes of temperature in August over Turkey

b. Hydrology and water resources

The annual average runoff discharge of the Syhan River is 282mm and available water resources of the basin are relatively stable. Since the 1990s, there has been no serious drought with dry-up of reservoirs, while in the future some drought may happen by reduction of runoff discharge caused by climate change. The estimated changes of the inflow to the Seyhan Reservoir is shown in **Fig. 6**.

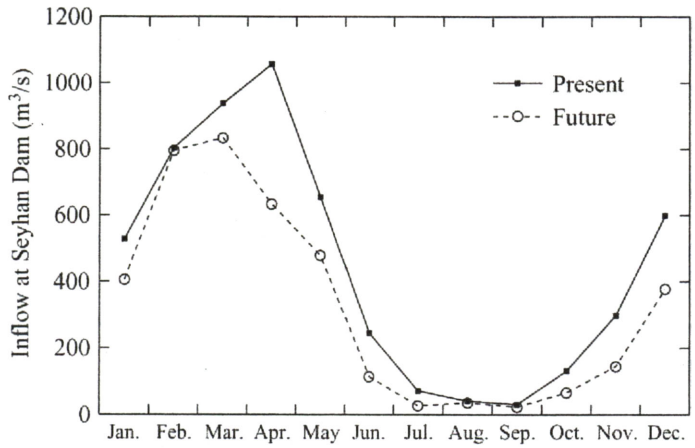

Fig. 6 Changes in the discharge of Seyhan River (Present: 1990s, Future: 2070s)

Sea-level rise will cause ill drainage in the lower region in the delta, while seawater intrusion into ground water will be very limited. In the delta region, irrigation depends only one % of it water supply on ground water.

c. Vegetation and crop productivity

In the Seyhan Basin, vegetation varies from lower coastal region to semi-alpine region of 1,000 meters or more above sea level. In the area below 600mm above sea level, original or natural vegetation is lost by human activities. It is predicted that global warming may expand the area with, steppe, deciduous broadleaf trees, and savanna and shrink semi-alpine evergreen trees in the basin (see **Fig.7**).

The increase of CO_2 concentration, temperature and water stress with climate change may affect production of major crops in the basin, including wheat in rain-fed condition and maize in irrigated land.

d. Irrigation and drainage

Water use in irrigation has been increasing. The reasons for the increase are diversification of cultivated crops, increased loss in delivery system caused by overage and ill-maintenance, and lack of intensives for water saving of the farmers. Soil salinity problem was serious after construction of irrigation systems in the lower delta and has been mitigated by leaching with much water application. The predicted water demand increase due to climate change could be managed by improvement of irrigation efficiency even with the present facilities.

e. Socio-Economy

The multi-regression analysis estimate future reduction of cereal production in the Adana region and rein-fed region with changes in temperature and rainfall due to global warming. On the other hand, the Input-Output model predicts the higher productivity of agricultural sector for the whole Turkey with global warming. Also, future admission of Turkey to EU may affect definitively the Turkish agriculture, especially in view of direct income support policy of EU.

4. Conclusions – Further Works and Challenges

Further works are required to realize the expected outcomes on two main subjects as follows:

a. integrated assessment of climate change impacts

The factors, mechanism, direction and extent of climate change impacts on agricultural production system, especially on land and water management, are to be figured out, depicting a elements and their relation map like **Fig.4** above. Relationships between a certain climate element and target factor or parameter, and changes in spatial distribution of target factor due to climate change are to be evaluated quantitatively or on GIS, with some range according to adaptation level. These figures and

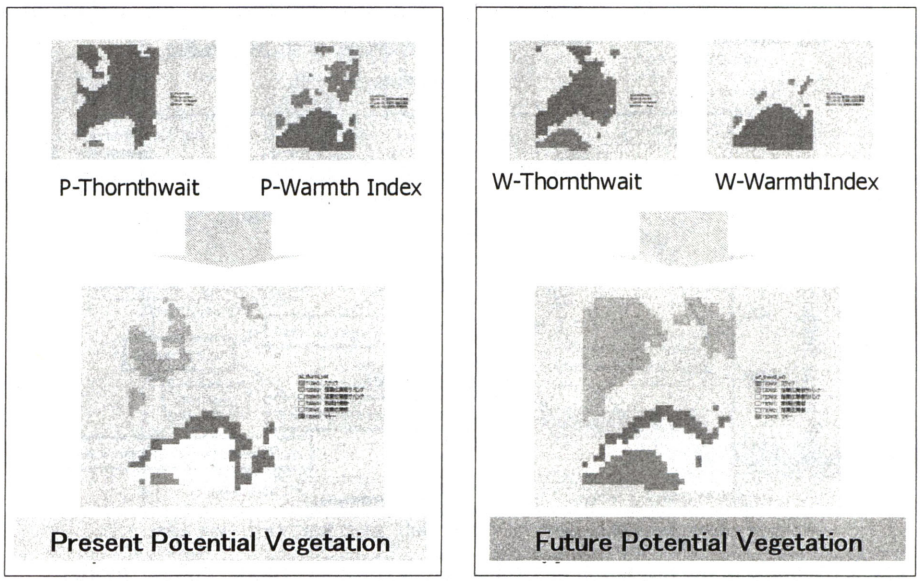

Fig. 7 Changes of potential vegetation Present and future with global warming (Tamai et al, 2005)

analyses could demonstrate the possible changes of production system with some scenarios of socio-economic conditions and provide the climate models with feedbacks and suggestions as well as necessary mentoring the climate change related parameters.

b. Structure and wisdom of agriculture in arid region

Not only the climate change impacts, but also implication of agriculture in local environment is to be discussed. In practice, agriculture-related or agriculture-induced environmental problems are described including their aspect, reason, and measures in the past and present, especially with special reference with climate changes. Based on the local knowledge on living with the resources and environment of the region, conditions for sustainable agriculture and society are to be suggested.

The distinctive feature of this approach is to assess the climate change impacts on agriculture production system with some effects by adaptations or other possible changes of related factors. For this integrated assessment, or during the process of this assessment, the local wisdom on managing land and water utilizing regional natural resources and environment for food production. This means that this approach may result in recognition of agriculture as an interface between natural system and human activities.

Acknowledgement

This article is a summary of the progress of the research project ICCAP of RIHN. The details of the progresses were reported in the International Workshop of ICCAP held in Kyoto in March 2006, which proceedings were published, and the following chapters or reports also shows the progresses with some additional findings after the workshop.

Here, the authors as the leader or coordinator of the project extend their special gratitude to all who are supporting this project, including the Evaluation Committee of RIHN and TÜBİTAK, related governmental organizations in Japan and Turkey, and colleagues and staffs of the universities and research institutes, of which researchers are participating in this project. This research is also supported financially in part by the JSPS (Japan Society for the Promotion of Science) Grant-in-Aid No.16380164.

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