Overview of the Progress of the ICCAP 2002-2004
Cross-disciplinary Approach to Impact Assessment of Climate Change on Agricultural Production in Arid Region

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1. Introduction - ICCAP, a cross-disciplinary approach to integrated assessment of climate change impacts on agriculture

The research project ICCAP (Impact of Climate Change on Agricultural Production System in Arid Areas) is an on-going project of RIHN (Research institute for Humanity and Nature), 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). In this paper, ICCAP is outlined focusing on its challenging aspect to develop the research topic for future cross-disciplinary approach and the progresses of the work are overviewed. The detailed activities and results of the project are reported in the following parts of this report.

RIHN was established in 2001, in Kyoto, Japan, with the aim of fundamentally solving global environmental problems, with the following understandings.

The so-called global environmental problems, such as global warming, loss of biodiversity, and depletion of water resources, can be said to be the consequences of humanity-nature interactions being manifested today in various parts of the world. One of the difficulties of assessing the global environmental problems is that many of them have appeared in different regions of the earth in a most unpredictable manner and caused by factors seemingly far removed from reality both in time and space, including "cultural" factors in the broad sense.

Such multi-faceted problems could not be solved by studies with a conventional approach. In fact, the measures taken hitherto were based on the idea of controlling nature and it became clear that such measures would only lead to a vicious circle.

Then, firstly we have to ask first the fundamental question of what is meant by the global environmental problem and to re-examine the concepts developed through the last century in this regard. Secondly, based on such perspectives we need to consider how we can sustain the global environment that has all the future possibilities and what sorts of life style we must adopt in order to achieve it. To build this foundation it is necessary to develop a new approach academically as well as in other fields.

With this understanding RIHN was founded in 2001 as a cooperative inter-university research organization in Kyoto, to carry out integrated research for the innovation of a discipline that will give us the solution to the global environmental problem (RIHN, 2002 http://www.chikyu.ac.jp/).

The ICCAP is a research project for integrated assessment of climate change impacts on agriculture, which was launched and being carried out as five year project from 2002 to 2007, based upon the basic policy of RIHN above. Therefore, the ICCAP is aiming to make clear the circle of interactions between climate system and human-agriculture system, and to build a new research field on the global environment, adopting a more integrated, cross-disciplinary overall perspective.

2. Objectives and Framework of ICCAP

2.1 Problems of land and water management in agriculture in arid areas

As the world population grows and demand for food increases, agriculture in arid areas is required to improve its productivity, while its development is severely restricted by limited water resources. In many arid regions, 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, while it enhanced the productivity of the moment. The changes in agricultural land and water management practices pose serious threats to the sustainability of agriculture itself.

Moreover, future global climate change could bring climatological and hydrological conditions in arid region with substantial changes in temperature, rainfall, and evapotranspiration and then lead to another challenge or constraint to the agricultural production system. What measures are required to sustain productivity in such an environment?

2.2 Main objectives of ICCAP

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, does the conventional 'wisdom' of agriculture overcome the future global climate change?

Trying to transcend 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.

2.3 Framework of the research

This research project, firstly, examines and diagnoses the structure of land and water management, secondly, aims to predict and assess the impacts of global warming or climate change and adaptability of the production system, and in this process, not only the future prediction but also integrated vulnerability assessment of the system is to be attempted to identify essential interrelations among various factors and critical values of the factors. Taking the scale of this project into account, it is intended to have grasp of the basic structure of the system firstly from the viewpoint of land and water management, since they are fundamental and dominating elements of agricultural production in arid areas. **Fig. 1** shows the basic framework of the agricultural production system and the project research.

3. Methodology and Case Study Area

3.1 Methodology

The research flow of ICCAP is shown in **Fig. 2**. Firstly, the present agricultural production system is assessed with an emphasis on land and water management to clarify its baseline vulnerability. The assessments include following elements: a) regional climate and meteorology, b) hydrology and water resources including irrigation and drainage, c) soil-water regime and plant growth, and d)

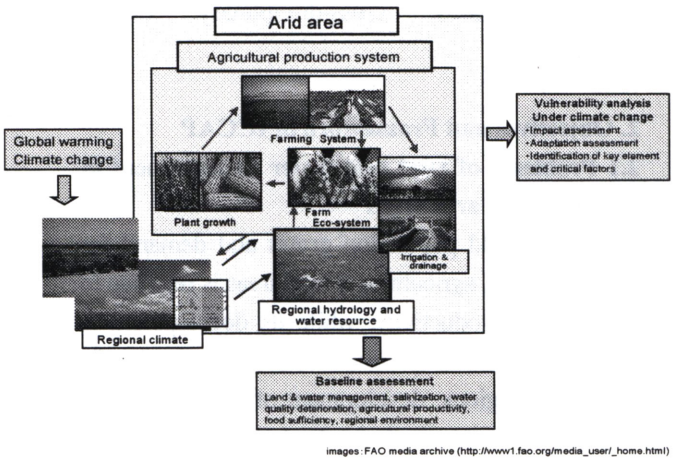

Fig.1 Basic Framework of the ICCAP

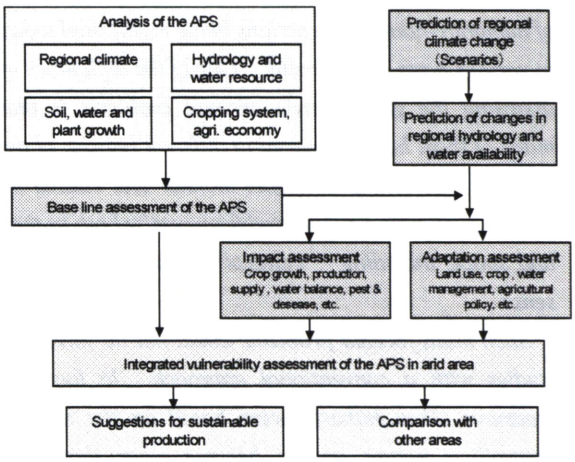

Fig.2 Flow of the research

socio-economics with land use management and cropping pattern.

Secondly, regional climate change in accord with the global climate change is estimated through simulations and its impacts and adaptations to it are evaluated. For the time being, precise and quantitative prediction of regional climate change seems not easy to be realized, therefore variance and characteristic of the change will be generated as some scenarios. In this process, the basic structure of production system and interactions among the elements will be made clear and integrated analysis will lead to an overall comprehensive understanding of the relation between natural system fluctuation and human activity.

In estimation and evaluation of the impact of the climate change and adaptation, it is structurally analyzed to identify dominating factors and critical values, which in turn will be used to clarify direction and extent of the possible change. From these results, important factors for adaptation will be revealed for the specific elements of the agricultural production. In this process, socio-economic adaptation of farm household, regional land and water management system, agricultural policies, and international food trade will be included in the analysis to give much concrete materials for considerations.

Land use and on-farm soil-water regime are to be dealt as core parameters to combine other elements, including regional climate, regional hydrology, plant and crop production, irrigation and drainage system, agricultural economics. The interactions among these elements are to be evaluated quantitatively with developing models. Changes of these interactions under the climate change scenarios will also be evaluated. The elements of "livestock farming" and "pest, disease and wildlife" shown in the figure might be involved in the future stage.

3.2 Case Study Area

The project selected case study areas in 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 (see **Fig.3**). The reasons why ICCAP selected the Seyhan River basin in Turkey are followings: a) The Mediterranean Region is said to be much sensitive to future climate change. b) Future productivity of wheat should be predicted in its present major growing area, since it is one of most important crops in the world. c) Basin-wide response to climate change should be analyzed, including changes in hydrological regime and water resources availability. d) It is desirable that different land and water use forms are included in the study basin, for example, rain-fed agriculture, irrigated agriculture, and livestock farming. e) Required data are available and research cooperation of field studies can be established.

The Seyhan River has its source in the Taurus Mountains and discharges into the Mediterranean Sea. The drainage area of the basin is 20,100 km^2 and its mean annual flow at the outlet of the basin is 8.0 billion m^3. In the coastal plain, where irrigation scheme is operational, the Mediterranean climate

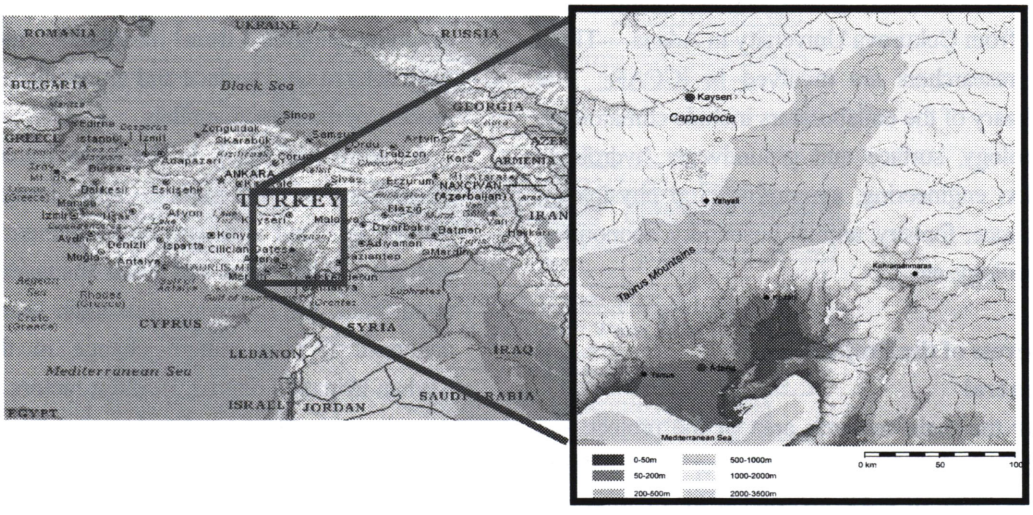

Fig.3 Main case study area: Seyhan River Basin in http://www.rootsweb.com/~mdeastgw/maps/turkey.gif

prevails, as it is hot and dry in summer while mild and rainy in winter. There in the plain, annual average rainfall is 650 mm, maximum temperature 46℃, minimum temperature is -8℃, and average temperature is 18° C. In the upper mountainous region, climate has continental features.

Now, the study area of this project is mainly the Seyhan River basin in the Mediterranean region of Turkey, and could be expanded to the Nile Delta of Egypt or other regions in the futures, according to the progress and outcomes in the Seyhan River Basin.

3.3 Research Organization

The ICCAP project organizes a research team, which consists of six sub-groups to tackle with six sub-topics, which are a) climate, b) hydrology and water resources, c) irrigation and drainage, d)crop productivity, e) vegetation and f) Socio-economics, with one project leader, i.e. Dr. Watanabe, the author of this paper, and one adviser, Dr. M. Matsubara of The National Museum of Ethnology. ICCAP is being implemented as a joint research with TÜBİTAK, The Scientific and Technical Research Council of Turkey, and TÜBİTAK organizes the Turkish Team with almost same structure with the RIHN Team. Dr. Rıza Kanber is a coordinator of the Turkish Team.

The collaborators of ICCAP consist of almost forty researchers including graduate students in the Japanese Team from fifteen universities and research institutes in Japan, and almost same number of researchers and engineers in the Turkish Team from five universities and governmental organizations, mainly from Çukurova University in Adana. Three Israeli researchers are involved in ICCAP. The disciplinary of the collaborators include climatology, meteorology, surface and groundwater hydrology, irrigation engineering, agronomy, crop physiology, soil science, forestry, animal husbandry, economics, anthropology, etc.

4. Progress of the Project

4.1 General

After the main research area of the project was shifted from Israel to Turkey during the feasibility study in 2001, ICCAP invested a lot of time and effort for setting up research framework and collecting basic information, with the cooperation with TÜBİTAK

Research progress of the first year 2002-2003 was summarized in the proceedings of the kick off meeting held in Adana in Turkey, July 2002 and in the proceedings of the international workshop held in Kyoto, January 2003. And, the research progress of the second year 2003-2004 is reported in the Interim Report, this volume itself, as the collection of the papers fro, sub-groups and participant group.

The project ICCAP is still in the stage of field observation, data collection and model development at the end of the second year. On the aspect of impact assessment of climate change, based on the discussions among the sub-groups, impacts are to be predicted with coordinated linkage of the models, which are being developed or applied in the projects. This linkage design is depicted in **Fig. 4**.

The future regional climate is predicted basically by the Regional Climate Models linked with the GCMs. With the output of RCM, future hydrological regime can be estimated with basin hydrology model. The future condition of groundwater is to be estimated by this basin hydrology model and the groundwater model that should treat future possible sea level rise.

Future crop production can be predicted by these predicted changes in meteorological and hydrological conditions, while changes in cropping pattern should be taken with predicted adaptations of farmers and agricultural organizations, which lead to different management practices.

Changes in land use and cover, and evapotranspiration from farmlands are to be feedbacks to land surface and atmosphere boundary process of the climate models.

As shown in **Fig.4**, in the basic framework for interaction of sub-models and integration of sub-topics, 'land and water management' is a key element. With 'land and water management' as a main focus, the following four main issues will be analyzed; i) crop pattern change in the Lower Seyhan irrigation district, ii) main factors that affect growth and production of main crops like wheat, iii) changes of land use in the upper Seyhan Basin (due to grazing, development of new farm land, and opening of forest), and iv) water budget of farm

plots, irrigation district, and the Seyhan Basin. Quantitative parameters and qualitative scenarios will be exchanged between sub-groups to outline structure of influence and impact on the whole system.

4.2 Present research topics

In the present stage, the sub-groups of ICCAP are devoting themselves to the following research topics.

a. Climate Sub-group:

- GCM(MRI-CGCM) ensemble runs
- RCM nested run with the analysis data and GCM
- recent precipitation change over the East Mediterranean Region
- Cloud likely to be formed by large-scale irrigation scheme

b. Hydrology and Water Resources Sub-group:

- Impact of sea level rise on movement and salinity of groundwater in the delta region
- Basin Hydrology Model Development
- Groundwater Model Development recent

c. Irrigation and drainage Sub-group:

- History and actual problems of irrigation system
- History and actual status of irrigation management transfer from government to water users association
- Irrigation water requirement estimation

d. Crop productivity Sub-group:

- Combined effects of CO_2 and soil moisture/salinity on productivity of major crops, mainly of wheat and maize.
- Measurement of actual evapotraspiration and its components with different methods.
- Prediction of crop productivity changes by future climate generated by GCM output

e. Vegetation Sub-group:

- Species composition and stand structure of plant communities
- Method of prediction of future vegetation with future climate

f. Socio-economic Sub-group:

- Farmers' perception and responses to climatic changes, technological changes and policy and institutional changes
- Regional economic and econometric approach to the interactions among climatic changes, agricultural market and policy
- Regional agricultural sector model analysis of the relation among products' structure, water use, agricultural policy, and climate changes
- Institutional economics analyses of the use of natural resources and commons

4.3 Progresses of the works of sub-groups

The progresses of each sub-group are summed up as follows.

a) Climate sub-group:

- The daily precipitation data produced by the MRI-CGCM ensemble runs under SRES-A scenario were analyzed. A decrease in precipitation around the Mediterranean region was significant.
- By analyzing precipitation data of Turkey

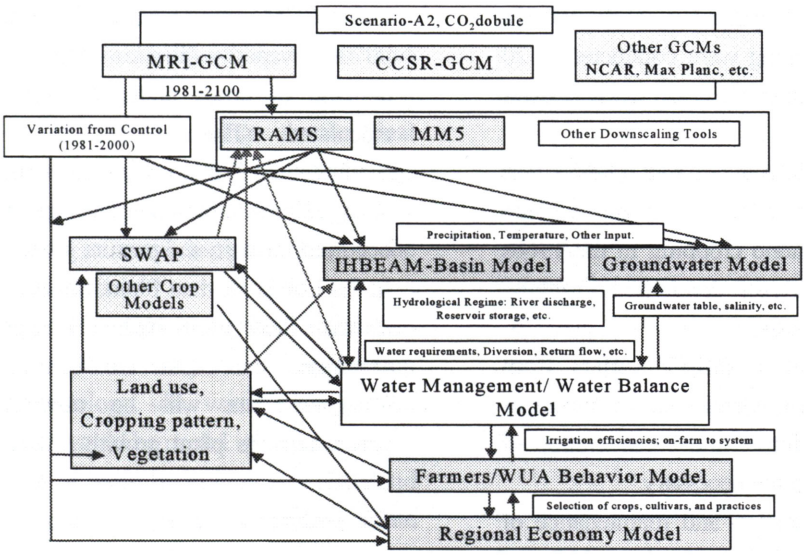

Fig. 4 Linkage of sub-models and

(1977-2000), the following trends became apparent; i) decrease of precipitation in the western region in January, ii) increase of precipitation for whole Turkey in April with a few exceptions, iii) increase of precipitation in whole Turkey in October except the southern region.

- Regional climate model (TERC-RAMS and MM5) was test-run, nested with MRI-GCM output (resolution of 280km.) Monthly rainfall distribution in the 2070s was estimated. The model still cannot simulate year-to-year variation of monthly precipitation. Appropriate nesting grid size and region for better resolution were examined.

b) Hydrology and water resource sub-group:

- Distributed hydrological model, 'Hydro-BEAM', was developed and modified. While collecting necessary input data for the Seyhan Plain, the model was test-run on the Yasu Basin of Shiga Prefecture, Japan. Reasonable reproducibility of the river flow was obtained.
- By field survey in the Lower Seyhan Plain, it became clear that irrigation is feeding groundwater and groundwater in the eastern region is flowing out to Ceyhan River.
- A saturated-unsaturated density dependent flow model for simulating salt-water intrusion was developed. Laboratory experiments were carried out to investigate influence of sea level rise.

c) Irrigation and drainage sub-group:

- Field trips for baseline assessment were carried out. Basic data for irrigation scheme were collected from State Hydraulic Works (DSI). Questionnaire and hearing were conducted at 20 Water Users Associations (WUAs) in the Lower Seyhan Basin.
- Present irrigation efficiency of the scheme was found to be below 50%. Irrigation scheme designed for cotton mono cropping in the 1960s has not been updated for diversified cropping pattern in the last 20 years.
- Lower part of irrigation district suffers from severe salinity problem. Assessment of impact of sea level rise in the future and consideration of possible counter-action are necessary.
- DSI handed over operation and maintenance of irrigation facilities to WUAs in the middle of 1990s. Some of WUAs suffer from financial difficulty due to their small sizes. The cost for rehabilitation of infrastructure also is immense burden for all WUAs.

d) Vegetation sub-group:

- Vegetation in the Seyhan Basin and the neighboring Ceyhan Basin has wide ecologic diversity, being exposed to cool climate of northern region and semi-arid climate of the southern region. It is characteristic of the Anatolian Peninsula.
- Seven permanent investigation plots were selected in the Seyhan and Ceyhan Basins. Each plot represents region's typical vegetation. Stand structure and productivity will be investigated in those plots.
- There are three main vegetation belts in the high mountain, which are; 1) sub-alpine grasslands above the timberline (above 2000m), 2) mountain forest consisting mainly of *Cedrus libani* and *Abies cilicica* between 1200m and 2000m, 3) Deciduous oak forest below 1200m.
- On the lower altitude, coniferous forest is found up to 1000m. Below 700m, a dense, *xerophyll* scrubland called 'machia' dominates. It can also be seen at the coastal level.
- On the plain, natural vegetation is barely found due to high cultivation pressure. Few solitary stands of *Wuercus ithaburensis* can be found. At the coastal zone of the plain, a complex wetland system is formed. Around the river estuaries, salt marshes cover large area.

e) Crop productivity sub-group:

- Using GCM output for rainfall and temperature of 2070s, evapotranspiration and irrigation water demand of crops under climate change were calculated. The methodology still needs modification. Preliminary result was, that no great change in evapotranspiration or water demand occurred for corn and pasture grass.
- In the Lower Seyhan Plain, on-site observation in a maize field (water budget, transpiration, etc) is continued and data are being accumulated. Obtained data will be used to determine parameters for plant growth models such as the SWAP.
- To analyze an effect of climatic change on physiology of wheat, growth chamber trial in Japan and on-site trial with different sowing time

in Çukurova University are being carried out. Results from these experiments will be used to develop a wheat growth model.

f) Socio-economic sub-group:

- Input-output Model was used to analyze the impact of agricultural crop production in Turkish economy. The results show that the influence of agricultural sector to the Turkish economy is rather small while the cereal sector receives great influence from the Turkish economy. In the next stage, regional econometric model will forecast the impact of climate variability on crop production.
- Legal institution of land ownership for pasture was studied so as to identify the issues for sustainable management of government, common and private land. Illegal occupation and rehabilitation of government pasture will be analyzed further.
- From rainfed and irrigated agricultural area, six villages were selected of household survey. Average household size is 4.3-5.5 persons per household. Land holdings are in average 21.2 ha in irrigated areas and 17.6 ha in rainfed areas. Farms in irrigated area employ more agricultural labors, about 2.5 times, compared to rainfed areas. Reliance on female labors in irrigated areas is about one fourth of that in reinfed areas. Also more tenants are found in irrigated areas.
- Based on the results of household survey, further analysis is underway to reveal resource use patterns of farmers and factors influencing them.

5. Expected Outcomes, Further Plan and Challenges

The ICCAP expects the followings as the final outcomes on the aspect of integrated climate change impacts on agriculture, while it needs further innovated approach in each discipline and in the manner of cross-disciplines.

1) Development of evaluation and simulation models for quantitative analysis of relationship among micrometeorology, soil, water, plant growth and salinity, which would be useful in arid areas.

2) Basic structure of basin hydrological regime and water balance in irrigated region, which can evaluate the role of irrigation on hydrological environment.

3) Development of a tool for integrated vulnerability assessment on agriculture in arid areas.

4) Regional-level climate change scenarios with less uncertainty linked with global climate change.

5) Prediction of changes in hydrological cycle and water resources availability in arid areas, and prediction of crop response to regional climate change and consequent irrigation water demand changes, corresponding to soil condition, farming system, irrigation management, etc.

6) Socio-economical evaluation of climate change impacts on regional agricultural production system and identification of important elements and critical points for agricultural production and irrigation management in arid areas.

The ICCAP is, as mentioned in the top of this paper, is a research project aiming to make clear the circle of interactions between humans and natural systems, and to build a new research field of the global environment, adopting a more integrated, cross-disciplinary overall perspectives. It is still quite challenging.

Acknowledgement

This article is a summary of the Research Project ICCAP. Here, the author as the leader or coordinator of the project extends his 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.

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