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.

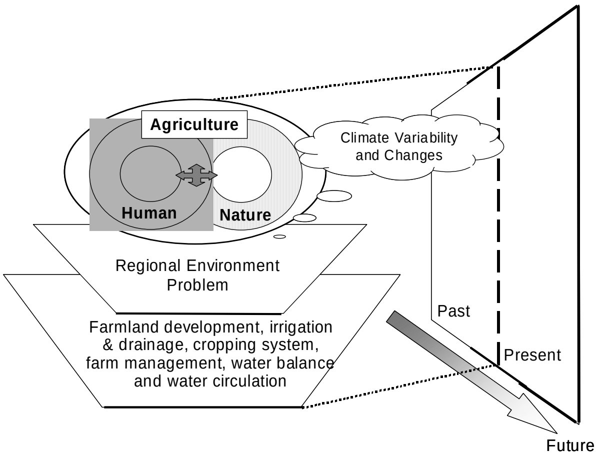

Fig. 1 Scope and framework of the research

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**.

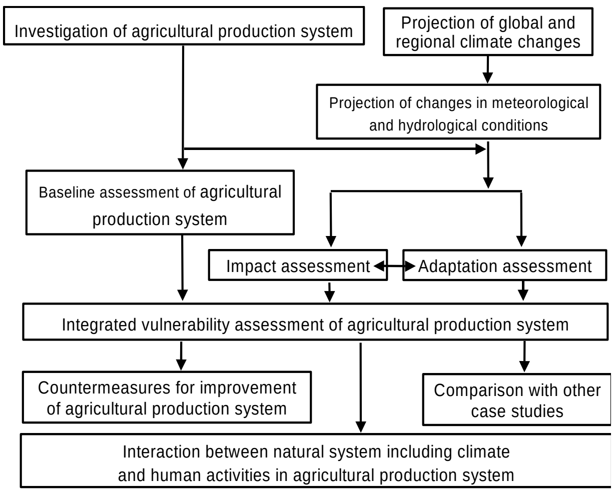

Fig. 2. Flow of research in the original plan

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.

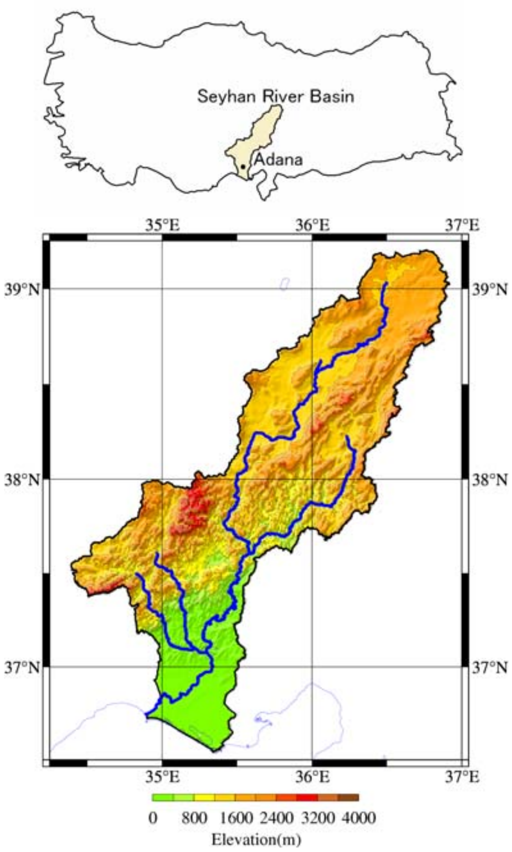

Fig. 3 The Seyhan River Basin of Turkey

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.

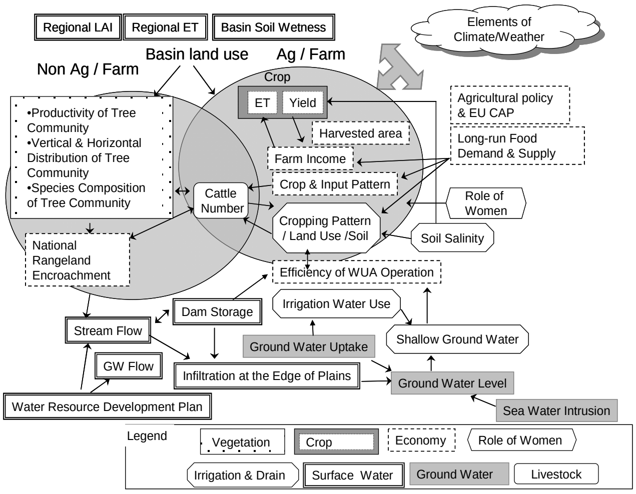

Fig. 4 Major components and course of climate change impacts on agricultural production system in the Seyhan River Basin

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".

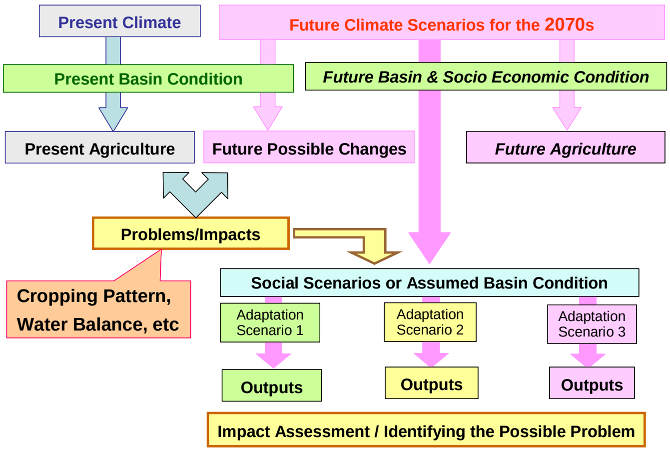

Fig. 5 Approach in integrated impact assessment
It is very difficult to predict the exact features of future agricultural production, even with future climate prediction, since the future socio-economic conditions can not be predicted with a certain reliable accuracy.

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.

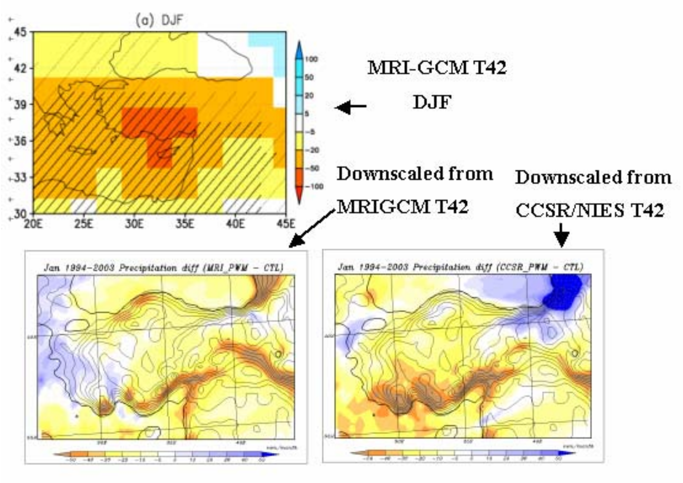

Fig. 6 Projected changes in the winter precipitation until 2070s of Turkey

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.

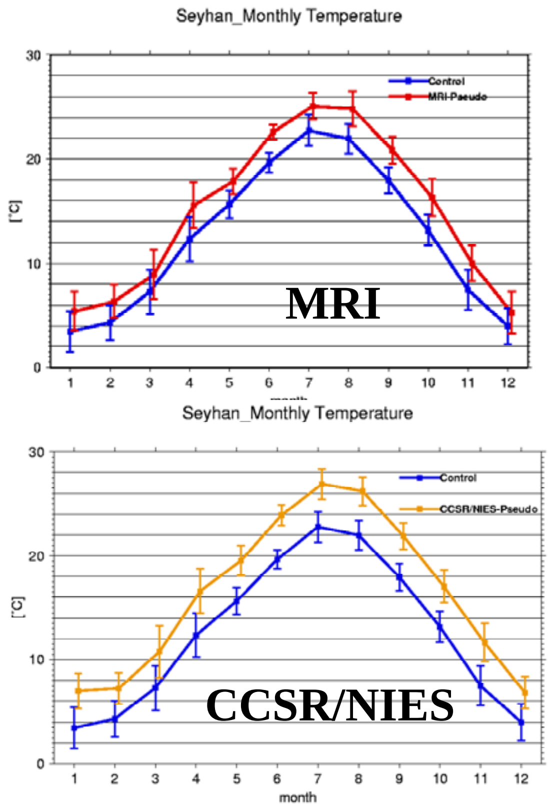

Fig. 7 Changes in monthly temperature in the Seyhan River Basin

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.

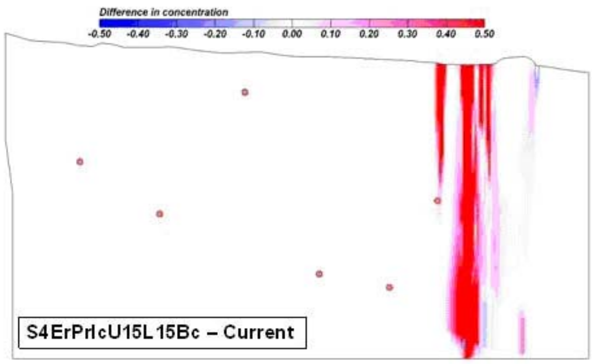

Fig. 8 Difference in groundwater salinity between the future with increased groundwater use and sea-level rise and the present. (unit: g/cm^3)

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**).

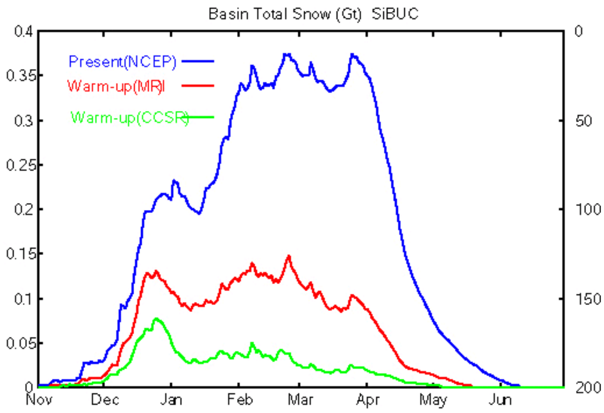

Fig. 9 Changes in total snow fall in volume equivalent to water (unit: 10^9 m^3)

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.

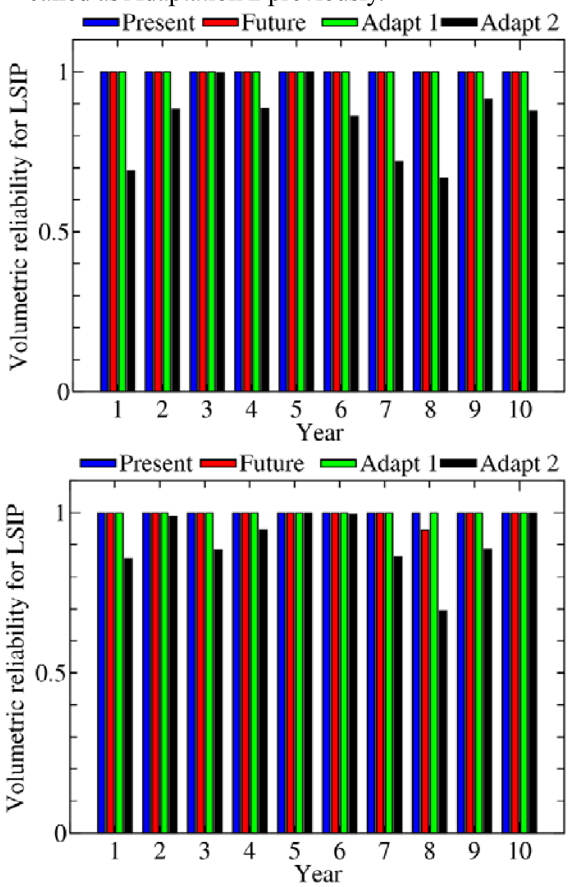

Fig. 10 Reliability changes
(Top: by MRI, Bottom: by CCSR/NIES).

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.

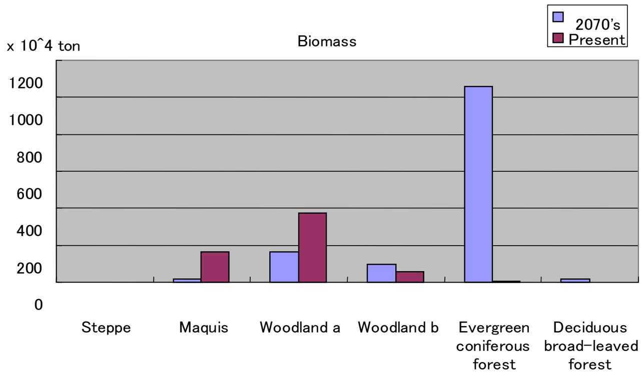

Fig. 11 Biomass of each vegetation types in present and future (in the 2070s)

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.

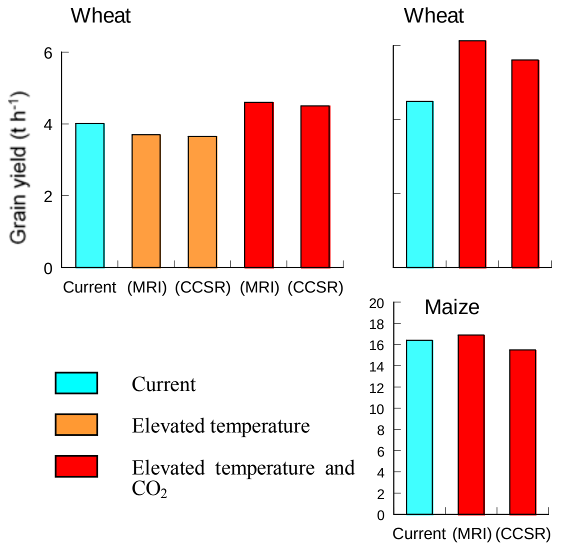

Fig. 12 Estimated grain yield in wheat and maize in the 2070's. (Left is from the simplified process model (SimWinc) and the right is from SWAP model.)

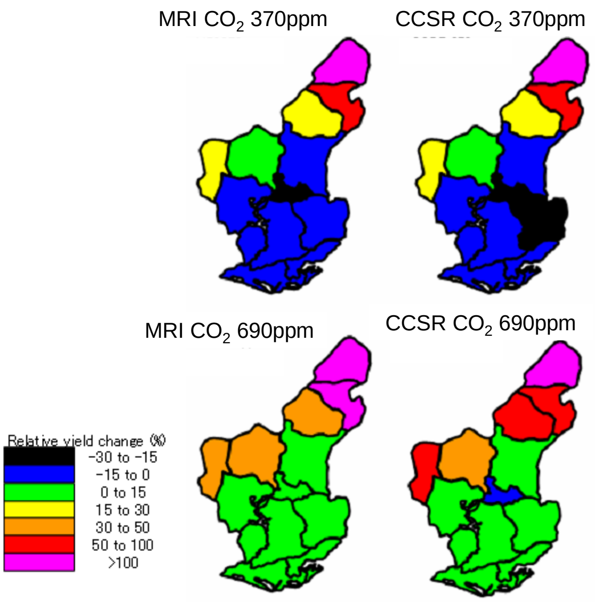

Fig. 13 Differences in changes of wheat grain yield in the 2070s among the counties in the Adana Province

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**).

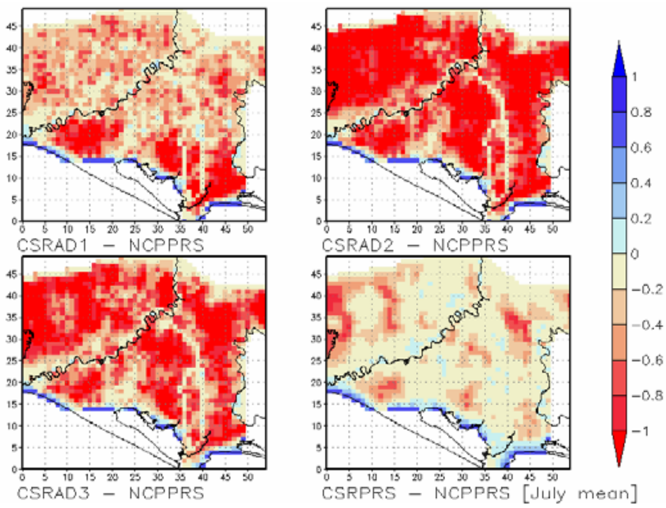

Fig. 14 Comparison of water table level between present and different adaptation scenarios (The case of CCSR runs for July average, Scenario 1: Top left, Scenario 2: Top right, Scenario 3: Bottom left, Present landuse: Bottom right)

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.

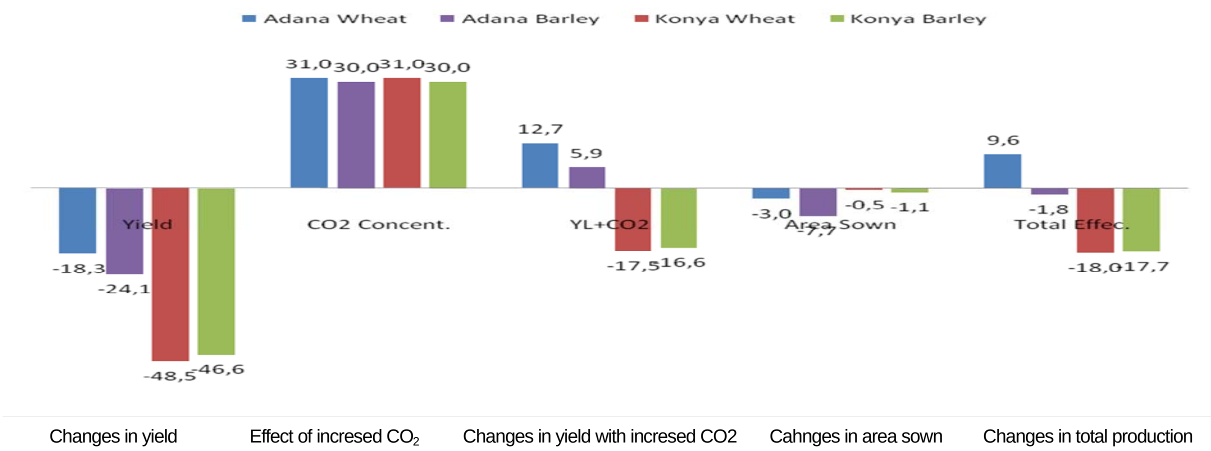

Fig. 15 Changes in yiled, area sown, and production of wheat and barley in Adana and Konya (the futures in the 2070s – the present)

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.

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