An Integrated Approach for Assessment of an Irrigation System in Lower Seyhan Plain, Turkey

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1. Introduction

Many large-scale irrigation projects in the arid and semi-arid regions are now facing structural changes. Water management responsibilities are being transferred from governments to end-users; water distribution management is becoming more complicated by diversifying cropping patterns; and the predicted climate change may further bring constraints on water resource availability and management options. Therefore an assessment of the existing irrigation systems' capacity is important if existing irrigation systems were to adapt to social and climatic changes.

The Lower Seyhan Irrigation Project (LSIP) is one of the largest irrigation projects in Turkey, which extends to the delta plain of Seyhan river basin with a total irrigated area of 133,000 ha (Fig.1). Gravity irrigation is conducted with the water supply from the big reservoirs in the upper stream. However, climate change experiments project a decrease of precipitation in this region. The plain has potential drainage and salinity problems, which may deteriorate either with saltwater intrusion caused by sea level rise, or with a change of water use in the district.

The rapid advance in computational capacity and the introduction of GIS in recent years enabled us to integrate a wide variety of data with respect to space and time. We initiated field works in 2002 with the ambition to collect and integrate as much data as possible and to analyze them with our newly developed model called the "Irrigation Management Performance Assessment Model" for simulating the systematic response of the whole LSIP to possible changes. Now four years have passed since the beginning of the project and though we are still on our way to the research goal, we would like to present the whole view of our project by introducing the methodology we chose and share experiences we obtained in the field, because we believe we are taking some new steps for the assessment of large irrigation systems.

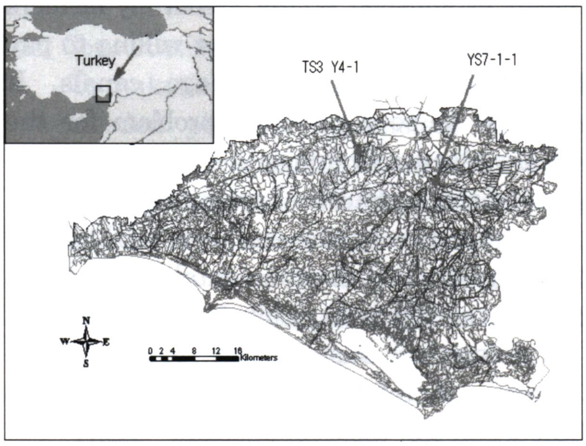

Fig. 1 Project area of the LSIP and situation of monitored canals.

2. Preparatory Questioning

In the summer of 2002, we tried to identify typical problems of the present system by visiting and questioning all water users associations (WUAs) in the LSIP. Although most previous research e.g. Scheumann (1997) and Cetin and Diker (2003) emphasized salinity and high groundwater to be a serious problem in the area, none of the WUAs have been given primary importance to those problems at the time. Instead, they were more concerned about the following four issues;

i) recent deficit of water during peak irrigation season,
ii) rehabilitation of canals,
iii) management and maintenance responsibility of drainage canals and
iv) collection of irrigation fee.

We have learned that the cropping pattern change over the last few decades and degradation of canals caused the water deficit problem because the system was originally designed mainly for cotton cropping nearly thirty years ago. While management responsibility of irrigation facilities was transferred from DSI to the WUAs, main drainage canals continued to be DSI's property. This was probably due to the fact that the burden of maintenance of drainage canals were a little too much for newly established WUAs. Generally farmers don't pay attention or are not willing to pay for maintenance of drainage canals. It remains to be a potential problem for the future because drainage is an indispensable part of the agricultural system in the LSIP, and ignorance by the end-user might bring huge cost and environmental burdens to future management. Collection of irrigation fee determines sustainability of WUAs. Dr. Umetsu therefore took this issue as an important sub-topic of our team.

While covering the whole command area of the LSIP for diagnosis was not realistic, visiting all WUAs gave us many insights for later fieldworks. We strongly recommend such methodology for similar research efforts in the future.

3. Need for Some Monitoring of Water Budget

3.1 Situation

Calculation of principle water demand for the LSIP is very simple. All WUAs use "DSI Sulamalarinda Bitki su Tutimleri ve Sulama Suyu Ihtiyaclar (1988)" for calculation of their irrigation water demands. A unit crop water demand multiplied by cultivation area is totaled for the whole command area to calculate water demand at the main canal inlet. They also consider transport loss and field application loss. During irrigation season, each WUA strictly monitors water intake from the main conveyance canal to its responsible main canal to guarantee its water demand. After the transfer of operation from DSI to WUAs, there seems to be a large inconsistency between their proposed irrigation demand before the season and their actual water intake during the season. From our impression there are several possible reasons for this.

i) WUAs are late to collect cropping plan from farmers.
ii) Some WUAs are not trained in operating software for water demand calculation.
iii) Water loss due to deterioration of canals is not well considered.

After the intake, there is no more monitoring at the secondary or tertiary canal level. Water distribution technicians control water allocation by exchange of information via transceivers. They are capable of managing water distribution by this opportunistic method because there is enough water at a moment, but it will be very difficult if water resources become less available.

3.2 Start of Measurement

Since there was no monitoring carried

out in the past, water budget structure of the LSIP was unknown. We felt a need to monitor actual water use to provide answers to some important questions before modeling the whole system, such as ;

i) cause of low irrigation efficiency,
ii) irrigation rule of end users,
iii) actual irrigation efficiency of each land use,
iv) relation between irrigation, drainage and fluctuation of shallow groundwater.

We chose two tertiary canals from the left and right banks of the Seyhan River (see Fig. 1) and started monitoring from the spring of 2004. YS7-1-1 in Gazi WUA on the left bank was a 'kanalet' type. Citrus and maize were mainly cultivated in the command area. TS3 Y4-1 was a concrete lined canal, which belonged to Yesilova WUA on the right bank. The main crops of this area were maize and watermelon.

During the course of measurement, we found out that farmers' actual irrigation practices were somewhat different from the rule established by DSI in the past. Firstly, water allocation within the tertiary canal was conducted on acquaintance base between farmers and they used mobile phones to communicate with each other. Secondly, distribution technicians were not strong controllers. Farmers preferred to take water from early morning and to continue until after dark. Therefore, distribution technicians were usually informed of water allocation after actual operation. Water demand tickets were not used for allocation planning, but rather used as a proof or a receipt, filled by technicians when they checked irrigation on site.

If we only estimated water use from water demand tickets without measurements, we would have mistaken that water management was just being neatly carried out as principle. Instead, we found out that annual total of irrigation water intakes and drainage from unit area exceeded 2,500mm and 1,500mm, respectively in the upper part of the LSIP. We also found out that the majority of this large amount of irrigation intake was lost from the canal as leakage or was dropped to drainage as tail water.

4. Data Integration for the IMAPM

4.1 Irrigation Management Performance Assessment Model

The most innovative part of this project is the development of the "Irrigation Management Performance Assessment Model". The IMPAM is a hydrological model specially developed for assessing performance of the irrigation system of a plot to district scale. As seen in the case of the LSIP, a large proportion of the water brought into an irrigation district moves much faster than Darcian flow i.e. flow in canal, leakage from canal recharging groundwater, and drainage flow etc. Whereas most one-dimensional crop water balance models mainly focus on soil water balance, the IMPAM is one of the first to consider the spatial effect of an artificial water path. Another distinct character of the IMPAM is its ability to assess the effects of mixed land use. The neighboring plots have water budget interaction through groundwater. The IMPAM is a quasi-three-dimensional distributed model so that it can represent realistic land use.

4.2 Construction of database

To make full use of the distributed model, we needed physical parameters of high resolution because the combined effect of the different parameters would ultimately be affected by the dataset of lowest resolution. In this sense, we were both fortunate and unfortunate in choosing the LSIP in terms of availability of data.

4.2.1 Soil

There was already an excellent soil database on GIS with high resolution established by the soil department of Çukurova University before the project was initiated. We were inspired of the high possibility of data integration when we first had a look at this database.

4.2.2 Meteorological data

As far as Lower Seyhan Plain is concerned, there are data from two automatic meteorological stations in Adana and Karatas available.

4.2.3 Irrigation intake

DSI keeps daily records of diversion from regulators to TS0 and YS0 and of direct intake from Seyhan Dam to main canals TS1 and YS1. But apart from that, even daily diversions to each main canal were not available in usable form. As explained in section 2.2, the method of building up seasonal irrigation demand is very simple, so if we had access to the cropping pattern with spatial reference, we could regenerate water demand in the past. Unfortunately, the cropping pattern record was only kept for the whole district scale. We strongly recommend DSI to be more cautious on data management, because they carry out very detailed buildup every year but not archiving those good records once they calculated the sums.

There was no measurement on drainage canals. So we have to use the reference water budget collected at two monitoring canals for extending the model over a whole district. This is a weak point of our study.

4.2.4 Shallow groundwater data

Since the 1980's, DSI has been measuring shallow groundwater (down to 4m from surface) and groundwater EC, monthly and once a year at peak irrigation season, respectively. The number of observation wells was 626 in the 1980's, and in the 1990's the number was increased to 1,134, covering nearly the entire command area of project phase I-III. Shallow groundwater dataset is the most reliable and has the highest spatial resolution of all water budget components so that the IMPAM will use this data intensively for calibration of the model. When data from the 1980's, 1990's and 2000's were analyzed by Ms. Donma, it was found that groundwater EC has been continuously decreasing in the most of parts whereas groundwater depth did not change so much.

4.2.5 Land use

As explained above, the cropping pattern for each plot should exist, but there is no management of data and only the total cultivated area for each crop was obtainable. Since the cropping pattern would largely

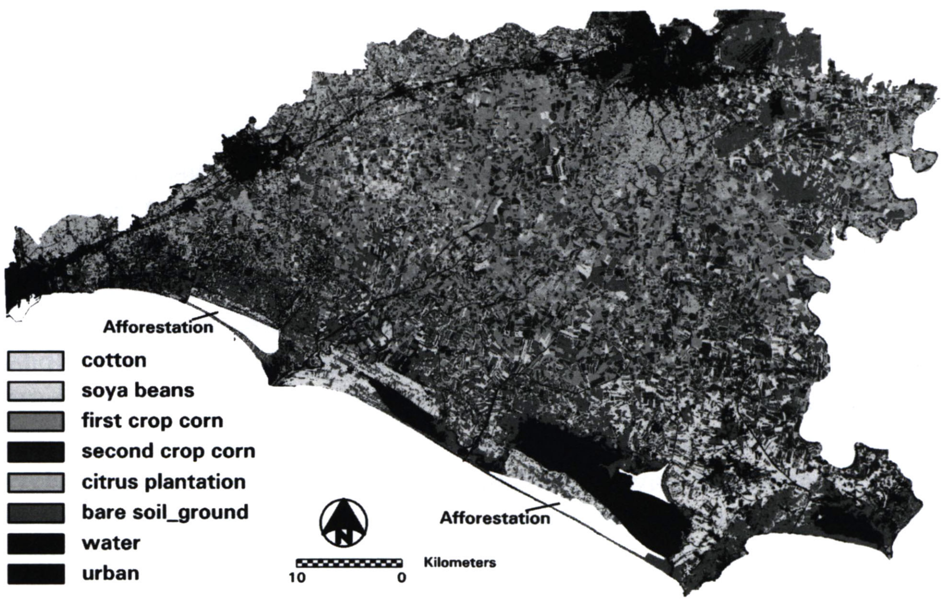

Fig. 2 Cropping pattern derived from Landsat image of August 2003.

influence water use, an image analysis of past remote sensing data was considered. Dr. Berberoğlu compared the Landsat image from year 2003 with the detailed cropping pattern record of a few WUAs, and succeeded in classifying major land use (Fig.2.) By following the same methodology we would be able to generate cropping patterns for the other years, as well.

4.2.6 Irrigation and drainage facilities

Water flow in irrigation and drainage networks are a much faster process compared to soil water movement and they can have a large impact on shallow groundwater fluctuations. Whereas soil hydraulic parameters have a dominant effect on water budget in a one dimensional crop water balance model, the influence of irrigation and drainage canal network density would become more dominant as we increase the calculation grid size. Irrigation and drainage canal networks density can easily be derived by the use of GIS and they can also reflect management and maintenance states.

5. Salinity Monitoring in the Lower Plain

Out of the 175,000ha originally planned for implementation of the LSIP, 133,000 ha is now reclaimed and receiving irrigation. The remaining area, called "phase IV area," is mainly lowland near the coast, and has no proper irrigation or drainage facilities installed yet. This area has been seriously affected by salinity in the past because of high groundwater and bad drainage. Although DSI plans to extend the irrigation facility to this area, only a few small-scale research efforts on the salinity problem were conducted in the past.

Since this phase IV area is a downstream part of the LSIP and probably most vulnerable to changes in environment, we decided to include this area in our study. We started to monitor the spatial distribution and temporal change of the shallow groundwater and soil salinity by field measurements and laboratory analysis in 2005.

We set twelve new observation wells and fifty fields of different land use for regular monthly observation. After a year of measurement, we would be able to see the general trend of groundwater fluctuation and soil salinity dynamics. Then we will include this area in the IMPAM and test its response to changes in water use. We are also employing satellite image analysis for detecting the historical change of land use and the change of severely saline regions within the project IV area.

6. Testing the System to Climate Change and Social Scenario

6.1 Climate change by pseudo warming

Spatial resolution of the outputs of the Global Circulation Model is very low (often 2.5 degrees) and often so different from actually observed data that the projection of "realistic" future changes is difficult. In this project, we use data downscaled with a special technique named "pseudo warming" (Kimura, 2005) Kimura first used the regional climate model RAMs with NCEP (National Centers for Environmental Prediction) reanalysis data as a boundary condition to represent the climate condition around the Seyhan Basin with high spatial resolution (8.3km). Then he added a climate change bias between the 10 years' average of the 1970's and the 10 years' average of 1994-2003 to this reanalysis data to produce a pseudo future boundary condition and then downscaled to generate the future climate (Fig.3). By this method, because the boundary condition are close to actually observed values, the regional climate is much more representative. Currently, the CGCM2 by MRI/JMA (Yukimoto et al., 2001) is used with scenario A2 to calculate climate change bias.

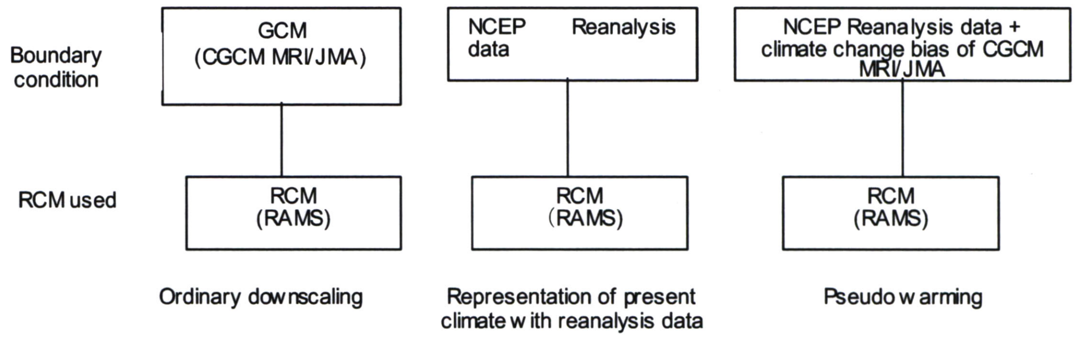

Fig. 3 Generation of pseudo warming data.

6.2 Socio-economical setting

The response of the irrigation system towards climate change can vary with assumed socio-economical settings. As shown in Fig. 4, while climate change directly affects crop response or water resources, socio-economical settings determine land use and the capacity of facilities for conserving water resources. The intention of this project is not to provide an accurate forecast, but rather try to test the response of the system against different assumed conditions to find potential hazards of the present system. We will use scenarios such as i) no change from present, ii) resource saving, environmentally conscious and iii) profit maximizing opportunistic and resource wastefulness. We will interpret these scenarios into quantitative parameters such as cropping pattern, irrigation method, water resource availability, management condition (efficiency) of canals, etc.

7. Conclusion: Towards True Inter-Disciplinary Approach

The project ICCAP is an inter-disciplinary project comprised of nearly a hundred researchers from Turkey, Japan and Israel. Apart from the authors belonging to irrigation subgroup, there are other researchers dealing with climate, basin hydrology, crop response, natural vegetation and socio-economic condition. The cross-disciplinary integration would be brought about by exchange of parameters and testing models under the same assumed social setting. Now we are in the process of sensitivity analysis in each group to determine critical factors that would be affected by climate change. **Figure 5** shows the whole picture of possible interactions in the project. Now we are trying to determine the main frame of interaction among subgroups. Then we will refine the social condition scenario by exchange of dialogue to achieve our ultimate goal, which is to project the systematic response of the whole agricultural system in the Seyhan

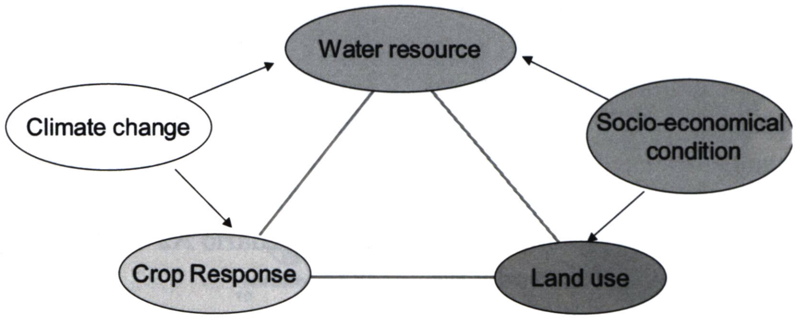

Fig.4 Irrigation as a system with its elements affected by climate change and socio economical condition.

Basin towards climate change.

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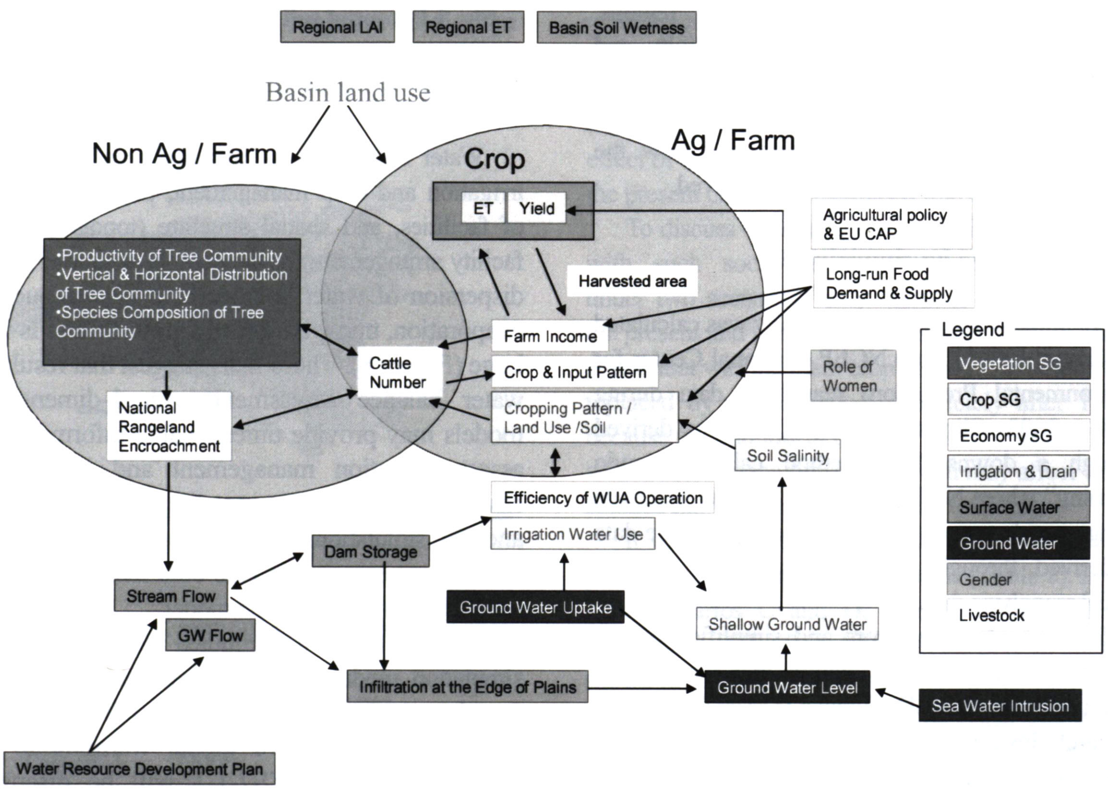

Fig.5 Possible interrelation among elements of agricultural production system in Seyhan Basin