Long-term Changes of Level and Salinity of Shallow Water Table in the Lower Seyhan Plain, Turkey

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1. Introduction

Lower Seyhan Irrigation Project (LSIP) is one of the largest irrigation projects in Turkey which extends on the delta plain of Seyhan river basin with a total planned area of 175,000 ha. With the water supply from the big reservoirs in the upper stream, gravity irrigation is conducted with water efficiency lower than 50%. Before the implementation of the project, wheat and cotton were cultivated with winter rainfall and residual soil water, respectively. When State Hydraulic Works (DSİ) started to implement the irrigation project in this area in the 1960s, the biggest challenge for the engineers was to deal with bad drainage and salinity problems widespread on the delta. Therefore implementation of irrigation was coupled with installation of subsurface drainage and construction of drainage canal networks.

By the 1980's, implementation of the project was complete in two thirds of the total surface area (133,000ha) and DSİ started monitoring of shallow water table level (monthly) and salinity (once a year), very intensively over the entire irrigated area.

Because DSİ only monitored water flow at main canal level and never monitored drainage flow in the past, shallow water table fluctuation and its salinity are the only spatially distributed, high resolution and continuous data which enables examination of the change in the water budget of the system over the long term.

In this study, we used the GIS to synchronize water table data with other features of the LSIP, such as remote sensed land use, canal properties and soil properties to find out their spatial influence on water budget. The data were compared at decadal interval to clarify the differences.

2. Long term changes in the irrigation environment

During the past 25 years, great changes occurred in the cropping pattern and the water management.

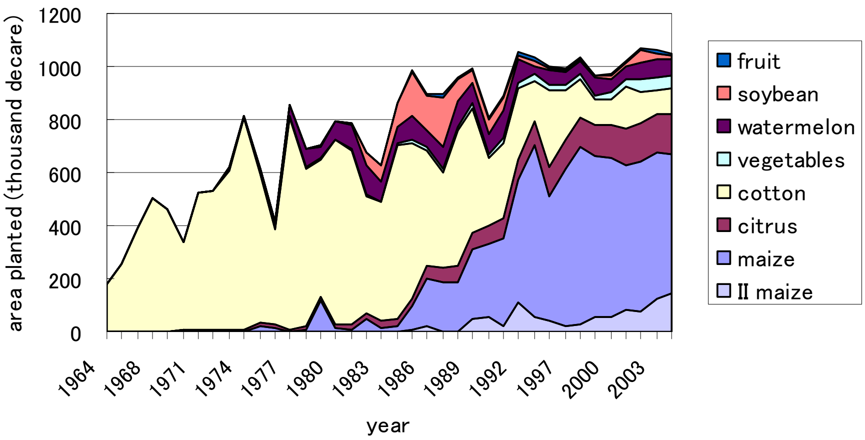

Fig. 1 Area planted for 8 major irrigated crops in Lower Seyhan Irrigation Project (1964-2004); Source: DSI. Year 2002 Yield Census Results for Areas Constructed, Operated and Reclaimed by DSI, various years.

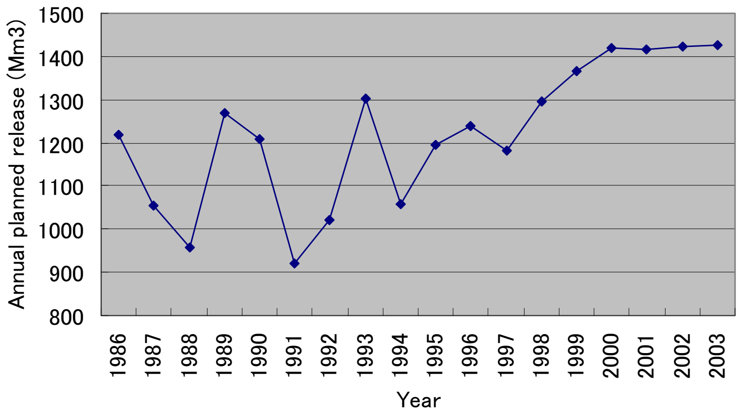

Fig. 2 Change in the planned water release to the LSIP.

Figure 1 illustrates the change in the cropping pattern in the LSIP. Until the 1990s, cotton was the major and dominant crop in the area. From mid 1980s, variety of crops started to increase and maize became the major crop by the mid 1990s. In the 2000s, cropping pattern has become somewhat stable with increased citrus area.

Figure 2 shows the change in the planned water release to the LSIP in the past two decades. The amount has been increasing with time, mainly due to shift in the cropping pattern and substantial increase in irrigated area in so called "phase IV" area near the coast where farm plots were not yet fully consolidated. Another significant change was the turn over of water management responsibility from DSİ to newly established water users associations (WUAs) in the mid 1990s. Due to degradation of canal, precipitation anomaly, conflicts between WUAs etc., the actual amount released nowadays seems far more than the planned value. Although consistent record on actually diverted water was not available, some data show that recent actual release is reaching nearly $2Gm^3$.

3. Material and method

3. 1 Topography and soil of the LSIP

The study area is the LSIP. Figure 3 shows the topography of the area. The delta is very flat, with maximum elevation of 40 meters above sea level in the north, with minimum ranging from zero in the south. The slope of the delta ranges between 0.1 and 1 %. The soil in the delta is alluvial which developed as deposits of the main rivers. Dominant soil in the delta is clayey loam to sandy or loamy clay.

3.2 The archive data used

For the hydrological record, cropping pattern, canal networks and shallow water table, we used archive data kept by DSİ. Precipitation record was obtained from State Meteorological Works (DMI), The depths of shallow water table observation wells were down to 4m from soil surface. Total number of observation wells was 626 in the 1980's, and the number was then increased to 1,134 in the 1990's, covering nearly entire command area of irrigated area.

Two sets of data from each decade (1984, 1985, 1992, 1993, 2002 and 2003) were chosen for analysis. After verifying that decadal change being much more significant than inter-annual variation, 3 sets of data (1985, 1993 and 2003) which could be compared with available satellite image were chosen for analysis. The wells which became immeasurable due to fall of water table beyond limit or by destruction were eliminated from analysis.

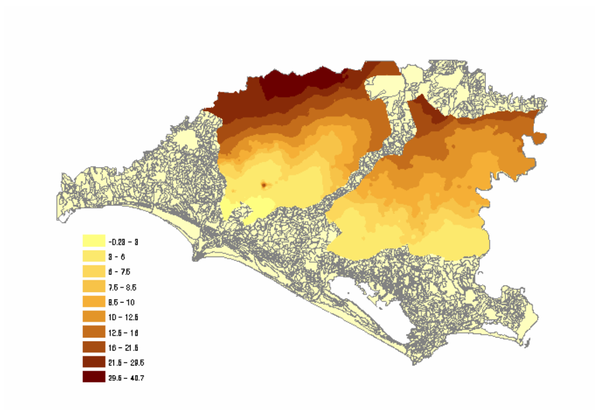

Fig 3 Topography of the irrigated area in the LSIP.

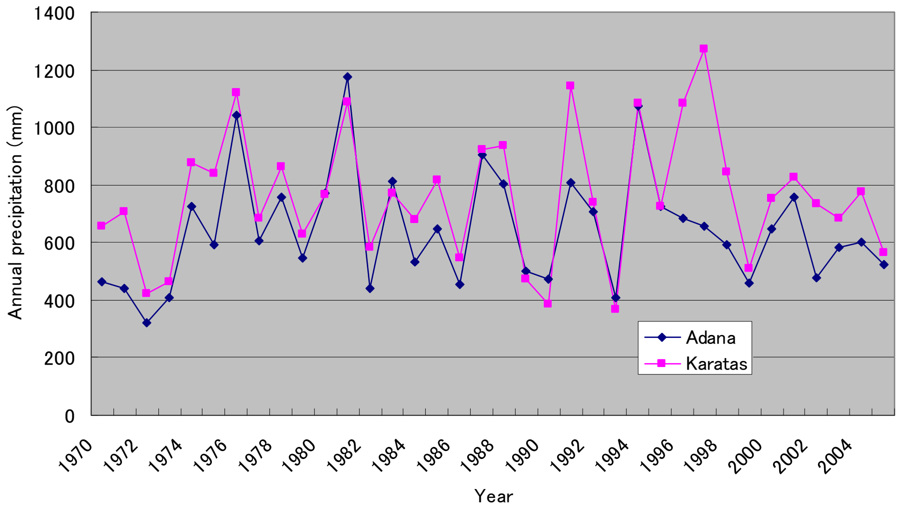

Fig.4 Precipitation in Adana and Karataş in the past 35 years

Figure 4 shows variation of precipitation in Adana and Karataş which are located at the northern and the southern edge of the delta, respectively. In the past 35 years no clear trend (increase or decrease) in precipitation was detected. The average precipitation of the two stations from October to next September was 660mm, 692mm and 569mm for 1984-1985, 1992-1993 and 2002-2003, respectively.

LANDSAT TM images for the summer of 1985, 1993 and 2003 were obtained and land use was classified using actual cropping pattern record as ground truth points. Boundary detection software (Definiens, Definiens co.) was used to detect farm plots. Compared to conventional method of classifying pixels, this improved the accuracy of land use classification. Figure 5 is one of the images obtained as the final products.

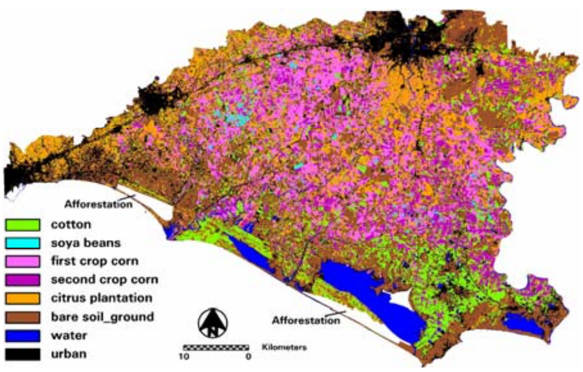

Fig. 5 Cropping pattern derived from Landsat image of August 2003.

3. Results and discussion

3.1 Effect of situation of drainage canal networks

To examine whether observation wells were located on representative locations, Euclidean distance between observation wells and nearest drainage canals were examined. The mean distances were 282m and 250m for the wells in 1980s and 1990s onwards, respectively. The distances seemed to be large enough for assuring the representative ness.

3.2 Shallow water table fluctuations.

Figure 6 compares average water table depth of different decades. There was no significant increase or decrease in water table depth observed in the past 20 years. Spatial distribution of minimum water depths observed in each area is shown in Fig. 7. Most of the area had relatively high water table, ranging between 50 and 100cm or between 100 and 150cm. The minimum depth did not show significant change over 20 years despite the increase in irrigation amount and possible degradation of subsurface drainages which were installed at the time of implementation of the project.

Figure 8 shows the months when minimum were observed in each well. Figure 9 shows the range of annual fluctuation. In 1985, minimum depth was observed either in mid summer (dominantly in cotton fields) or around January in the most of the area and the degree of fluctuation was quite large. In

1993, new peaks appeared in June-July (mainly in maize fields) and in November-December (mainly in harvested maize fields). In 2003, large area on the right bank had peak in winter and left bank had no clear peaks. The range of fluctuation was very narrow in this year. Water table fluctuation seems to have lost clear seasonal trend because of diversification of cropping pattern and substantial increase in irrigation.

3.3 Salinity distribution in shallow water table

Figures 10 shows change in electrical conductivity of shallow water table. In the LSIP, sodium ion dominantly contributes to EC thus measured value represents degree of salinity. Measurement was carried out during peak irrigation season (July). Although there may have been dilution effect by increased irrigation application, it is quite definite that salinity of shallow water table has been consistently decreasing over the years.

Salinity was severe when rain-fed cotton was cultivated before the implementation of the project. In that time, dry summer climate was the major driving force for bringing salt to soil surface. After the implementation, soil water flux in summer was also reversed to downward by irrigation. Recently the total applied water to the field exceeds 1500mm (precipitation and irrigation) and this has probably contributed to decrease of salinity. Irrigation water supplied from Seyhan dam has very low sodium content and the increase in its use would also work for decline in salinity. Without knowing the origin of salt, it is not appropriate to say that soil was leached out of soil profile in the last 20 years. However, at least it has been suppressed below the root zone with contributions from good network of the drainage system.

4. Conclusion

While many parts of the world suffer from increasing salinity problems associated with excessive irrigation, Lower Seyhan Plain seems to be a fortunate exception because

i) introduction of summer irrigation to winter rainfall Mediterranean Climate kept soil water flux always downward,
ii) although subsurface drainage must have deteriorated with time, there is no clear sign of water table becoming critically high, even with increased irrigation,
iii) good drainage networks quickly carry away surplus water and avoid water logging,
iv) irrigation water supplied from upstream has low salt content and there is no hazard for secondary salinization.

From this analysis it was found that land use clearly has influence on spatial distribution of water table. Water table seems to be kept high because of excessive irrigation and thus may decline in future if more efficient irrigation were carried out. For avoiding further salinity risk in the future, farmers in this area should primarily use river water and avoid groundwater uptake, especially near the coastal zone.

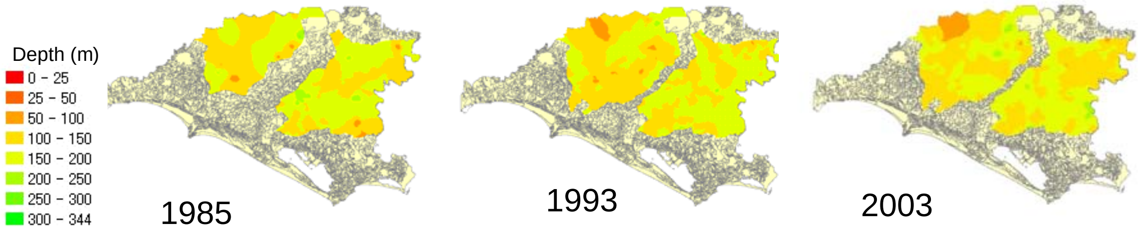

Fig.6 Annual average depth of shallow water table in the LSIP.

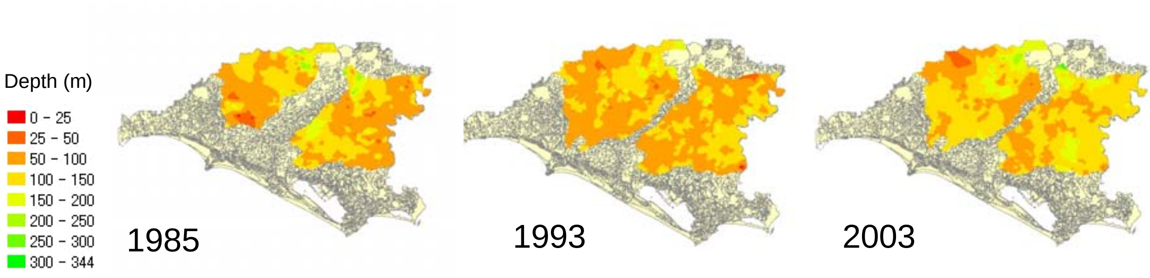

Fig.7 Annual minimum depth of shallow water table in the LSIP.

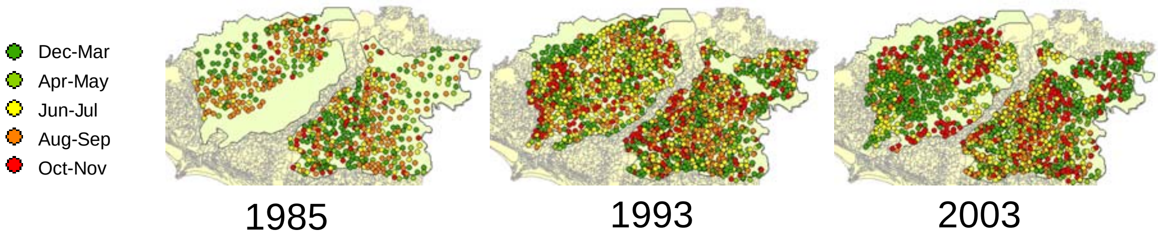

Fig. 8 Month for the occurrence of minimum depth.

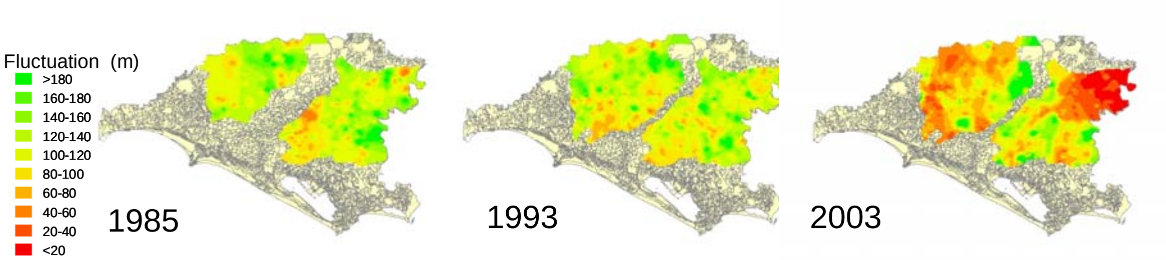

Fig.9 Annual fluctuation range of shallow water table in the LSIP.

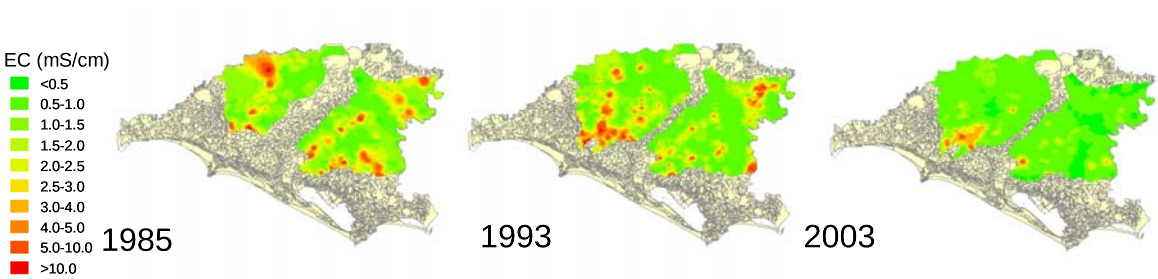

Fig. 10 Electrical conductivity of shallow water table in July in the LSIP.