Water Scarcity and Alternative Cropping Patterns in Lower Seyhan Irrigation Project: A Simulation Analysis

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1. Introduction

Water scarcity is a major concern for agricultural production in arid areas where the amount of rainfall is limited. According to the IPCC climate change scenario, it is often indicated that the summer temperature increases and winter rainfall decreases in the Mediterranean region (IPCC, 2001). How agricultural sector, or farmers will adapt the changes in future water scarcity in face of global warming? One way is to change cropping patterns and make adjustment for available water resources. Another way might be to change farming practices by adjusting cultivation period and/or applying appropriate crop rotations.

The purpose of this simulation analysis is to assess the water availability in 2070 and the possible cropping pattern and the farmer welfare in Lower Seyhan Irrigation Project (LSIP). We use expected value-variance (E-V) model which is used to analyze risk. The model maximizes total gross revenue of irrigated agricultural production of all water user associations according to the risk aversion coefficient. Higher values of risk aversion coefficient indicate more risk aversion. The solution of the model will give proportion of cropping area in LSIP to be allocated to different crops to maximize gross revenue per decare under different risk aversion levels. By assuming future water scarcity in the LSIP, the simulation was run with i) current water use level, ii) 10% water reduction case, and iii) 20% water reduction case. Results shows that under the risk aversion level of 1%, area under citrus, vegetables, melon, and fruit was 12.4%, 1.3%, 76.6% and 9.8% respectively. This cropping pattern yielded average gross revenue of 975 YTL per decare. Under the variability of gross revenue, farmers are more likely to choose high value added crops such as citrus, melon, vegetables and fruit.

Organization of the paper is as follows. The first section reviews water use and cropping patters in lower Seyhan irrigation project. The second section explains the method of analysis and data set used in the analysis. The third section presents the results of simulation analysis and the last section concludes the paper.

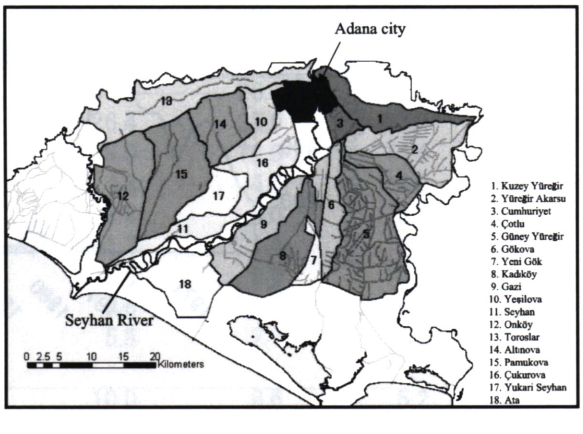

Figure 1. Lower Seyhan Irrigation Project and Water Users Associations

2. Water Use and Cropping Pattern in Lower Seyhan Irrigation Project

For agricultural development in Turkey, three types of government intervention played an important role. Those are an access to credit facilities, price support policies, and the provision of irrigation infrastructure (Hale, 1981). The Lower Seyhan Irrigation Project (hereafter LSIP) in Adana is initiated by the Turkish government as one of the important irrigation projects located in southern Turkey (Figure 1). The Government constructed The Seyhan Dam in 1956 for the purposes of irrigation, power generation and flood protection. The reservoir can store 1.2 billion cubic meters that supply irrigation water to LSIP. Until 1993 small-scale irrigation systems were transferred to water users at a pace of about 2,000 hectares per year. DSI encouraged farmers to organize Irrigation Groups (IGs) or Water User Groups (WUGs) with limited responsibility for operation and maintenance. After 1994, large-scale irrigation systems including Lower Seyhan Irrigation Project (LSIP) started to be transferred to water users associations (Tekinel, 2001; Donma, 2004; Umetsu et al. 2005). Since then, water users associations have been playing an important role for water allocation at the secondary and tertiary canals and the end-use in addition to DSI (General Directorate of State Hydraulic Works).

Figure 2 shows the area planted for eight major irrigated crops in lower Seyhan river basin during the period between 1964 and 2004. During the 1960s, after the construction of the Seyhan Dam, cotton production expanded very rapidly. However, since the early 1980s, other crops such as maize, soybean, melon and citrus increased gradually. And during the early 1990s, the area planted by maize surpassed that of cotton. Since the early 2000s, high value crops such as citrus and vegetable production are gradually increasing.

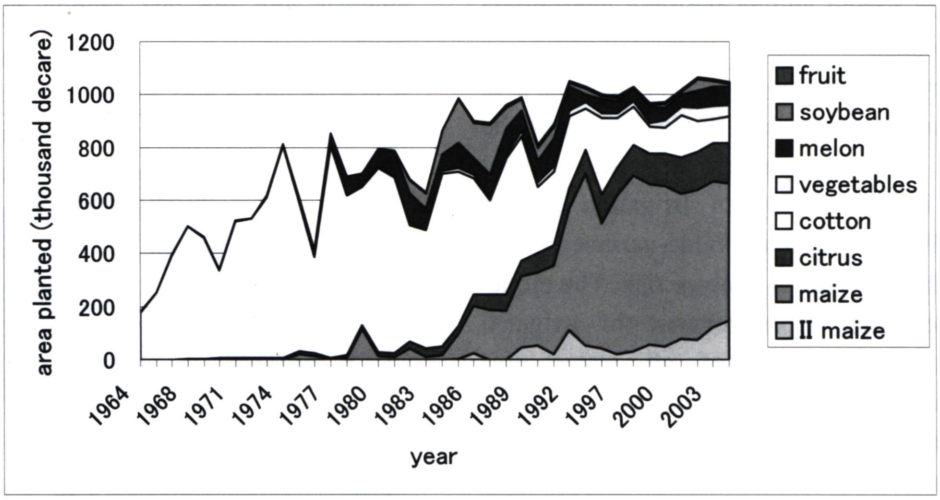

Figure 2. Area planted for 8 major irrigated crops in Seyhan (1964–2004)
Source: DSI. Yield Census Results for Areas Constructed, Operated and Reclaimed by DSI. Various years.

Table 1. Major irrigated agricultural crops in LSIP in 2002

rank	area of production	%	production value	%	gross revenue	YTL/da
1	maize	56.57	citrus	38.90	strawberry	2,417
2	citrus	13.51	maize	33.43	citrus	1,180
3	cotton	7.36	melon	9.86	fruit tree	1,086
4	vegetables	6.30	vegetables	6.24	vineyard	875
5	melon	5.63	cotton	4.98	melon	718
6	soybean	4.38	soybean	1.40	greenhouse and II vegetables	640
	total	93.75	total	94.81	average	426
					average (2005 price)	707

Source: DSI (2003b) Transferred Irrigation Association Year 2002 Observation and Evaluation Report, DSI Region VI, Lower Seyhan Irrigation Project, Operation and Maintenance Department. II vegetables=second crop vegetables

Table 1 shows the major agricultural crops in LSIP in 2002 cropping season. The largest area was planted by maize (56.57%), followed by citrus (13.51%), cotton (7.36%), vegetables (6.30%), melon (5.63%) and soybean (4.38%). In terms of production value, the highest value comes from citrus (38.90%), maize (33.43%), melon (9.86%), vegetables (6.24%), cotton (4.98%) and soybean (1.40%). Thus these major six crops covered 93.75% of total irrigated area and yielded 94.81% of total gross revenue of LSIP in 2002. Crops that yield highest gross revenue per decare are strawberry (2,417 YTL/da) and citrus (1,180 YTL/da) followed by fruit tree and vineyard.

Table 2 summarizes the result of Delphi forecast given by the staff members of water users association in LSIP in 2005. This method is typically used by the engineering sector to predict when the particular technology would

Table 2. Delphi forecast of cropping pattern in LSIP by WUA

	(a) Seyhan 2003 (observed)	(b) Seyhan 2033	(c) Seyhan by each WUA 2033	(d) Seyhan by WUA control	(e) Seyhan by WUA 10% water reduction	(f) Seyhan by WUA 20% water reduction
maize	53.3	40.6	42.6	31.9	26.3	21.3
citrus	14.2	21.3	23.9	26.4	25.9	27.2
cotton	8.7	10.9	9.0	9.0	12.9	14.4
melon	7.0	8.2	6.5	4.8	4.5	4.9
vegetables	4.8	6.2	7.8	8.8	8.0	5.3
onion	1.4	2.0	1.4	1.3	1.4	1.5
soybean	2.0	4.9	4.2	7.4	8.6	9.2
fruit	0.7	1.7	2.0	4.6	4.7	5.1
others	7.7	4.1	2.7	5.8	7.7	9.0
100%						
II maize	12.0	13.9	11.8	10.0	6.6	5.2
II vegetables	2.3	4.2	2.0	3.7	3.1	2.8

Source: Data in 2003 are from DSI (2004) Year 2003 Yield Census Results for Areas Constructed, Operation and Reclaimed by DSI. DSI Operation & Maintenance Department, Ankara.
Other information are from authors' interview survey (2005).
II maize = second crop maize; II vegetabels = second crop vegetables

be available in the future. Here Delphi forecast was used to obtain WUA staff members' view on the future cropping patterns in the year 2033. The column (a) shows the actual cropping pattern reported in 2003. Maize acreage is 54.3% followed by citrus, cotton, melon and vegetables. The column (b) indicates the forecast of the cropping pattern of entire LSIP (Seyhan). In this case, maize cultivation is reduced to 40.6% and citrus, cotton and melon increased. The column (c) shows forecasts for each WUA command area and then aggregated using land share parameters. Again maize area reduced and citrus area increased. Usually the decision of the cropping pattern is made by the individual farmers and then they are aggregated and reported to DSI by water users associations for planning water allocation for the next irrigation season. The column (d) shows the cropping pattern assuming WUA has a full control of their command area. In this case, maize and melon decreased and citrus, vegetables and soybean expanded compared to 2003 cropping pattern. Additional questions were made in case of 10% and 20% water reduction case in column (e) and (f) respectively. In this case, maize cultivation is reduced to less than a half and citrus, cotton, soybean and fruit expanded. By the reduction of the water resources, farmers are more likely to choose high value crops such as citrus, vegetables and fruit.

3. Method and data

3.1 Method

In order to estimate the optimal land resource allocated to various crops under different risky alternatives, expected value-variance (E-V) model was used. This model is used to analyze decision making in risky situations and maximizes expected total return (or gross revenue) under different levels of variance of total return. In this model, expected return can be increased only at the expense of a larger variance of return (Harwood et al., 1999). In other words, if you are risk-averse farmer, you want to maximize expected return while choosing the low variance of return. Using this E-V model, it is possible to analyze optimal decision making under risky situations. The specification of expected value-variance (E-V) model is as follows:

$$\text{Max } Z = \sum_j \bar{c}_j X_j - \Phi \sum_j \sum_k s_{jk} X_j X_k \qquad (1)$$

$$\text{s.t} \quad \sum_j p_j X_j \le b \qquad (2)$$

$$\sum_j X_j = 1 \qquad (3)$$

$$\text{and} \quad X_j \quad >= 0 \quad \text{for all } j,$$

where X_j is the proportion of land allotted to j^{th} crop, $\bar{c}_j$ is the mean gross revenue per decare for crop j, s_{jk} is the covariance of gross revenue between crop j and crop k, p_j is the water requirement per decare of j^{th} crop, and b is the maximum amount of water available per decare for irrigation and Φ is the risk aversion coefficient. Higher values of risk aversion coefficient indicate more risk aversion by decision makers. The solution of the model will give proportion of the area to be allocated to different crops to maximize gross revenue per decare under different risk aversion levels. The equation (2) indicates that the to amount of water used in the farm per decare is equal to or less than the total available water per decare for LSIP.

3.2 Data

In the simulation, the following data set was used. The total water availability in 2002 was obtained from the *Briefing of WUA and Year 2002 Management Activity Report* (DSI, 2002). Table 3 shows the water availability in LSIP under the water scarcity scenario. The actual water released for LSIP in 2002 was 1,424 million m^3. The conveyance efficiency in LSIP and on-farm application efficiency under furrow irrigation are considered to be 0.8 and 0.6 respectively. Then it is assumed that the

Table 3. Water availability in LSIP under the water scarcity scenario

(a)	conveyance efficiency	0.8		
(b)	application efficiency	0.6		
(c)=(a)x(b)	total efficiency	0.48		
(d)	actural water released for LSIP	1,424	million m3	2002
(e)=(d)x(c)	actural water available for LSIP	683.52	million m3	2002
(f)	total service area of LSIP	1,168,830	decare (da)	2002
(g)=(e)/(f)	water availability per decare	584.79	m3/da (mm)	
(h)=0.9(e)/(f)	water availability per decare under 10% water reduction case	526.32	m3/da (mm)	
(i)=0.8(e)/(f)	water availability per decare under 20% water reduction case	467.84	m3/da (mm)	

Source: (d) from DSI (2002) Briefing of WUA and Year 2002 Management Activity Report, DSI Region VI, Adana;
(f) from DSI (2003b) Transferred Irrigation Association Year 2002 Observation and Evaluation Report,
DSI Region VI, Lower Seyhan Irrigation Project, Operation and Maintenance Department.

overall water use efficiency in LSIP is 0.48. This figure[1] is multiplied by the actual water released and resulted in 683.52 million m^3 of water available for irrigation in whole LSIP. The total service area in 2002 was 1,168,830 decares. By dividing the actual amount of water available by the total service area in LSIP, the annual water availability of 585mm per decare for the base case was estimated.

The gross revenue per decare from production of each crop in LSIP from 1996 to 2004 was obtained from the annual report of *Yield Census Results for Areas Constructed, Operated and Reclaimed by DSI* (DSI, 1997-2005)[2]. Because of limited information on production cost during this period, only gross revenue for each crop was used for simulation instead of net return. The value of gross revenue for each year was re-evaluated with 2005 price so that the high inflation during this period is taken into account. The real monetary value depreciated to one thirtieth during this period.

Eight major crops[3] are chosen for the analysis. Those are maize, citrus, cotton, vegetables, melon, soybean, fruit and 2nd crop maize (II maize). The first six crops covered about 94% in terms of area planted as well as gross revenue of production in LSIP in 2002 (Table 1).

Table 4 indicates irrigation water requirement of major crops in LSIP. The information on water requirement was obtained from *DSI irrigated crop water consumption and irrigation water requirement* (Özgenç and Erdoğan, 1988) that most of the WUAs follow when they estimates total irrigation water before the cropping season. The highest water user is fruit (762 mm) followed by citrus (661 mm) and maize (569 mm).

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[1] Rıza et al. (2004) Country Report: Turkey Irrigation Systems Performance.

[2] Every year, water users associations report their cropping pattern, price, yield and gross revenue per decare for major crops. This data is aggregated to make a yield table for Seyhan (LSIP).

[3] Wheat is not included in this analysis because wheat is not an irrigated crop. The area cultivated by wheat in 2004 was about 21.9%. The second maize is usually cultivated after wheat.

Table 4. Irrigation water requirent of major crops in LSIP

crop	irrigation water requirement (mm/decare)
fruit	762.14
citrus	661.44
maize	569.03
soybean	539.02
cotton	524.18
II maize	391.41
vegetables	229.21
melon	195.88

Source: Nuran Özgenç, Faruk Cenap Erdoğan. (1988)
DSI irrigated crop water consumption and irrigation water requirement.

4. Simulation results

The amount of irrigation water available for LSIP in 2070 is expected to decrease because of the decrease in precipitation by 5-10 mm in most of the months according to the pseudo-warming experiment by ICCAP [4]. Assuming that the availability of irrigation water in 2070 is going to decrease, the simulation of E-V model was run with i) current water use level (585 mm), ii) 10% water reduction case (526 mm), iii) 20% water reduction case (468 mm).

Table 5 shows the simulation result of base case. This table indicates the land allocation to various crops in LSIP with risk aversion parameter (RAP) between 0 and 0.01. In this base scenario, when farmers do not care any risk (when RAP=0), area under citrus and melon is 83.5% and 16.5% of the total irrigated land with average gross revenue of 2,045 YTL per decare. At the risk aversion level of 1%, area under citrus, vegetables, melon, and fruit is 12.4%, 1.3%, 76.6% and 9.8% respectively. This cropping pattern yielded average gross revenue of 975 YTL per decare in 2005 price. Considering that the actual gross revenue per decare was 707 YTL in 2002 (Table 1) and 703 YTL under the risk aversion parameter of 2%, the risk aversion level of LSIP farmers may fall between 1% and 2%.

High risk aversion parameter yielded low gross revenue per decare. Under risk aversion level of 0.5% and 1%, water resources are under utilized resulting in redundant or idle water resources of 197 mm and 276 mm respectively. This means that in these cases, water is not the constraining factor in the model.

Similarly Table 6 and Table 7 show the simulation results under 10% and 20% water reduction case for LSIP. The reduction of water availability resulted in lowering citrus production, which is water intensive, and increasing melon production, which is high value with relatively high income variability, between 0 and 0.1% risk aversion level.

Under the water constraint and variability of gross revenue, farmers are more likely to choose high value added crops such as citrus, melon, vegetables and fruit.

5. Conclusions

This paper tried to consider the water availability in 2070 and the possible cropping pattern and the farmer welfare in Lower Seyhan Irrigation Project (LSIP). We use expected value-variance (E-V) model which is used to analyze risk. The model maximizes

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[4] The Research Project on Impact of Climate Changes on Agricultural Production System in Arid Areas

Table 5. Land allocation in LSIP under base case
(585 mm water availability)

RAP	0	0.0005	0.001	0.005	0.01
citrus	83.54	83.54	83.54	41.27	12.38
cotton					
vege					1.26
melon	16.46	16.46	16.46	58.73	76.58
fruit					9.78
gross revenue/da	2044.89	1945.55	1846.22	1243.47	974.68
shadprice	2.09	1.69	1.28		
idle				196.77	275.51

RAP: Risk Aversion Parameter

Table 6. Land allocation in LSIP under 10% water reduction case
(526 mm water availability)

RAP	0	0.0005	0.001	0.005	0.01
citrus	70.98	70.98	70.98	41.27	12.38
cotton					
vege					1.26
melon	29.02	29.02	29.02	58.73	76.58
fruit					9.78
gross revenue/da	1922.56	1845.17	1767.78	1243.47	974.68
shadprice	2.09	1.75	1.40		
idle				138.29	217.03

RAP: Risk Aversion Parameter

Table 7. Land allocation in LSIP under 20% water reduction case
(468 mm water availability)

RAP	0	0.0005	0.001	0.005	0.01
citrus	58.42	58.42	58.42	41.27	12.38
cotton					
vege					1.26
melon	41.59	41.59	41.59	58.73	76.58
fruit					9.78
gross revenue/da	1800.23	1741.39	1682.56	1243.47	974.68
shadprice	2.09	1.80	1.52		
idle				79.82	158.55

RAP: Risk Aversion Parameter

total gross revenue of agricultural production in entire LSIP according to the risk aversion coefficient. At the risk aversion level of 1%, area under citrus, vegetables, melon, and fruit is 12.4%, 1.3%, 76.6% and 9.8% respectively. This cropping pattern yielded average gross revenue of 975 YTL per decare in 2005 price.

There may be some factors that were not considered in the model which caused irrigation water in LSIP water not utilized fully. For example, the water requirement provided by the DSI (Özgenç and Erdoğan, 1988) that most water users associations follow may not reflect the current on-farm water use levels. By making some adjustment for the water requirement, it may possible to improve the model and simulation results.

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6. References

Donma, Sevgi, Mustafa Pekel, Selim Kapur, Erhan Akça. (2004) “Integrated Rural Development in River Basin Management: The Seyhan River Basin Example.” Paper presented at Pilot River Basin Management Conference in 22-24 September, Brindisi, Italy.

DSI. (2002) Briefing of WUA and Year 2002 Management Activity Report, DSI VI Region, Adana.

DSI. (1997-2005) Yield Census Results for Areas Constructed, Operated and Reclaimed by DSI. DSI Operation & Maintenance Department, Ankara.

DSI. (2003b) Transferred Irrigation Association Year 2002 Observation and Evaluation Report. DSI VI Region, Lower Seyhan Irrigation Project, Operation and Maintenance Department.

Hale, William. (1981) The Political and Economic Development of Modern Turkey. London: Croom Helm.

IPCC (2001). Climate Change 2001: The Scientific Basis. IPCC Third Assessment Report. Cambridge: Cambridge University Press.

Nuran Özgenç, Faruk Cenap Erdoğan. (1988) DSİ SULAMALARINDA BİTKİ SU TÜTKETİMLERİ VE SULAMA SUYU İHTİYAÇLARI. DSI irrigated crop water consumption and irrigation water requirement.

Kanber, Rıza, Mustafa Ünlü, Erol H. Cakmak, Mekin Tüzün. (2004) Country Report: Turkey Irrigation Systems Performance. Ankara.

Palanisami, K., Chieko Umetsu and C.R. Ranganathan. (2005) Groundwater Management in Hard rock regions: Influence of Cost of Uncertainty and Alternative Crops in South India. Working Paper. Research Institute for Humanity and Nature, Kyoto, Japan.

Tekinel, Osman. (2001) Participatory Approach in Planning and Management of Irrigation Schemes. Advanced Short Course-Appropriate Modernization and Management of Irrigation Systems, Kahramanmaraş, Turkey.

Harwood, Joy, Richard Heifner, Keith Coble, Janet Perry, Agapi Somwaru. (1999) Managing Risk in Farming: Concepts, Research, and Analysis. Economic Research Service, U.S. Department of Agriculture. Agricultural Economic

Report No.774.

Umetsu, Chieko, Sevgi Donma, Takanori Nagano, Ziya Coşkun. (2005) "The Efficient Management of Water User Associations: The Case of Lower Seyhan Irrigation Project in Turkey." In *An Economic and Institutional Analysis of the Impacts of Climate Change on Agriculture and Farm Economy in Eastern Mediterranean and Central Anatolia Regions in Turkey.* pp.79-90. Research Institute for Humanity and Nature (RIHN), Kyoto Japan.