気候変動とセイハン河下流灌漑プロジェクトの作物選択
―MRI-GCM と CCSR-GCM による地域分析

Climate Change and Alternative Cropping Patterns in Lower Seyhan Irrigation Project: A Regional Simulation Analysis with MRI-GCM and CCSR-GCM

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1. Introduction

The purpose of this paper is to assess the regional impacts of climate change on agricultural production systems in Seyhan river basin in Turkey. We estimate the water availability in the 2070s using the regional precipitation data from pseudo warming experiment and assess the possible cropping pattern and the farmer welfare in Lower Seyhan Irrigation Project (LSIP).

2. Method and data

In order to estimate the optimal land resource allocated to various crops under different risky alternatives, expected value-variance (E-V) model was used. In this model, expected return (or gross revenue) can be increased only at the expense of a larger variance of return (Harwood et al., 1999). 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:

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

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

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

and $X_j >= 0$ 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.

Eight major crops, maize, citrus, cotton, vegetables, melon, soybean, fruit and 2nd crop maize (II maize) are chosen for the analysis. 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 overall water use efficiency in LSIP is 0.48. This figure 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.

3. Scenarios

For assessing the regional impacts of climate change on agricultural production systems in the 2070s, we used seven cases for simulation. Those include a base case, scenario 1 (low water

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Table 9. Simulated cropping pattern of LSIP with MRI-GCM and CCSR-GCM

	2002	2070s MRI-GCM			2070s CCSR-GCM		
scenario	base	S-1	S-2	S-3	S-1	S-2	S-3
water availability (mm)	585	469	429	579	398	330	480
citrus	22.00	22.05	22.09	21.94	21.86	18.32	21.84
cotton	59.33	23.96	15.11	48.29	4.34		25.97
vegetables	7.04	4.36	3.60	6.44	2.98	3.17	4.74
watermelon (+maize)		41.35	51.69	12.90	64.03	78.51	38.82
fruit	11.63	8.28	7.50	10.43	6.80		8.64
gross revenue (YTL/da)	718	707	703	716	696	670	708
shadow price of water (YTL/m3)		0.101	0.117	0.056	0.164	0.796	0.116
idle water (mm)	23.51						

Risk aversion parameter = 1%

development), scenario 2 (high water development with expanded irrigated area) and scenario 3 (high water development with 150mm groundwater use) using two types of climate change information given by MRI-GCM and CCSR-GCM.

4. Simulation Results

Table 9 shows the simulation results. Under the water constraint and variability of gross revenue, farmers are more likely to choose high value added crops relative to water requirement such as melon, citrus, cotton, fruit and vegetables. However this combination of crops in 2070s, under the water availability of 429 mm with high water development and expanded irrigated area, will result in 703 YTL per decare, lower than the base case where the average gross revenue was 718 YTL per decare.

Because CCSR projected precipitation decrease and surface temperature increase in Seyhan River basin, the potential water available for downstream LSIP is also 70-100 mm smaller under CCSR. As a result, comparing to MRI cropping patters, CCSR cropping pattern is more dominated by watermelon which is water efficient in terms of gross revenue generated per unit of water.

5. Conclusions

The future investment should target more efficient use of water resources by various alternative options. Especially, incentive mechanism is required for introducing on-farm technology and water pricing systems that save water substantially if the expansion of the irrigated area is continuing at the upstream and downstream of the Seyhan River basin. The current furrow irrigation system for major field crops needs to be transferred to more efficient on-farm technology if the water scarcity is going to be intensified.

The option of cultivating high gross revenue generating crops such as citrus, fruit and vegetables needs to allow risk of annual gross revenue variability. However, this option may cause environmental pressure on land and water resources in LSIP by introducing more intensive use of pesticides and fertilizers. These options should be assessed carefully for the sustainability of agricultural production systems such as environmentally acceptable crop rotations and agronomic adaptations to prevent crop failure.

6. References

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