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Determination of Optimal Cropping Pattern Due to Water Deficit: A Case Study in the South of Iran

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Abstract: Determination of optimal cropping pattern is essential for arid and semiarid regions with deficit water resources. Fars province is located in the southern part of I.R. of Iran with mean annual precipitation from 50 to 1000 mm and in most parts of this province water resources for agriculture are deficit. Jahrom region with semi-arid climate is located in Fars province with mean annual rainfall of 373 mm. In this study optimal cropping pattern was determined for this region based on water deficit condition. For this purpose, multi-objective programming approach was applied in order to reduce water consumption use. The results of this study showed that, there was trade offs among reduce water use, reduce risk and getting a specific gross margin. Also, the results showed that, wheat tended to increase, causing from price supporting program, indicating the government intervention trace in farmers cropping pattern. Therefore sustainable use of resources is affected by output condition in market. Furthermore, the area of maize and vegetables were increased in all of selected solutions as compared to their current area. Also, the findings of this study performed intended polices in crop markets may alter the water usage.

Key words: Optimal cropping pattern · Water deficit · Wheat · Iran · Jahrom

INTRODUCTION

Determination of optimal cropping pattern is essential for arid and semiarid regions with deficit water resources. Some studies have done in different parts of the world about determining the optimal cropping pattern due to water deficit. Kumar and Khepar [1] demonstrated the usefulness of alternative levels of water use over the fixed yield approach when there was a constraint on water in India and modified a fixed yield model to incorporate the stepwise water production functions using a separable programming technique, which applied to determine optimal cropping patterns. Maleka [2] determined optimal cropping patterns in the Gwembe Valley, Zambia, by using Target MOTAD Model and the results indicated an optimal cropping pattern of growing sorghum, rice and soyabeans, which was different from the initial cropping pattern of sorghum, sunflower, cotton and maize. Mainuddin *et al*. [3], formulated a monthly irrigation planning model for determining the optimal cropping pattern and the groundwater abstraction requirement in the Sukhothai Groundwater Development Project in Thailand. Garg and Ali [4] developed a model to schedule the sowing dates of the crops which considered optimal cropping patterns in Dadu canal command of Lower Indus Basin in India. Haouari and Azaiez [5] proposed a mathematical programming model for optimal cropping patterns under water deficits in dry regions. Singh *et al*. [6], formulated a linear programming model to suggest the optimal cropping pattern giving the maximum net return at different water availability levels in the command of Shahi Distributory, India. Kipkorir *et al*. [7], developed a dynamic programming optimization model that considers the competition of crops in a season, both for irrigation water and cultivated area in northern Tunisia and the results indicated that the model can be a valuable tool for regional agencies or irrigation authorities in determining seasonal cropping pattern for a region at the beginning of the season. Khare *et al*. [8], presented a simple economic-engineering optimization model to explore the possibilities of conjunctive use of surface and groundwater using linear programming with various hydrological and management constraints and to arrive at an optimal cropping pattern for optimal use of water

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resources for maximization of net benefits in the Sapon irrigation command area of Kulon Progo Regency, Yogyakarta province, Indonesia. Also, the same study was done by Khare *et al*. [9] to determine an optimal cropping pattern for optimal use of water resources for maximization of net benefits in India. Darwish *et al*. [10] investigated the economic feasibility of land application in the presence of a reservoir with different capacities and to compare the outcome to the application without a storage reservoir and a 5-year dynamic linear programming model was developed by them to determine the optimal cropping pattern in Tyre region, South Lebanon.

Fars province is located in the southern part of Iran, at 50°30′ to 55°38′ longitude and 27°3′ to 31°42′ N latitude, with an arable land area of 1.32 million km^2. The majority of the rain producing air masses enter the region from the west and the north-west, yielding relatively high precipitation amounts for those areas. Towards the south and south-east, rainfall is decreases. Furthermore, winter precipitation in the north-west area is in the form of snowfall, but for other areas it is mostly in the form of rain. The mean annual precipitation for the province ranges from 50 to 1000 mm [11,12]. Therefore, most of the parts of this province is arid or semarid. Also, in most parts of this province water resources for agriculture are deficit. Jahrom region is located in Fars province with mean annual rainfall of 373 mm and the climate of this region is semi-arid.

The main objective of this research was to develop an optimal cropping pattern due to water deficit for selected farmers of Jahrom region, Fars province, south of Iran. The main considerations in developing the patterns to reduce risk, reduce water consumption and to provide the interest level of return and multi-objective programming framework was applied in order to get the cropping pattern.

MATERIALS AND METHODS

Multi-Objective Programming: In this study, providing a specific amount of revenue and reduced water consumption were considered to get the minimum risk. For this purpose, multi-objective programming approach was applied in order to trace the all objectives. This approach enables achievement of several objectives subjected to resources restriction. However, several solutions obtained instead of a unique solution, implicating trade offs across objectives [13].

$$Max,\ Z(x) = (Z_1(x), Z_2(x), \ldots, Z_h(x), \ldots, Z_k(x)),$$
$$Z_1(x) = Z1(x_1, x_2, \ldots, x_n)$$
$$Z_h(x) = Zh(x_1, x_2, \ldots, x_n)$$
$$\vdots$$
$$Z_k(x) = Zk(x_1, x_2, \ldots, x_n)$$
$$Subject\ to: \quad X \in F, X \geq 0$$

Where $Z = (Z_1, Z_2, \ldots, Z_k)$ is the vector of objective function with element; Z_i, $I = 1, 2, 3, \ldots, k$ are individual objective function, X_i , i = 1, 2, … and *n* is the area allocated to the cultivation of crop *i*. Multi-objective decision making problems may be solved in three ways to generate efficient set: weighting, constraint and multi-criterion simplex methods. The constraint method is more preferred [13]. In the constraint method, the objective function will be optimized while the remaining *k-1* objectives are considered as constraints of the model. For example, for minimization case it can be formulated as follow: Min Z(x) = (Z_1 …).

The constraint method yields a large number of efficient solutions that can be selected some of them using cluster analysis [14]. In this study in order to cluster analysis for solutions, the amount of objectives including gross margin, water use and risk in terms of gross margin's variance were normalized and then a criterion was defined covering the three objectives. To do this, the solution with the highest gross margin was valued 1, assigning values less them 1 to other gross margin levels appropriately. In the case of water use and risk, the solutions with the highest value received zero and value 1 was regarded for the lowest water use and gross margin variance. In two step cluster analysis at first the number of clusters were recognized. Then, k-mean cluster approach may be used to determine the cluster of each observation. Cluster analysis as a primary solution assigns each observation to the cluster with lowest distance mean with respect to the observation value. Then using the flowing distance function it changes the clustering such a way that minimize the distance as follows [15]:

$$d(x,y)=\sqrt{(x-y)'A(x-y)}$$

Where $A = S^{-1}$ and S is variance–covariance matrix of sample. This approach is useful even when the number of clusters in not known.

Risk: Farm decisions are affected by risk, leading to technical and allocative inefficiency in using production factors. So, it is needed to incorporate risk in decision making. We considered variance of income as a measure of risk. Variance of income comes from output *i* with gross margin of R_i can be stated as follow [13].

$$V(I) = \sum\sum \sigma_{ij} X_i X_j \qquad i, j = 1, 2, ..., n$$

Where σ_{ij} is variance-covariance matrixes of output *i* and x_i is the levels of cultivation.

In this study, the objective function was defined as minimization of the risk. Target MOTAD is another model that incorporate the risk in decision making. Advantage of target MOTAD over MOTAD is that minimize deviations from a special level of income as farmer goal [2]. Another avantage of the TMOTAD is that generates efficient solutions that hold second order stochastic dominance [16]. Target MOTAD developed by Teure [17] is as follow.

$$Max\, E(Z) = \sum_{j=1}^{n} C_j X_j$$

Subhect to:

$$\sum_{j=1}^{n} a_{ij} X_j \le b_i$$

$$\sum_{j=1}^{n} c_{kj} X_j + y_k \ge T$$

$$\sum_k p_k y_k \le \lambda$$

$$\lambda = M \to 0$$

$$X_j, y_k \ge 0$$

Where *E(z)* denotes expected return of *j*th activity, x_j is cropping area of crop *j*, a_{ij} is the technical requirement of *i*th activity provided from *i*th resource, b_j also states the level of *i*th resource, *T* is target return, e_{ij} is return of activity *j* in *k*th period, P_k states the probability of incidence of period *k*, λ is a constant, ranging from Zero to *M* with a high level amount for M. Determination of *T* is controversial. McCameley and Kliebenstein [18] have developed an approach to determine a range for *T*. According to the their approach if x^* is defined as income maximizing activity, determined by simple linear programming, then W^* may be defined as follow:

$$W^* = \sum_{j=1}^{n} C_{kj} X_j$$

The values are located between the highest and the lowest value of w^*.

Modeling to Generate Alternatives: As we knew it may not to incorporate some economical and social features in linear programming approach. Attempting to develop more flexible pattern of solutions can be considered as a contribution to make linear programming solution more practical. Nearly optimal solutions that cover the optimal solutions with a little deviation are of contributions granting more flexibility to solutions generated by simple linear programming. This approach is known as modeling to generate alternatives (MGA). MGA is performed in different ways. However Hop-Skip-Jump (HSJ) is the most common approach. This approach, for the case of maximization variable with Zero value in optimal solution, obtained by simple linear programming as follow [19]:

$$\max: X_i, \quad X_i = 0$$

$$Subject\,to: \quad C_i X_i \ge (1 - j) Z^*$$

$$A_i X_i \le b_j$$

$$X_i \ge 0$$

Where Z^* is the value of optimal solution obtained by linear programming, *j* is the deviation from optimal solutions, *C* is vector of objective function, X_i is the activity and *A* is the matrixes of limitation of coefficients. Constraints of model include limitation of access to land, water, labor, capital, crop rotation and risk related constrains and some other constrains special for solving multiobjective programming problems by restricted method (including constraint of given income and water usage). Water constraint was deal with using seven constraints. The case of labor was also same as water. In the case of land constraint seven period of time was recognized to be different during a crop year. Total available cost of last period formed the capital available to perform. In the case of constraints of determined gross margin, in the left hand side, the coefficients of objective function were used. In the case of water constraints also the mentioned coefficients were the water usage. Data used for analysis was obtained by completing and interviewing with randomly selected farmers of Jahrom, Fars province, south of Iran. Data set used for risk analysis containing price and yield time series that were gathered from provincial Statistical Yearbooks.

RESULTS AND DISCUSSION

Target MOTAD and Min Variance risky approaches were applied for selected farmers in the study area. Min Variance was applied to develop risk-minimized patterns associating with different levels of income. Then, targets of risk minimizing and income providing were couple with reduced water consumption from current level to its minimum level bearing the current level of income.

Farmers of Jahrom district were divided into two homogenous groups based on their average activity scale including 11 and 15 hectares, separately and average gross margin of the groups are 1545 and 1380 $ per hectare, respectively.

The existing and optimal cropping patterns of group one are presented in Table 1. Based on the findings in conventional optimal pattern of the group one, wheat was dropped in optimal cropping patterns, despite its high share of nearly three-fourth of total cultivated area. However, the cultivated area of Maize and Vegetables increased. Based on optimal pattern, selected farmers' income can be raised by 14 percent. In the case of both of risky models, cropping area of wheat and broad been were reduced in favor of Maize and Vegetables. The results of risk minimizing model on the condition of providing current income and different amount of water, revealed that water consumption can be reduced by 14.7 percent. In general, it is inferable that if risk reducing is associated with low water consumption, the results will be different from the previous pattern in that cropping area of maize, vegetables and broad been were reduced in favor of wheat. On the other hand, selection based on cluster analysis showed that risk minimizing patterns associated with reduced water consumption are more qualified [18-19].

The existing and optimal cropping patterns of group two are presented in Table 2. In this group cultivated area of wheat and vegetables were increased, cultivated area of maize and barley were decreased and broad been was dropped from optimal cropping pattern. However, the gross margin of optimal solution compared to current one is 20 percent higher. Cultivated area of wheat was increased in both of target MOTAD and min variance models. Barley were not emerged in target MOTAD model, however, in min variance model associated with lower target income entered the optimal pattern. Cultivated area of maize was decreased in both of risky models with income increment continually. However, more reduction was in target MOTAD model. Vegetables also was reduced in both of risky models with increment of

Table 1: The existing and optimal cropping patterns of group one

Cultivated area (ha)	existing cropping patterns	optimal cropping patterns
Wheat	8.0	0.0
Barley	0.0	0.0
Maize	1.7	9.6
Vegetables	0.8	1.4
Broad been	0.5	0.0

Table 2: The existing and optimal cropping patterns of group two

Cultivated area (ha)	existing cropping patterns	optimal cropping patterns
Wheat	8.4	10.0
Barley	2.4	0.7
Maize	3.0	2.2
Vegetables	0.5	2.1
Broad been	0.8	0.0

risk. Broad been in all levels of income of min variance model, except for maximum income, revealed an increasing trend but was dropped in maximum income. However, in Target MOTAD model the reverse trend was observed. In Min Variance model, like Target MOTAD model, associated with reduced water goal, cultivated area of wheat was increased with increased risk and decreased water consumption. Barley was also dropped from pattern by increasing water constraining. The priority of Maize felled by decreasing water consumption, however, its priority raised in high levels of water reduction. The case for vegetables was also similar to maize. Cultivated area of broad been increased as water decreased at first, but it decreased with more reduction in water consumption dropping from pattern at the minimum water consumption level, finally. Also, the findings of this class of farmers reveled that, there was trade off between goals of return increment, risk minimizing and reducing water consumption. Based on cluster analysis, it was found that selected patterns are ones with high acreage of wheat and maize [15-19].

CONCLUSIONS

The results of this study showed that, there was trade offs among reduced water use, reduced risk and getting a specific gross margin. At high level of risk, wheat tended to increase, causing from price supporting program, indicating the government intervention trace in farmers cropping pattern. Therefore sustainable use of resources is affected by output condition in market. Also, area of maize and vegetables were increased in all of selected solutions as compared to their current area.

In the case of the vegetables main constraint is its labor intensity, expecting to have more value added using more labor or a more mechanized production process. The crop combination of the risk-minimized patterns were so close to the current cultivation pattern of farmers, indicating implicitly that selected farmers are risk avers. Based on the results it is expected to reduce the water usage in addition to conserve the current gross margin and not imposing more risk. Moreover, the findings of this study performed intended polices in crop markets may alter the water usage. However, due to conflicts and trade offs among the objectives, following a special target may lead other one to margin.

REFERENCES

1. Kumar, R. and S.D. Khepar, 1980. Decision models for optimal cropping patterns in irrigations based on crop water production functions. Agricultural Water Management, 3: 65-76.
2. Maleka, P., 1993. An application of target MOTAD model to crop production in Zambia: Gwembe Valley as a case study. Agricultural Economics, 9: 15-35.
3. Mainuddin, M., A.D. Gupta and P.R. Onta, 1997. Optimal crop planning model for an existing groundwater irrigation project in Thailand. Agricultural Water Management, 33: 43-62.
4. Garg, N.K. and A. Ali, 1998. Two-level optimization model for Lower Indus Basin. Agricultural Water Management, 36: 1-21.
5. Haouari, M. and M.N. Azaiez, 2001. Optimal cropping patterns under water deficits. European J. Operational Res., 130: 133-146.
6. Singh, D.K., C.S. Jaiswal, K.S. Reddy, R.M. Singh and D.M. Bhandarkar, 2001. Optimal cropping pattern in a canal command area. Agricultural Water Management, 50: 1-8.
7. Kipkorir, E.C., A. Sahli and D. Raes, 2002. MIOS: a decision tool for determination of optimal irrigated cropping pattern of a multicrop system under water scarcity constraints. Irrigation and Drainage, 51: 155-166.
8. Khare, D., M.K. Jat and Ediwahyunan, 2006. Assessment of conjunctive use planning options: A case study of Sapon irrigation command area of Indonesia. J. Hydrol., 328: 764-777.
9. Khare, D., M.K. Jat and J.D. Sunder, 2007. Assessment of water resources allocation options: Conjunctive use planning in a link canal command. Resources, Conservation and Recycling, 51: 487-506.
10. Darwish, M.R., M. Sharara, M. Sidahmed and M. Haidar, 2007. The impact of a storage facility on optimality conditions of wastewater reuse in land application: A case study in Lebanon. Resources. Conservation and Recycling, 51: 175-189.
11. Fooladmand, H.R. and A.R. Sepaskhah, 2004. Economic analysis for the production of four grape cultivars using microcatchment water harvesting systems in Iran. J. Arid Environments, 58: 525-533.
12. Sadeghi, A.R., A.A. Kamgar-Haghighi, A.R. Sepaskhah, D. Khalili and S.H. Zand-Parsa, 2002. Regional classification for dryland agriculture in southern Iran. J. Arid Environments, 50: 333-341.
13. Francisco, S.R. and A. Mubarik, 2006. Resource allocation tradeoffs in Manila's peri-urban vegetable production systems: An application of multiple objective programming. Agricultural Systems, 87: 147-168.
14. Raju, K.S. and D.N. Kumar, 1999. Multicriterion decision making in irrigation planning. Agricultural Systems, 62: 117-129.
15. Johnson, R.A. and D.W. Wichern, 2000. Applied multivariate statistical analysis. John Wiley Inc.
16. Hardaker, J., R. Huirne and J. Anderson, 1997. Coping with risk in agriculture. CAP International, New York.
17. Tauer, L.M., 1983. Target MOTAD. American J. Agricultural Economics, 65: 606-610.
18. McCameley, F. and J.B. Kliebenstein, 1987. Describing and identifying the complete set of Target MOTAD solutions. American Journal of Agricultural Economics, 69: 669-676.
19. Willis, C. and M.S. Willis, 1993. Multiple Criteria and Nearly Optimal Solutions in Greenhouse Management. Agricultural Systems, 41: 289-303.