Analysis of simultaneous effect of water access requirements in Regional Water Corporation of West- Azerbaijan and risk factor on cultivation optimal pattern

Sepideh Taghizadeh[1], Hossein Navid[1], Mostafa Jamshidifar[2], Reza Fellegari[1]

(1. *Department of Agricultural Machinery, Faculty of Agriculture, The University of Tabriz, Iran*;
2. *Department of Agricultural Economics, Faculty of Agriculture, The University of Tabriz, Iran*)

Abstract: In vast farms management, especially in multi-crop cultivation case, planning for a combination of crops cultivation has always been of high importance to achieve the maximum income, by taking into account imposed limitations and the risk of different activities. According to the fact that in traditional models of farm programming because of not attention to risk, its results differ from what farmer do in reality, considering the risk farm programming should be well thought. MOTAD model (Minimization of the Total Absolute Deviation) is a mathematic programming model that enters risk into decision making related to farm activities and provides different programs. A main feature of this model is that the risk is calculated by negative deviation from efficiency amount as total multiplication. In recent years, serious declining of water table problem forced Regional Water Corporation of West- Azerbaijan province to impose limitations for extra water use of wells in order to sustain "Mako, Poldasht" water resources. These limitations result in lowering available water level (The most important input for farming), and create changes in cropping patterns and income level of farmers in this area. The aim of this study is analyzing improved cropping considering water limitations and in risk conditions. Data have been collected from farmers and Agriculture "Jihad" Management of town of Mako for duration of 1 387-1 388. According to the results of the research, the real cultivation plan that is now being implemented throughout the region carries a high risk and low income. Based on results, if the farmer uses the optimal cultivation pattern during the so-called water access limitation, watermelon harvest will be excluded from the optimal cultivation pattern. Also, alfalfa will enter the cultivation plan with the expected income level of 1 067 billion Rials (100 Rials = US$0.01). If the farmer uses improved cropping pattern in limitations in risk it will decrease total income as 171.36 billion Rials, to when the water limitations is not implemented.

Keywords: cultivation optimal pattern, risk, MOTAD, agricultural water management
DOI: 10.3965/j.issn.1934-6344.2011.03.026-032

Citation: Sepideh Taghizadeh, Hossein Navid, Mostafa Jamshidifar, Reza Fellegari. Analysis of simultaneous effect of water access requirements in Regional Water Corporation of West- Azerbaijan and risk factor on cultivation optimal pattern. Int J Agric & Biol Eng, 2011; 4(3): 26－32.

1 Introduction

1.1 Importance of water resources management in Iran

Today growing population of world has increased the need for agricultural products and consequent increased pressure on utilization of resources that is required for those products[1,2]. Agricultural activities are the main user of water from surface to ground water in rural areas[3-6]. In many developing countries, water is a major factor constraining agricultural output, and income of the world’s rural poor[7]. Iran, with the average rainfall of 260 mm per year and having limited water resources, is among the world's dry countries. Overdraft of groundwater leads to decline in groundwater level[8]. Also using water for irrigation of agricultural products is high in Iran. Table 1 compares water use for three crops

Received date: 2011-01-18 **Accepted date:** 2011-09-01
Biographies: Hossein Navid, Assistant Professor in agricultural machinery engineering, Faculty of agriculture, university of Tabriz; Email: navid@tabrizu.ac.ir; **Reza Fellegari,** Email: r.fellegari@ yahoo.com.
Corresponding author: Sepideh Taghizadeh, Master of science in agricultural machinery engineering, Faculty of agriculture, university of Tabriz; Email: staghizadeh87@ms.tabrizu.ac.ir.

in Iran and global average[9].

Table 1 Comparison of water use for agricultural irrigation products

	World use/m^3·ha^{-1}	Iran use/m^3·ha^{-1}
Wheat	4 500-6 500	6 400
Vegetables	7 000-10 500	17 900
Beet	5 500-7 500	10 000-14 000

One of the far-fetched goals of the strategic water management of the country is to balance between the existing water demands with the least possible cost[10]. An operating policy consists of mainly a schedule of water releases over different periods of the planning horizon and allocation of water among competing crops at each release[11]. In addition to rational water use, there is a need for selecting economically viable cropping patterns for a given area and available resources. Those cropping patterns can be attained through the use of optimization models[12]. In Orissa, India, to develop a long-term sustainable land and water management strategies for the aforementioned issues in humid regions, the district administration realized the need for crop planning and water resources management policies with deterministic and stochastic methods[13].

1.2 Study area

This study was conducted on "Poldasht, Mako" in west-Azerbaijan (see Figure 1).

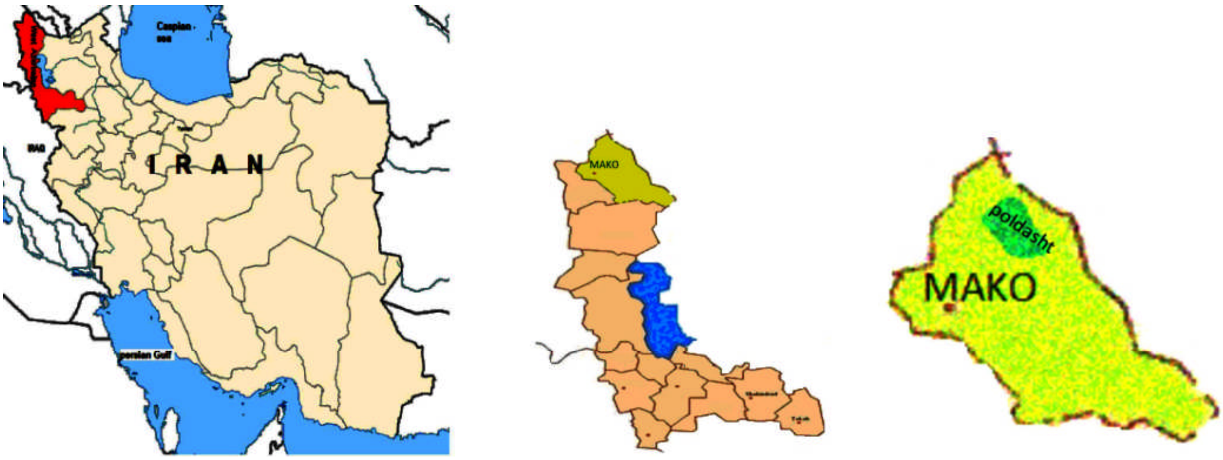

Figure 1 Map of "Poldasht, Mako" in west-Azerbaijan in Iran

"Poldasht, Mako" in west-Azerbaijan plain is a fertile agricultural area where people live on agriculture and to some extent animal husbandry. This capacity has caused population density in the villages of Poldasht. The most important agricultural crops of Poldasht, Mako plain are wheat, beet, water melon, sunflower, and alfalfa. Two major problems of this plain include: increasing process of declining underground water level and reduction of water supplies. According to the latest monthly statistics and measurements, the monitored wells are in a critical condition[14]. Regional Water Corporation of west-Azerbaijan (RWCWA) has decided to impose limitations on water resource use in order to sustain water supplies. The installing of water counter resulted in 30% decrease in water use. Agricultural water management must be coordinated with, and integrated into the overall water management of the region[15].

1.3 Risk effect in optimal cultivation pattern

Torkamani and Abd-shahi[16] stated that obtaining an amalgam of crops which can reach the maximum consistent income out of expenditure for the farmer or the minimum expense of making a consistent income is of special significance. The purpose of the linear programming is to maximize the target function considering several limitations (resources) and decision factors (activities) simultaneously[17]. Singh and Singh[18] studied maximizing the production and income, through cultivation optimal programming in a sample study about "Mahi kumand" Indian. The results of this study showed that the cultivation programming in the area increased the production from 60% to 96% and the net income from 23% to 26%[18]. Gholami[19] tried to determine the optimal cultivation sequence by using the linear programming in order to define the optimal pattern of the cultivation sequence to obtain the net income and comparing it to the current situation in a 1 hectare farm in "Bojnurd" town. Agricultural activity is considered as a risky activity because of its main dependence on nature and climatic and environmental conditions. Moreover, the farmers face a group of the various risks and inconsistency of production costs which makes their incomes unstable[20]. Torkamani[21-22] has concluded that the severity of the risk has usually a negative relation with the development level of countries, so in the third world countries, tolerating the risks resulting from economical and natural hazards is more difficult for the farmers[21]. Randhir and Krishnamoorthy[23] discussed the priority of a reliable, even low income to a high and unstable one for majority of farmers[18].

1.4 The need to focus on water resource management in agricultural expenditure

Lin, et al.[24] and Paris[25] found out that being careless towards the risk in an older model of the linear programming of a farm, has often resulted in a consequence that differs from what the farmers have done in reality. For resolving this problem and regarding the risk factor, several models are given and being used in the optimal plan of the farm from which MOTAD model, non linear programming, final limited risk model, Focus-less model, Advanced- MOTAD model, and Target- MOTAD model can be mentioned. MOTAD model has been widely used for determining the optimal cultivation pattern in two recent decades. Researchers such as Haouari and Azaiez[11] who used this model for determining optimal cropping patterns under water deficits region, Kehkha, et al.[26] for risk analysis in "Fars" province farms using risky programming methods, and Daneshvari kakhaki et al.[1] for the cultivation pattern of oil seeds, used Target- MOTAD model the purpose of the current research is to analyze the risk effects and shortage of production premises, especially the new water limitation which was exerted by the RWCWA. The research is aimed to study the use of risky programming method in designing a cultivation pattern for the farms of "Poldasht" village with 320 hectares. Furthermore, a comparison of the optimal cultivation pattern was carried out before and after the so-called water supplies limitation by RWCWA.

2 Materials and methods

Anomalous use of water supplies and recent drought years has made the RWCWA to exert some limitations on extra-access to water in the wells for preserving water resources.

One of the tactics used by the RWCWA is to install automated counters of water and electricity which controls the volume of water usage during day and night. For preserving and developing agricultural condition in Poldasht area, preservation and optimal use of resources without polluting the natural ecosystem are to be regarded seriously.

For using the water rationing, managing agricultural water optimally and introducing appropriate cultivation pattern for a good income of a farmer, linear programming was used. Also, for considering risky conditions, regarding the cost and amount of previous year's production, MOTAD was utilized. It should be mentioned that because of a 5 year contract between the farmers of this area and Sugar Corporation of West-Azerbaijan province in 2009, farmers are required to exert a 30 hectares crop period of sugar beet in their cultivation pattern, so 30 hectares sugar beet cultivation is considered as one of the primary pre- requisites of this research.

2.1 Theoretical principles of methodology

Theoretical basis of MOTAD model is to maximize the expected desirability as it follows:

$$U = c + aR + b.\min(R - T) \quad (1)$$

Where, R is income; T is income level, "min" is a minimum function and "a, b and c" are constants. Because the mentioned desirability is increasing and concave in R (and disjointed in T), given individual is risk- elusive[27].

MOTAD programming model is a linear proximate of Quadratic Risk Programming (QRP). For solving the estimation problem of required variance-covariance matrix (QRP), Hazell and Norton[27] proposed using Mean Absolute Deviation (MAD) from their average mean. Thus in MOTAD model, measuring risk is carried out on the basis of MAD criteria. This criterion can easily be incorporated into linear programming pattern and executed by typical software of solving these kinds of problems. Because user's income has normal diversity, the same solutions can be offered using QRP model with parametric desired income change of MOTAD pattern. Hazell and Norton[27] showed that X_j and δ_{jk} indicate activities level and variance matrix between activity outcome of k and j respectively, so total outcome variance can be determined as follows[22]:

$$V = \sum_j \sum_k X_j X_k \delta_{jk} \tag{2}$$

V must be minimized in programming problem solving with QRP model. Similarly, Hazell and Norton[27] demonstrated that following equation can be used for calculating δ_{jk}:

$$\delta_{jk} = (\frac{1}{T-1}) \sum_s (c_{js} - c_j)(c_{ks} - c_k) \tag{3}$$

Where, T is the amount of sample observations under study, c_{js} is jth activity outcome in the year S, and c_j is the outcome of the sample. Hazell and Norton[27] also showed that with the above mentioned equation, the variance estimation of the total outcome, required for QRP model, can be computed as follows:

$$V = F\left\{\frac{1}{2}\sum_{t=1}^{T}\left|\sum_j c_{jt}x_j - \sum_j c_j x_j\right|\right\} = F\{MAD\} \tag{4}$$

Where, F is a coefficient that connects the sample MAD with the pilot variance. Definitely, $F= T\pi/2(T-1)$. If the farm income deviation from its own average, is positive in year t, it will be shown by Y_t^+ and if it is negative, we show it Y_t^-, so:

$$Y_t^+ - Y_t^- = \sum_j c_{jt} x_j - \sum_j c_j^- x_j \tag{5}$$

Y_t^+ and Y_t^- are both positive, so they measure modulus of deviation extent of the farm income from mean. Out of these two, just one can be more than zero in a year. Also, deviation at the same time cannot be both positive and negative, so $\sum T_t = 1(Y_t^+ - Y_t^-)$ calculates the total modulus of income deviation extents for a given cultivation plan. So, various MAD estimations equal:

$$V = F\{1/T \sum_t (Y_t^+ + Y_t^-)\}^2 \tag{6}$$

because F/T^2 is constant, V can be divided as:

$$W = (\frac{T^2}{F})V = \left\{\sum_t Y_t^+ + Y_t^-\right\} \tag{7}$$

W can be root squared; because arranging plans using $W^{0.5}$ is like arranging them through W. Thus we will have the following programming option of a second type formula:

$$\text{Minimize} \qquad W^{0.5} = \sum_{t=1}^{T} (Y_t^+ + Y_t^-) \tag{8}$$

$$\text{ST} \qquad \sum_{j=1}^{n} (c_{jt}^- - c_j^-) X_j - Y_t^+ + Y_t^- = 0 \tag{9}$$

$$\sum_{j=1}^{n} c_j^- X_j = \lambda \tag{10}$$

$$\sum_{j=1}^{n} a_{ij} X_j \le or > b_j \tag{11}$$

$$X_j,\ Y_t^+,\ Y_t^- \ge 0$$

Because the target faction of this model is to minimize the sum of deviation modulus, Hazell and Norton[27] called it MOTAD model[28]. The general form of MOTAD model is as follows:

$$\text{Minimize} \qquad z = \sum_{h=1}^{n} Y_h^- \tag{12}$$

$$\text{ST} \qquad \sum_i^n a_{ij} x_j \le b_j \quad j=1,000,m \tag{13}$$

$$\sum_i^n (c_{hi} - g_i) x_i + Y_h^- \ge 0 \quad h=1,000,s \tag{14}$$

$$\sum_i^n f_i x_i = \lambda \qquad \lambda = 0 \to z\ ,\ x_i \ge 0 \tag{15}$$

Where, z is the sum of gross income modulus of different range of activities from their mean amounts; Y_h^- is the negative modulus of total gross income deviation in year h from their mean output; x_i is the production activity level i; a_{ij} is item j level for each unit from i activity; b_j is the existing supply j access; c_{hi} is the programmed i activity output in year h; g_i is the mean amount of gross output of i agricultural activity; f_i is the programmed i activity output and λ is the constant parameter of zero to z of the total expected gross output.

The more concise form of MOTAD model can also be formulated. The total negative deviations of less than mean incomes ($\sum_{t=1}^{t} Y_t^-$) must always equal to the total positive deviations more than mean ($\sum_{t=1}^{t} Y_t^+$). So, for obtaining the $W^{0.5}$, it would be sufficient to minimize one of these total outcomes and multiple it to 2. This calculation has easily be done in the following MOTAD model:[10]

$$\text{Minimize} \quad 0.5W^{0.5} = \sum_{t=1}^{T} Y_t^- \tag{16}$$

$$\text{For every } t\text{: } ST \quad \sum_{j=1}^{t} (c_{jt} - c_j^-) x_j + Y_t^- \geq 0 \tag{17}$$

The limitations considered for the farm include land, water (fall, spring and summer), machinery (fall and spring) capital, and work force (fall, and spring).

This research has been done in two stages 1. Using risk programming model, without considering the exerted limitation by the RWCWA. 2. Using risk programming model considering above limitation.

Table 2 MOTAD model Matrix

	Wheat	Watermelon	Beet	Alfalfa	Sunflower	Year1	Year2	Year3	Year4	Year5		Right side
Goal function	620.000	722.000	634.000	1 074.00	688.806	0	0	0	0	0		max
Erformance pexpectations	0	0	0	0	0	1	1	1	1	1	=	λ
Land	1	1	1	1	1	0	0	0	0	0	≤	320
Water autumn/m³	2 200	0	0	2 100	0	0	0	0	0	0	≤	450 000
Water spring/m³	4 000	2 700	3 800	3 500	3 000	0	0	0	0	0	≤	800 000
Water summary/m³	0	5 000	5 200	3 500	3 000	0	0	0	0	0	≤	400 000
Machinery autumn/h	6	4	4	20	5	0	0	0	0	0	≤	1 400
Machinery spring/h	2	6	9	10	7	0	0	0	0	0	≤	1 000
Machinery summary/h	5	4	11	14	6	0	0	0	0	0	≤	1 500
CAPITAL	430	600	800	530	500	0	0	0	0	0	≤	110 000
Labor Force autumn (person-day)	6	1	11	5	0	0	0	0	0	0	≤	1 500
Labor Force spring (person-day)	4	15	8	8	12	0	0	0	0	0	≤	1 500
Labor Force summary (person-day)	6	18	12	11	18	0	0	0	0	0	≤	1 820
Beet	0	0	0	0	0	0	0	0	0	0	≥	30
Year1	-159	-402	-184	-514	-62.896	1	0	0	0	0	≤	0
Year2	-80	-222	-134	-154	-18.645	0	1	0	0	0	≤	0
Year3	-100	-92	-84	244	-8.285	0	0	1	0	0	≤	0
Year4	-51	785	14	106	19.528	0	0	0	1	0	≤	0
Year5	76	877	416	206	294.246	0	0	0	0	1	≤	0

3 Results and discussion

By increasing the expected income level, the target function or minimized risk amount increases. Table 3 shows that with a low expected income of 748 billion Rials (100 Rials = US$0.01), the lands gone under beet and sunflower cultivation will be 30 ha, and 80.9 ha, respectively; and wheat, watermelon, and alfalfa crops will not enter the cultivation pattern with this amount of risk. With increasing E_i quantity (Expected income), the area under two crops, i.e., wheat and alfalfa cultivation will increase and this process will continue up to 1 251 billion Rials from which on the area under alfalfa cultivation will be reduced but wheat will continue to increase. So it can be concluded that there is a direct relation between the increase in the risk of the plan and increase in the area under wheat cultivation. Also, with increasing E_i, the plan of the area under sun flower cultivation will decrease, and in the maximum expected E_i, will be closer to zero. Also watermelon will enter the pattern just in a maximum area E_i, i.e., 1 416 billion Rials that this issue can be related to the high variation of the crop cost so that the possibility of its entrance to the pattern exists only if the farmers are risk-taking. By comparing the cultivation pattern given based on this research and the traditional pattern, we can also find out that the traditional pattern has high risk and very low income. Table 4 in which the water limitations by the RWCWA has been considered, shows that wheat crop, as mentioned above, with increasing E_i, continues to increase in the area under cultivation, but in the expected income level of 974 billion Rials, with increasing E_i, the area under cultivation of wheat will be constant and with increasing E_i we won't see any changes in the area cultivated by this crop. Also watermelon won't enter the cultivation pattern in any amount of E_i because of its high water demand and higher risk. Similarly, in the case of water limitation, as previous conditions, the area under beet cultivation won't be more than 30 hectares. If we exclude 30 hectares cultivation from the pattern, we obtain that this crop will exit the cultivation pattern because of its high water demand; alfalfa and wheat can substitute it.

Also, alfalfa won't enter the cultivation pattern up to E_i =974. Starting from this amount, it will enter the pattern and of maximum E_i is cultivated to 34 hectares. Sunflower is cultivated to 41.3 hectares because of its low water demand and also low risk up to E_i = 974 billion Rials. But with increasing E_i and consequently the including of the crops with high production risk in the cultivation pattern, the area under sunflower cultivation increases to 1 hectare.

Table 3 Summary of output for MOTAD model solution before consideration of water limitations by RWCWA

E_i	Wheat	Watermelon	Beet	Alfalfa	Sunflower	Gain Plot
	1	2	3	4	5	
1 416	140.3	23	30	17	0.8	216 366
1 251	73.9	0	30	32.6	36.4	201 576
1 154	51.4	0	30	31	44.8	198 531
747	0	0	30	0	80.9	190 652
Current pattern	40	5	30	7	35	184 000

Table 4 Summary of output for MOTAD model solution after consideration of water limitations by RWCWA

E_i	Wheat	Watermelon	Beet	Alfalfa	Sunflower	Gain Plot
	1	2	3	4	5	
974	80.5	0	30	34	1	199 230
947	80.5	0	30	0	41.3	193 621
624	24.04	0	30	0	41.3	189 553
474	0	0	30	0	42	182 623

Just as Tables 3 and 4 show, if inputs have been used based on improved pattern of cropping, water limitation won't have any effects on products in lower risks. Also if farmer accepts high risks in production, water limitation can decrease total income as 171.36 billion Rials, but according to beneficial effects of this plan in water conversation, this decrease is explainable.

Figures 2 and 3 show the relationship between risk and expected income with and without water limitations exertion.

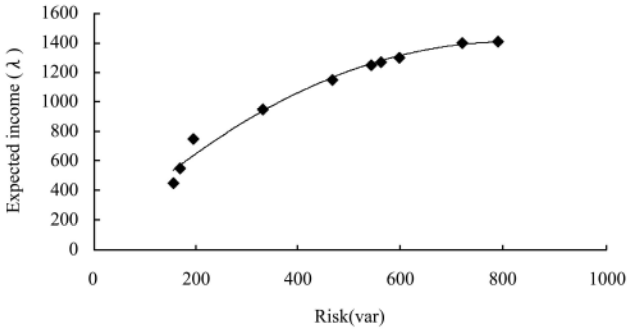

Figure 2 Relationship between risk and expected income (λ) before consideration of water limitations by RWCWA

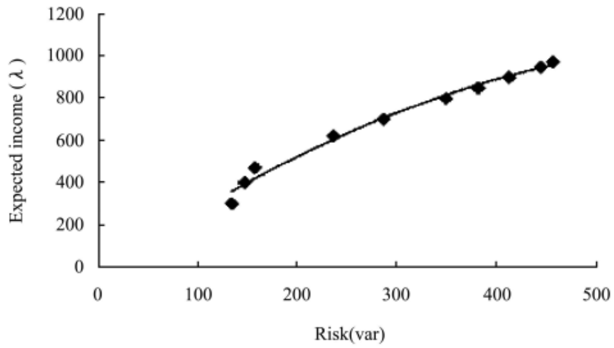

Figure 3 Relationship between risk and expected income (λ) after consideration of water limitations by RWCWA

It is obvious that there is similar process between no water limitation case and that of limitation exerted by the RWCWA in the area under sunflower cultivation:

$$Y=-517.9 + 2E\text{-}5(var)^3 - 0.023(var)^2 + 9146(var) \quad (18)$$

$$R^2=0.991$$

$$Y=-155.0 + 3E\text{-}06(var)^3 - 0.006(var)^2 + 5.347(var) \quad (19)$$

$$R^2=0.983$$

"Y indicates the gross income of quintuple activities in "Poldasht" plain, and "var" is the deviation of the gross interest of whole farm.

4 Conclusions and recommendations

This paper had compared the results of MOTAD model, with and without considering the exerted limitation by the RWCWA in risk conditions. The aim of this study was analyzing improved cropping pattern considering water limitations and in risk conditions. The results show that if the farmer use improved cropping pattern in limitations, the total income will decrease as 171.36 billion Rials.

According to results, watermelon and alfalfa have more water consumption. Since watermelon and alfalfa are not strategic products, farmers are proposed to take them out from cultivation pattern. Also because of high water demand of beet, we propose to exclude it from the cultivation pattern.

Results showed that by water limitation, the area under farming was decreased. Due to the needed water for production is less in sprinkler irrigation, we propose for the application of sprinkler irrigation. Also, increasing the farmers' knowledge about the constancy of water supplies will be useful for facilitating the acceptance of automated water counters. Finally, we propose that this study to be extended for other dry and limited water resources areas.

Acknowledgements

Authors would like to thank Dr. Pourgol-Mohammad and Ms. Eklami for technical review of the manuscript and their contribution.

[References]

[1] Daneshvar Kakhki M, Youssefzade S, Ghodrati Azadi H. Investigation of the substitution capability of oilseeds in cropping pattern. Am. J. Applied Sci., 2009; 6: 1995–2000.

[2] Oster J D, Clothier B E, Wichelns D. History of agricultural water management. Agric. Water Management, 2006; 86(1-2): 3–8.

[3] Charbonneau R, Kondolf G M. Land use change in California, USA: nonpoint source water quality impacts. Environmental Management, 1993; 17(4): 453–460.

[4] Chen B. Climate change and pesticide loss in watershed systems: A simulation modeling study. J. Environ. Inform., 2007; 10(2): 55–67.

[5] Huang G H. A hybrid inexact-stochastic water management model. Eur. J Oper. Res., 1998; 107(1): 137–158.

[6] Nie X H, Huang G H, Wang D, Li H L. Robust optimization for inexact water quality management under uncertainty. Civ. Eng. Environ. Syst., 2008; 25(2): 167–184.

[7] Regassa E N, Munir A H, Gina E C, Helle M R, Lawrence S, Barbara V K. Agricultural water management and poverty linkages. Agric. Water Management, 2010; 97(4): 520–527.

[8] Tavakoli M A. Report organization of water supplies management of Iran. 2009.

[9] Manochehri G. Boltan Committee Water. Problems of coordinate pattern water, 2008; 6: 4–6.

[10] Radmehr A. Report of development perspective Agenda of Iran. 2008.

[11] Haouari M, Azaiez M N. Theory and methodology optimal cropping patterns under water deficits. Eur J. Oper. Res., 2003; 130(2001): 133–146.

[12] Wallace J S, Batchelor C H. Managing water resources for crop production. Phil. Trans. R. Soc., 1997; London B 352, 937–947.

[13] Sethi L N, Panda S N, Nayak M K. Optimal crop planning and water resources allocation in a coastal groundwater basin, Orissa, India. Agric. Water Management, 2006; 83(3): 209–220.

[14] Torabi J. Annual report on the regional water company in West Azerbaijan. 2009.

[15] Bouwer H. Integrated water management: emerging issues and challenges. Agric. Water Management, 2000; 45(3): 217–228.

[16] Torkamani J, Abd-shahi A. Using multi-period mathematical programming model in determining the optimal farm. J. Res & Dev. Agric. Econ., 2000; 32: 35–51.

[17] Chizari A, Ghasemi A. Application of mathematical programming in determining land crops. J. Agric. Econ. Res & Dev., 1999; 28: 61–76.

[18] Singh A K, Singh J P. Production and benefit maximization through optimal crop planning-a case study of Mahi Command. Indian J. Soil Cons., 1999; 27：152–157.

[19] Gholami M. Determine the optimum crop rotation, using linear programming Case Study: 110 hectare farm in the city of Bojnourd. J. Agric. Sci & Natur. Resour. Gorgan., 2003; 1: 17–24.

[20] Vieth R G. An evaluation of selected decision in Northern Thailand. J. Agric & Applied Econ., 1991; 28(2): 381–391.

[21] Torkamani J. Decision criteria in risk analysis: An application of stochastic dominance with respect to a function, Iran Agric. Res., 1996; 15: 1–18.

[22] Torkamani J. Measuring and incorporating attitudes toward risk into mathematical programming model: the case of farmer, kavar district Iran. Iran agric. res., 1996; 15: 85–99.

[23] Randhir O T, Krishnamoorthy S. Optimal crop planning under production risk in tankfed south India Sarms. Indian J. Agric. Econ., 1993; 48: 87–678.

[24] Lin W, Dean G, Moore C. An empirical test of utility versus profit maximization in agricultural production. Am. J. Agric. Econ. 1974; 56: 497–508.

[25] Paris Q. Revenue and cost uncertainty, generalized mean-variance, and linear complementarily problem. Am. J. Agric. Econ., 1979; 61, 268–275.

[26] Kehkha A, Soltani Mohammadi G H, Villano R. Agricultural risk analysis in the Fars province of Iran: A risk-programming approach, University of New England. Working Paper Series in Agricultural and Resource Economics, 2005.

[27] Hazell P, Norton R. Mathematical programming for economic analysis in agriculture. MacMillan Publishing Company, New York. 1986.

[28] Watts M, Held L. A comparison of MOTAD to TARGET MOTAD. Canada J. Agric. Econ., 1984; 32, 85–175.

[29] Kumar B. Trade off between return and risk in farm planning: MOTAD and TARGET MOTAD approach. India agric. econ., 1995; 50: 193–199.