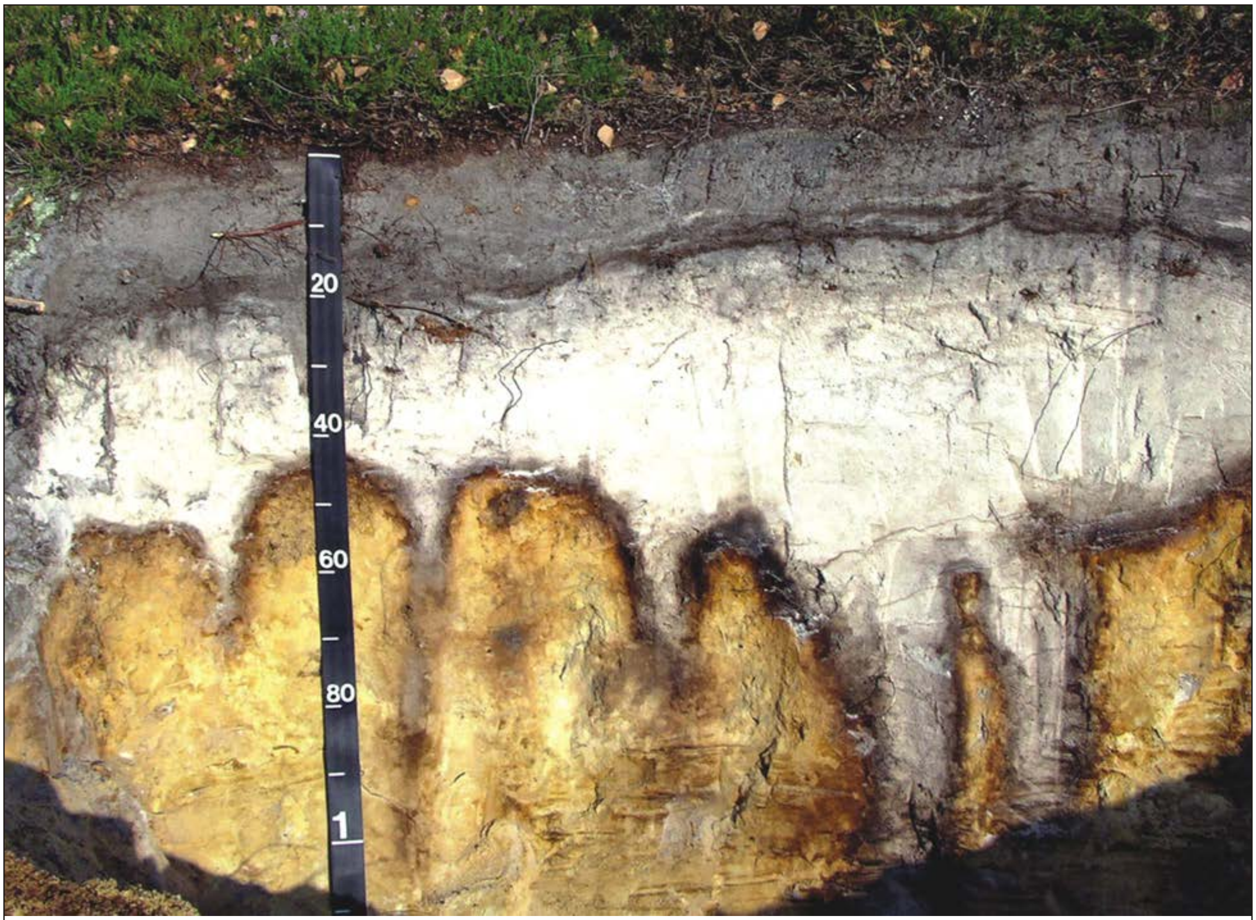

International Journal of Soil Science

ISSN 1816-4978

Academic Journals Inc.

www.academicjournals.com

International Journal of Soil Science 7 (4): 157-167, 2012
ISSN 1816-4978 / DOI: 10.3923/ijss.2012.157.167

Land Use Management in Order to Maximizing Benefit and Minimizing Soil Erosion

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ABSTRACT

Proper and organized use of natural resources can help preserve this valuable asset. Land use optimization science can be especially useful in this regard. The main purpose of the study is to present an appropriate model for optimized allocation of lands with the purpose of gaining the maximum benefit and minimizing soil erosion in Jajrood watershed. This watershed is located in the southeast of the province of Tehran, Iran. To determine the best land use combination, first the net profit amount in every land use was calculated and then soil erosion was determined in every land use. Finally, the multi-objective linear programming model was used to solve the optimization problem based on simplex method. The optimization results showed hat the area of irrigated farming lands and rangelands should be reduced and orchards should be increased. The results also indicate that after optimization was employed, profitability increased up to 70.9% and soil erosion decreased 36.15%. The results of sensitivity analysis show that the increase in the minimum area of rangelands and the decrease in the maximum summation area of orchard and irrigated farming contributed to a reduction in profit. In addition to these results, the study shows that increasing the area of rangelands and irrigated lands can drastically increase soil erosion, which is due to the high erosion rate of these two kinds of land use.

Key words: Allocating land use, linear programming, optimization, simplex method, soil erosion

INTRODUCTION

Inappropriate and uncontrolled use of natural resources can downgrade their quality and destroy them. Sustainable development and optimized use of natural resources involves effective utilization of the existing resources without damaging the assets and resources of next generations (Clark, 1996). It takes 300 years for 1 cm of soil to be formed (Triphati, 2001). Therefore, it is vital to prevent soil erosion to preserve it as a natural asset (Morgan, 1986).

One of the methods that commonly used for reducing erosion and increasing income is to use lands correctly and systematically. There are many factors affecting on the type and extent of erosion in a watershed. One of the factors is how the lands are used. Over the past years, this issue has played an important role in erosion, as a result of technological advancements introduced in nature (Garcia-Ruiz *et al*., 1997). Therefore, the kind of use of lands is an important factor in erosion and production of sediments in watersheds (Kassas, 1983).

At present, scientific and optimized management of agriculture and natural resources are considered to be important items in sustainable development. In order to obtain maximum profit by one of the suitable administrative methods for achieving sustainability and optimized land allocation, we can optimize land use in watersheds through linear programming and Geographic Information System (GIS) and by considering the unfavorable needs and limited resources of the earth (Riedel, 2003). Although finalizing superb economic choices should be accompanied by taking into account biological considerations, ecosystems' sustainability and social issues (Pfaff and Sanchez-Azofeifa, 2004; Ducourtieux *et al.*, 2005), the basis of economic development in many societies is founded upon good land preparation and economic calculation debate (Pasour, 1983). The application of different optimization methods have been developed in recent years in such a way that most of administrative and logical measures have been based on relevant research.

Benli and Kodal (2003) in their study on the optimization of land use in southeast of Antalya, Turkey, highlighted programming for the purpose of maximizing profit obtained from agricultural lands, in spite of shortage of water. Nguyen and Egashira (2004) emphasized the increase in the use of agricultural and forest lands in Tran Yen, Japan, through appropriate land allocation for different uses. Singh and Singh (1999) investigated the multi-objective linear programming model for optimizing land use in the north of China. The results show that if the resources are used properly, the preservation of soil and provision of food and income for rural inhabitants will be continuously improved.

Nikkami *et al.* (2002) utilized the optimization model to decrease environmental and economic effects of soil erosion caused by mismanagement of land use activities in one of the sub-basins of Damavand watershed, Iran. Multi-objective linear programming Simplex Method was used in the study. The findings show 5% decrease in sediment generation and 134% increase in annual profit of the region under study.

Nikkami *et al.* (2009) used multi-objective linear programming in a study on the basin Kharestan watershed which is situated north-west of Iqlid, in the province of Fars, Iran. They determined the optimal land use level to decrease erosion and increase the income of the inhabitants of the basin, concluding that the current land use levels were not appropriate for decreasing erosion and increasing the income of the inhabitants. The results showed that if land use is optimized, the degree of soil erosion and the profitability of the entire watershed under standard land use circumstances will respectively decrease 53.2% and increase 207.98%.

Rounsevell *et al.* (2003) studied the modelling of spatial use distribution of agricultural lands to maximize profit in two regions in England. Multi-objective linear programming was utilized to enhance income and decrease soil erosion in the basin of Brimvand watershed, in Iran. The findings indicate that the application of optimization of land use can contribute to total income up to 18.62% and decrease soil erosion about 7.87% (Sadeghi *et al.*, 2009).

Different researches show that by using linear programming the area of land uses may be modified in such a way that maximum profit and minimum erosion can be resulted. Thus, given the extent of erosion and sediment generation in Iran, it is obvious that the application of optimization science in land use in watersheds of Iran including Jajrood watershed is necessary. This basin was selected as the region for investigation because of its different existing land uses, vastness and the different climates in its various parts. The purpose of the present study was to present a model for determining the optimal use level based on an increase in profit and a decrease in erosion.

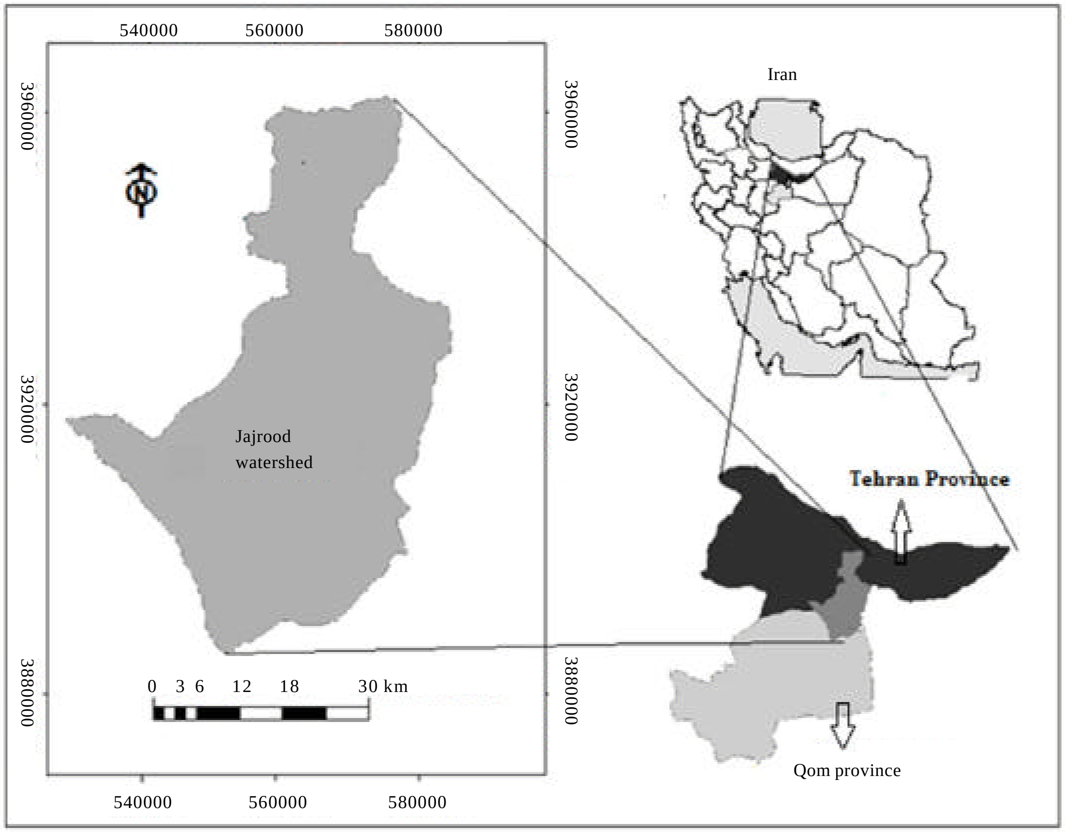

Fig. 1: General schematic view of Jajrood watershed, Iran

MATERIALS AND METHODS

Study area: The Jajrood watershed with an area of 187384 hectares, is situated south-east of the province of Tehran, in Iran (Fig. 1). The basin has cold winters, hot summers and a semiarid climate. The annual average rainfall in the basin is 265.4 mm and the maximum, minimum and average of temperature are respectively 22.8, 9.2 and 16.1°C. The highest and lowest spots in the basin are respectively 2531 and 810 m from the sea level and the average slope of the basin is 7.4% (OES, 2008). The existing land uses include irrigated farming, rangelands, orchards, urban spots and barren lands. The areas of these uses are respectively 80909, 66113, 12879, 13879 and 24177 ha (OES, 2008).

Data acquisition: Landsat 7 satellite images (ETM^+) in 2010 were taken in two seasons and then various colour combinations were designed to distinguish defects and phenomena from the images. The map of diffusion of different land uses under the current conditions was plotted, by using the images and matching them with the existing reports. Given the results, irrigated farming use with 43.19% and orchard use with 1.02%, respectively covered the maximum and minimum levels as far as the uses were concerned in the region under investigation. The other uses including rangelands (36.23%), barren lands (11.40%), urban parts (7.40%) and other spots (0.76%) covered the rest of the region. The land use map under standard circumstances was utilized based on land resources and capability studies (OES, 2008).

In order to determine the necessary coefficients for solving the optimization problem, certain information was received from Soil Conservation and Watershed Management Research Institute (SCWMRI) in Tehran, Iran. The information includes: water resources and their accessibility, soil properties, topography, erosion status, vegetation cover. In addition, some information like matching the land uses and erosion features map were completed by going to the region.

The range of the area under cultivation, yield, production costs and the price of each of the agricultural products for sell were all collected through the existing information in the Agricultural Jihad Management Center of Varamin and Pakdasht, asking the farmers and present users working in the basin. The major agricultural crops in the basin include wheat and barley, alfalfa, vegetables and summer crops. The main orchard crops include pistachio, pomegranate, olive, grape, walnut, fig, persimmon and some apple, cherry, greengage. Calculating the profitability of the rangelands was based on forage production, which was ultimately calculated by determining the total digestible nutrients. The rangelands of the basin are divided into three groups of average, weak and too weak, according to the plant types in the rangeland and the amount of total digestible nutrients was determined based on kilograms per hectare (OES, 2008).

Estimating the extent of soil erosion was determined according to the Modified Pacific Southwest Inter-Agency Committee (MPSIAC) for each of the hydrologic units (Johnson and Gebhardt, 1982; Sadeghi *et al.*, 2009; Chamheydar *et al.*, 2011). First the sedimentation rate, then the degree of sedimentation and finally, given the Sediment Delivery Ratio (SDR), the soil erosion rate was calculated based on ton per hectare over a year (t ha^{-1} $year^{-1}$) for every land use. The MPSIAC method is composed of 9 factors including surface geology, soil erodibility, climate, runoff, topography, vegetation cover, land use, surface erosion and gully erosion.

Formulating the problem: The problem of land use optimization with the purpose of maximizing profit and minimizing soil erosion was carried out through the following stages.

The outline of the optimization problem with the purpose of maximizing profit is as follows:

$$\text{Max}(Z_1)=\sum_{i=1} C_{Bi}X_i \tag{1}$$

where, Z_1 is the annual net profit based on million Iranian Riyals per year (mIR $year^{-1}$), C_{Bi} is the annual net profit per land use based on million Iranian Riyals per hectare per year (mIR ha^{-1} $year^{-1}$), X_1 is the area of each land use (ha), i is the land use number and n is the total number of land uses. Eq. 1 can be presented as follows:

$$\text{Max}(Z_1)=\sum_{i=1}[A]_{i1}[-[(A]_{i2}+A_{i3})]X_i \tag{2}$$

where, A_{i1} is the gross profit for every land use, A_{i2} is the production costs spent for each land use and A_{i3} represents the costs wasted on soil caused by erosion in every land use.

The second objective was to minimize soil erosion as represented in the following formula:

$$\text{Min}(Z_2)=\sum_{i=1}^{n} C_{Ei}X_i \tag{3}$$

where, Z_2 is total soil erosion (t $year^{-1}$), C_{ei} is annual soil erosion for every land use (t ha^{-1} $year^{-1}$), X_i is the area of each land use (ha), i is the land use number and n is the total number of land uses.

The constraints of the model are as follows:

$$X_1 \geq B_1 \tag{4}$$

$$X_1 \leq B_2 \tag{5}$$

$$X_3 \geq B_3 \tag{6}$$

$$X_2 \geq B_4 \tag{7}$$

$$X_1, +X_3 \leq B_5 \tag{8}$$

$$X_1, X_2, X_3 \geq 0 \tag{9}$$

$$X_1+X_2+X_3 = B_6 \tag{10}$$

where, X_1, X_2 and X_3 represent, respectively the area of orchard lands, rangelands and irrigated farming. B_1 through B_6 represent respectively the minimum area of orchards and the maximum area of orchards, the maximum area of irrigated farming, the minimum area of rangelands, the maximum summation area of orchard and irrigated farming and the total of all of the areas.

Application of model to Jajrood watershed: Table 2 is shown the simplex table of optimization model for Jajrood watershed that based on maximizing benefit and minimizing soil erosion. The objective functions for Jajrood watershed are as follows:

$$Max(Z_1) = 151.09X_1+4.72X_2+37.91X_3 \tag{11}$$

$$Min(Z_2) = 8.1X_1+18.92X_2+16.46X_3 \tag{12}$$

where, Z_1 is annual net profit (mIR $year^{-1}$), Z_2 is total soil erosion (t $year^{-1}$) and X_1, X_2, X_3, respectively represent orchard lands area, rangelands and irrigated farming (ha).

The following constraints are taken into account for objective functions:

- The first constraint is related to the minimum area of orchards because gardeners do not tent to narrow this use due to it high profitability:

$$X_1 \geq 1904.27 \tag{13}$$

- The second constraint is related to the maximum area of orchards. According to the map the maximum capability of the lands that can be turned into orchards is 10603.58:

$$X_1 \leq 10603.58 \tag{14}$$

- The third constraint is related to the minimum area of irrigated farming the capability of which, according to the map, should not be less than 79157.28 ha:

$$X_3 \geq 79157.28 \tag{15}$$

- The fourth constraint is the minimum area of rangelands, which according to land capability evaluation, should not be less than 59166.57 ha:

$$X_2 \geq 59166.57 \tag{16}$$

- The fifth constraint is concerned with shortage and availability of water. The total orchard lands and irrigated farming cannot exceed 86556.08:

$$X_1 + X_3 \leq 86556.08 \tag{17}$$

- The sixth constraint entails that the area of none of the uses can be less that zero:

$$X_1,\ X_2,\ X_3 \geq 0 \tag{18}$$

- The seventh constraint entails that the summation of the use area of the orchard, rangeland and irrigated farming should be 148927.43:

$$X_1 + X_2 + X_3 = 148927.43 \tag{19}$$

The sensitivity analysis was also carried out for the benefit maximization and soil erosion minimization objective functions.

RESULTS

Table 1 and 3 showed that optimization, the area of irrigated farming and rangelands decreased by 2.16 and 5.66%, whereas the area of the orchards increased by 288%. Profitability in orchard lands reached 151.09 while it was 123.04 mIR ha^{-1} year^{-1}; that is to say, it increased 22.8%. The increase in profitability of rangelands and agricultural lands were 19.5 and 69.5%, respectively.

The results also reveal that the total percentage of the basin considerably increased in such a way that the total income of the basin increased by 70.9%. In addition, there was a decrease in the erosion of the whole basin as the total erosion was decreased by 505452.4138 t year^{-1} (36.15%).

The results of sensitivity analysis show the linear nature of the changes. Figure 2 and 3 reveal that the model is more sensitive to the minimum area of irrigated farming (B3), the minimum of

Table 1: Area, benefit and surface erosion before optimization in Jajrood watershed, Iran

Land use	Area (ha)	Net income (mIR ha^{-1} year^{-1})	Total income (mIR year^{-1})	Erosion rate (t ha^{-1} year^{-1})	Erosion (t year^{-1})
Orchard	1904.27	123.04	234301.38	4.242	8077.913
Range	66113.63	3.95	261148.84	11.613	767777.585
Irrigated farm	80909.53	22.36	1809137.09	7.690	622194.285
Total	148927.43		2304587.31		1398049.783

Table 2: Simplex table of land use optimization, Jajrood watershed, Iran

Function	X1	X2	X3	Modality	Right hand side
Objective					
1	151.09	4.72	37.91	Max	0
2	-3.042	-6.824	-5.615	Max	0
Constraints					
1	1	0	0	>	1904.27
2	1	0	0	<	10603.58
3	0	0	1	>	79157.28
4	0	1	0	>	59166.57
5	1	0	1	<	86556.08
6	1	1	1	=	148927.4

Table 3: Result of land use optimization in Jajrood watershed, Iran

Land use	Area (ha)	Net income (mIR ha^{-1} $year^{-1}$)	Total income (mIR $year^{-1}$)	Erosion rate (t ha^{-1} $year^{-1}$)	Total erosion (t $year^{-1}$)
Orchard	7398.8	151.09	1117884.69	3.042	22507.14960
Rangeland	62371.35	4.72	294392.77	6.824	425622.0924
Irrigated farm	79157.28	37.91	3000852.48	5.615	444468.1272
Total	148927.43	------	4413129.94	-------	892597.3692

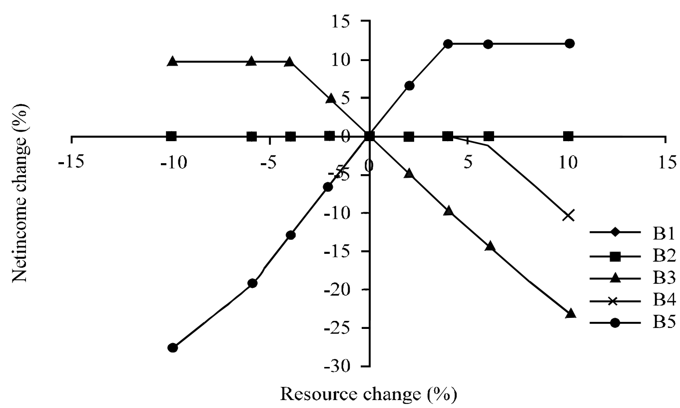

Fig. 2: Sensitivity analysis of benefit maximization function in Jajrood watershed, Iran, B1, B2, B3, B4 and B5 are minimum allowable area of orchard, maximum allowable area to orchard, minimum area of irrigated farming, minimum area of rangeland and summation of orchard and irrigated farming, respectively

area of the rangeland (B4) and the maximum summation area of orchard and irrigated farming (B5) than other factors (B1 and B2). The results of sensitivity analysis for the objective function of maximizing profit show that the minimum increase in the area of irrigated farming and in the area of rangelands have decreases the in total profit. Besides this decrease, the total agricultural and orchard area have decreased the profit (Fig. 2).

The results of sensitivity analysis of the soil erosion minimization function reveal that an increase in the area of irrigated farming and rangelands can drastically increase erosion, as a result of high degree of the erosion in these two uses. Also, a decrease in the maximum summation area

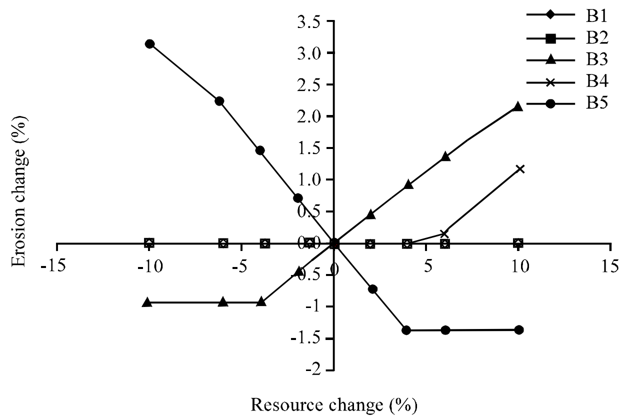

Fig. 3: Sensitivity analysis of erosion minimization function in Jajrood watershed, Iran, B1, B2, B3, B4 and B5 are minimum allowable area of orchard, maximum allowable area to orchard, minimum area of irrigated farming, minimum area of rangeland and maximum summation area of orchard and irrigated farming, respectively

of orchard and irrigated farming has increase in erosion; this means there is need in extending the area of rangelands. Changes in other constraints did not have a significant effect on the total profit (Fig. 3).

DISCUSSION

The results observed in Table 3 emphasize the maximization of profit and minimization of erosion. The analysis of the results also reveals that there is a successful link between economic and environmental consequences in the basin, which were confirmed by Recatala *et al*. (2000), Shively and Coxhead (2004), Peel and Lloyd (2007) and Gezelius and Refsgaard (2007). In the present study, the problem of linear optimization was successfully solved by multipurpose ADBASE software program (Sadeghi *et al*., 2009; Steuer, 1995).

Doubtlessly, the reason for the increase in the total income and the decrease of total erosion is replacing orchard lands with high income and replacing low erosion with rangelands and irrigated farming. using appropriate management like cultivating alfalfa among the trees in orchards, improving irrigation system, using crop rotation in agricultural lands, controlling livestock grazing, seeding and pitting will increase production and decrease erosion, which corresponds to the results found by Sadeghi *et al*. (2009) and Chamheydar *et al*. (2011).

The results of this experiments are in line with the work of Singh and Singh (1999) who utilized linear programming in solving optimization problems for maximizing production and profit in a region in India. Amir and Fisher (1999) used linear optimal model for analyzing crops production based on different scenarios in Israel. Also, Salman *et al*. (2001) introduced a linear optimization programming model for analyzing inter-seasonal allocation of water for irrigation in Jordan. Nikkami *et al*. (2002) presented a model in order to minimizing soil erosion and increasing profit for the Damavand basin in Iran. Xevi and Khan (2005) used their findings in analyzing the objectives of crop production with different constraints in Australia.

The sensitivity analysis of objective profit maximization functions (Fig. 2) and minimizing soil erosion (Fig. 3) shows that the objective functions are sensitive to an increase or decrease in changeable limitation functions and that the optimal changes are linear, but the sensitivity is more intense in certain resources (Sadeghi *et al*., 2009). In the profit maximization function, an increase in the minimum area of irrigated farming and in the minimum of rangelands decreased the total profit because it limited the orchard areas which would bring about high profit. Also, a decrease in the maximum summation of agricultural and orchard lands decreased the profit, which was due to the expansion of low-profit rangelands (Chamheydar *et al*., 2011; Sadeghi *et al*., 2009).

In the soil erosion minimization function, the expansion of irrigated farming lands and rangelands can drastically increase erosion, which is due to high degree of erosion in these two kinds of use. In addition, a decrease in the maximum summation area of orchard and irrigated farming increased erosion, as a result of the expansion of rangelands. Any change in other constraints did not have a considerable effect on the total profit and erosion (Chamheydar *et al*., 2011; Sadeghi *et al*., 2009).

Due to economical and social problems in the region, basin's inhabitants don't show much tendency to stay in the basin and their migration to other cities is one of the negative consequences of this problem. In this study, as far as environmental and economical issues are concerned, it is suggested that part of the irrigated farming and rangelands can be converted into orchards. However, changing the use of the lands through optimization can not be confidently employed in the basin. Clearly, before making the changes, the characteristics of the region and the interests of the inhabitants should be carefully studied to avoid any unexpected problems.

Yet, an optimal strategy, like some plans, may not be always successful, which is because of incertitude in the managing the watershed. Luo and You (2007) have addressed this problem in issues concerned with controlling soil erosion. Given the views of the basin's inhabitants, governmental support including financial aid and offering agricultural guarantees can help encourage the inhabitants of the region in the process of making the changes and encourage the beneficiaries in the basin to offer their contributions, which are among the issues addressed by Wang *et al*. (2004).

Optimal use of the lands can not only help control all of the constraints in the basin under study, it can also improve the economical and social status, the environmental stability and sustainable development in the basin.

ACKNOWLEDGMENTS

This project was supported by Soil Conservation and Watershed Management Research Institute (SCWMRI), Tehran, Iran and executed as a Ph.D. thesis in the Department of Soil Sciences, Faculty of Agriculture, Sciences and Researches Branch, Islamic Azad University, Tehran, Iran. Authors express their gratitude for financial support and facilitation of the research.

REFERENCES

Amir, I. and F.M. Fisher, 1999. Analyzing agricultural demand for water with an optimizing model. Agric. Syst., 61: 45-56.

Benli, B. and S. Kodal, 2003. A non-linear model for farm optimization with adequate and limited water supplies: Application to the South-East Anatolian Project (GAP) Region. Agric. Water Manage., 62: 187-203.

Chamheydar, H., D. Nikkami, A. Pazira and M. Ghafouri, 2011. Soil loss minimization through land use optimization. World Applied Sci. J., 12: 76-82.

Clark, D., 1996. The future urban world. Global City, 46: 582-582.

Ducourtieux, O., J.R. Laffort and S. Sacklokham, 2005. Land policy and farming practices in Laos. Dev. Change, 36: 499-526.

Garcia-Ruiz, J., T. Lasanta and F. Alberto, 1997. Soil erosion by piping in irrigated fields. Geomorphology, 20: 269-278.

Gezelius, S.S. and K. Refsgaard, 2007. Barriers to rational decision-making in environmental planning. J. Land Use Policy, 24: 338-348.

Johnson, C.W. and K.A. Gebhardt, 1982. Predicting sediment yields from Sagebrush rangelands. Proceedings of the Workshop on Estimating Erosion and Sediment Yield on Rangelands, March 7-9, 1982, Tucson, Arizona, pp: 145-156.

Kassas, M., 1983. The global biosphere: Conservation for survival. Mazangira, 7: 2-13.

Luo, B. and J. You, 2007. A watershed-simulation and hybrid optimization modeling approach for water-quality trading in soil erosion control. Adv. Water Res., 30: 1902-1913.

Morgan, R., 1986. Soil Erosion and Conservation. Longman Scientific and Technical Publisher, USA., Pages: 298.

Nguyen, T.T. and K. Egashira, 2004. Land use effectiveness by farm households after land and forest allocation at Tran Yen district, Yen Bai province. J. Fac. Agric. Kyushu Univ., 49: 461-466.

Nikkami, D., M. Elektorowicz and G.R. Mehuys, 2002. Optimizing the management of soil erosion. Water Qual. Res. J. Can., 37: 577-586.

Nikkami, D., M. Shabani and H. Ahmadi, 2009. Land use scenarios and optimization in a watershed. J. Applied Sci., 9: 287-295.

OES, 2008. Malmo Dam renewable natural resources studies. Forests, Rangelands and Watershed Management Organization, Tak Sabz Consulting Engineering Company, Tehran, Iran.

Pasour, E.C., 1983. Land use planning: Implications of the economic calculation debate. J. Libr. Stud., 7: 127-139.

Peel, D. and M.G. Lloyd, 2007. Neo-traditional planning. Towards a new methos for land use planning? J. Land Use Policy, 24: 396-403.

Pfaff, A.S.P. and G.A. Sanchez-Azofeifa, 2004. Deforestation pressure and biological reserve planning: A conceptual approach and an illustrative application for Costa Rica. Resour. Energy Econ., 26: 237-254.

Recatala, L., J.R. Ive, I.A. Baird, N. Hamilton and J. Sanchez, 2000. Land-use planning in the Valencian Mediterranean region: using LUPIS to generate issue relevant plans. J. Environ. Manage., 59: 169-184.

Riedel, C., 2003. Optimizing land use planning for mountainous regions using LP and GIS towards sustainability. Indian J. Soil Conserv., 34: 121-124.

Rounsevell, M.D.A., J.E. Annetts, E. Audsley, T. Mayr and I. Reginster, 2003. Modelling the spatial distribution of agricultural land use at the regional scale. Agric. Ecosyst. Environ., 95: 465-479.

Sadeghi, S.H.R., Kh. Jalili and D. Nikkami, 2009. Land use optimization in watershed scale. Land Use Policy, 26: 186-193.

Salman, A.Z., E.K. Al-Karablieh and F.M. Fisher, 2001. An inter-seasonal agricultural water allocation system (SAWAS). Agric. Syst., 68: 233-252.

Shively, G. and I. Coxhead, 2004. Conducting economic policy analysis at a landscape scale: Examples from a Philippine watershed. Agric. Ecosyst. Environ., 104: 159-170.

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

Steuer, R.E., 1995. Manual for ADBASE Multiple Objective Linear Programming Package. Faculty of Management Science, Brooks Hall, University of Georgia, Athens, GA., USA.

Triphati, R.P., 2001. Soil Erosion and Conservation. New Age International (P) Ltd., New Delhi, India, ISBN-13: 9788122403053, Pages: 316.

Wang, X., S. Yu and G.H. Huang, 2004. Land allocation based on integrated GIS-optimization modeling at a watershed level. Landscape Urban Planning, 66: 61-74.

Xevi, E. and S. Khan, 2005. A multi-objective optimization approach to water management. J. Environ. Manage., 77: 269-277.