International Journal Of Geo Science & Environment Planning
IJGSEP
An Interactive Open Access Journal of the Universal Geosciences Union

Efficiency Evaluation of LP-MOLA, FLP-MOLA and GP-MOLA Mathematical-Spatial Optimization Models in Environmental Planning

Afshin Honarbakhsh [a], Mahdi Pajoohesh [b], Maryam Zangiabadi [c], Moslem Heydari [d,*]

Associate Professor in Hydrodynamic and River Engineering [a]
Assistant Professor in Erosion and Sedimentation [b]
Associate Professor in Operations Research [c]
PhD Student in Watershed Management and Planning [d]

Article info

Article history:
Received 06 Novemver 2016
Accepted 06 December 2016
Available online 1 Junuary 2017

Keywords:
Environmental Planning,
Land Use Optimization, Mathematical Optimization, Linear Programming,
Fuzzy Linear Programming, Goal Programming

Abstract

In recent years, due to absence of integrated watershed management in most regions, natural resources have witnessed numerous damages with severe floods as one of its consequences which further leads to economic, social and environmental damages. Presently, there is no optimal utilization of land in most watersheds hence no optimal model matching with facilities and objectives is used in the watersheds. Thus, management and planning are essential for the proper utilization, protection and revival of these resources. This study aims to develop some mathematical-spatial optimum utilization environmental plans in watershed using LP, FLP and GP mathematical optimization approaches including environmental and economic objectives while considering social issues. About the LP model the results showed that the proposed model can decrease the amount of soil erosion to 9 percent and can increase benefit to 96% respectively. About the FLP model the results showed that this proposed model can decrease the amount of soil erosion to 12 percent and can increase benefit to 200% respectively. About the GP model the results showed that the land use optimization can increase benefit to 97% and decrease erosion to 12%, respectively. Furthermore the result of performing spatial optimization indicated that people are still making use of land that does not follow the optimized procedure in the current condition. It is obvious land use structure indicate some displacement of land uses because of optimal spatial allocation of them on the basis of FAO measurements. In addition to, the results demonstrated the efficiency of the proposed models.

*Corresponding author. Tel.:+989131850756
E-mail address: heydari_moslem@yahoo.com

INTRODUCTION

The watersheds as a means of exploitation of natural resources, has always been considered by policy makers and planners of countries for sustainable development. Meanwhile, the logical and systematic use of upstream resources that eliminates dangers for downstream areas has been regarded as one of the most important policies of natural resources managers. Thus, the use of multi-objective decision making methods of planning such as linear programming (LP), Fuzzy linear programming (FLP) and goal programming (GP) will be useful for optimal land allocation and environmental planning.

Nowadays, inappropriate land use, urban and industrial development along with different pollutions emanating from it gives rise to loss of natural resources and further leads to destructive floods, soil erosion, sedimentation and filling reservoirs of dams and other various environmental, economic and social damages.

Water and soil are the most important natural resources of a country and are known to underpin the sustainable development of countries. For successful protection of these valuable resources, there is need to choose an integrated approach and a system for managing the hydrologic response units (HRUs) and to consider the mutual relationships between different parts of a watershed system (http://watershedmg.com/). The location of a watershed is the most complex environmental problem that threatens the livelihood of millions of people, particularly in developing countries. The relationship between land use, soil and water, in addition to the combination of downstream and upstream lands, coupled with the consideration of the demands of numerous beneficiaries of watershed, are interesting issues in the management discussion of watersheds.

Initially conceived as an application of single objective linear programming by Charnes and Cooper (1955, 1961), also, goal programming (GP) model is first introduced by them (cited by Steuer, 1985). GP gained popularity in the 1960s and 70s from the works of Ijiri (1965), Lee (1972), and Ignizio (1976) (cited by Steuer, 1985). Allocation of limited resources to the defined activities with the aim of increasing the efficiency and finding the optimal solution is referred to linear programming. In fact the linear programming is a simple kind of mathematical programming. In LP, the objective function as well as every constraint displayed as linear. The main parts of the linear programming model involve:

1. The objective function: represent maximizing or minimizing the performance of the model.
2. Functional constraints: represent the limitation of resources to achieve the objective of the model, besides are displayed as (≤), (≥) or (=).
3. Non – functional constraints or the constraints of decision variables. The decision variables are variables that the decision makers have control over them and that represent the amount or level of performance of an activity (product or services); they are displayed with (x_j). These variables can be used either positive, rarely negative or unrestricted.

Unrestricted variable is one which can be positive, negative or zero. The constraints with such form ($x_j \geq 0$) are non-negative constraints. The general structure of a linear programming model is as follows:

$$\text{Max (Min)} \quad Z = c_1x_1 + c_2x_2 + \ldots + c_nx_n \qquad (1)$$

s.t.

$$a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n \ (\leq, =, \geq)\ b_1$$
$$a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n \ (\leq, =, \geq)\ b_2$$
$$\vdots$$
$$a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n \ (\leq, =, \geq)\ b_m$$
$$x_j \ (\geq 0 \text{ or } \leq 0 \text{ or unrestricted}) \quad j = 1, 2, \ldots, n$$

where:

Z: indicates the value of objective function, which is displayed as linear function and its amount will be determined after problem solving.

X_j: a decision variable and its amount will be determined after problem solving.

C_j: is the objective function coefficient or the value of per unit of activity (product or services) in the objective function. This numeric coefficient is active in problem.

$a_{ij:}$ represents the technological coefficient or the amount of i resource applied to perform a unit of j activity, and it is an active coefficient in problem.

$b_{i:}$ The active value on the right hand side of constraints which express the availability of resources or the demand ceiling.

Also, the researchers concluded that fuzzy model allows the decision maker determine the significance of the individual objectives, and is more compatible with natural environment. In this study, the RHS coefficient of linear programing model is fuzzy. The general form of the model is as follows:

$$\text{Max} \quad Z = \sum_{j=1}^{n} c_j x_j \qquad (2)$$

s. t.

$$\sum_{i=1}^{m} a_{ij} x_j (\geq, =, \leq) \tilde{b_i} \quad i = 1, 2, \ldots, m$$

$x_j \geq 0$, $j = 1, 2, \ldots, n$

Z: is fuzzy decision function which must maximize the amount of membership value (λ),

$\tilde{b_i}$: is the fuzzy RHSs of constraints. To solve the above model the membership function of $\tilde{b_\iota}$ defines as follows:

$$\mu_{\tilde{b_i}(x)} Z = \begin{cases} 1 & \text{if} \quad x \leq b_i \\ \frac{b_i + p_i - x}{p_i} & \text{if} \quad b_i \leq x \leq b_i + p_i \\ 0 & \text{if} \quad x \geq b_i + p_i \end{cases} \qquad (3)$$

x is a real number. For each vector, such as $X = x_1, x_2, \ldots, x_n$, first the degree which the ith constraint could be satisfy by X vector is calculated by the following equation:

$$\tilde{D_i} = \tilde{B_i} \left(\textstyle\sum_{j=1}^{n} a_{ij} x_j\right) \qquad (۴)$$

$\tilde{D_i}$ sets are actually fuzzy sets which their share space $(\cap_{i=1}^{m} \tilde{D_i})$, constitutes the feasible solution space. Thus to determine the solution Space, the lower limit (Z_L) and upper limit (Z_U) should respectively calculated based on the classical linear programming models as follows:

$$\text{Max} \quad Z = \sum_{j=1}^{n} c_j x_j \qquad (5)$$

s. t.

$$\sum_{i=1}^{m} a_{ij} x_j \leq b_i \quad i = 1, 2, \ldots, m$$

$x_j \geq 0$, $j = 1, 2, \ldots, n$

and

$$\text{Max} \quad Z = \sum_{j=1}^{n} c_j x_j \qquad (6)$$

s. t.

$$\sum_{i=1}^{m} a_{ij} x_j \leq b_i + p_i \quad i = 1, 2, \ldots, m$$

$x_j \geq 0$, $j = 1, 2, \ldots, n$

Then the fuzzy set of optimal values ($\tilde{G}$) is defined as follows:

$$\mu_{\tilde{G}(x)} = \begin{cases} 1 & \text{if} \quad Z_U \leq \sum_{j=1}^{n} c_j x_j \\ \frac{\left(\sum_{j=1}^{n} c_j x_j\right) - Z_L}{Z_U - Z_L} & \text{if} \; Z_L < \sum_{j=1}^{n} c_j x_j < Z_U \\ 0 & \text{if} \quad \sum_{j=1}^{n} c_j x_j \leq Z_L \end{cases} \qquad (7)$$

To solve the above fuzzy model, using the algorithm proposed by Bellman and Zadeh (1970), the fuzzy model is converted to the crisp LP as follows:

$$\text{Max} \;\; \lambda \qquad (8)$$

$$\lambda(Z_U - Z_L) - \left(\sum_{j=1}^{n} c_j x_j\right) \leq -Z_L$$

$$\lambda\, p_i + \left(\sum_{i=1}^{m} a_{ij} x_j\right) \leq b_i + p_i$$

$\lambda, x_j \geq 0$

In the above model, $\lambda \leq 1$ and the best is $\lambda = 1$

$$\left[\left(\cap_{i=1}^{m} \tilde{D_i}\right) \cap \tilde{G}\right] \qquad (۹)$$

The method is known as symmetric algorithm (quoted from the Kooreh Pazan, 1387).

In addition to, GP is now an important area of multiple criteria optimization. The idea of goal programming is to establish a goal level of achievement for each criterion. GP is ideal for criteria with respect to which target (or threshold) values of achievement are of significance. Goal programming is distinguished from linear programming by:

The conceptualization of objective as goals, The assignment of priorities and/ or weights to the achievement of the goals, The presence of deviational variables d_i^+ and d_i^- to measure overachievement and underachievement from target (or threshold) levels t_i and the minimization of weighted-sums of deviational variables to find solutions that best satisfy the goals.

Usually, a point that satisfies all the goals is not feasible. Thus, one must try to find a feasible point that achieves the goals as closely as possible. The way in which such points are found using priority and/ or weighting structures defines goal programming.

A multiple objective problem may have four types of goal criteria, as: greater than or equal to, less than or equal to, equality and range. So, the target values are values on or above which, on or below which, at which, or between which one wish to reside.

A goal programming problem with, for instance, one of each type of goal criterion is expressed as:

International Journal Of Geo Science & Environment Planning
IJGSEP
An Interactive Open Access Journal of the Universal Geosciences Union

goal $\{c^1x = z_1\}$ $(z_1 \geq t_1)$
goal $\{c^2x = z_2\}$ $(z_2 \leq t_2)$
goal $\{c^3x = z_3\}$ $(z_3 = t_3)$
goal $\{c^4x = z_4\}$ (z_4 € $[t_4^{□}, t_4^{µ}]$
The information in parentheses on the left specifies the values of the z_i to be achieved (if possible) in relation to stipulated t_i target values.
The general structure of the model used in this study is as follows:
Find x so as to
Minimize

$$Z = PL_1(d_1^-, d_1^+), PL_2(d_2^-, d_2^+), \ldots, PL_r(d_3^-, d_3^+) \ldots \quad (10)$$

Subject to

$$Z_j(x) - d_j^+ + d_j^- = Z_j^* \quad \text{for } j = 1, 2, 3, \ldots, n$$

$$g_i(x) - d_i^+ + d_i^- = b_i^* \quad \text{for } i = 1, 2, 3, \ldots, m$$

$$x, d_j^-, d_j^+ \geq 0$$

Where;
Z: objective function (achievement function); a vector of r priorities.
X: a vector of decision variables.
PL_r: The rth priority level or hierarchical priority associated to goals.
$Z_j(x)$: The jth goal.
$g_i(x)$: The ith constraint.
d_i^- and d_j^-: negative deviations or the degree of under achievement from the j goals and the i constraint.
d_i^+ and d_j^+: positive deviations or over achievement from the goal j and the constraint i.
b_i* and z_j*: targets or aspiration levels for the goal j and the constraint i.
n: The number of goals and m: the number of constraints, unlike conventional optimization objective function, achievement function measure the degree of non-achievement.
It is also necessary that in addition to the extraction of optimal area of land uses by the method mentioned, optimal spatial situation of different land uses be determined, ensuring that it be performed using multi objective land allocation (MOIA).

LP was used by Yeo *et al*, (2004), in order to optimize the land use for decreasing the runoff, the result of this study was that if the land use is optimized, the amount of runoff would decrease 15 to 20 percent.
According to the studies, the systemic planning hasn't been used in Iran in the fields of optimal use of natural resources and watershed management using programming model. Salyani (1996), has performed some researches in the field of cultivation model for the plans of water resources development. Pishdad *et al*, (2008), in the investigation of the effects of land use change on the soil erosion in the Cheraghveise watershed using EPM model, after determining the optimal land use, concluded that the amount of land erosion is reduced about 7133 Ton per year by the land use optimization.

In a study on a farm land of 70 ha, Akbari and ZahediKeyvan (2007) alongwith a consideration of the comments and experiences of farmers revealed that a combination of fuzzy hierarchical analytical method with the common linear programing (LP) model shows a more precise and compatible results with the real world condition. In a research, Han *et al*. (2011) reviewed the development of a multi objective model with the interval parameters. The developed model was implemented for the allocation of water resources with different qualities to urban, agricultural and industrial consumers in Dalian city in China. This model is looking for maximizing the economic, social and environmental profits. The results show that the ratio of the reused water to the entire water is gradually increasing, so the ratio of the consumption of agricultural water to the whole consumption of water is decreasing.

Amini (2013) implemented the FGP approach in the east of Isfahan; and a quantitative analysis of the obtained findings suggest the superiority of FGP approach over other models in terms of simultaneous access to objectives.

Some researchers used multi-objective techniques in watershed management. For example: in a case study in Mahi Command region, in India, Singh (1999) implemented the minimization of production and profit using optimal cultivation programming. In this study, if the maximization of production is considered as the main objective, only 86.6% of the region was allocated to the cultivation of wheat and vegetables. The total use of water resource and employment of manpower was recorded as 63.72 and 29.54%, respectively. The result of this study showed that the cultivation programme in the region increased the degree of products from 60 to 96%.
Fokes and Meser (2012) maximized the protection of forests in the US using GP. They concluded that GP is flexible enough for the manager to consider both ecological and political factors.
Mohseni *et al*. (2003) demonstrated how a multi-objective linear function, by changing the weight coefficients of priority, can provide various objectives in order to optimally manage land use. This study was conducted to suggest and compare different alternatives for optimum utilization of resources in the Garmabdasht sub-watershed of Gorgan using goal programming, as well as

socioeconomic and environmental objectives. The results showed that the proposed pattern using goal programming (GP) had acceptable and flexible outputs when compared with the linear programming (LP) techniques.

The findings of Daliry *et al*. (2009) indicated that, in the case where GP is correctly formulated, more acceptable results may be achieved for analyzing the watershed system in comparison with LP. This study was carried out in Garmabedasht watershed in Gharaso, Golestan and it was found that besides the 2% reduction in sediment from the allowed rate, resources allocation on the basis of this method, has led to maximization of the income of beneficiaries by up to 5% from the intended rate. This was measured in terms of the restrictions in the available capital and the relative achievement of other objectives.

Arkhi *et al*. (2013), explored the effect of land use optimization on soil erosion and water sedimentation in Cham Gardlan dam watershed using GIS. They concluded that if proper and compatible land uses with environmental and natural conditions are selected with the aim of optimal use of nature, there would be a dramatic decrease in erosion and sediments produced in this watershed.

Chamheidar et al. (2011) used multi-objective technique for minimizing soil erosion and its food elements and showed an increase of residents of Abo Abass basin in Khozestan Province. The results of this study showed that the current level of land use is not appropriate and under optimal conditions, the level of forest plantation lands increased between 1.81 and 55.7%, respectively, range lands remain unchanged and the level of irrigation of agricultural lands and dry farming lands decreased by 67.5 and 37.4%, respectively. Moreover, in the case of the optimization of land use in the current conditions and without land management, erosion rate decreased by 3.2%, in the case of the application of land management in the current levels of land use, it decreased by 35.3% and in the standard conditions of land use, it decreased by 47.2%. Furthermore, the rate of food loss reduced by 2.5% and the rate of profit increased by 29.7%.

The purpose of this study was to use the linear programming, fuzzy linear programming, preemptive goal programming and multi objective land allocation approaches to present optimal plans of land use that is compatible with agricultural science and natural resources.

MATERIALS AND METHODS

This study region is one of the upstream sub watersheds of Zayandehrood watershed and has an area of about 135 km^2 and is located between 50° 5′ 42" to 50° 18′ 34" eastern longitude and 32° 22′ 2" to 32° 29′ 23" northern latitude. In terms of climatic conditions, this watershed has an average annual rainfall of about 1350 mm and an average annual temperature of 9°C. The average amount of erosion in this basin is about 10.5 ton per hectare in a year, SDR is about 24% and the amount of sediment is about 2.5 ton per hectare in a year.

To effectively conduct this research, the watershed boundary was first drawn using the maps at scale of 1:25000 and physical parameters of the watershed which includes perimeter and area etc. was extracted. Thereafter, land use map was prepared using 1:25000 scale topography maps and Google Earth satellite images. This map was controlled in the field work and adapted to real condition. Investigation of the land use map reveals the development of residential areas, especially the city of Chelgerd, gardens and water installations. In preparing the exact slope map, the contour map was first made at the scale of 1:25000 with contour intervals of 20 m. Thereafter, the map of summits was prepared. Next, to avoid creating flat areas on the site of summits, contour map and summits map was integrated and DEM made on the basis of integrated map.

Other basis maps produced includes: Roads map, the map of water ways and some of long water ways of watershed, springs map, water installations map, the map of residential areas, the map of nomadism settlement regions, mines map, gardens map, the map of agricultural lands, the separated map of agricultural lands of dry farming as well as irrigated agriculture areas, rangelands map, the map of rock mass lands, and lastly the separable map of manageable and unmanageable areas were prepared. It shows the watershed areas in which there is the possibility of management and planning. The map also illustrates the current land use of these lands.

To investigate the criterion of accessibility to water in the study area, the available data of surface and ground water in the region were first received. To estimate the amount of available water in the area of interest, crop water requirement for the dominant plant and tree species (fruit and fruit less trees) in the area should be calculated. So, by interviewing the different beneficiaries of the watershed in field work, water constraints experienced, and the forms of irrigation as well as approximate amount of crop water requirement were investigated. Thereafter, using meteorological information and FAO

Penman-Montieth method, ETo and CWR were calculated more precisely. It should also be mentioned that the USDA Soil Conservation Service method was used for effective rain calculation (Allen *et al*. 1998). Finally, by comparing accessible water (the amount of water available in the watershed on the basis of harvesting licenses of Water Resources Corporation Bureau) with the amount of water requirement calculated, no constraint about water was observed for developing gardens and irrigated agricultural lands.

In calculating utility coefficient of different land uses and cultivations as well as the dominant trees of watershed, field visits along with general interview were first conducted with beneficiaries (ranchers, farmers and gardeners and …), and the initial information were collected. Thereafter, through the use of agricultural statistics and official information of Natural Resources Department and agricultural organization in addition to subtracting the costs, the net profit obtained from any land use was calculated. It is one of the applied objective function coefficients (C_j). Based on the importance of social issues in the management and planning of the watershed, field operations and interview with the various beneficiaries of the watershed were performed and the information obtained from it has been used in the various stages of work implementation, such as discussion on land use comparisons, social problems like employment, constraints of water resources, etc. Also, another objective function coefficient considered in this study is the amount of erosion produced in each land use, and that was extracted from the study by Pajoohesh *et al*. (2011). Additionally, the suitability land use map was made on the basis of slope, soil depth and accessibility of water resources criterions in the manageable areas using Guidelines and Bulletins of FAO (1976, 1983, 1984, 1985, 1990 and 1992). Information of this map together with ideas of the beneficiaries and managers of watershed are the core bases for determining the type of objectives and the values on the right-hand side (RHS) of constraints in the model.

work steps are as follows:

The process of linear programming:

- Determining the goal
- Determining the decision variables
- Determining the function coefficients of goal (c_j) for sediment attribute
- Determining the constraints
- Formulation and solving the problem
- Finding the optimal values of the decision variables and goal

The process of fuzzy linear programming

- Determining the fuzzy goal
- Determining the decision variables
- Determining the function coefficients of fuzzy goal (c_j) for sediment attribute
- Determining the constraints
- Extracting the Z_L and Z_U for fuzzy goal
- Formulation and solving the problem
- Finding the optimal values of the decision variables and goal

The process of goal programming

- Determining the goals
- Determining the decision variables
- Determining the function coefficients of fuzzy goals (c_j) for benefit and sediment attributes
- Determining the constraints
- Formulation and solving the problems
- Finding the optimal values of the decision variables and goals

The process of multi-objective land allocation

- Producing 12 fuzzy criterion maps
- Producing 6 suitability maps
- Producing 6 ranked suitability maps
- Introducing the optimal values of the decision variables to MOLA
- Finding the optimal spatial situation of land uses or the mathematical-spatial optimized maps

The linear programming developed model with environmental protection approach is as follows:

$$\text{Min } Z = 14.11x_1 + 12.73x_2 + 15.05x_3 + 13.12x_4 + 5.1x_5 + 14.02x_6 \qquad (10)$$

S.t.

$x_1 \geq 8762.4$

$x_1 < 8932.05$

$x_2 \geq 1271.18$

$x_2 < 1389.00$

$x_3 \geq 1400$

$x_3 < 2810.13$

$x_4 \geq 99.33$
$x_4 < 900$
$x_5 \geq 8.75$
$x_5 < 16$
$x_6 \leq 95.21$
$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 = 12951.80$
$x_1, x_2, x_3, x_4, x_5, x_6 \geq 0$

Using priority structure, two GP models were developed as follows:
Model 1: When the goal at the highest priority level is related to the benefit attribute and the goal at the second priority level is related to the erosion attribute. The economic criterion has priority toward the environmental criterion.

Model 2: When the goal at the highest priority level is related to the erosion attribute and the goal at the second priority level is related to the benefit attribute. The environmental criterion has priority toward the economic criterion. The aforementioned problems are as follows:

Model 1: (11)

$$\text{Min} \quad Z = P_1(d_1^-, d_1^+), P_2(d_2^-, d_2^+)$$

s.t. $1595950x_1 + 27996150x_2 + 3334720x_3 + 392049470x_4 + 47770730x_5 + 1595950x_6 - d_1^+ + d_1^- = 150494153400$

$18.54x_1 + 14.03x_2 + 15.79x_3 + 16.37x_4 + 7.5x_5 + 16.2x_6 - d_2^+ + d_2^- = 161897.5238$

$x_1 \geq 8454.59$
$x_1 < 8508.411$
$x_2 \geq 1234.335$
$x_2 < 1389.009$
$x_3 \geq 590.868$
$x_3 < 2728.679$
$x_4 \geq 96.453$
$x_4 < 2301.529$
$x_5 \geq 8.498$
$x_5 < 120.586$
$x_6 \leq 95.218$
$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 = 12951.8019$
$x_1, x_2, x_3, x_4, x_5, x_6, d_1^-, d_1^+, d_2^-, d_2^+ \geq 0$

Model 2: (12)

$$\text{Min} \quad Z = P_1(d_1^-, d_1^+), P_2(d_2^-, d_2^+)$$

s.t. $18.54x_1 + 14.03x_2 + 15.79x_3 + 16.37x_4 + 7.5x_5 + 16.2x_6 - d_1^+ + d_1^- = 161897.5238$

$1595950x_1 + 27996150x_2 + 3334720x_3 + 392049470x_4 + 47770730x_5 + 1595950x_6 - d_2^+ + d_2^- = 150494153400$

$x_1 \geq 8454.59$
$x_1 < 8508.411$
$x_2 \geq 1234.335$
$x_2 < 1389.009$
$x_3 \geq 590.868$
$x_3 < 2728.679$
$x_4 \geq 96.453$
$x_4 < 2301.529$
$x_5 \geq 8.498$
$x_5 < 120.586$
$x_6 \leq 95.218$

The different lexicographic optimization stages cannot be solved simultaneously. They must be formed and then solved sequentially because each subsequent stage needs optimality information from the previous stage. Hence, solving a preemptive GP is a dynamic process.

$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 = 12951.8019$
$x_1, x_2, x_3, x_4, x_5, x_6, d_1^-, d_1^+, d_2^-, d_2^+ \geq 0$

The min problem for Z_L has infeasible solution and for this reason the linear programming problems for estimating Z_L and Z_U have calculated in max status as follows:
The linear programming problems for estimating Z_L:

Max = z; (13)
$z = 14.11*x_1 + 12.73*x_2 + 15.05*x_3 + 13.12*x_4 + 5.1*x_5 + 14.02*x_6;$
$x_1 <= 8932.05;$
$x_2 <= 1389.009;$
$x_3 <= 1620;$
$x_4 <= 900;$
$x_5 <= 16;$
$x_6 <= 95.218;$
$x_1 >= 8762.404;$
$x_2 >= 1271.1823;$
$x_3 >= 590.868;$
$x_4 >= 99.332;$
$x_5 >= 8.7519;$
$x_6 >= 0;$
$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 = 12951.8019;$
$x_1 >= 0;$
$x_2 >= 0;$
$x_3 >= 0;$
$x_4 >= 0;$
$x_5 >= 0;$
$x_6 >= 0;$
The linear programming problem for estimating Z_U is as follows:
Max = z; (14)
$z = 14.11*x_1 + 12.73*x_2 + 15.05*x_3 + 13.12*x_4 + 5.1*x_5 + 14.02*x_6;$
$x_1 <= 9027.268;$
$x_2 <= 1503.44;$
$x_3 <= 2810.1355;$
$x_4 <= 1824.06;$
$x_5 <= 120.59;$
$x_6 <= 95.218;$
$x_1 >= 8762.404;$
$x_2 >= 1271.1823;$
$x_3 >= 590.868;$
$x_4 >= 99.332;$
$x_5 >= 8.7519;$
$x_6 >= 0;$
$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 = 12951.8019;$
$x_1 >= 0; x_2 >= 0;$
$x_3 >= 0; x_4 >= 0;$
$x_5 >= 0; x_6 >= 0;$
and atlast the fuzzy linear programming is as follows:
Max = λ; (15)
$\lambda (183460-181316.4)-(14.11x_1 + 12.73x_2 + 15.05x_3 + 13.12x_4 + 5.1x_5 + 14.02x_6)<=181316.4;$
$95.218 \lambda + x_1 <=8932.05;$

$114.431\ \lambda + x_2 <= 1503.44;$
$1190.1355\ \lambda + x_3 <= 2810.1355;$
$924.06\ \lambda + x_4 <= 1824.06;$
$104.59\ \lambda + x_5 <= 120.59;$
$0\lambda + x_6 <= 95.218;$
$x_1 >= 8762.404;$
$x_2 >= 1271.1823;$
$x_3 >= 590.868;$
$x_4 >= 99.332;$
$x_5 >= 8.7519;$
$x_6 >= 0;$
$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 = 12951.8019;$
$x_1, x_2, x_3, x_4, x_5, x_6, \lambda \geq 0$

Where, x_1, x_2, x_3, x_4, x_5, and x_6 are the decision variables of the model and indicate the amount of land that must be allocated to the rangeland, irrigated agriculture, dry farming, garden, forest plantation and forest land uses, respectively.

RESULTS AND DISCUSSION

In the present study, Simplex methods were used to solve the problems. Tables 1 and 2 show some important results after solving the LP problem by the simplex method, and the solution value for decision variables of model.

Alsotables 1 and 2 show the total contribution of decision variables to the objective functions and the reduced cost values. The total contribution of a decision variable to the objective function is equal to the multiplication of its final solution and the objective function coefficient.

As shown in Table 1, rangelands in LP model contributed more to the objective functions.

The reduced cost value indicates how much the objective function coefficient on the corresponding variable must be improved before the value of the variable will be positive in the optimal solution. In the case of a minimization problem, "improved" means "reduced" and in the case of a maximization problem, "improved" means "increased". Any basic variables must have a reduced cost that is exactly 0. However, the reduced cost value is only non-zero when the optimal value of a variable is zero. The reduced cost of a variable interprets as the amount of penalty one would have to pay to introduce one unit of that variable into the solution. According to table 1 in LP model all variables have a reduced cost of 0 and are basic variables. Also, the constraint summary for the models is shown in tables 2. It include the surplus or slack variables and shadow price of each constraint.

The slack variable is the variable added to the left-hand side of a less than or equal to (≤) constraint to convert the constraint into an equality. The slack variable is the starting basic variable for the constraint. It can be interpreted as the unused resource or right-hand side.

The surplus variable is the variable subtracted from the left-hand side of a greater or equal to (≥) constraint to convert the constraint into an equality. It can be interpreted as the amount over the requirement or right-hand side.

The shadow price of a constraint is the marginal change of the objective function when the right-hand side value of that constraint increases by one unit.

According to table 2, in LP model, there was a corresponding maximum decrease in C6.

In other words, the objective value would fall by 15.05 units in the minimization model.

The decision variables and corresponding constraints, which had more positive and negative amount of shadow price, are more important.

Table 1. The decision variables and their solution values and the total contribution of them for LP model.

Decision Variable	Solution Value (hectare)	Total Contribution	Land Use Area Before Optimization (hectare)	Increase or Decrease in Comparision to Current Condition (%)	Reduced Cost
X_1	8932.05	126031.22	8762.4	Increase (1%)	0
X_2	1389.01	17682.08	1271.18	Increase (9%)	0
X_3	1619.52	246373.85	2510.13	Decrease (54%)	0
X_4	900	11808	99.33	Increase (906%)	0
X_5	16	81.6	8.75	Increase (82%)	0
X_6	95.22	1314.69	0	Forest Potential	0

Table 2. The reduced cost values, slack or surplus variables and Shadow Price values for LP model.

Constraint	Slack or Surplus Variables	Shadow Price	Constraint	Slack or Surplus Variables	Shadow Price
C1	169.65	0	C7	800.67	0
C 2	0	-0.94	C8	0	-1.93
C 3	117.82	0	C9	7.25	0
C 4	0	-2.32	C10	0	-9.95
C 5	219.52	0	C11	0	-1.03
C 6	1190.61	0	C12	0	15.05

Tables 3 and 4 show some important results after solving the FLP problem by the simplex method, and the solution value for decision variables of model.
Also tables 3 and 4 show the total contribution of decision variables to the objective functions and the reduced cost values.
As shown in Table 3, rangelands in FLP model contributed more to the objective functions too.

According to table 3 in FLP model all variables have a reduced cost of 0 and are basic variables too. Also, the constraint summary for the models is shown in tables 4. It include the surplus or slack variables and shadow price of each constraint.
According to table 4, in FLP model, there was an equal corresponding maximum decrease or increase for all constraints because of their equal shadow price.

Table 3.The decision variables and their solution values before and after optimization and their increase or decrease in comparision to current condition, the total contribution and the reduced cost values for FLP model.

Decision Variable	Solution Value (hectare)	Total Contribution	Land Use Area Before Optimization (hectare)	Increase or Decrease in Comparision to Current Condition (%)	Reduced Cost
X_1	8840.54	124740.11	8762.4	decrease (1%)	0
X_2	1393.47	17738.91	1271.18	increase (9%)	0
X_3	1666.43	25079.8	2810.13	Decrease (59%)	0
X_4	936.05	12280.99	99.33	Increase (940%)	0
X_5	20.08	102.41	8.75	increase (229%)	0
X_6	95.21	1334.95	0	Forest potential	0

Table 4. The constraint summary for FLP model.

Constraint	Slack or Surplus Variable	Shadow Price	Constraint	Slack or Surplus Variable	Shadow Price
C1	78.14	0	C 4	836.71	0
C 2	122.29	0	C 5	11.32	0
C 3	1075.56	0	C 6	95.21	0

Tables 5 and 6 show some important results after solving the problem by the simplex method, and the solution value for decision variables of models GP1and GP2, respectively.
Tables 7 and 8 show the total contribution of decision variables to the objective functions and the reduced cost values. As shown in Table 7, for model 1, x_4 or gardens in G1 and x1 or rangelands in G2 contributed more to the objective functions, and for model 2 as shown in table 8, x_1 or rangelands in G1 and x_4 or gardens in G2 contributed more to the objective functions.

According to table 7 in model 1 x_6 is a non-basic variable and has a reduced cost of -1738770.00 for G1 and 0.41 for G2. So, it is necessary to pay a penalty to introduce this variable into the solution. In other words, the objective value would fall by 1738770.00 units in a maximization model or increase by 0.41 units in a minimization model. Table 7 shows that model 1 x_6 is a non-basic variable and had a reduced cost of -1738770.00 for G1 and 0.41 for G2.

Table 5. The decision variables and their solution values for GP model 1.

Decision Variable	Land Use	Solution Value (hectare)
x_1	rangeland	8454.59
x_2	irrigated agriculture	1389.01
x_3	dry farming	686.09
x_4	garden	2301.53
x_5	forest plantation	120.59
x_6	forest	0

Table 6. The decision variables and their solution values for GP model 2.

Decision Variable	Land Use	Solution Value (hectare)
x_1	rangeland	8454.59
x_2	irrigated agriculture	1389.01
x_3	dry farming	2728.68
x_4	garden	163.72
x_5	forest plantation	120.59
x_6	forest	95.22

Table 7. The total contribution and reduced cost values of decision variables for GP model 1.

Goal Level	Decision Variable	Total Contribution	Reduced Cost
G1	x_1	13493102592.00	0
G1	x_2	38886903808.00	0
G1	x_3	2287910912.00	0
G1	x_4	902313279488.00	0
G1	x_5	5760480768.00	0
G1	x_6	0	-1738770.00
G2	x_1	156748.11	0
G2	x_2	19487.80	0
G2	x_3	10833.33	0
G2	x_4	37676.03	0
G2	x_5	904.40	0
G2	x_6	0	0.41

Table 8. The total contribution and reduced cost values of decision variables for GP model 2.

Goal Level	Decision Variable	Total Contribution	Reduced Cost
G1	x_1	156748.11	0
G1	x_2	19487.80	0
G1	x_3	43085.84	0
G1	x_4	2680.10	0
G1	x_5	904.4	0
G1	x_6	1542.53	0
G2	x_1	13493102592.00	0
G2	x_2	38886903808.00	0
G2	x_3	9099380736.00	0
G2	x_4	64186310656.00	0
G2	x_5	5760480768.00	0
G2	x_6	151963168.00	0

As shown in Table 8, in model 2, all decision variables had a reduced cost of 0 and they are basic variables that exist in the optimal solution.
Also, the constraint summary for models 1 and 2 is shown in tables 9 and 10. They include the left-hand side, right-hand side, surplus or slack, and shadow price of each constraint.
The right-hand side of a constraint usually is a constant value that represents the maximum (≤, =) or minimum (≥) requirement. The left-hand

side value of a constraint is equal to the sum of the decision variable value times its coefficient in the constraint. When the left-hand side value of a constraint is equal to its right-hand side value, the constraint is tight; otherwise, it is loose.

According to Table 9, in model 1, there was a corresponding maximum increase in C8 and corresponding maximum decrease in C1 for goal 1, (maximization problem). Also, there was a corresponding maximum increase and decrease in C1 and C10, respectively for goal 2 (minimization problem).

In other words, the objective value would fall by 1738770.00 units or would increase by 388714752 units in a maximization model and would fall by 8.29 units or increase by 2.75 units in a minimization model.

Table 9. The constraint summary for GP model 1.

Constraint	Left Hand Side	Right Hand Side	Slack or Surplus	Shadow Price Goal 1	Shadow Price Goal 2
C1	8454.59	8454.59	0	-1738770.00	2.75
C2	8454.59	8508.41	53.82	0	0
C3	1389.01	1234.33	154.67	0	0
C4	1389.01	1389.01	0	24661430.00	-1.76
C5	686.09	590.87	95.22	0	0
C6	686.09	2728.68	2042.59	0	0
C7	2301.53	96.45	2205.08	0	0
C8	2301.53	2301.53	0	388714752.00	0.58
C9	120.59	8.50	112.09	0	0
C10	120.59	120.59	0	44436008.00	-8.29
C11	0	95.22	95.22	0	0
C12	12951.80	12951.80	0	3334720.00	15.79

Table 10. The constraint summary for GP model 2.

Constraint	Left Hand Side	Right Hand Side	Slack or Surplus	Shadow Price Goal 1	Shadow Price Goal 2
C1	8454.59	8454.59	0	2.17	-390453536.00
C2	8454.59	8508.41	53.82	0	0
C3	1389.01	1234.33	154.67	0	0
C4	1389.01	1389.01	0	-2.34	-364053312.00
C5	2728.68	590.87	2137.81	0	0
C6	2728.68	2728.68	0	-0.58	-388714752.00
C7	163.72	96.45	67.27	0	0
C8	163.72	2301.53	2137.81	0	0
C9	120.59	8.5	112.09	0	0
C10	120.59	120.59	0	-8.87	-344278752.00
C11	95.22	95.22	0	-0.17	-390453536.00
C12	12951.80	12951.80	0	16.37	392049472.00

As shown in Table 10, in model 2, there was a corresponding maximum decrease in C8 and corresponding maximum increase in C1 for goal 1 (minimization problem), as well as a corresponding maximum decrease in C1 and C11 for goal 2 (maximization problem). In this case, the gardens had a shadow price of 0.

In preemptive GP, users frequently address sensitivity concerns by rotating priorities. If there are r priority levels, there are r! different ways of rotating the priorities. Normally, a user will select a small number of these possibilities and then resolve the

problem for each of them. The result is usually a group of some of the most different goal-efficient points in solution set. In this study, based on rotating priorities, the two proposed models were formulated and analyzed. The sensitivity analysis of the objective function coefficient (c_j) for LP model showed that c1 is the most important coefficient and its changes caused more changes in the objective function solution.

As c1 increased by 5%, the amount of erosion increased to 1.02 %.

The sensitivity analysis of the objective function coefficient (c_j) for FLP model showed that c1 is the most important coefficient and its changes caused more changes in the objective function solution. As c1 decreased by 5%, the amount of erosion decreased to 4%.

The sensitivity analysis of the objective function coefficient (c_j) for GP models showed that c1 and c4 are the most important coefficients and their changes caused more changes in the objective function solution. As c1 increased by 5%, the amount of erosion increased to 2.29 and 1.91% in model 1, and as c4 increased by 5%, the benefit increased to 4.61 and 4.91% in model 2, respectively. In the table 11 models have been compared on the basis of their effects on the amount of profit and erosion and changes in land uses. To evaluate the produced models, measurement model, is used as an evaluation criterion.

Table 11. models comparision

Model / Index	Measurement	LP	FLP	GP1	GP2	Corrent Condition
Erosion (ton per year)	178487.48	181311.69	181277.19	181569.25	181311.69	203982.84
Decrease in comparision to corrent condition (%)	13	12	12	11	12	-
Benefit ($)	5837575.95	3698042.49	3789103.67	3716282.11	3694511.36	1885922.17
Increase in comparision to corrent condition (%)	309	96	200	97	95	-
R^2 in relation to measurement condition	-	0.9667	0.9658	0.9552	0.9667	-

Figures. 1 to 13 shows the result of performing spatial optimization.

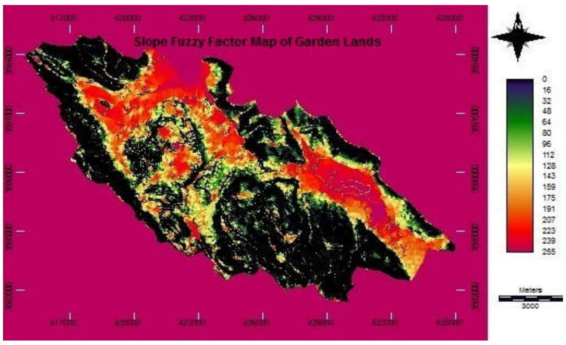

Figure 1. Slope fuzzy factor map of gardens

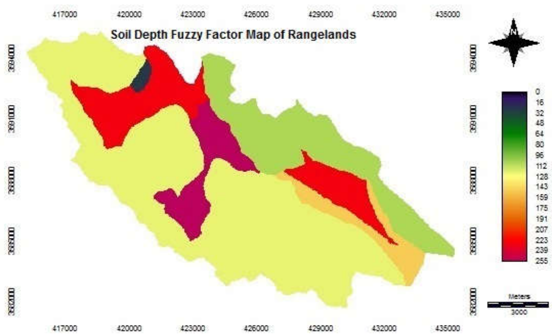

Figure 2. Soil depth fuzzy factor map of rangelands

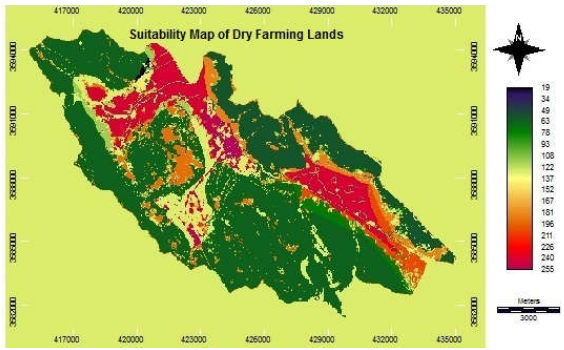

Figure 3. Suitability map of dry farmings

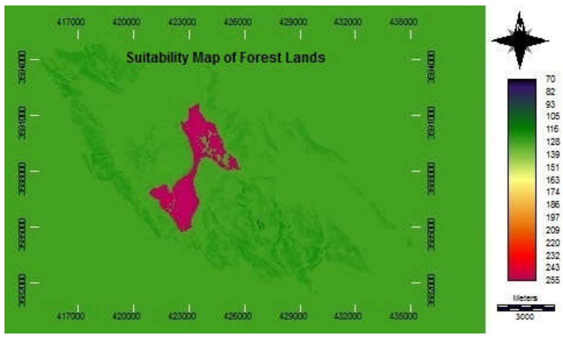

Figure 4. Suitability map of forest

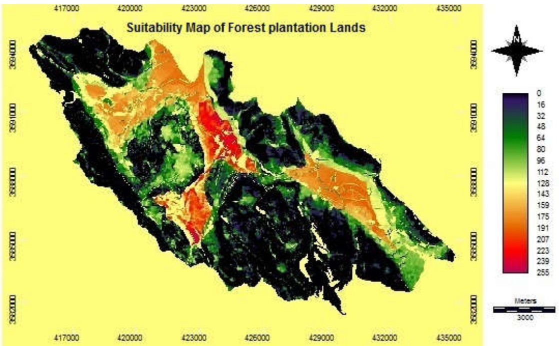

Figure 5. Suitability map of forest plantations

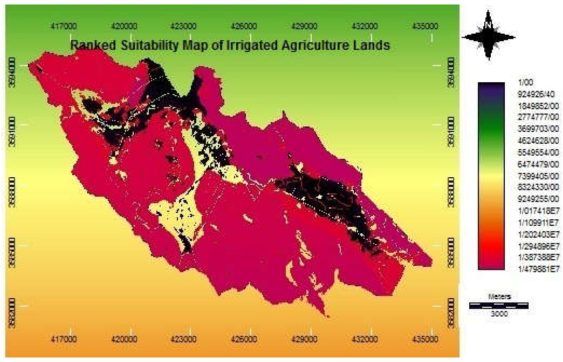

Figure 9. Ranked suitability map of irrigated agricultures

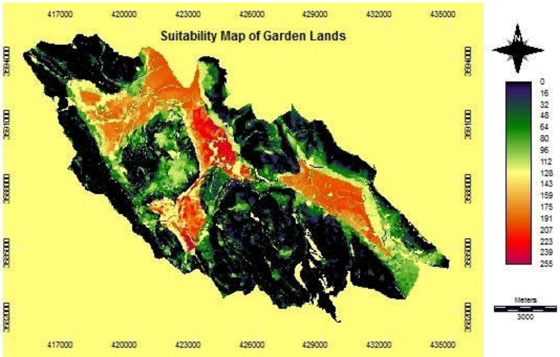

Figure 6. Suitability map of gardens

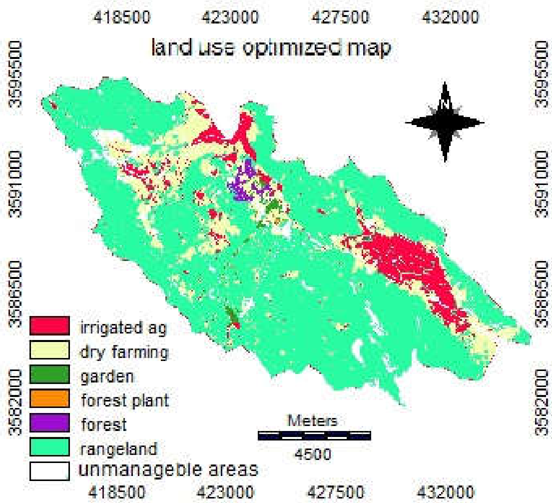

Figure 10. Land use optimized map for LP model

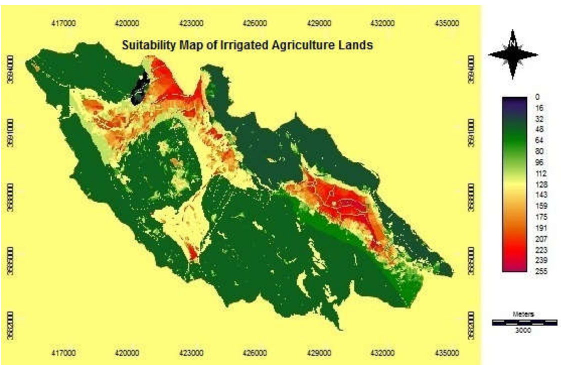

Figure 7. Suitability map of irrigated agricultures

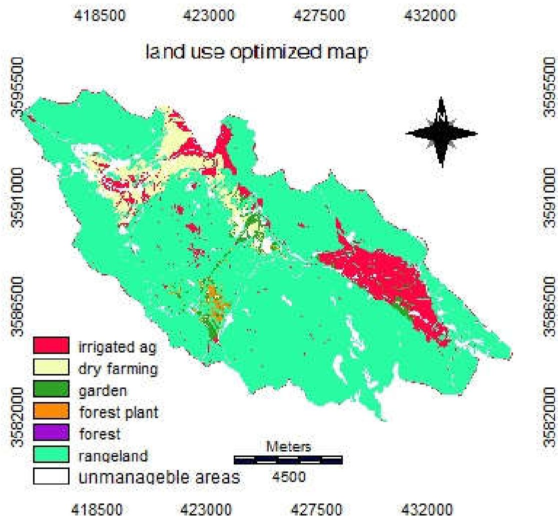

Figure 11. Land use optimized map for FLP model

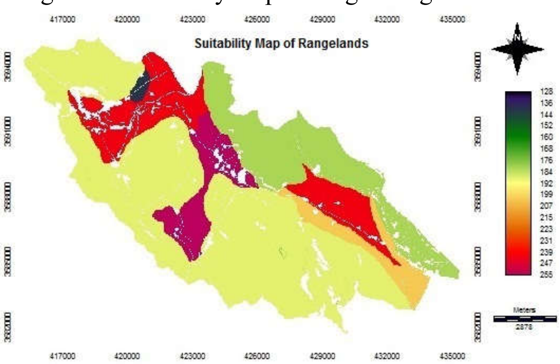

Figure 8. Suitability map of rangelands

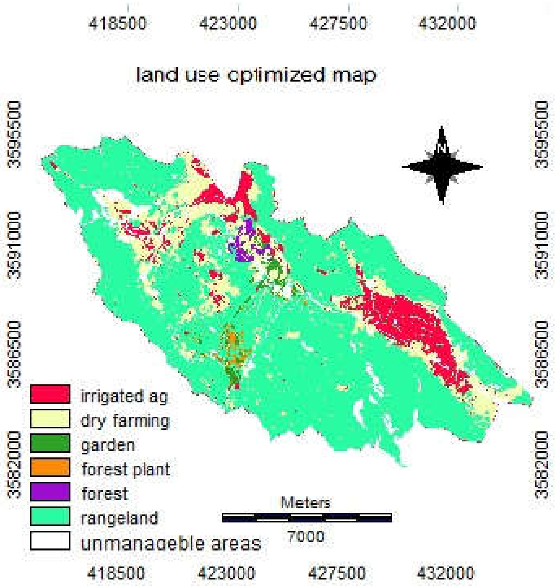

Figure 12. Land use optimized map for GP1 model

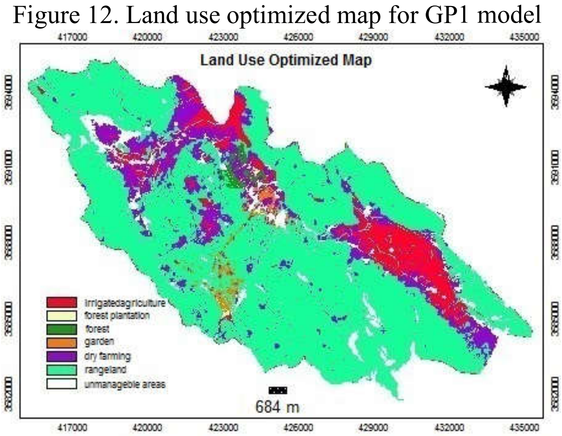

Figure 13. Land use optimized map for GP2 model

CONCLUSION

About the LP – MOLA model the results showed that the proposed combined model can decrease the amount of soil erosion to 9 percent. Also, the results indicated that under optimized condition, the area allocated to dry farming lands will decrease about 54% and the area of rangelands, irrigated agricultures, gardens and forest plantation will increase about 1%, 9%, 906% and 82% respectively. About the FLP – MOLA model the results showed that this proposed combined model can decrease the amount of soil erosion to 12 percent too. Moreover, the results indicated that under optimized condition, the area allocated to dry farming lands will decrease about 59% and the area of rangelands, irrigated agricultures, gardens and forest plantation will increase about 1%, 9%, 94% and 229% respectively. About the GP – MOLA model the results showed that the land use optimization can increase benefit to 97% and decrease erosion to 12%, respectively. Besides, the results indicated that under optimized condition, the area allocated to dry farming lands will decrease about 33% and the area of rangelands, irrigated agricultures, gardens and forest plantation will increase about 0%, 9%, 906% and 82% in model 1 with benefit attribute priority and the area allocated to dry farming lands will decrease about 54% and the area of rangelands, irrigated agricultures, gardens and forest plantation will increase about 1%, 9%, 906% and 82% in model 2 with erosion attribute priority respectively. Furthermore the result of performing spatial optimization indicated that people are still making use of land that does not follow the optimized procedure in the current condition. It is obvious land use structure indicate some displacement of land uses because of optimal spatial allocation of them on the basis of FAO measurements and also some area development or remaining unchanged of gardens, irrigated agricultures, forest plantations and rangelands and decrease of dry farming lands. In addition to, the results demonstrated the usefulness and efficiency of the proposed models due to their flexibility and capability to simultaneously provide both optimum values and location of production resources.

References

Akbari, N.; Zahedi Keyvan, M., (2007). Application of fuzzy logic in determination of suitable crop cultivation pattern in a farm (Approach: fuzzy goal programming), Journal of Agricultural Economics 1(2): 13–35.

Allen, R. G.; Pereira, L. S.; Raes, D.; Smith, M., (1998). Crop evapotranspiration: guide-lines for computing crop water requirements. In: FAO Irrigation and Drainage Paper No. 56. FAO, Rome, Italy.

Amini, A., (2013). Planning and Optimal Allocation of Agricultural Production Resources under Uncertainty; Application of Multi-Objective Fuzzy Goal Programming approach, Geography and Environmental Planning Journal 51(3): 107–128.

Arkhi, S.; Yoosefi, S.; Rostamizad, Gh., (1392). Survey the effect of land use optimization in decreasing erosion and sedimentation of Chamgardlan dam watershed using GIS, Geography and Territorial Spatial Arrangement, 6, 75-84.

Brengle, K. G., 1982. Principles and practices of dry land farming, Translated Version, JDM Press, Mashhad, Iran, 236p.

Chamheydar, H.; Nhkkami, D.; Pazira, A.; Ghafouri, M., (2011). Soil loss minimization through land use optimization. World Applied science Journal, 12, 76-82.

Daliri, F.; Seraji, H. S.; Kholghi, M., (1388). Watershed system planning and management using optimization model (Case study: Gharmabdasht Watershed), Journal of Range and Watershed Management, Iranian Journal of Natural Resources, 62(2), 247-256.

FAO, 1992. Guidelines for land use planning. Prepared by the Interdepartmental Working Group on Land Use Planning, Soils Bulletin 66, Rome.

FAO. 1976. A Framework for Land Evaluation, Soils Bulletin 32, Rome.

FAO. 1983. Guidelines: Land Evaluation for Rainfed Agriculture, Soils Bulletin 52, Rome.

FAO. 1984. Land Evaluation for Forestry, Forestry Paper 48, Rome.

FAO. 1985. Guidelines: Land Evaluation for Irrigated Agriculture, Soils Bulletin 55, Rome.

FAO. 1990. Guidelines: Land Evaluation for Extensive Grazing, Soils Bulletin 58, Rome.

Fooks J. R.; Messer K.D., (2012). Maximizing conservation and in-kind cost share: Applying goal programming to forest protection, Journal of Forest Economics, 18, 207–217.

Hamdi, A. T., 2002. Operations research: an introduction. Eighth Edition., University of Arkansas press, Fayetteville, 840 pp.

Han, Y.; Huang, Y.F.; Wang, G.Q.; Maqsood, I., (2011). A multi-objective linear programming model with interval parameters for water resources allocation in Dalian city, Water Resource Management, 25: 449–463.

http://watershedmg.com/

Kooreh Pazan, A., 2008. Principles of fuzzy set theory and its applications in models of water engineering problems, Amir Kabir University Press, 262 p.

Mahler, P. J., 1979. Manual of land classification for irrigation (third revised edition), Soil Instituted of Iran, Tehran, Iran, 205, 103 P.

Mohseni Saravi1, M.; Farzanegan, M.; Koupahi, M.; Kholghi, M., (1382). Optimum utilization pattern of watershed resources using goal programming, Iranian Journal of Natural Resources, 1,2, 3-16

Nikkami, D., (1999). Optimizing the management of soil erosion using GIS, PhD thesis, Concordia University, 108 p.

Pajoohesh, M.; Gorji, M.; Taheri, m.; Sarmadiyan, F.; Mohamadi, j.; Samadi, H., (1390). Effect of land use on sediment yield using GIS in Zayandehrood upstream basin, Iran water research Journal, 5(8), 143-152.

Pimentel, D.; Harvey, C.; Resosudarmo, P.; Sinclair, K.; Kurz, D.; Mcnair, M., et al., (1995). Environmental and economic costs of soil erosion and conservation benefits, Science, 267 (5201), 1117-1123.

Pishdad Salmanabad, L.; Najafinejad, A.; Salmanmahini, A., (1387). Survey the effects of land use change on soil erosion in Cheraghveise watershed. Journal of agricultural sciences and natural resources, 5(1): 141-149.

Salyani, T., (1375). Design the crop pattern in water resources projects. Agricultural economics and development, 4(15): 91-93.

Singh, A. K.; Singh J. P., (1999). Production and benefit maximization through optimal crop planning: a case study of Mahi Command, Indian, Journal of Soil Conservation, 27(2), 152-157.

Steuer, R. E., (1985). Multiple criteria optimization: theory, computation, and application. John Wiley&Sons, New York, chapter 10, 282-303.

Yeo, I.; Gordon, S. I.; Guldmann, J., (2004). Optimizing patterns of land use to reduce peak runoff flow and non-point source pollution with an integrated hydrological and land-use model. AMS Online Journals Access Control, 6(8): 1–20.