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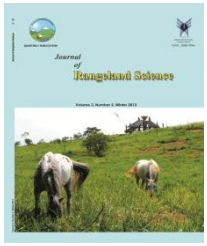

Full Length Article:

Prediction of Land Use Management Scenarios Impact on Water Erosion Risk in Kashidar Watershed, Azadshahr, Golestan Province

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Abstract. Soil erosion is a serious problem especially in northern parts of Iran. One the most important side effects on soil erosion may be the decline in qualities of soil refers to agricultural productivity. So it is very important to assess the soil erosion risk for the sustainable development of agriculture. This study outlines ways undertaken to provide a new tool to manage water erosion from physical and economical perspectives. Kashidar Watershed in north of Iran is used as a case study. The focus of this study is on exploring the economic and physical impacts of eight land use-based scenarios for water erosion management as well as conducting a trade-off analysis using the Multi-Criteria Decision Making (MCDM) technique. This involves developing a modeling system to assist decision makers in formulating scenarios, analyzing the impacts of these scenarios on water erosion, interpreting and suggesting appropriate scenarios for implementation in the area. This study was conducted with object of modeling and assessing soil erosion risk in Kashidar Watershed with the application of IMAGE\LDM. Rainfall erosivity index, relief index, soil erosivity index and land cover index were four basic factors used in IMAGE\LDM. Soil erosion risk can be divided into six groups. Furthermore, the spatial distribution characteristics were also analyzed with the application of GIS in the view of elevation, land use types. Among 8 scenarios for water erosion management, most appropriate ones that have minimum proportion of high water erosion hazard classes, maximum gross margin and minimum establishment cost were chosen as best scenarios.

Key words: Land use, Water erosion, Trade-off analysis, MCDM, Kashidar Watershed

1. Introduction

Economic development and human welfare largely depend on optimum utilization of natural resources (Karunakaran, 2012). Successive crops planting cause cropland economic efficiency reduction. Continuing this process will lead to a big reduction in farmer's income (Singh, 2008). Improper selection and cultivation of traditional crops will exacerbate the problem (Maroyi, 2012). Appropriate land use selection in the agricultural field increase farmer's income (Karunakaran, 2012). Thus revision of agricultural land use is very useful for agricultural area unites, income increment, and land use application improvement. Kashidar watershed ecosystem has a vital role for economy of the region. Golestan Natural Resources bureau, (2009) recommended an integrated management with these goals; 1) to increment community awareness and skills in order to implement the conservation and rehabilitation of land in agricultural systems, and 2) to establish agricultural land use system based on the ability of land to support sustainable land use. Land use conflicts in Kashidar Watershed area are associated with the preservation of ecosystem where erosion and sedimentation rate is very high and they will improve farmers' welfare and income, to attain food security, poverty spread prevention and to provide jobs (Hengki *et al*., 2012).

More than 80% of native people in Kashidar Watershed live below the poverty line. Kashidar Watershed farmlands are mainly rain fedcultivation. Income obtained from this type of farming is not enough for farmers living costs. One of the best ways to increase farmers' income, is land use management of these lands. The appropriate land use selection due to farmers' income increases. Land use change requires compliance consideration with the technical, economical and social characteristics. Therefore, a scenario planning is required to achieve optimum sustainable farming systems (Nikkami, 2009).

Severe erosion usually causes a decrease in producing agricultural products, which demonstrates the strong impact of usage on the amount of erosion (Martha, 2004). Suitable land use selection reduces soil erosion (Martha, 2004). Soil erosion in Kashidar Watershed is higher than normal amount (Golestan Natural Resources Bureau, 2009). Land use management scenarios for reducing phosphorous leak to lower Green Bay in the State of Michigan using the SWAT were used. This research result showed the best land use management scenarios to reduce the phosphorous leak (Baumgart and Fermanich, 2008). The Unit Stream Power based Erosion/Deposition model was applied to predict land use management scenarios impact on water erosion. Results showed that the whole erosion from urban areas scenarios was higher than other land use scenarios (Leh *et al*., 2011). Revised Universal Soil Loss Equation (RUSLE) model and Geographic Information Systems (GIS) with geo-statistical techniques were adopted to study different land use management scenarios impact on water erosion risk. Results showed that the RUSLE model was a good method to estimate soil erosion risk in different scenarios because it was simple, fast and economical to use (Ferreira and Panagopoulos, 2012).

A model used for regional soil erosion evaluation is semi-quantitative methods. The Integrated Model to Assess the Global Environment (IMAGE) is a dynamic integrated assessment modeling framework for global change. Land degraded model is one of the basic models of IMAGE (Tingting, 2008). The aim of this study was to use the Integrated Model to Assess the Global Environment (IMAGE)- Land Degrade Model (LDM)

to evaluate the soil erosion risk in Kashidar Watershed.

2. Materials and Methods

The study area is located in Southern East of Golestan Province, Iran. Geographically the study area lies between 55°27' to 55°40' E and 36°56' to 37°5'N, the altitude of area is 950-2500 m above sea level with an area of 15017 ha. The study area accommodates 6 villages (Golestan Natural Resources Bureau, 2009). Map of the study area in Iran and Golestan Province showed in (Fig. 1).

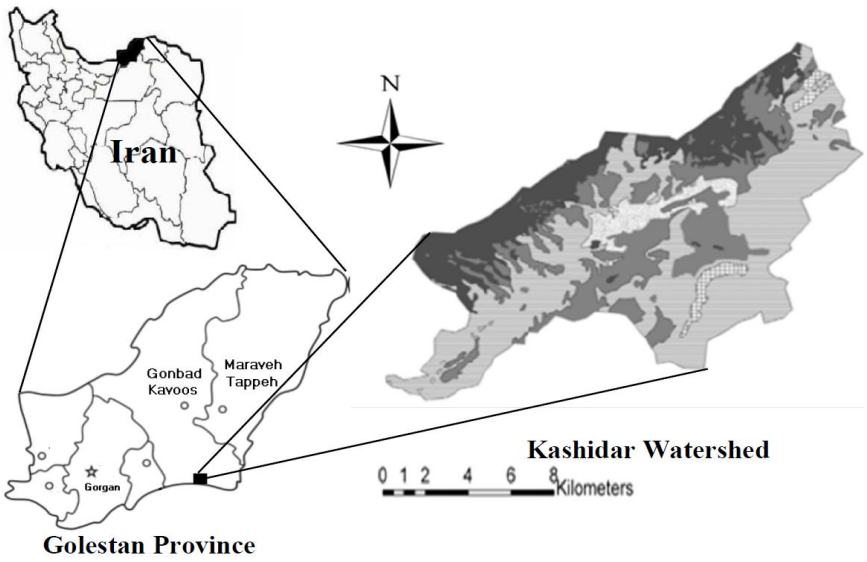

Fig. 1. Map of the study area in Iran and Golestan Province

The Integrated Model to Assess the Global Environment (IMAGE)- Land Degrade Model (LDM) was used to evaluate the soil erosion risk in the study area. The (IMAGE)- Land Degrade Model (LDM) input map layers include rainfall erosivity index (R-factor), relief index, soil erodibility index and land cover index (Tingting, 2008).

Among the four major factors affecting the soil erosion, rain is the main agent for erosion, which reflects the potential rate of soil erosion. Not all rainfalls can induce soil erosion except those showers of high intensity. So the erosivity of rainfall is mainly determined by the intensity of rainfall events. Rainfall in Kashidar Watershed is very unevenly distributed, which mainly concentrates in spring season, so the rainfall data from March to June was used to calculate R-factor. According to IMAGE-LDM, the monthly average intensity of rainfall (mm/day) was selected as the indication of rainfall intensity. If the maximum monthly average of rainfall intension of three months exceeds 2mm/day, the R-factor is assigned 1. If the maximum monthly average of rainfall intension of three months belongs to 0 to 2mm per day, the R-factor is assigned 0. If the value between these two extremes a linear relation is assumed (Tingting, 2008).

Based on these factors LDM model provides a map that shows the susceptibility and potential sensitivity to water erosion in Kashidar Watershed. Potential susceptibility and sensitivity to water erosion is ranged from E1 to E6. From E1 to E6, the potential susceptibility and sensitivity to water erosion gradually increased (Tingting, 2008).

These maps were prepared and superimposed using the ArcGIS software to estimate the water erosion severity over the study area. The Spearman rank correlation coefficient was calculated to evaluate the accuracy of hazard zonation (Mesdaghi, 2004). To develop management scenarios, all feasible management actions were listed and all of the possible combinations of those actions were considered. In order to determine the feasible management actions, all the planning constraints such as time, costs, labor, efficiency, and regulations were considered. The feasible management actions for the southern parts of Kashidar Watershed are enclosure, Forage cultivation and orchard planting. Assuming the present condition as a base case scenario, the number of new scenarios will be $2^n - 1$, in which n is the number of management actions. The base case scenario is regarded as scenario one and the other scenarios are compared with it (Heathcote, 1998). The scenario development rules are shown in (Table 1).

Table 1. Rules for land use-based scenario development for the Kashidar Watershed

Management Action	Suitable Areas (before Implementation of Action)	Condition after Implementation of Actions
Enclosure	Poor & moderate rangelands	Moderate & good rangelands
Forage cultivation	Dry land farm	Moderate agricultural land
Orchard planting	Irrigated farm lands	Good agricultural land

For each scenario, the land cover pattern map was synthesized using the query command of the ArcGIS software. By assuming that the other four input maps of the LDM model are not changing by the management actions, the water erosion hazard map for each scenario was created. The LDM is based on the concept of soil susceptibility and sensitivity to water erosion. Susceptibility to water erosion is based on the current terrain erodibility and rainfall erosivity. Sensitivity to water erosion describes the chance that water erosion will occur accounting for the actual land use and land cover. According to LDM, soil erosion susceptibility and sensitivity index were calculated. On the basis of water erosion-sensitivity index, soil erosion risk grade can be determined (Tingting, 2008). The eight land use-based scenarios developed for the study area by combining all different management actions is shown in (Table 2).

Table 2. Land use-based scenarios developed to manage the water erosion in the Kashidar Watershed

Management Action	S1	S2	S3	S4	S5	S6	S7	S8
Enclosure	-	+	-	-	+	-	+	+
Forage cultivation	-	-	+	-	+	+	-	+
Orchard planting	-	-	-	+	-	+	+	+

The extent of water erosion hazard classes for each scenario was compared with classes of the present condition (base case scenario). The Kappa index of agreement was used for comparison purposes. Several criteria and indices can be used to select the best scenario among various scenarios. Usually a set of criteria which include the public attitude and values are suggested (Heathcote, 1998). However, in this study, the physical and economical criteria were used. Differences between water erosion hazard maps at the present condition after implementation of each scenario were used as the physical index. To sum up, the ordinal values of water erosion hazard classes had been multiplied by their extent and gathered to obtain the value of the physical index. Since the implementation of each scenario results into changes in the dry mass production, total gross margin and establishment costs were used as two indices of economic criteria. Total gross margin is described as the gross income minus the variable costs associated with an enterprise/activity (Heathcote *et al*., 002).

The total gross margin generated from a given set of management activities is calculated by Equation 1.

$$G = \sum_{j=1}^{m} \left(P_j Y_j - C_j\right) A_j \qquad \text{Equation 1}$$

Where:

G is total gross margin;

P_j is price of crop j (Iranian Rials per production unit, kg);

$Y_j$is yield of crop j per unit area (ha);

C_j running cost of crop j (Iranian Rials per unit area);

m is the number of crops, and

A_j is the area under crop j.

The values of input parameters used in the economic calculations were obtained from the previous rangeland management studies conducted in the study area (Golestan Natural Resources Bureau, 2009).

For land use-based scenarios the establishment costs are identified as labor cost and seed price. The establishment costs of each management scenario were calculated by Equation 2.

$$E = \sum_{i=1}^{n} d_i \left(A_i - \bar{A}_i\right) \qquad \text{Equation 2}$$

Where,

E is establishment costs;

d_i is the cost of the management activity i;

A_i is the area of activity i;

$\bar{A}_i$ is the area of activity i for base case scenario; and n is the number of management actions.

Therefore, the costs of each management scenario are the sum of all actions costs.

The linear scale transformation had been used to convert the original index values into standardized index values. There are various methods of linear scale transformation. In this study, the method of maximum standardization had been applied. In this method, to standardize a benefit effect, the value of each index was divided by the highest value of the index across different scenarios. For instance, to standardize the gross margin index, its value for each scenario was divided by the highest value of the index across different scenarios. For a cost effect, such as water erosion (the physical index) and establishment costs (an economic index) Equation 3 had been used:

$$\text{score}_{\text{standardized}} = 1 - \frac{\text{score}_i - \text{score}_{\min}}{\text{score}_{\max}}$$

(Equation 3)

The Delphi method was used to assign weights to the indices. For this purpose, a panel of six experts in natural resources management had been addressed and requested to weight the indices on a given scale of 0 to 1. After gathering the responses, they had been collated and returned back to the contributors and requested to revisit the weights in case of inconsistency. This process was repeated until a consensus

was reached on the weights assigned to the criteria. Multiple Criteria Decision Making (MCDM) technique had then been applied to evaluate the scenarios. For each scenario, the standardized score of indices had been multiplied by their corresponding weights and summed up to provide a criterion for evaluation purpose. The scenarios with higher total sum of weighted scores were identified as the best ones. For visual comparison of the index values associated with each scenario, segment diagram presentation was utilized. A sensitivity analysis was carried out to determine the dependency of results to the weights of the indices (Knack, 1996).

3. Results

3.1. Model analysis

The input parameters of the LDM model were estimated and summed up to predict the water erosion severity of the study area across the management scenarios and their respective water erosion hazard maps were then synthesized. For instance, (Fig. 2 and Table 3), show the water erosion hazard map and the extent of water erosion hazard classes of the study area for the present condition, respectively.

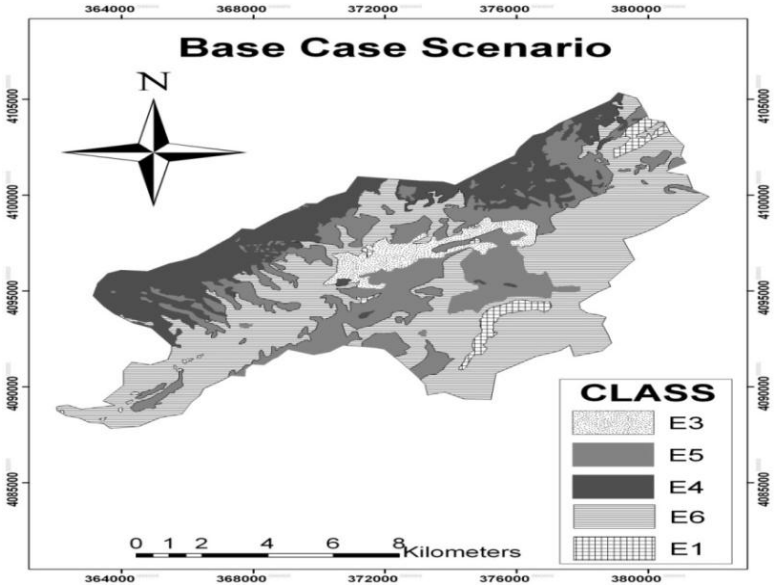

Fig. 2. Water erosion hazard map of the Kashidar Watershed for the present conditions

Table 3. Distribution of water erosion hazard classes for the present condition (base case scenario) From E1 to E6 in the Kashidar Watershed

Hazard Class	E1	E2	E3	E4	E5	E6	Sum
Area (ha)	982	0	1446	3303	3754	5531	15017
Area (%)	6.5	0	9.5	22	25	37	100

There was no area with E2 water erosion hazard class in Kashidar Watershed (Table 3). Also the water erosion hazard maps corresponding to scenarios containing single actions were displayed in (Fig. 3). According to the LDM model, the differences observed in the water erosion hazard maps of the management scenarios are due to the changes in two input indices of land cover and relief indices.

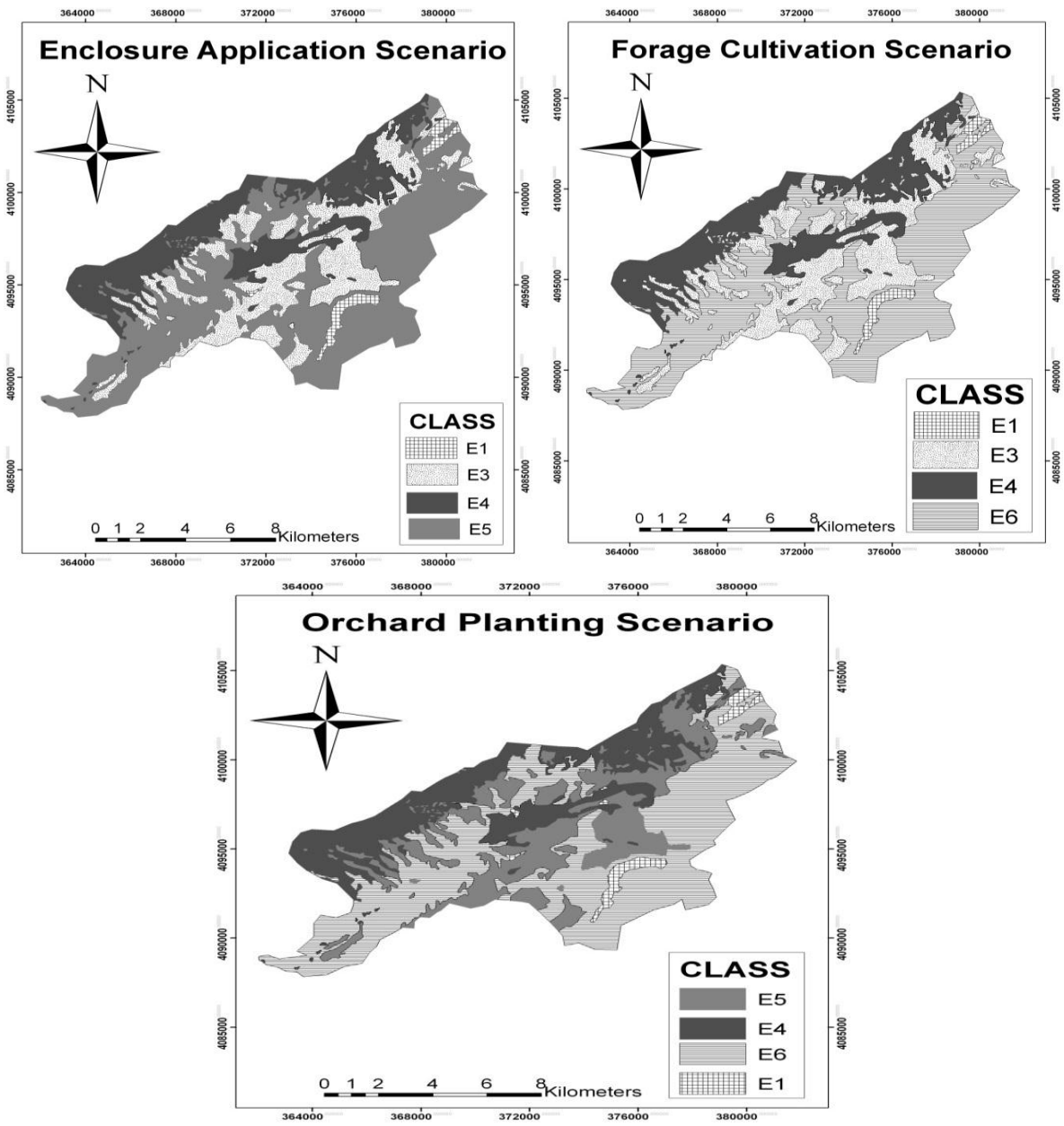

Fig. 3. Water erosion hazard maps corresponding to the single action management

The water erosion hazard map of the present condition was compared with those of the other management scenarios pairwise. (Table 4), presents the Kappa-index agreement of water erosion hazard for scenario1 against the other scenarios. As shown in the table, the degree of agreement varies from 0.01 to 0.4. The low degree of agreement indicates the significant impact of the management scenarios. The minimum and maximum degrees of agreement correspond to the S8 and S7, respectively. This is mostly due to the extent of the areas allocated to the management actions. For instance, in Scenario 8 all the management actions were implemented over the whole study area while in Scenario 4 only a limited proportion of the study area, suitable for the action, was allocated to orchard planting.

Table 4. The Kappa-index of agreement of water erosion hazard for scenario1 against the other scenarios

Scenario	S2	S3	S4	S5	S6	S7	S8
Kappa index	0.09	0.03	0.07	0.11	0.08	0.11	0.16

The Spearman correlation coefficient indicated the conformity between the hazard classes of water erosion map predicted by the LDM model and ground evidences. It varies between -1 (a perfect negative correlation) and +1 (a perfect positive correlation). This indicates the appropriate performance of the LDM model to assess water erosion hazard classes in the Kashidar Watershed.

3.2. Indices analysis

The following assumptions were made to quantify the economic indices. The price of unit of dry mass production is 4000 IRI Rls. The enclosure and forage cultivation will increase the dry mass production by 100 and 7000 kg.ha^{-1}, respectively. The implementation of each scenario incurs some establishment costs which are about 20 and 200 million IRI Rls per hectare for forage cultivation and Orchard planting actions, respectively. There was no establishment cost for enclosure. In addition, for some actions there were some running costs (variable costs) which should be figured out. They include preparation, re-plantation, enclosure, maintenance, and harvesting costs. For fifteen-year decision horizon, the total costs of forage cultivation and orchard planting were estimated 300 million and 3,000, million IRI Rls per unit area. (Fig. 4), illustrates the change in total gross margin (Terms of ten million Rials) for each scenario and (Fig. 5), shows the establishment costs (Terms of ten million Rials) corresponding to each scenario.

To quantify the physical index, the water erosion hazard maps corresponding to various scenarios were used. For each scenario, the rank of each water erosion hazard class was multiplied by its extent and summed up to obtain the quantitative value of the physical index. (Fig. 6), displays the quantitative value of the physical index for various management scenarios.

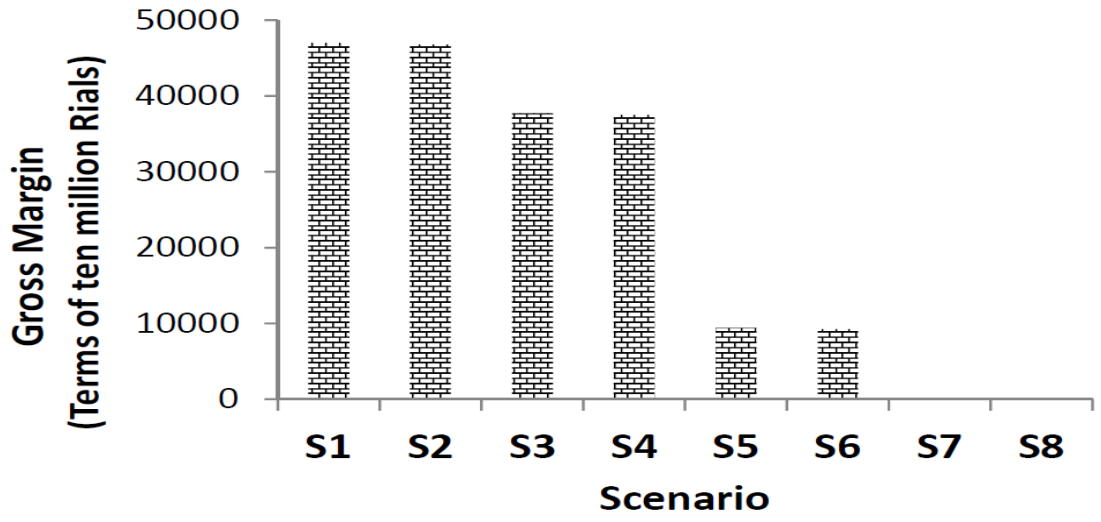

Fig. 4. The change in total gross margin across eight management scenarios

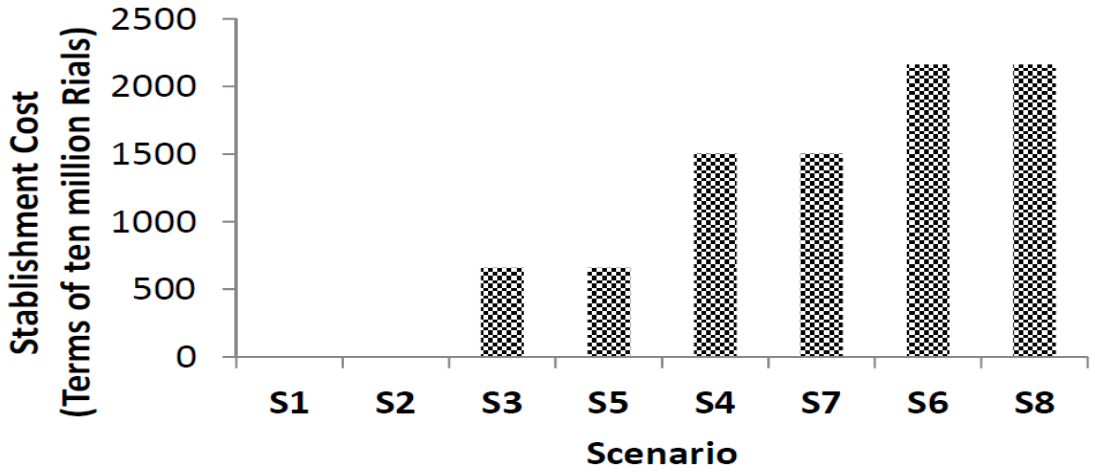

Fig. 5. The establishment costs across eight management scenarios

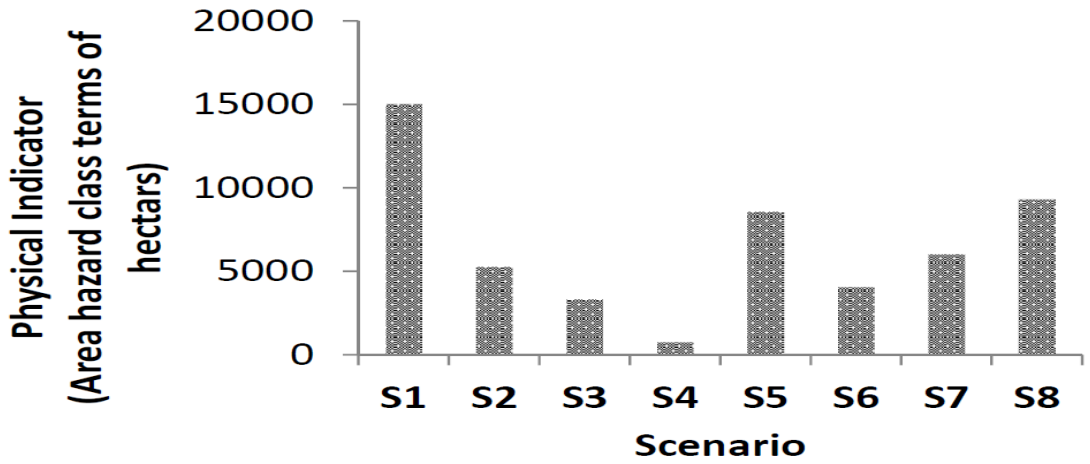

Fig. 6. The physical index across the management scenarios

3.3. Trade off analysis

The Delphi approach was applied to assign the weights to the indices. Based on this approach the weights of water erosion (physical index), gross margin, and establishment costs (economic indices) was determined as 0.4, 0.4, and 0.2, respectively. After standardization of the indices, their values were multiplied by their weights and summed up to obtain the final score for each scenario. The scenarios S8, S5, S7, and S2 ranked from 1 to 4, respectively.

A suitable visual technique assists in representing and interpreting multivariate data sets. Thus, segment diagram presentation was utilized to represent the outcome variables corresponding to each management scenario (Fig. 7). In segment diagrams the values of variables were scaled independently so that the maximum value (or 'best') in each variable was 1 and the minimum (or 'worst') was 0.0 Segment diagrams facilitate comparison between cases. To facilitate comparison among the management scenarios in segment diagrams, for those variables with adverse impacts, their inverted values were represented in the diagrams. This was the case for 'establishment costs' and 'physical index'. That is, an 'increase' in all variables corresponds to a good outcome. Hence, the radii of the diagrams show the level of achievement of management objectives considering all impact indices.

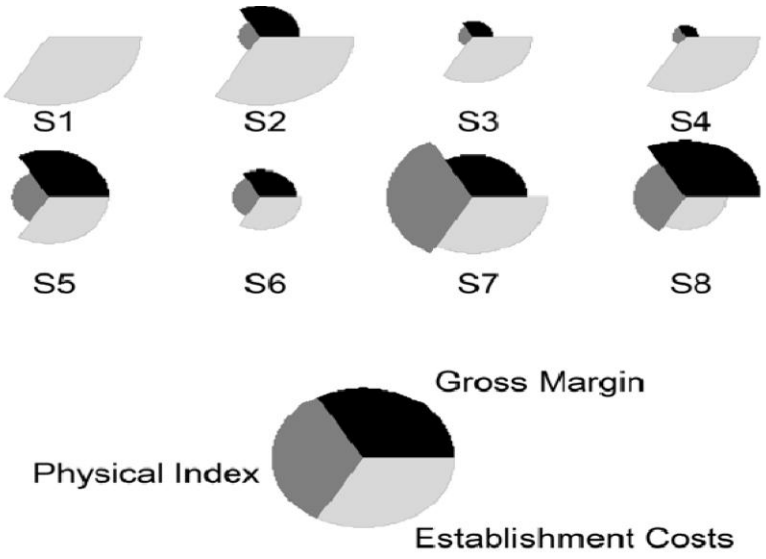

Fig. 7. Values of impact indices for the 8 management scenarios in the Kashidar Watershed

Trade-off analysis indicates that the scenarios S8, S5, S7 and S2 were the best scenarios to control water erosion hazard in the Kashidar Watershed. To investigate the robustness of the results, a sensitivity analysis was carried out. To this end, we used three different perspectives, in each a specific index was emphasized on.

4. Discussion

Based on the LDM model, land cover and relief indices are the two important parameters controlling the water erosion rate and hazard. Therefore, selection and implementation of best land use types and management practices are necessary to control water erosion in a region. Using a scenario-based approach is a straight forward and efficient way to choose the best land use type over an area. Since each management scenario may have some positive and negative physical and/or economical impacts, a MCDM approach was applied to trade off the impacts and chooses best scenario/s.

The Spearman correlation coefficient indicated a high conformity between the hazard classes of water erosion map predicted by the LDM model and ground evidences. To develop the scenarios, the technical limitations related to the management actions had been considered. It was also assumed that there were no serious ecological and social limitations for implementation of the management actions. In other words, all of the scenarios were considered to be feasible.

Considering the physical index, the best scenario was the one that corresponds to an erosion map with a minimum proportion of high water erosion hazard classes. While considering the economic indices, the scenarios which result in minimum establishment costs and maximum total gross income are identified as best scenarios. The scenario S7, S8, S5 and S6 were appropriate scenarios when only the physical index is considered (Fig. 6). Considering the total gross income index, the scenarios S8, S5, S7 and S2 were among best group of scenarios. Regarding the establishment costs, the best group of scenarios was identified as S1, S7, S5 and S8. However, when the physical and economic indices were collectively considered the order of best scenarios differs markedly. To do this, a MCDM approach had been used. Based on this approach, the scenarios S8, S5, S7 and S2 had been ranked as best ones to control water erosion in the study area. To evaluate the different management scenarios, they had been

compared with the present condition. This was similar to the methodology implemented by Cerck (1996), Armanino *et al*. (2000), and Sadoddin (2006).

The sensitivity analysis indicated that the results of the MCDM were not significantly affected by the different perspectives. The result of the sensitivity analysis indicated that four scenarios of S8, S5, S7 and S2 were among best scenarios regardless of the weighting perspectives. These four scenarios are identical with the scenarios which were chosen by the Delphi approach as best scenarios. This indicates the robustness of the approach implemented in this study.

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پیش‌بینی اثرات سناریوهای مدیریت کاربری اراضی بر خطر فرسایش آبی (مطالعه موردی: حوزه آبخیز کاشیدار، شهرستان آزاد شهر، استان گلستان)

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چکیده

فرسایش آبی در ایران و بخصوص بخش‌های شمالی این کشور شدید است. یکی از مهمترین اثرات جانبی فرسایش آبی کاهش کیفیت خاک برای تولید محصولات کشاورزی است. بنابراین ارزیابی خطر فرسایش آبی برای توسعه پایدار در بخش کشاورزی ضروری است. این تحقیق جهت دستیابی به ابزاری جدید برای مدیریت فرسایش آبی با توجه به عوامل فیزیکی و اقتصادی انجام شد. حوزه آبخیز کاشیدار در شمال ایران به عنوان مطالعه موردی انتخاب شد. تجزیه و تحلیل اثرات فیزیکی و اقتصادی ۸ سناریو مدیریت کاربری اراضی با استفاده از روش تصمیم‌گیری چند معیاره انجام شد. روش تصمیم‌گیری چند معیاره یک سیستم مدل سازی برای کمک به تصمیم‌گیران در فرموله کردن سناریوهای پیشنهادی، تجزیه و تحلیل اثرات این سناریوها در فرسایش آبی، تفسیر و پیشنهاد سناریوهای مناسب برای پیاده سازی در منطقه است. این مطالعه با هدف مدل سازی و ارزیابی خطر فرسایش آبی در حوزه آبخیز کاشیدار با استفاده از مدل IMAGE\LDM انجام شد. شاخص‌های توان فرسایشی بارش، پستی و بلندی، فرسایش پذیری خاک و پوشش سطحی چهار عامل اساسی مورد استفاده در مدل IMAGE\LDM هستند. خطر فرسایش آبی در شش کلاس طبقه‌بندی شده است. علاوه بر این، توزیع فضایی ارتفاع و انواع استفاده از زمین نیز مورد ارزیابی قرار گرفت. تجزیه و تحیل‌های انجام شده نشان داد که از میان ۸ سناریوی مختلف مدیریت فرسایش آبی سناریوهایی که مساحت کلاس‌های خطر فرسایش آبی آنها حداقل، درآمد ناخالص حداکثر و هزینه استقرار حداقل است، سناریوهای برتر هستند.

کلمات کلیدی: کاربری اراضی، فرسایش آبی، تجزیه و تحلیل، MCDM، حوزه آبخیز کاشیدار