Multi Criteria Analysis for Finding the Best Economical Pitting Sites against Rangelands Degradation

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Abstract

Decision making for Rangeland degradation control is very complicate and strongly need to apply computer and multi criteria analysis. In this study aim is finding the best economical pitting sites for reduction degradation in rangelands. Pitting is a mechanical soil and water conservation by making pits in surface. By storing the rainfall water in pits, vegetation cover will be better and rangelands degradation will be reduced. Hable Roud watershed in north of Iran had many spatial data. The research techniques are multi criteria analysis and decision support. Spatial natural and environmental data is used. Some criteria are needed to find the best economical pitting sites. In this watershed, a model with these spatial factors (sediment yield ...), economic factors (proximity to roads ...) and constraints (slope less than 10% ...) was designed. These maps were entered to computer and rasterised and by SMCE module in ILWIS software were analyzed. Maps were standardized in value range between 0 till 1. They were weighted by AHP or direct method. Compositing of these prepared layers were done by SMCE. Output was composite index map. This map was classified and prioritized for pitting measures. This model can help to decision making and measure ends anticipatory be faster, easier and more exactly.

Keywords: Multi Criteria Analysis, decision making, pitting Sites, Rangeland Degradation

1 Introduction

Soil conservation planning is too complicate because there are multi criteria that must be considered. Pitting is a mechanical soil and water conservation by making pits in surface with 20 to 15 cm depth and 15 to 25 cm width and 1 m length. The big side must be parallel to contour lines. Distance of rows should be 0.8 until 1 m and surface of pits occupy 10% until 20% of land surface (Moghaddam, 1998). By storing the rainfall water in pits, vegetation cover will be better and rangelands degradation is reduced. In this study aim is finding the best economical pitting sites for reduction degradation in rangelands. The research techniques are multi criteria analysis and

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decision support. Spatial natural and environmental data is used. Environmental concepts are becoming common and ever more important parts of decision support models, which are a vital part of decision support systems (Žnidaršič et al., 2006). Development of environmental decision support systems (EDSS) is rapidly progressing. The sustainable management of natural resources has a growing research focus as the awareness of the complexity of interactions between socio-cultural, economical and biophysical system components is increasingly acknowledged. As better data and methods become available, the complexity of the system representation is augmenting. At the same time, realism and relevance are increasing and allowing direct support for management and policy development (Matthies et al., 2007). FuzzyCell is a system designed and implemented to enhance commercial GIS (Geographic Information System) software, namely ArcMap® with fuzzy set theory. FuzzyCell allows users to (a) incorporate human knowledge and experience in the form of linguistically defined variables into GIS-based spatial analyses, (b) handle imprecision in the decision-making processes, and (c) approximate complex ill-defined problems in decision-making processes and classification (Yanar and Akyürek, 2006). Analyses using the spatial decision support systems (SDSS) show that restrictions on soil loss to the "tolerance level" (T) cause average farm income to decline by only 4%, a reduction that is nearly eliminated if the Conservation Reserve Program (CRP) is available to farmers as an income-generating alternative (Lant et al., 2005). Conventional Multiple Criteria Decision Making (MCDM) techniques have largely been non-spatial. They use average or total impacts that are deemed appropriate for the entire area under consideration (Tkach and Simonovic, 1997). However, in this study all factors and constrains are spatial. The data driven approach, sometimes called data mining, is considered as very promising, because theory in general in many disciplines is poor and spatial data is becoming increasingly available (rapid move from a data poor environment to a data rich environment). Spatial multicriteria decision analysis requires data on the geographical locations of alternatives and/or geographical data on criterion values. To obtain information for the decision making process the data are processed using MCDM as wells as GIS techniques. Spatial multicriteria decision analysis is a process that combines and transforms geographical data (the input) into a decision (the output). This process consists of procedures that involve the utilization of geographical data, the decision maker's preferences, and the manipulation of the data and preferences according to specified decision rules. In this process, multidimensional geographical data and information can be aggregated into one-dimensional values for the alternatives. The difference with conventional multicriteria decision analysis is the large number of factors necessary to identify and consider, and, the extent of the interrelationships among these factors. These factors make spatial multicriteria decision analysis much more complex and difficult (Malczewski, 1999). GIS and MCDM are tools that can support the decision makers in achieving greater effectiveness and efficiency in the spatial decision-making process. The combination of multi-criteria evaluation methods and spatial analysis is referred as Spatial Multiple Criteria Evaluation "SMCE". SMCE is an important way to produce policy relevant information about spatial decision problems to decision makers (Sharifi and Retsios, 2003).

2 Study Area

Hable Roud watershed is in north of Iran. The area is located between latitudes 35° 13' 55" to 35° 57' 31" North and longitudes 51° 51' 39" to 53° 08' 46" East and. its rainfall varies between 150 to 550 mm bottom-up. Average annual rainfall is 318 mm. average elevation is 2052 m. Climate is arid and semi arid cold. Stones are dolomite, lime, marl with gypsum and salt, andesite, basalt, cinite, dasite and tuff in mountain part. In plain parts there are alluvial and calluvial materials from quaternary. There are 69 villages with 234 average populations (Figure 1). For sediment yield mapping MPSIAC (Modified Pacific Southwest Inter-Agency Committee) (Vente and Poesen, 2005) method was used.

Figure 1: Position of Hable Roud in Iran

3 Methods

3.1 SMCE (Spatial Multiple Criteria Evaluation) Definition

Criteria may be of two types: factors and constraints. Factors are generally continuous in nature (such as the slope gradient or roads proximity factors). Proximity maps were made by buffering around line, point or polygon features. They indicate the relative suitability of certain areas. Constraints, on the other hand, are always Boolean in character. They serve to exclude certain areas from consideration. Factors and constraints can be combined in the SMCE.

Tradeoff is the degree to which one factor can compensate for another; how they compensate is governed by a set of factor weights sometimes called tradeoff weights. Factor weights are given for each factor such that all factor weights, for a set of factors, sum to one; they indicate the relative importance of each factor to the objective under consideration. A factor with a high factor/tradeoff weight may compensate for low suitability in other factors that have lower factor/tradeoff weights.

In addition to tradeoff, any SMCE is also characterized by some level of assumed risk that will strongly influence the final suitability map. Factor maps: natural (sediment yield, less steeper slope, and isohyets), economic factors (proximity to roads, proximity to villages) and constraints: (slope less than 10%, land use rangeland, geomorphology faces not rock and stone, not villages, not roads, not rivers, and rainfall upper 100 mm yr^{-1} are suitable) (Figure 2). These spatial data were used to designing the suitable pitting sites by entering to sub program "SMCE" from ILWIS 3.3 (Integrated Land and Water Information System) (GIS) software.

These maps changed to raster with unique georeference and pixel size. Criteria tree for the goal mechanical soil conservation Sites Selection was designed.

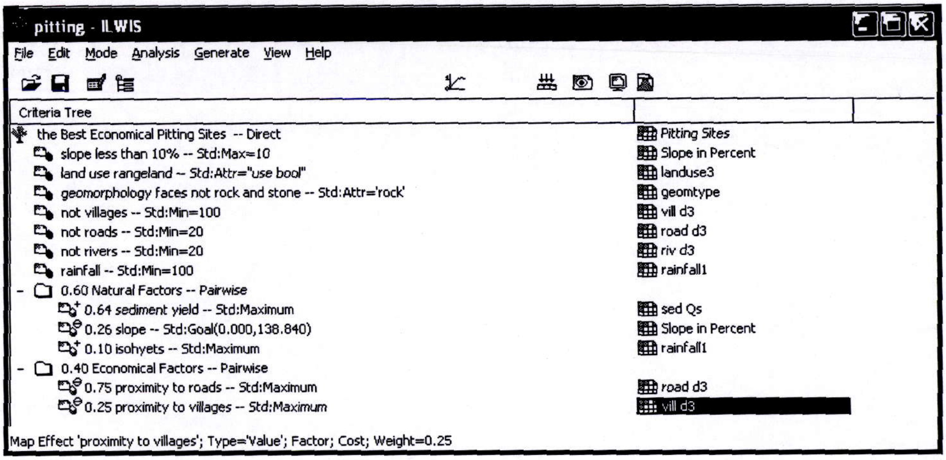

Figure 2: Designing criteria tree model and standardization and weighting the factors and constraints

3.2 Standardization

Standardization converts a quantitative image to a new image expressed as standardization scores.

Standardization of factors (benefits+ and costs-): output values range between 0 and 1; Standardization of constraints; output values are either 0 or 1.

For standardization of factors, you must select one of the following linear standardization functions: Maximum, interval, goal (formulas 1 to 6). In this study, maximum linear functions were used.

In maximum method, the following formulas will be used:

Benefit factor = value / maximum input value (1)

Cost factor = 1 - (value / maximum input value) + (minimum input value / maximum input value) (2)

In interval method, the following formulas will be used:

Benefit factor = (value - minimum input value) / (maximum input value - minimum input value) (3)

Cost factor = 1 - (value - minimum input value) / (maximum input value - minimum input value) (4)

In goal method, the following formulas will be used:

Benefit factor = (value - minimum input value) / (minimum goal value - minimum input value) (5)

Cost factor = 1 - (value - minimum input value) / (maximum goal value - minimum input value) (6)

3.3 Standardization of Constraints

Unlike factor standardization, standardized constraints cannot be compensated by good performance of other criteria. Standardized constraints will either obtain value 0 (not performing) or value 1 (performing). Standardization constraints methods are unequal to zero, minimum, maximum, inside, outside.

For Boolean landuse map, standardization, "TRUE passes, FALSE will be blocked" was used. This means that all input pixels with value True will be included in the output map; all pixels with value False (except rangelands) will be excluded from the output.

3.4 Weights

Weigh multiple factors (benefits and costs) and optional groups under the main goal, and/or weigh multiple factors and optional groups under a sub goal. Assigning weights is needed in order to indicate the relative importance of these factors with respect to the main goal or to optional sub goals.

Direct Method: Decision maker has to specify weight values himself. These user-defined weights are automatically normalized (Figure 3).

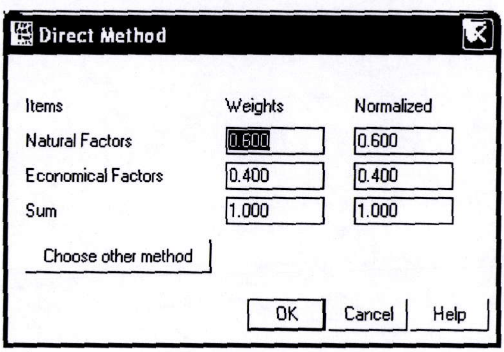

Figure 3: Direct Method was used for weighting

Pairwise Comparison: Decision maker goes through all unique pairs and assigns Saaty weights (in words). From these weights, normalized weights are calculated (Saaty, 1984).
Rank Ordering: Decision maker assigns a rank-order to the items. From this rank-order, normalized weights are calculated. Weights are always numbers between 0 and 1. Weights cannot be negative in Figure 2 see standardize and weight methods that are selected.

4 Results

From Saaty matrix with the best consistency ratio the eigenvector i.e. the relative weights of factors, was calculated. Constraints do not give weight, because they were standardized for being or elimination not a gradient effect. The constraints by Boolean method eliminated from watershed. For example in slope 10% in maximum standardization is upper limit, line for pass i.e. factors effect in area by slope lesser than 10%.
Saaty matrix for factors was performed. Sediment yield gained the biggest weight (0.64) and inconsistency was 0.02. Maximum standardization for natural factors was used.

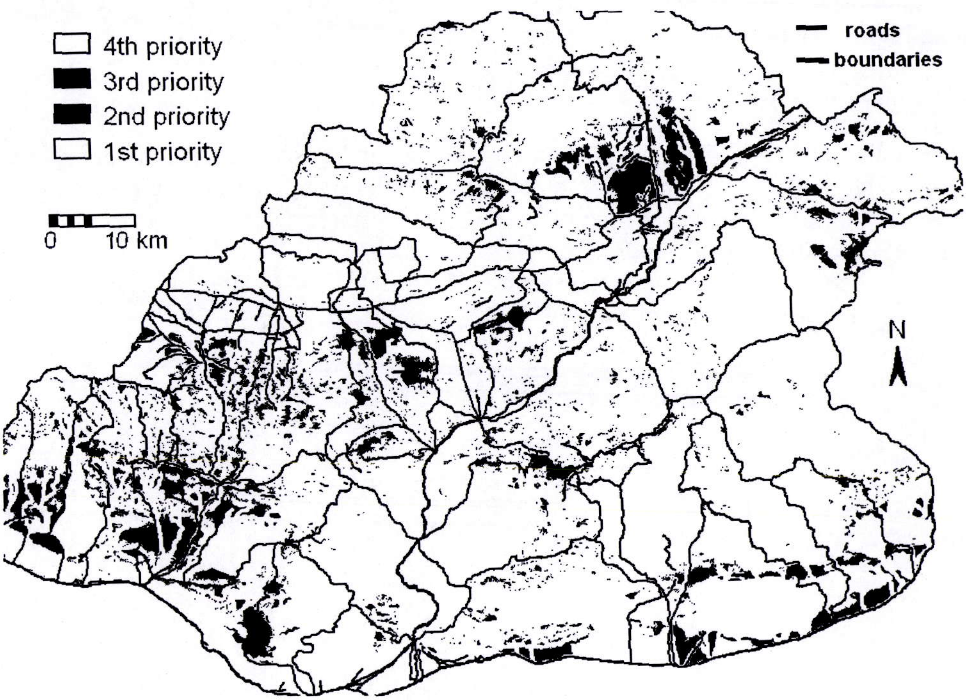

Figure 4: Suitable sites and their priorities for pitting in rangelands

Slope was cost factor and tows other were benefit factor. Maximum method was used for proximity factors. These cost factors were weighted by Pairwise Comparison method and biggest gained by proximity to roads. Composite index map (CIM) in range 0 until 1 was generated by SMCE procedure. Near 0 values in this map had lesser degradation and rainfall and had high distance from roads, villages and had steep slope and near 1 vice versa. Majority pixels in the composite index map got value between 0.55 and 0.95, thus classifying by considering this range was done. In lowest slopes with highest degradation, i.e. value near 1 was recommended 1st priority of pitting (Figure 4).

5 Conclusion

Until making composite index map was design phase. GIS and computer aided to decision maker and stakeholders to composite and analysis multicriteria. After that is selection phase that decision makers by considering some issues are deciding to do projects. This model can help to decision making and measure ends anticipatory be faster, easier and more exactly. Anticipatory aspect is estimating the expense for these conservation measures with considering area of recommended pitting sites. By the way, decision makers can compute the benefits of the project for some years before implementations.

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References

Lant, C.L., Kraft, S.E., Beaulieu, J., Bennett, D., Loftus, T., Nicklow, J., (2005). Using GIS-based ecological–economic modeling to evaluate policies affecting agricultural watersheds, Ecological Economics, Volume 55, Issue 4, Pages 467-484.

Malczewski, J., (1999). GIS and Multicriteria Decision Analysis, John Wiley & Sons, Inc, New York.

Matthies, M., Giupponi, C., Ostendorf, B., (2007). Environmental decision support systems: Current issues, methods and tools, Environmental Modelling & Software, Volume 22, Issue 2, Pages 123-127

Moghaddam, M.R., (1998). Range and Range Management, Tehran University Pub., Tehran.

Saaty, T.L., Vargas, L.G., (1984). Comparison of Eigenvalue and logarithmic least squares and least squares methods in estimating ratios. Mathematical modelling, Vol. 5, pp. 309-324.

Sharifi, M.A., Retsios, V., (2003). Site selection for waste disposal through Spatial Multiple Criteria Decision Analysis, III International Conference on Decision Support for Telecommunications and Information, Society, 4 - 6 September 2003, Warsaw, Poland.

Tkach, R.J., Simonovic, S.P., (1997). A new approach to Multi-criteria decision making in water ressources. Journal of Geographic Information and Decision Analysis, 1(1):25-43.

Vente, J. de, Poesen, J., (2005). Predicting soil erosion and sediment yield at the basin scale: Scale issues and semi-quantitative models, Earth-Science Reviews Volume 71, Issues 1-2, Pages 95-125 .

Yanar, T.A., Akyürek, Z., (2006). The enhancement of the cell-based GIS analyses with fuzzy processing capabilities, Information Sciences, Volume 176, Issue 8, Pages 1067-1085.

Žnidaršič, M., Bohanec, M., Zupan, B., (2006). proDEX – A DSS tool for environmental decision-making, Environmental Modelling & Software, Volume 21, Issue 10, Pages 1514-1516.