Biological Soil Conservation Planning by Spatial Multi-Criteria Evaluation Techniques (Case Study: Bonkuh Watershed in Iran)

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Abstract—This paper discusses site selection process for biological soil conservation planning. It was supported by a value-focused approach and spatial multi-criteria evaluation techniques. A first set of spatial criteria was used to design a number of potential sites. Next, a new set of spatial and non-spatial criteria was employed, including the natural factors and the financial costs, together with the degree of suitability for the Bonkuh watershed to biological soil conservation planning and to recommend the most acceptable program. The whole process was facilitated by a new software tool that supports spatial multiple criteria evaluation, or SMCE in GIS software (ILWIS). The application of this tool, combined with a continual feedback by the public attentions, has provided an effective methodology to solve complex decisional problem in biological soil conservation planning.

Keywords—GIS, Biological soil conservation planning, Spatial multi-criteria evaluation, Iran

I. INTRODUCTION

THIS paper discusses an application of spatial multi-criteria evaluation (SMCE). An introduction to this field can be found in [7], who contributed to bridging the gap between geographical information systems, GIS, and multi-criteria decision analysis, MCDA. SMCE was applied here in support of a watershed management problem of the Bonkuh watershed in Iran.

In the last decade or so, the combination of Geographical Information Systems (GIS) and multicriteria evaluation (MCE) has been routinely adopted as an approach to assess the suitability of an area. MCE in a GIS environment (or spatial multicriteria evaluation, SMCE) is a procedure to identify and compare solutions to a spatial problem, based on the combination of multiple factors that can be, at least partially, represented by maps [9]. This approach takes advantage of both the capability of GIS to manage and process spatial information, and the flexibility of MCE to combine factual information (e.g., soil type, slope, infrastructures) with value-based information (e.g., expert's opinion, quality standards, participatory surveys). Taking into account both technical elements and people's values and perceptions is essential to build consensus around a decision, to reduce conflicts [4; 13; 10; 6; 3].

SMCE is commonly applied to land suitability analysis [see reviews in 8; 14; 1; 5]. However, relatively few studies incorporate stakeholders and public's opinion [4].

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Objective in this paper was biological soil conservation planning by spatial multi-criteria evaluation (SMCE) in GIS software (ILWIS: Integrated Land and Water Information System).
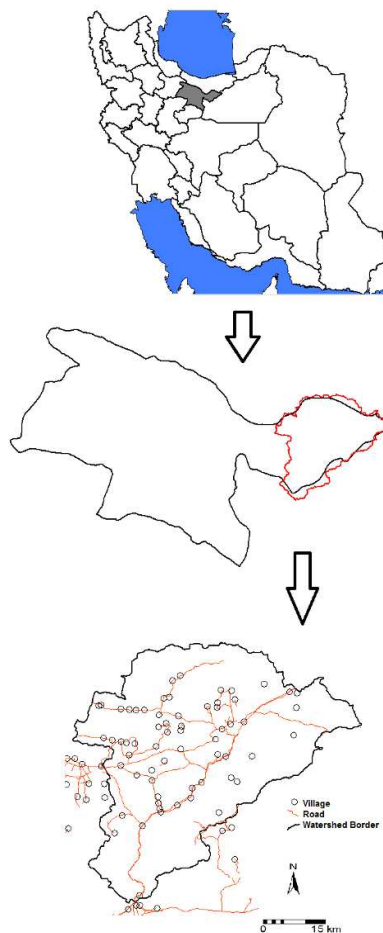

Fig. 1 Bonkuh Watershed in Tehran Province, Iran

II. METHODS

A. Study Area

The studied area is a part of Firuzkouh city, which are located between Firuzkouh city in the north, and Garmsar city in the south. This watershed is located between the longitude 52° 13′18′′ to 53° 8′ 37′′and latitude 35° 17′ 36′′ to 35° 57′ 6′′ and the area is about 327100 hectares. The average of annual temperature in Firuzkouh station is 10.6 °C and rainfall annual average is 282mm.

B. SMCE (Spatial Multiple Criteria Evaluation)

Criteria may be of two types: factors and constraints. Factors are continuous in nature (such as the slope gradient or roads proximity factors). Proximity maps were made by buffering around line, point or polygon features (Figure 3). They indicates 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.

Constraint maps in this study were (geomorph landuse, elevation, road and village). Natural factor maps were (sediment yield, vegetation cover, less steep slope, and isohyets). Economic factors maps were (proximity to roads, proximity to well, proximity to spring and proximity to villages) (Figure 2). These spatial data were used for biological soil conservation planning by entering to sub program "SMCE" from ILWIS 3.31 (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.

C. 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 Boolean 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 will be excluded from the output.
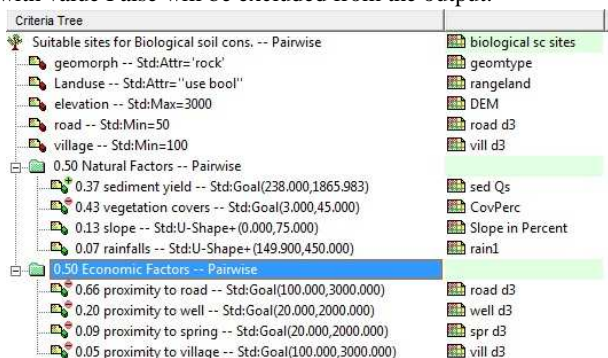
Criteria Tree	
Suitable sites for Biological soil cons. -- Pairwise	biological sc sites
geomorph -- Std:Attr='rock'	geomtype
Landuse -- Std:Attr="use bool"	rangeland
elevation -- Std:Max=3000	DEM
road -- Std:Min=50	road d3
village -- Std:Min=100	vill d3
0.50 Natural Factors -- Pairwise	
0.37 sediment yield -- Std:Goal(238.000,1865.983)	sed Qs
0.43 vegetation covers -- Std:Goal(3.000,45.000)	CovPerc
0.13 slope -- Std:U-Shape+(0.000,75.000)	Slope in Percent
0.07 rainfalls -- Std:U-Shape+(149.900,450.000)	rain1
0.50 Economic Factors -- Pairwise	
0.66 proximity to road -- Std:Goal(100.000,3000.000)	road d3
0.20 proximity to well -- Std:Goal(20.000,2000.000)	well d3
0.09 proximity to spring -- Std:Goal(20.000,2000.000)	spr d3
0.05 proximity to village -- Std:Goal(100.000,3000.000)	vill d3

Fig. 2 Criteria tree for biological measures planning

Weights

Assigning weights is needed in order to indicate the relative importance of factors with respect to the main goal or to optional sub goals. There are some weighing methods that pairwise comparison method was selected here.

In this method decision maker goes through all unique pairs and assigns Saaty weights (in words). From these weights, normalized weights are calculated [15] (Figure 2).

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 [12].

III. RESULTS

From Saaty matrix with the best consistency ratio the eigenvector i.e. the relative weights of factors, was calculated (Figure 2).

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 value in this map had lesser degradation and rainfall and had high distance from roads, villages and had steep slope and near 1 vice versa (Figure 3).
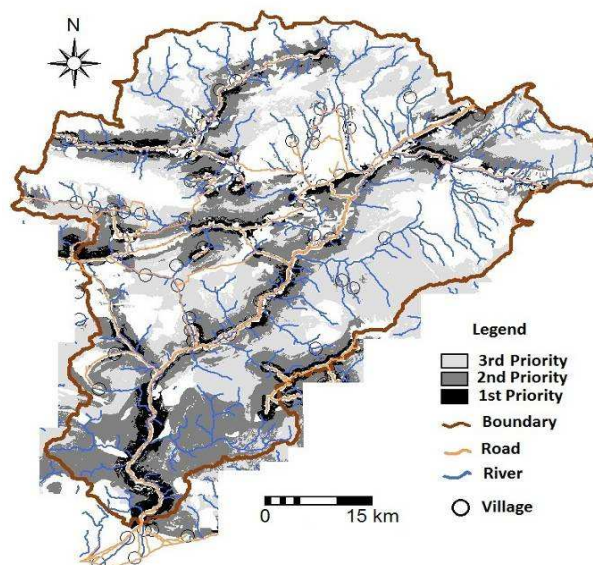

Fig. 3 Final map of biological measures priorities in Bonkuh watershed

IV. CONCLUSION

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 suitable sites. By the way, decision makers can compute the benefits of the project for some years before implementations. SMCE is commonly applied to land suitability analysis [8; 14; 1; 5] and in this research, SMCE was used for land suitability for biologic conservation too.

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