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CROPLAND SUITABILITY ASSESSMENT AND CONFUSION MATRIX EVALUATION WITH GIS

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ABSTRACT

*Aim of the research is to test multi-criteria method for suitability valuation with GIS method in cropland of Bornuur, Mongolia. The research has following steps: (i) to value the suitable land for cropland with basic condition (constraint mapping) (ii) to value the suitable land with Multi-criteria (factor mapping) analysis; iii) to check the integrated suitability assessment image with confusion matrix. Basic condition or constraint map is drawn with Boolean logic method. Weighted value for analysis had been calculated using "ranking hierarchy". Weighted linear model are used for it. Cropland factors hierarchy is sorted out through pair wais comparison technique. The relative weight is calculated using analytical hierarchy processing (AHP) method for sorting factors based on previous researches and shows following values: S=organic matter*0.36+ (A+B) horizon*0.22+ soil texture*0.16 + slope*0.08+ soil moisture*0.06+ altitude*0.04+ soil stoniness* 0.02+ exch. bases* 0.02 + pH*0.02. To check the accuracy and agreement the field study materials archived in 1989-2009 and performed model map had been used in confusion matrix evaluation. It could be concluded that suitability map is prpcessed somewhat correct according to the result of overall accuracy 0.83, matched cells 72-95% and Kappa coefficient 0.8 results. Correspondingly the places modeled for an exploration area for the cropland was matched to the current location of agricultural land possessions.*

KEYWORDS: cropland survey; GIS - MCDA; AHP; capability analysis; multicriteria analysis

INTRODUCTION

Without using natural soil resources human beings are not able to survive. Agricultural land occupies approximately 37.5 percent of the world's land area [1]. By the end of 2013, Mongolian arable land was 911691.43 hectares which is 0.8 percent of the Mongolian total land resources. Whereas 57.2% of the total cultivated areas were under soil erosion process. The soil degradation rate of the total eroded plots after state land evaluation (1998-2013) evaluated as following result: 33.4% is lightly and 9.32% is moderately eroded and strong and extreme degree of soil erosion area reached to 13.2%. Soils in total cultivated area have mostly poorer humus (2% lower) content. 60 percent of the total cultivated area has soil with 2.0% humus content. Soil humus in most cropland has thickness within the range of

15-25 cm. However, about 20 percent of the areas has 25 cm and over thick humus layer [2,3] which are significant available land resource for agricultural development. Presenting well developed agricultural zone Bornuur as an example, the general goal of this paper is to demonstrate the new tool combining multi-criteria assessment with GIS to locate suitable arable plot. The research hypothesis of the paper is multi-criteria decision analysis has capabilities for combining the geographical information system data and confusion matrix into alternative tool for agricultural land survey and should to practice into Mongolian land management planning.

MATERIALS AND METHODS

The general scope of this paper is to express opportunities of combining Multi-Criteria Decision Analysis (MCDA) with geographical information systems (GIS) for suitable cropland suitability survey. Following objectives are: (i) Demonstrate way of MCDA and GIS corporate tool in the survey process for selection of cropland new plots; (ii) Identify physical and geographical criterion for carrying out a spatial MCDA for new cropland production development plots; (iii) Perform an accuracy assessment to compare relative certainty of model with ground truth data using *confusiong matrix*. The study based on geographical information system (GIS) and multi-criteria decision analysis (MCDA) methods. As to our knowledge, no scientific studies have been reported on physical planning of cropland in Mongolia where spatial MCDA is used [4]. Together with the fact that in the past, most arable land survey studies of Mongolia are carried out without spatial MCDA with GIS techniques and omitted confusion matrix control of model giving us good reason for the need of new concept tools, which is presented at this paper. Constraint maps describing minimum requirements for the site selection and factor maps using weighting factors (calculated from The Analytical Hierarchy Process (AHP) software) are produced using developed criterion and constraint. The relevant information obtained for the arable land suitability had been converted into the required constraint layers: (i) Not be located in settlement areas; (ii) Avoid forest reserved areas; (iii) Be on a gentle slope <10 percentage; (iv) Be near to water reserve, but not in buffer zone; (v) Not be located in national parks or mining area. The constraint layers were subsequently overlaid consecutively; by using the OVERLAY multiply function to produce a single suitability Boolean image [4,5]. The factor maps, on the other hand, first had to be multiplied with their corresponding weights from the AHP, and thereafter, summed together into one combined factor map. Finally, the combined constraint map and the combined factor map were multiplied together. The general equation is

$$S = \sum_{i=1}^{n} w_i F_i \prod_{j=1}^{m} C_j \qquad (1)$$

Where S is the total suitability score, w_i is the weight corresponding to factor map i, and C_j is constraint map j.

The confusion matrix can provide a variety of measures for accuracy. The most accepted among all measures are the percentage of correctly matched classes, the percentage of misclassified (omitted) and the overall accuracy [6,7]. Other broadly used measure of map accuracy that may be derived from a confusion matrix is the Cohen's kappa coefficient of agreement or the *K* statistics (Eq.2), which gives a guide to the chance of agreement between map classification and the reference data [8,9,10].

$$K = \frac{n\sum_{i=1}^{q} n_{ii} - \sum_{i=1}^{q} n_{i+}n_{+i}}{n^2 - \sum_{i=1}^{q} n_{i+}n_{+i}} \qquad (2)$$

K-kappa coefficient, ni - number of pixels, nii – nember of matched pixels, q – number of class

RESULT

The Analytical Hierarchy Process (AHP) [11] is one of the popular methods which are based on the additive weighting model [12,13]. The weights will be combined each other in large number of alternatives, to perform a pair wise comparison [14]. To derive values for criteria weights, we used the AHP as the weight solicitation technique [15,16] to check that the scale of weights is valid; we evaluated the weights with a method developed by Brandt [6]. A pair wise comparison is a way of weighting the different factors in correct relation to each other (Eq.3 and Tab.1). The suitability score of each pixel in the map can be calculated from the weighted linear combination of factors by Eq.3:

$$S = \sum w_i x_i \qquad (3)$$

Where S - suitability to the objective being considered
w_i - weight of factor i [the sum of all weights equal 1]
x_i -criteria score of factor i

According to the our literature studies main factors presenting cropland productivity are soil organic matter, humus layer or recently A+B horizons, soil texture, appearance of stones near surface, soil moisture, exchangeable bases and soil reaction [17, 18, 19,20].

Table 1

Ranking and weighting of factors for cropland suitability survey

№	*Name of criteria*	*Individual rate*	*Pair wise comparison weight*	*AHP calculated relative weight*
1	Organic matter	1	4 compared to slope gradient	0.3598
2	A+B horizon	2	3 compared to slope gradient	0.2244
3	Soil texture	3	1/2 compared to organic matter	0.1570
4	Slope gradient	4	1/3 compared to soil horizon	0.0808
5	Soil moisture	5	2 compared to stoniness	0.0658
6	Altitude	6	1/3 compared to soil texture	0.0445
7	Stoniness	7	1/2 compared to soil moisture	0.0295
8	Exchangeable bases	8	1/2 compared to altitude	0.0210
9	pH	9	1/4 compared to soil moisture	0.0171

Thus weighted linear combination of factors through equation (I) had been calculated *S=organic matter*0.36+ (A+B) horizon*0.22+ soil texture*0.16 + slope*0.08+ soil moisture*0.06+ altitude*0.04+ soil stoniness* 0.02+ exch. bases* 0.02 + pH*0.02.*

Creation of factor maps considering soil organic content, humus layer, and soil surface, stoniness, altitude, pH, slopes and aspect and final single factor maps presenting variety of values regarding each factors weight and their cell values (Fig.1).

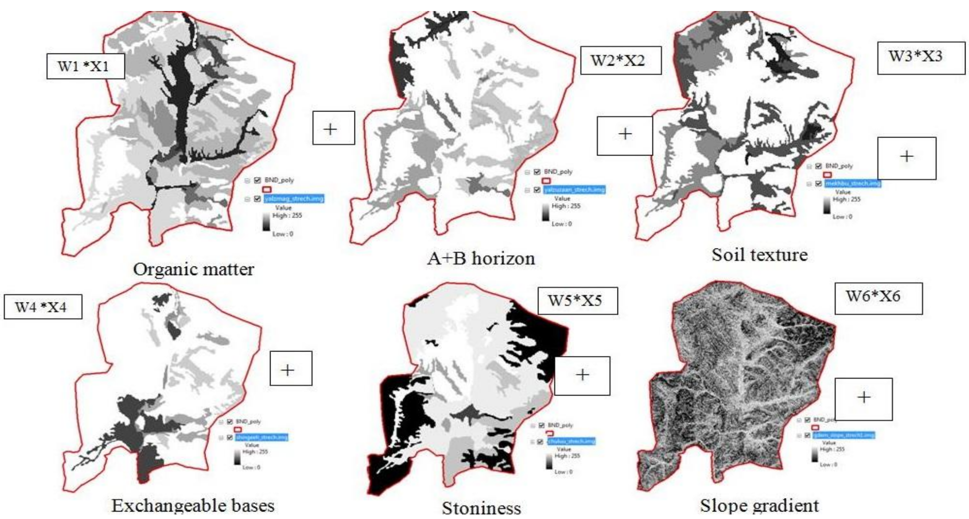

Figure 1. Main factors' raster maps used in cropland survey

To represent the suitability, all factors were normalized, meaning in this case that the value ranges of factor maps were stretched from 0 to 255 value of grayscale color. The grayscale color map includes achromatic shades, which positioned exactly between white and blank color. This means that 0 (blank white color) is considered to be of very high suitability and 255 (dark black color) of very low suitability, irrespectively of factor type (criteria). As they all contained the whole range of values between 0 and 255, the maps produced could serve as continuous representations of cropland suitability score. Final map shows suitable areas which are far from city contamination, not placed in prohibited areas: forest and national park by the reason of environmental protection. It is also not in the buffer zones of river and avoided steep slopes (Fig.2).

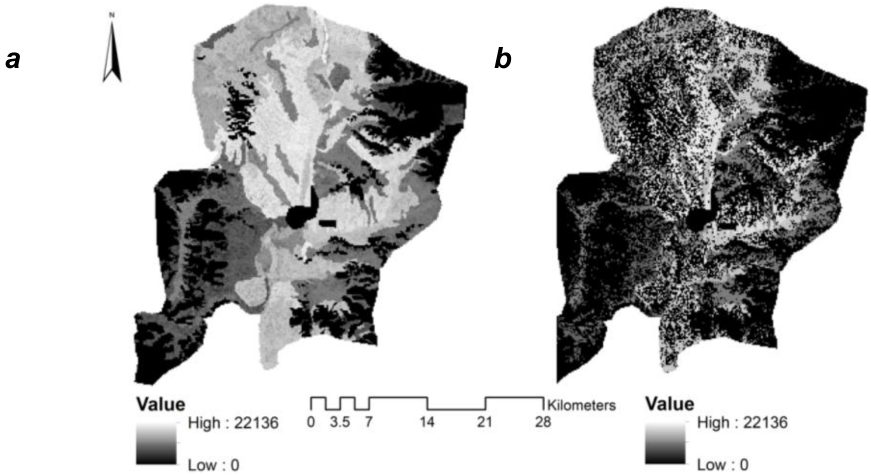

Figure 2. Suitable sites for cropland development a. factor map without constraint, b. final suitability assessment map of all factors evaluated with constraint consideration

For the data validations accuracy assessment confusiong/error matrix (table 3) had been calculated compare with field soil survey as a reference data carried on during 1989-2009's archive data (Fig.5) in Agency of Administration of Land Affair, Geodesy and Cartography of Mongolia (ALAGaC).

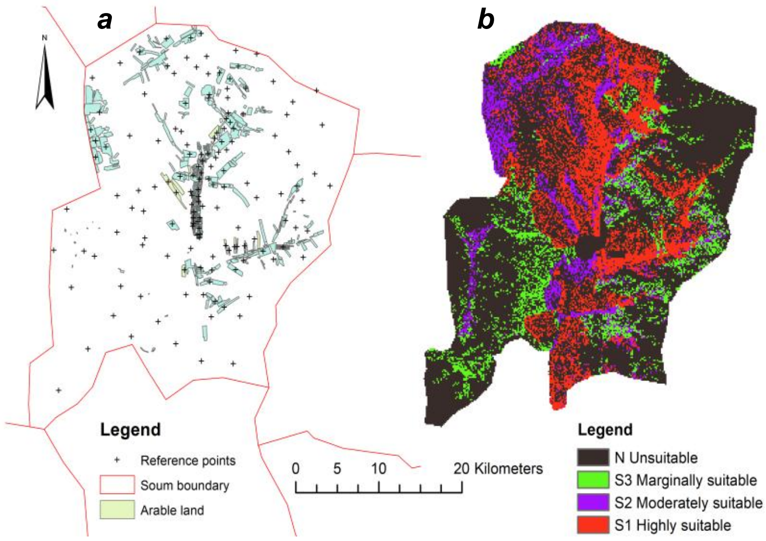

Figure 5. Comparison of reference data with suitability map a. reference points derived from archive data, b. final suitability assessment map reclassified into 4 classes

In general, the final suitability map was sufficient accurate and closely presentative to the referenced field survey datas of archive material. The overall accuracy compared with references is 0.83, meaning that 83% of the pixels are identically classified in both maps. It appears that the final suitability map resembles previous field survey data's area where assessed as suitable. Most illustrative and satisfied prove was Kappa coefficient 0.80 value which is presenting good survey precision of our poduced suitability map (tab.2).

Table *2*

Confusion matrix[1]

Suitability classes	Reference cells	Suitability compared cells	Matched cells	Commission %	Ground truth %
S1 Most suitable	46	58	42	72	91
S2 Suitable	23	19	17	89	74
S3 Less suitable	15	18	13	72	87
N Unsuitable	66	55	52	95	79

[1]Overall accuracy 0.83 [1]Kappa coefficient 0.80

DISCUSSION AND CONCLUSION

In Mongolia, GIS and remotely sensed data and GIS overlaying technique are started to use for agricultural land suitability evaluation and new development site selections by MCDA has successful future in that direction. These tools allow performing environmental and landing management activity more precise, quick and inexpensive ways. Multi criteria analysis has also more demonstrative effect to decision makers. Furthermore, it clearly demonstrates the effectiveness of using remotely sensed data for agricultural site selection. GIS and Multi criteria decision analysis integration is the best suited scientific tool for handling such natural resource management issues [21, 22, 23]. Overall, It is clear that the result would be changed if more soil and geological or relevant data are used in MCDA factor. It could be conclude that suitability map is processed somewhat correct according to the result of overall accuracy 0.83, matched cells 72-95% and Kappa coefficient 0.8 results. Correspondingly the places modeled for new exploration area of the crop production had been matched to the current location of agricultural land areas of Bornuur. this study shows that the chosen criteria is perceptive and uncomplicated. It should considered in the future how to deal within large area which has uncertainty alternatives. In our studies the main factors presenting cropland productivity are soil organic matter, humus layer or recently A+B horizons, soil texture, appearance of stones near surface, soil moisture and soil reaction. Some scholars (e.g.: Chen et al [23], Myagmartseren and Myagmarjav [4]) recently prepare to exclude the exchangeable bases from the main factor list. However, Mongolian scientist such as Purevtseren [17], Tserenbaljir and Enkmaa [18] included it as the main factors at their literatures.

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