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Suitability of Wheat, Maize, Sugar Beet and Potato Using MicroLEIS DSS Software in Ahar Area, North-West of Iran

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Abstract: Sustainable agriculture is the main goal of land evaluation. The current study deals with land suitability evaluation of Ahar soils, 9000 ha approximately, located in East Azarbaijan. The decision support system, MicroLEIS DSS (Microcomputer land evaluation Information system) was used to evaluate the suitability for wheat (*Triticum aestivum*), maize (*Zea maize*), sugar beet (*Beta vulgaris*) and potato (*Solanum tubersum*). To date, a computerized program has never been used before to evaluate an area in Islamic Republic of Iran. Therefore, Almagra model constituent of this DSS software was selected in order to make strategies related to land suitability evaluation at a regional level. Soil morphological and analytical data were carried out for 44 sampling points based on grid survey and stored in SDBm plus database. The control section data between 0 and 50 cm appropriate to annual crops were calculated by "soil layer generator" to apply and run the Almagra model. Flunentic Haploxerepts and Vitrandic Calcixerepts in total of the 1050 ha were identified as marginal and/or not arable lands while the rest of soil subgroups can be considered as the best agricultural land. Typic Xerorthents under cultivation of all crops were classified as moderate suitable soil (S3). Vertic Haploxerepts has high suitability for all of the selected crops except potato. In this research, the main recognized soil limitation factor was texture in the total of 1670 ha of lands for potato cultivation and 274 ha for the rest of crops (S3t). Calcium carbonate was the secondary limitation factor where the soils of the study area were classified as highly suitable (S2c) soil mainly for maize and potato. The obtained results reveal that the evaluated crops could be arranged according to their soil suitability classes as follows: wheat < maize < sugar beet < potato. This arrangement reflects the priority for agricultural utilization.

Key words: Almagra model % MicroLEIS DSS % SDBm plus % Sustainable agriculture

INTRODUCTION

Agro-ecological innovations are necessary to develop a new and truly sustainable agriculture that reverses environmental deterioration and, at the same time, augments the supply of food [1]. A specific agricultural use and management system on land that is most suitable according to agro-ecological potentialities and limitations is the best way to achieve sustainability [2]. In this study, Almagra model constituent of MicroLEIS DSS software was selected in order to make strategies related to land suitability evaluation at a regional level to stand on the main factors that are affecting the soil suitability and productivity.

Land evaluation is a tool for land use planning. There are many models for simulation and many computer packages for application of land evaluation in land-use planning [3]. Since the late 1980s, MicroLEIS DSS has evolved significantly towards a user-friendly agro-ecological decision support system for sustainable land use and management [4]. To date, it has never been used as a useful tool in land evaluation for any area of Iran. MicroLEIS software has been used to evaluate the soil suitability of Banagar El-Sokkar area in Egypt for some specific crops [5]. He found that the dominant suitability subclasses are S2l, S2tl and S3l with soil properties and topographic conditions as main limiting factors.

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Land suitability using MicroLEIS program was used to predict the effect of water table and salinity on the productivity of wheat in sugar beet area, West Nubaria, Egypt [6]. The results showed that the productivity of wheat crop will decrease due to increasing salinity and shallow water table depth, as a result of mismanagement practices.

Evaluation of land use potential and suitability of ecosystems in Antakya, Turkey, for reforestation, research, arable farming and residence using MicroLEIS DSS [7] showed that a total of 478 ha of land had the potential for residential use in the west and north of Antakya. It was determined that the majority of the land was suitable for reforestation and recreation uses in the north and north-west of Antakya and their total area was 1511 ha.

MicroLEIS DSS application in Pampean region of Argentine with special reference to humid or semi-humid subtropical climate showed that a conversion of grassland into cropland is the major land-cover process during the last 10 years, accounting for about 28% of increase of cultivated land area [8].

Although increasing consideration is being given to agricultural diversification and to lower input agriculture, it is still important to identify optimum land use systems for resource sustainability and environmental quality based on bioclimatic deficiency and climate change impact in the future scenario. Using Cervatana and Terraza models constituents on MicroLEIS system in Ahar (Iran) and Seville (Spain) soils [9] showed that by climate change, only wheat will be converted from moderate to good suitability in the study area of Ahar, while none of the crops will change its land suitability in Seville area on the future scenario. Cervatana model resulted that almost 12% of the total area (including Fluventic Haploxerepts, Vitrandic Calcixerepts and some parts of Typic Calcixerepts and Typic Xerorthents) should be reforested with suitable shrub species and not dedicated to agriculture, to minimize land degradation [10].

The main aim of this research work is to evaluate the soils of Ahar province for agricultural development and crop diversification to achieve the sustainable agriculture using MicroLEIS system and to present the obtained results as land suitability maps using the GIS.

MATERIALS AND METHODS

Study Area: Study area covers about 9000 ha and is located between 47°00′00″ to 47°07′30″ east longitude and 38°24′00″ to 38°28′30″ north latitude (Fig. 1). Its slopes range from < 2 to 30% and the elevation is from 1300 to 1600 m above sea level. Flat, alluvial plain, hillside and mountain are the main physiographical units in the study area.

The field work was carried on the basis of general semi-detailed survey through the whole study area with special reference to 1 km distance between the sampling points based on grid survey method. Forty four profiles have been selected to represent the variation in the soils of the study area. The exact location of the soil profiles were defined in the field by using the GPS.

Soil: The multilingual soil database SDBm plus [11] was used to store and manipulate the large amount of soil data which included field site descriptions and soil profile characteristics; standard soil analytical data and soluble salts data; and soil physical analytical data, especially with reference to infiltration and water retention. Major facilities of the SDBm plus include input, edit, print, selection and file generation. The "soil layer generator" option represents a useful interface between the SDBm plus and the land evaluation and geographical information systems. The control section data to apply the Almagra model for annual crops was 0-50cm. The main soil variables of the soil types characterised in the Ahar study area are summarised in Table 1. These soil attributes were the input variables for applying several of the Almagra model.

According to the USDA Soil Taxonomy [12] and FAO Soil Classification [13], the dominant soils are classified as Inceptisols (Cambisols), Entisols (Regosols) and Alfisols (Luvisols). Additionally, 10 soil subgroups were obtained. Typic Calcixerepts (Calcaric- Cambisols) is the major subgroup (Fig. 1).

MicroLEIS DSS: General capability evaluation using Cervatana model of MicroLEIS program in this area [10] showed that eight application soil subgroups are classified as arable or best agricultural lands and another two as marginal lands. Typic Calcixerepts, Typic-Haploxerepts, Vertic Calcixerepts, Vertic Haploxeralfs, Calcic Gaploxerepts and Vertic- Haploxerepts presented the highest suitability for most agricultural crops (S1 class) and corresponded 22.8%, 7%, 5.6%, 3.1%, 1.83% and 1.43% of the studied area, respectively. Soil and topography limitation factors are two basic agents to classify Fluventic Haploxerepts and Vitrandic Calcixerepts subgroups and part of Typic Calcixerepts (2.42%) and Typic Xerorthents (4.84%). The marginal land, which represented 11.75% of the area, is currently dedicated to

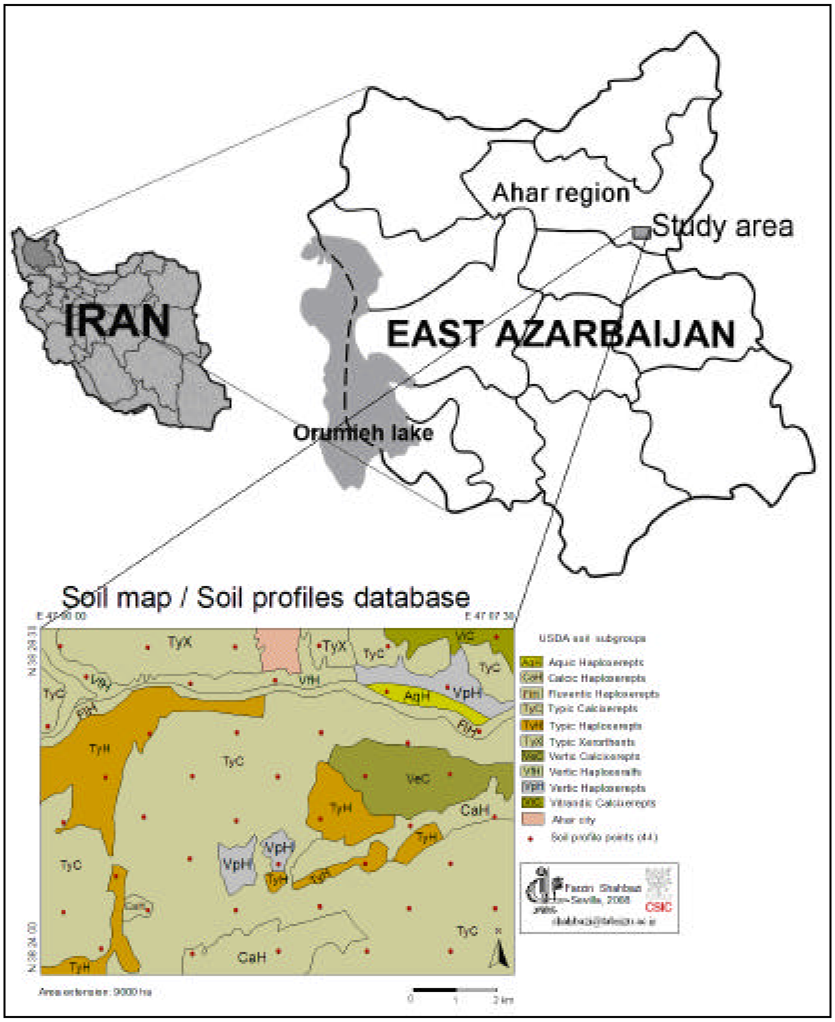

Fig. 1: Site and soil classification map of study area dealt with sampling points

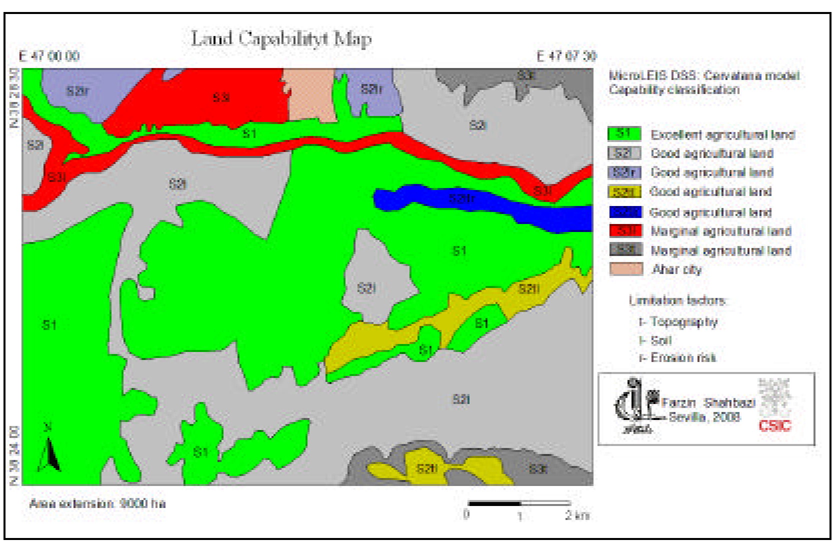

Fig.2: General Land Capability Map of Ahar area using MicroLEIS DSS [10]

Table 1: Summary of major soil variables* of the soil types characterized in the study area

	Soil physical properties			Soil chemical properties**			
USDA Soil Subgroups	Useful depth (cm)	Texture	Coarse fragment (%)	CCE (%)	ESP	EC (dS/m)	pH (p)
Aquic Haploxerepts	130	Clay loam	1.30	11.36	4.21	2.47	8.14
Calcic Haploxerepts	147	Clay	7.16	19.65	2.54	1.52	8.26
Fluventic Haploxerepts	119	Sandy clay loam	22.76	10.26	6.00	0.77	8.71
Typic Calcixerepts	151	Clay loam	10.92	18.31	2.14	1.49	8.23
Typic Haploxerepts	128	Clay loam	6.40	14.80	1.82	0.95	8.27
Vertic Calcixerepts	140	Clay	4.00	17.87	3.10	1.25	8.42
Vertic Haploxeralfs	185	Clay	0.80	13.80	5.36	2.10	8.48
Vertic Haploxerepts	135	Clay loam	12.78	14.58	3.72	2.00	8.32
Vitrandic Calcixerepts	150	Clay	12.26	14.91	1.32	0.70	8.46
Typic Xerorthents	62	Sandy clay loam	10.80	6.82	1.07	1.00	7.90

* Mean value of selected parameters measured in the topsoil (0-50 cm).

** CCE= calcium carbonate equivalent; ESP= exchangeable sodium percentage;

EC= electrical conductivity; pH (p) = potential of hydrogen in saturated paste

agricultural use. Changes in the unusable soil subgroups from natural habitat to intensively tilled agricultural cultivation were one of the primary reasons for soil degradation. Optimum land use should be applied when the moderate arable lands are considered as the natural habitat cultivation area. Also, 45% of the study area was classified as a good capability lands with soil limitation factor (Fig. 2).

Almagra model constituent of MicroLEIS software is an automized application of this soil suitability method, which matches soil characteristics of the soil unit with growth requirements of each particular crop; and results in the crop growth limitations being provided by the computer. The modelling phase involves the following main stages:

- Selection of land attributes: land characteristics and associated land qualities;
- Defining of relevant land use requirements or limitations: land use response or degradation level;
- Matching of land attributes with land use requirements; and
- Validation of the developed algorithms in other representative areas.

Following the criterion of maximum limitation, each factor has a definite action and the verification of the degree of a single variable is sufficient to classify the soil in the corresponding category [14]. According to the generalization level set up for each soil diagnostic in a semi-quantitative procedure depending on the gradations considered for each of the criteria selected and on the different agricultural uses, five suitability classes have been determined: Class S1 (optimum); Class S2 (High); Class S3 (moderate); Class S4 (marginal) and Class S5 or N (not suitable). The subclasses are indicated by the letters corresponding to the maximum limiting factors including: Texture (t), drainage (d), calcium carbonate (c), salinity (s), exchangeable sodium percent (a), suitable depth (p) and profile development (g). In this study, four annual traditional crops namely, wheat, maize, sugar beet and potato were considered according to the available soil condition.

Integrating MicroLEIS DSS with GIS system for mapping and analyzing data allows to use the spatial techniques to expand land evaluation results from point to geographic areas, using soil survey and other related maps [15 and 16]. Input of MicroLEIS DSS results into GIS helps to extract information to be used and displayed as thematic geo-referenced maps. This level of assessment is what policy decision usually required [17]

RESULTS AND DISCUSSION

For detailed study of soil (e.g. this research work), application of MicroLEIS models such as Almagra model can be reflected the land properties of the whole natural region of Ahar region. Therefore, the results of this benchmark sampling points analysis of land use and management can be extrapolated to large geographical areas associated with additional spatialization studies. None of agricultural management system will have a

Table 2: Summary of suitability classification according to extended area (ha).

Land utilization Types	Optimum (S1)	High (S2)						Moderate(S3)	
		t	c	s	a	g	p	t	s
Wheat	2430	5140	93	0	245	378	0	274	176
Maize	180	5177	7505	0	245	378	0	274	176
Sugar beet	0	5300	270	176	7700	378	93	274	0
Potato	0	6600	6450	810	245	378	0	1670	176

Limitation factors: texture (t), calcium carbonate (c), salinity (s), saturated sodium (a), useful depth (p) and profile development (g)

negative environmental impact when applied on land with very low suitability for agricultural uses. Following a semi-quantitative procedure and according to the generalization level set up for each soil subgroup, the area under investigation has been divided into three relative suitability classes; Optimum (S1 class), high (S2 class) and moderate (S3 class). The marginal (S4) and not-suitable (S5) area were not determined for selected utilization types. In this research, out of the thirty nine soil investigated points; only twelve sites in the total of 27%; one site in the total of 2% areas were of optimum suitability for wheat and maize, respectively. While, any area was not recognized as optimum suitable lands for potato and sugar beet crops. The main recognized soil limitation factor was texture in the total of 1670 ha of lands for potato cultivation and 274 ha for the rest of crops (S3t). Drainage (d) limitation factor was not appeared in the study area as a limitation factor and profile development factor (p) was too except 93 ha area cultivated on sugar beet. Carbonate calcium is the secondary limitation factor to classify the study area as a highly suitable (S2c) mainly on cultivation of maize and potato. Salinity in the total of 800 ha of the study area due to high suitability classes (S2s) on cultivation of potato. On the other hand, saturated sodium is the main limiting factor for cultivation of sugar beet (S2a) in the total of 770 ha of study area. As a matter of fact, annual selected crops are considered the tolerant crops to high level of exchangeable sodium except sugar beet.

Suitability classification according to extended area (ha) affected by limitation factors are summarized in Table 2.

In regard to ground truth data obtained, some soil subgroups such as Aquic haploxerepts, Typic calcixerepts, Typic Haploxerepts, Vertic Calcixerepts and Vertic Haploxerepts have had sensitive cultivation condition because of saturated sodium percentage. Profile development (g) as a limitation factor, was only recognised in Vertic Haploxeralfs which covered an area of 378 ha.

In Almagra soil suitability model, the evaluation results are presented in the form of a matrix, that is, a two dimensional array with rows including the soil characteristics and columns consisting of the soil units (investigated soil profiles) for which an evaluation was

Table 3: Soil unites and suitability classes of each profile for wheat, maize, sugar beet and potato resulted by Almagra model

S.A.No:*	Wheat	Maize	Sugar beet	Potato	USDA soil subgroups
1	S3t	S3t	S3t	S3t	Typic Xerorthents
4	S2c	S1	S2pca	S2t	Typic Xerorthents
5	S1	S2c	S2a	S2tcs	Typic Calcixerepts
7	S2tg	S2tcg	S2tag	S2tcsg	Vertic Haploxeralfs
8	S2tg	S2tcg	S2tag	S2tcg	Vertic Haploxeralfs
9	S2tag	S2tcag	S2tg	S2tcsag	Vertic Haploxeralfs
10	S1	S2c	S2a	S2tcs	Aquic Haploxerepts
11	S2t	S2tc	S2ta	S3t	Vertic Haploxerepts
12	S1	S2c	S2a	S2tc	Typic Calcixerepts
13	S2t	S2tc	S2ta	S3t	Typic Haploxerepts
14	S2t	S2tc	S2ta	S2tc	Typic Calcixerepts
15	S2t	S2tc	S2ta	S2tc	Typic Calcixerepts
16	S3s	S3s	S2csa	S3s	Typic Calcixerepts
18	S2t	S2tc	S2ta	S2tc	Typic Haploxerepts
19	S1	S2c	S2a	S2tc	Typic Calcixerepts
20	S2t	S2tc	S2ta	S2tc	Typic Calcixerepts
21	S2t	S2tc	S2ta	S2tc	Vertic Calcixerepts
22	S1	S2c	S2a	S2tc	Vertic Calcixerepts
23	S1	S2c	S2a	S2tc	Typic Calcixerepts
24	S2t	S2c	S2ta	S2tc	Typic Calcixerepts
25	S1	S2c	S2a	S2tc	Typic Calcixerepts
26	S1	S2c	S2a	S2tc	Typic Haploxerepts
27	S1	S2c	S2a	S2tc	Calcic Haploxerepts
28	S2t	S2tc	S2ta	S2tc	Calcic Haploxerepts
29	S2t	S2tc	S2ta	S2tc	Typic Haploxerepts
30	S2t	S2tc	S2ta	S2tc	Typic Calcixerepts
31	S2t	S2tc	S2ta	S2tc	Vertic Haploxeralfs
32	S2t	S2tc	S2ta	S2tc	Typic Haploxerepts
33	S2t	S2tc	S2ta	S2tc	Typic Calcixerepts
34	S1	S2tc	S2at	S2tc	Typic Calcixerepts
35	S2ta	S2tca	S2t	S2tcsa	Calcic Haploxerepts
36	S2t	S2tc	S2ta	S3t	Typic Calcixerepts
37	S1	S2c	S2a	S2tc	Typic Calcixerepts
38	S1	S2c	S2a	S2tc	Typic Calcixerepts
39	S2t	S2tc	S2ta	S3t	Typic Calcixerepts
40	S2t	S2tc	S2ta	S2tc	Typic Calcixerepts
41	S2t	S2tc	S2ta	S2tcs	Calcic Haploxerepts
42	S2t	S2tc	S2ta	S2tc	Calcic Haploxerepts
43	S3t	S3t	S3t	S3t	Typic Calcixerepts

*Soil units No: 2, 3, 6, 17 and 44 were classified as not arable lands resulted by Cervatana model

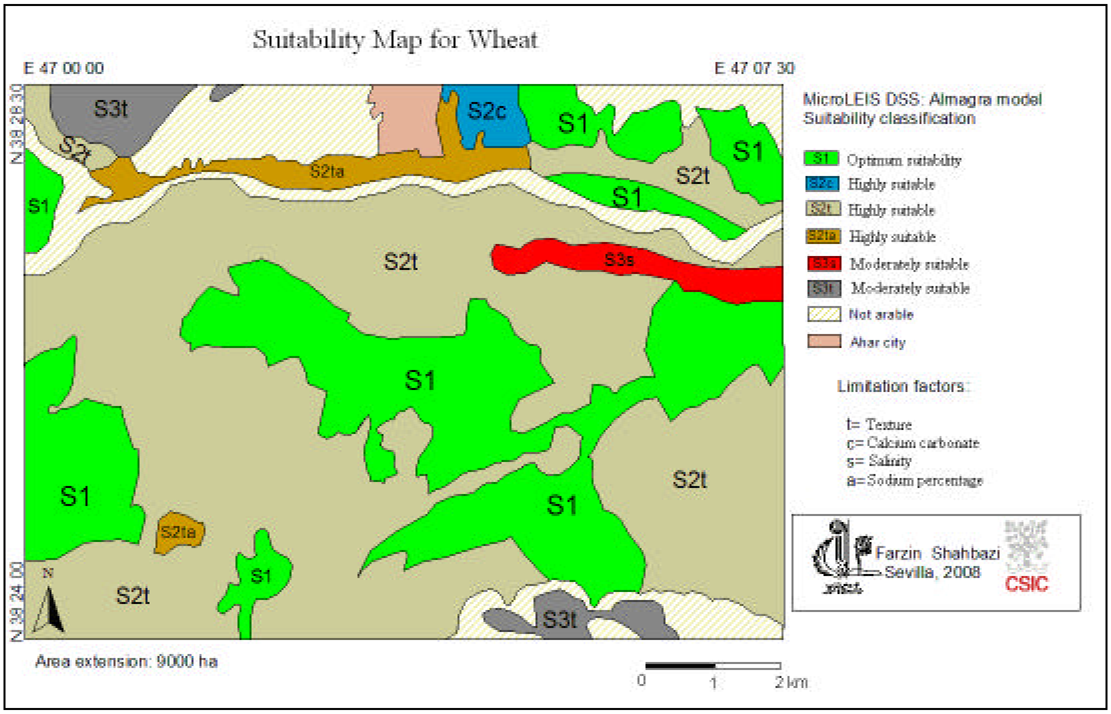

Fig. 3: Land suitability map for wheat in Ahar region

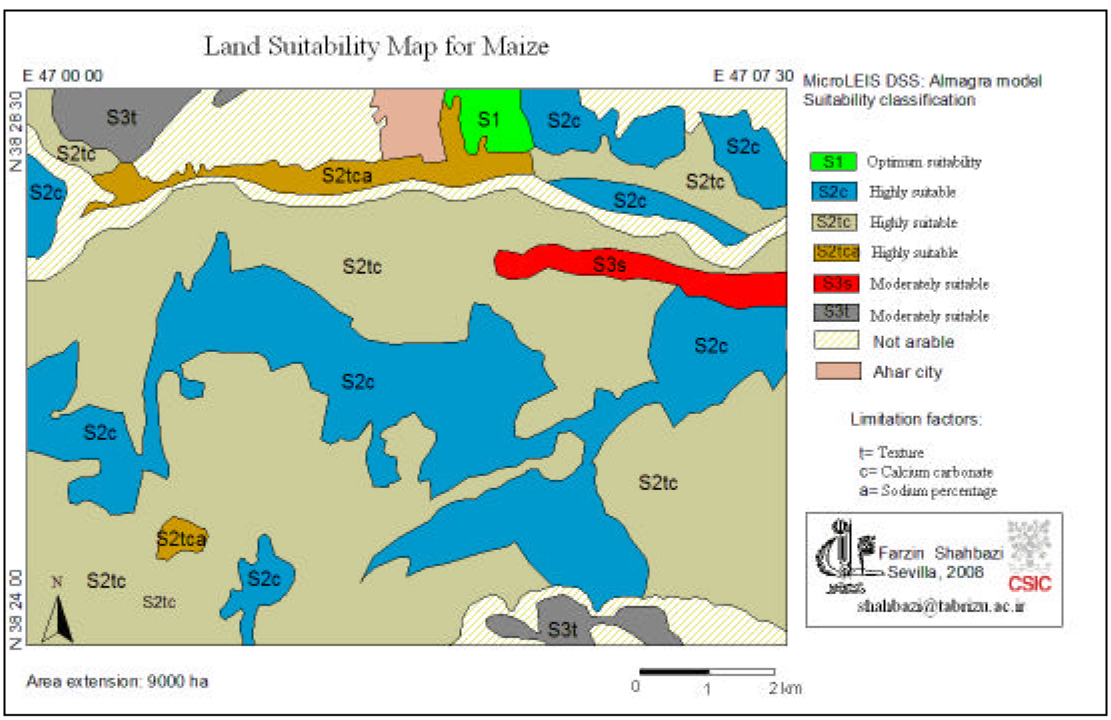

Fig.4: Land suitability map for maize in Ahar region

computed. The intersection of two (i.e. the cells of the matrix) is considered as the result. The overall soil suitability of a soil component was assessed through the maximum limitation method; this means that, the suitability is taken from the most limiting factor of soil characteristics.

The current research work used ArcView GIS software for mapping and analyzing, the data of soil survey and other related maps to present basic data and model results on a map for each selected crop separately. It helps to extract information from the evaluation models to be used and displayed as thematic geo-referenced maps. Combining soil evaluation models through GIS improves evaluation models and enables an analysis more relevant to policy making than the original basic data which in example are presented for wheat and maize as strategic crops in Fig. 3 and 4.

More detailed results of applying the Almagra (agricultural soil suitability) model in the 39 benchmark soil profiles (eight soil subgroups) previously classified as agricultural lands are shown in Table 3.

In general, data revealed that soil with vertic properties were highly suitable for annual crops. It is worth to mention that Typic Xerorthents show clearly moderately suitability for any studied crops in this research.

CONCLUSIONS

Agricultural lands identification, according to its own ecological potentialities and limitations, is the first major objective of land use planning. At the same time, the second major objective is to predict the inherent suitability of each soil unit for supporting a specific crop over a long period of time. In a particular area, both complex tasks can be developed through agro-ecological land evaluation analysis such as using MicroLEIS.

Out of the thirty nine soils investigated points; only twelve sites in the total of 27% and one site in the total of 2% areas were found to be optimum suitability for wheat and maize, respectively. While, any area was not recognized as optimum suitable lands for potato and sugar beet crops.

Soils with vertic properties used to present an excellent capability for most of the traditional crops. However, an appropriate agricultural management system must be taken into consideration when these soil types become under cultivation.

This study is qualitative evaluation for the actual soil parameters to realize a precise and objective interpretation for the area under consideration and its suitability for a wide range of crops. It can be concluded that the most effective soil parameter that influence the suitability classification in the studied area was soil texture. Also, salinity has been distinguished as a limitation factor in some cases which can be removed from these soils through leaching, especially by using the high quality of irrigation water and applied management programs. On the other hand, the soil maps for agricultural suitability designed in this research can be helpful in carrying out the management processes.

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