Available online at www.elixirpublishers.com (Elixir International Journal)

Agriculture

Elixir Agriculture 42 (2012) 6516-6519

ISSN: 2229-712X

Land suitability modeling for sustainable agriculture using MicroLEIS DSS and remote sensing in an arid region of Iran

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ARTICLE INFO

Article history:

Received: 12 December 2011;

Received in revised form:

19 January 2012;

Accepted: 30 January 2012;

Keywords

Decision support systems,

Sustainable management,

Land,

ASTER images.

ABSTRACT

Assessment of land response to certain land uses is necessary to reach the sustainable land management. In this study Almagra model from MicroLEIS DSS and remote sensing technology were used to determine the suitability of land for main crops in an arid region east of Tehran (Iran). The weighted average of land and soil characteristic were obtained from representative soil profiles in each land mapping unit, through digital classification of satellite images and entered to the model. Land suitability maps for each crop were presented as thematic maps by integrating soil map with determined land suitability classes in GIS. The results showed that %55 of the area has moderate to high suitability for wheat, alfalfa, maize and melon. Salinity, alkalinity and soil texture are considered as the main soil restrictions for studied crops in this area. According to the obtained results, the priority of the selected crops should be considered as wheat, alfalfa/ melon and maize, respectively. Application of remote sensing technology accompany with land suitability models helped to enhance the abilities of this model by both saving the data compilation time and generating georeferenced data to overlay with other information layers and spatialization in GIS.

Introduction

Sustainable land management deals with the improvement of agricultural land uses along with their logical planning in order to improve soil degradation. Land evaluation study which is regarded as a bridge between land resources inventories and land use planning (De la Rosa et al. 2004) is an essential way to achieve the sustainable land management (FAO 1993). The framework for land evaluation provided by FAO (1976), which is considered as a flourishing point in land evaluation studies (Rossiter 1996), has suggested the assessment of land suitability for specific purposes as a basis of land use planning. Almagra component of MicroLEIS (De la Rosa et al. 2004) designed as a computerized decision support system based on the criteria of FAO (1976 & 1981) to evaluate land suitability. It evaluates the most important land characteristics on crop production for different agricultural land uses, according to the gradation matrices argued by Beek & Bennema (1972). During last few years, MicroLEIS has been used as an expert system for choosing the best decisions to overcome the wide range of agro-ecological problems in some parts of the world especially in semi-arid regions. This program has been also applied successfully in cold regions (Kelgenbaeva 2002). Darwish et al. (2006) and Wahba et al. (2007) have used almagra, to determine the land suitability in some parts of Egypt. This study was carried out to find out the priority of main crops using MicroLEIS program in an arid area east of Tehran regarding to the importance of land suitability evaluation in such regions. It has also tried in this study to enhance the efficiency of MicroLEIS system using remote sensing not only by decreasing the time and budget which are necessary for land resource inventories (Morris et al. 2000; Burroughs & McDonnel 1998; Gotterfield 2003) and compilation of site and soil data, but also by generating of geo-referenced digital thematic maps in order to best integration in GIS.

Materials and methods

Eivanekey region in Semnan province, an arid regeon in center of Iran was chosen for this research. Eivanekey is situated 60 km south east of Tehran and is located between 51°, 55′ to 55°, 10′ N and 35°, 15′ to 35°, 23′ E geographic coordinates (Fig.1). The research area covers an extension of 15000 ha and is laid on alluvial deposits of quaternary and gypsiferous-calcareous marls of Miocene-Oligocene. Gravelly colluvial and alluvial fans, piedmont and flood plains as well as low lands are the major land types of the area. Elevation varies between 900 to 1075m asl and slope ranges from 0 to 5 percent in this region. Lands are used for irrigated winter wheat and barley, maize, alfalfa, melon and pomegranate orchards in EivanFiekey.

Figure 1. Location of the study area

Soil moisture and temperature regimes are aridic and thermic, respectively according to 20-years period (1989-2005) climatic statistics of Garmsar synoptic station which is the nearest station to the area.

Soil survey was carried on after supervised image classification of all ASTER bands and separation of the land

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units by soil classification and sampling within each land unit in order to and controlling the boundaries. For this purpose, 54 soil observations (auger and profile) through stratified random method were analyzed within the discriminated land units obtained from digital image classification (fig. 2). At last 9 soil units were recognized in the study area. The result of the image classification and field observations were imported into ArcGIS 9.1 and the soil map of area was generated consequently (fig. 3 and table 1). Weighted average of land and soil characteristics between 0 and 100cm from soil profiles representative of each land mapping units were calculated using "File layer generators" and stored into SDBm plus (table 2). Useful depth (cm), degree of profile development, drainage, stoniness percentage, texture, carbonate percentage, electrical conductivity (dS/m) and exchangeable sodium percentage are land characteristics required by Almagra model.

The Almagra model of microLEIS system evaluates land suitability for pre-defined agricultural crops in an automatic way based on FAO framework of land evaluation (FAO 1976). It matches site and soil characteristics of the discriminated land units with each selected crops' requirements. In the final step, the land suitability classes are calculated by the model and are shown by the computer. Five suitability classes (S1, Optimum; S2, High; S3, Moderate; S4 Marginal and S5, not suitable) are defined to show the final results, according to the level of limitation consider for each soil or site diagnostic criteria using maximum limitation method (sys et al. 1991). Corn, melon, alfalfa and winter wheat which are the main crops of the study area were selected for this research.

In this research, ArcGIS 9.1 was used to integrate soil map with the obtained results from the model and presentation of the geo-refrenced land suitability maps.

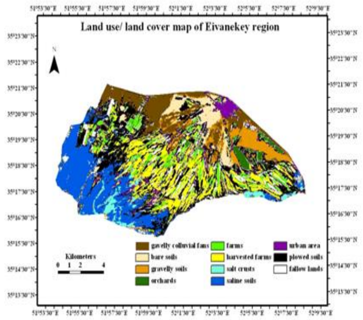

Figure 2. The land use/ land cover map of the study area obtained from ASTER image classification

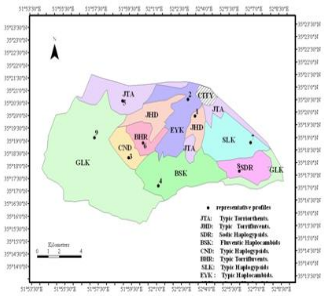

Figure 3. The soil map of the study area and the position of representative soil profiles.

Results and discussion

The results of Almagra model is shown in tables 3 and 4. It indicates the existence of soil depth and texture, salinity and alkalinity, drainage and carbonates as the major land limitations in the study area. Regarding to the results very severe restrictions of soil depth and salinity in Typic Torrifluvents (soil unit JHD) and Gypsic Haplosalids (soil unitGLK) have made about %45 of total area unsuitable for all selected crops. Sodic Hapologypsids, however, are marginally suitable only for alfalfa. In contrast, another Typic Torrifluvents (soil unit BHR) and Typic Haplogypsids that cover about %7 of the area have the best quality among all other soils, since have optimum suitability for wheat and high suitability for melon, corn and alfalfa. Soil texture and salinity are the most important soil limitations for corn and alfalfa in the rest of the soil units, so that soil units 4 and 8 have been classified as S3 because of salinity, despite of their heavy soil textures optimum for these crops (beek & bennema 1972; sys et al. 1993). Similarly, soil unit 2 is moderately suitable for corn and alfalfa due to light soil texture in spite of its low soil salinity. Soil salinity also is the main constraint for winter wheat and melon yield in this region. Therefore, electrical conductivities higher than 4 and 6 dS/m are the reasons for putting %29 and %41 of the lands into class S3 for melon and wheat respectively. Based on the results of Almagra model the best priority of the selected crops in the study area is considered as winter wheat, alfalfa and melon/ corn. The land suitability maps for each studied crop were prepared in GIS and are shown in figures 4 to 7.

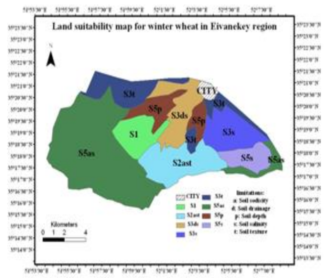

Figure 4. Map of land suitability for winter wheat in Eivanekey region based on the results of Almagra model

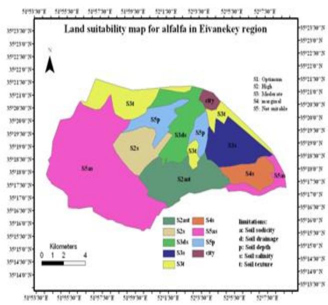

Figure 5. Map of land suitability alfalfa in Eivanekey region based on the results of Almagra model

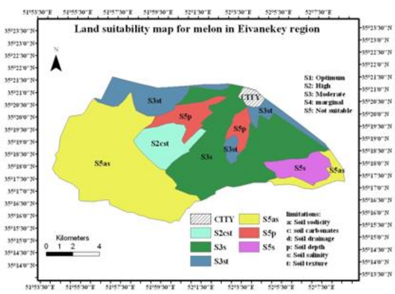

Figure 6. Map of land suitability for corn in Eivanekey region based on the results of Almagra model

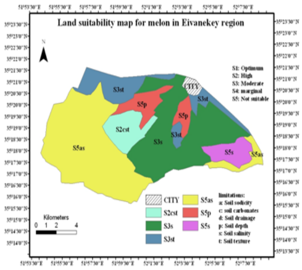

Figure 7. Map of land suitability for melon in Eivanekey region based on the results of Almagra model

Conclusions

The results of this research showed that %50 of total area was suitable for wheat, alfalfa, melon, and corn. About %5 of the area is marginally suitable only for alfalfa because of high soil salinity. Existence of very high soil salinity and sodicity and low soil depth are the main limitations made the rest of the non-suitable for agriculture. Since the study area is located in arid regions of Iran and regarding to the value of water for agriculture in such regions, it is impossible to establish rangelands or forest areas for preventing the soil erosion. Therefore it is recommended to use mechanical techniques for soil conservation especially to prevent wind erosion. Furthermore deep Typic Torrifluvents and Typic Haplogypsids showed the highest quality for crop production in this region as there are no sever soil limitations in those soils. Accordingly it was concluded that winter wheat, alfalfa, melon / corn are the proper crops in the Eivanekey region.

The land suitability results and maps following soil resources inventories in this study can be a motivation in choose the best decisions to reach the sustainable land management. The application of computerized system as decision support systems can lead to the correct decisions in addition to saving the time and budget. The use of remote sensing technology can ameliorate the performance of Almagra model in creating geo-referenced map to overlay in GIS.

Acknowledgements

We wish to thank college of Agriculture and Natural Resources, University of Tehran for supporting this research.

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Table 1. Taxonomic names of existing soil units in the study area (USDA 2006& WRB 2006)

Land unit	Soil Classification
JTA	Sandy- skeletal, mixed, thermic, Typic Torriorthents
JHD	Loamy-skeletal, mixed, active, calcareous, thermic, Typic Torrifluvents
SDR	Fine, mixed, semiactive, thermic, Sodic Haplogypsids
BSK	Fine, mixed, semiactive, thermic, Fluventic Haplocambids
CND	Fine silty, mixed, active, thermic, Typic Haplogypsids
BHR	Sandy-skeletal over loamy, mixed, active, calcareous, thermic, Typic Torrifluvents.
SLK	Clayey over loamy-skeletal, mixed, semiactive,thermic, Typic Haplogypsids
EYK	Fine, mixed, semiactive, thermic, Typic Haplocambids
GLK	Fine silty, mixed, active, Gypsic Haplosalids

Table 2. Weighted average of soil characteristics between o and 100 cm in Eivanekey region

Soil unit	Slope %	ECe dS/m	pH	Gypsum %	CaCO3 %	ESP %	CEC Cmol/kg	Sand %	Silt %	Clay %	Texture class
JHD	2-5	4.2	7.8	tr	17.6	2.8	10	76	11	13	SL
EYK	2-5	6.8	7.9	tr	20.2	10.5	17.6	10	34	56	SiC
CND	0-2	3.7	8	4.4	16.7	2.9	10.5	19	51	30	SiCL
BSK	0-2	5.3	7.9	2	20.2	5.4	17.5	13	41	46	SiC
JTA	2-5	4.8	8	0	9.7	6.9	11	82	9	9	LS
BHR	0-2	2.7	8	0	17.5	3.5	11	61	17	22	SCL
SLK	2-5	5.9	7.8	1	15.8	8.8	13	54	12	34	SCL
SDR	0-2	11.2	7.7	3.8	16.6	14.4	17.5	16	36	48	C
GLK	2-5	31.1	7.6	6.7	11.5	45.7	12.3	29	47	24	L

Table 3. Land suitability results derived from Almagra model for the study area

Soil unit	Winter wheat	Melon	Alfalfa	Corn
JHD	S5p	S5p	S5p	S5p
JTA	S3t	S3st	S3t	S3t
SDR	S5s	S5s	S4s	S5s
SLK	S3s	S3s	S3s	S3as
BSK	S2ast	S3s	S2ast	S3a
CND	S1	S2cst	S2s	S2c
BHR	S1	S2cst	S2s	S2c
EYK	S3ds	S3s	S3ds	S3as
GLK	S5as	S5as	S5as	S5as

Table 4. Percent of total area which is covered by each land suitability classes.

Land suitability classes	Winter wheat	Melon	Alfalfa	Corn
Optimum (S1)	6.82	0	0	0
High (S2)	11.92	6.82	18.74	6.82
Moderate (S3)	29.1	41.2	24.35	41.02
Marginal (S4)	0	0	4.78	0
Not suitable (S5)	4.78	4.78	0	4.78