Turk J Agric For
27 (2003) 145-153
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Geographic Information System and Remote Sensing Based Land Evaluation of Beypazarı Area Soils by ILSEN Model

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Received: 16.09.2002

Abstract: Land evaluation is of great importance in guiding decisions on land uses in terms of their potential and conserving natural resources for future generations. The main objective of this study was to determine land resources and to evaluate land utilization types and their suitability in Beypazarı area soils. In addition to field studies, digital soil and land use related (satellite data, DEM and digital geology maps) data were used and analyzed with remote sensing (RS) and geographic information systems (GIS) techniques and a new digital soil map and database were generated for the study area. Soils were classified using soil taxonomy. RS and GIS techniques were successfully applied in this land evaluation study. An ILSEN computer model was used to determine potential land use groups and suitability classes for agricultural uses of Beypazarı area soils. The suitability map for agricultural uses results showed that 42.8% of the study area soils were not suitable for agricultural use and that 90.4% of these soils are classified as lithic xerorthents. Only 12.7% of the study area soils were found to be highly suitable for agricultural uses. These soils were classified as typic xerofluvents (30.7%), typic haploxerepts (42.4%) and fluventic haploxerepts (26.9%).

Key Words: Land mapping units, Land qualities, Land utilization type, Land evaluation

Coğrafi Bilgi Sistemleri ve Uzaktan Algılama Teknikleri Kullanılarak Beypazarı Yöresi Topraklarının ILSEN Modeli ile Arazi Değerlendirmesi

Özet: Arazilerin potansiyel durumlarına göre kullanılmasına karar vermek ve gelecek nesiller için doğal kaynakların korunmasında arazi değerlendirmenin büyük önemi bulunmaktadır. Bu çalışmada, Ankaranın kuzey batı kısmında bulunan Beypazarı yöresindeki arazi kaynakları ve onların arazi kullanım türlerinin (AKT) dikkate alınmasıyla uygunluk durumlarının belirlenmesi amaçlanmıştır. Arazi çalışmaları yanında, uydu verileri, sayısal arazi yükselti modeli, ve sayısal jeoloji haritaları gibi toprak ve arazi kullanımı ile ilişkili veriler uzaktan algılama (UA) ve coğrafi bilgi sistemleri (CBS) ile analiz edilerek yeni toprak haritası ve veri tabanı hazırlanmış, topraklar Toprak Taksonomisine göre sınıflandırılmıştır. UA ve CBS teknikleri arazi değerlendirme çalışmasında başarıyla uygulanmıştır. ILSEN bilgisayar modeli, Beypazarı topraklarının potansiyel arazi kullanım gruplarının ve tarımsal arazi kullanımı uygunluk değerlerinin belirlenmesinde başarıyla kullanılmıştır. Tarımsal Kullanıma Uygunluk haritası sonuçları, Beypazarı topraklarının %42.8'inin tarımsal kullanımlara uygun olmadığını ve bu toprakların %90.4'ü Lithic Xerorthents olarak sınıflandırılmıştır. Çalışma alanının sadece 12.7'si tarımsal kullanım bakımından en iyi araziler olarak bulunmuştur. Bu alanlar, genelde, Typic Xerofluvents (%30.7), Typic Haploxerepts (%42.4), ve Fluventic Haploxerepts (%26.9) olarak sınıflandırılmıştır.

Anahtar Sözcükler: Haritalama ünitesi, Arazi kaliteleri, Arazi kullanım türleri, Arazi değerlendirme

Introduction

The world population has been increasing rapidly for many years. According to experts, if this increase continues at the present rate, the population will double in the next 60 years. However, our land resources are not infinite. The Food and Agriculture Organization of the United Nations (FAO) (1993) has indicated that there is an urgent need to match land types and land uses in the most practicable and logical way to continue sustainable production and to meet the needs of society while conserving fragile ecosystems.

Land evaluation is concerned with the assessment of land performance when used for a specified purpose (FAO, 1977). In other words, land evaluation is likely to be the prediction of land potential for productive land use types, and then generally a comparison or match of the requirements of each potential land use with the characteristics of each kind of land. The results are a

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measure of the suitability of each kind of land use for each type of land (Dent, 1981; Beek, 1978).

A distinction is made between qualitative land evaluation, mainly based on expert judgment, and quantitative land evaluation based on process simulation models. Land evaluation and quantitative land use systems analysis are used to support sustainable land use planning. The FAO framework for land evaluation provides guidance for land suitability assessment in developing countries where data scarcity often constrains modeling. The integration of bio physical and socio economic information and the sustainable use of land resources are important principles. In quantified land evaluation, process- oriented models make use of quantitative expressions of land qualities (Beek et al., 1997)

There have been many examples of damage to natural resources and inappropriate land use operations or types in the world. Therefore, land evaluation has a very important role in bringing about such understanding and in presenting planners with a comparison of the requirements of different kinds of land use. In addition, land evaluation is an essential step in land use planning and its aim of conserving basic resources for the community for sustainable use and of meeting its needs (Young, 1987).

Şenol et al. (1996) prepared a database for the Agricultural Research and Implementation Farm of Çukurova University, using geographic information systems (GIS), and evaluated the land use by means of the ILSEN computer model. Their results showed that the accuracy of the cartographic materials was very important for good land evaluation assessment. They suggested changing the boundaries, shape and infrastructure of the cultivated plots.

Patil et al. (2001) used GIS and remote sensing (RS) technology to evaluate land utilization for regional development in Thailand. A detailed GIS analysis was carried out to create a comprehensive database, including land use, soil suitability, socio economic data and rainfall. Current land use was studied using GIS, satellite RS, field observations and published records. They found that current traditional agricultural practice was neither helping to upgrade socio economic status nor utilizing the land to its best in most of the study area. They concluded that a multi-layer GIS analysis would make it easier to develop a framework for the optimum use of land areas and could increase production yields while preserving the environmental conditions.

Ali and Sato (2001) stated that GIS and RS may play a vital role at the stages of exploration and analysis of local resources, planning and evaluation.

Başayiğit and Şenol (2001) used the Şenol land evaluation method and the ILSEN computer model to evaluate Türkgeldi state farm soils' agricultural and non-agricultural uses. The detailed soil survey map and report on the Türkgeldi state farm was interpreted and eight different land characteristics and 30 different sub-level land utilization types were used in the research. Inappropriate land uses were observed, and the importance of land use planning was emphasized.

Ano et al. (1998) reported that a recently developed land evaluation study in Spain was highly dependent on the most significant international methodology. They indicated that the lack of a methodological framework suitable for the biophysical characteristics of the Mediterranean region was serious. They proposed a new methodology that considers the particular characteristics of the soils and the environmental problems of Mediterranean agricultural lands. The edaphic resource was studied from a holistic point of view, and several stages were distinguished in the evaluation processes. Firstly, a set of intrinsic and extrinsic soil characteristics are selected and ranked. Secondly, parameters are assessed and grouped into two indexes: capability and vulnerability. The capability index refers to the intrinsic vocation of both the soil and its physical surroundings, and it determines land capability for farming use. The vulnerability index shows the potential limitations on land use due to human activity. The effects of these limitations are either the deterioration of the edaphic system functions or the modification of its properties.

The main objectives of this research were to determine land resources and their suitability classes for land use types in the Beypazarı region near Ankara. The FAO Framework (1977) for Land Evaluation was applied to the study area (29,128 ha) to assess land suitability for four major land use (dry farming, irrigation, forage and forest-Rangeland) groups, using the Şenol and Tekeş computer model (1995).

Materials and Methods

The survey was conducted in the Beypazarı area located to the northwest of the city of Ankara (Figure 1). H27c2 and H27c3, 1:25.000 scaled map sheets were chosen as the study area (approximately 29,560 ha). The study area consists of various topographical features (flat, rolling, hilly and mountainous), and the elevation varies from 450 m to 1600 m above mean sea level. Average annual precipitation and temperatures are 390 mm and 13.1 °C respectively. According to Thornthwaite (1948), the study area was classified as $(C_2B'_2\ s_2b'_3)$ which is dry to semi-arid, 2nd step mesothermal, under a sea climate effect that has a water deficit during the summer. According to the Soil Survey Staff (1999), the soil moisture and soil temperature regimes were xeric and mesic, respectively.

Data obtained from a Landsat 5 TM scene acquired on 9 September 1998 and a 3-arc second DEM were used to obtain land cover classification and landform characterization. Digital geologic map sheets of the study area were integrated with landform and land cover layers, and different soil-land units were obtained. Each soil land unit was analyzed according to its coverage, land cover, parent material and topographical properties, and soil profile pit locations were determined. Twenty-four soil pits were opened and 20 of these were sampled to determine the physical and chemical properties of the study area soils. After laboratory analyses (Soil Survey Staff, 1996), the soils were classified using soil taxonomy (1999).

Georefencing and geocoding processes were applied to Landsat Thematic Mapper data, and the image was geometrically corrected and rectified using 1:25,000 scale topographic maps and GPS data collected in the field. In order to determine land use groups for the study area and its environment, and to support the

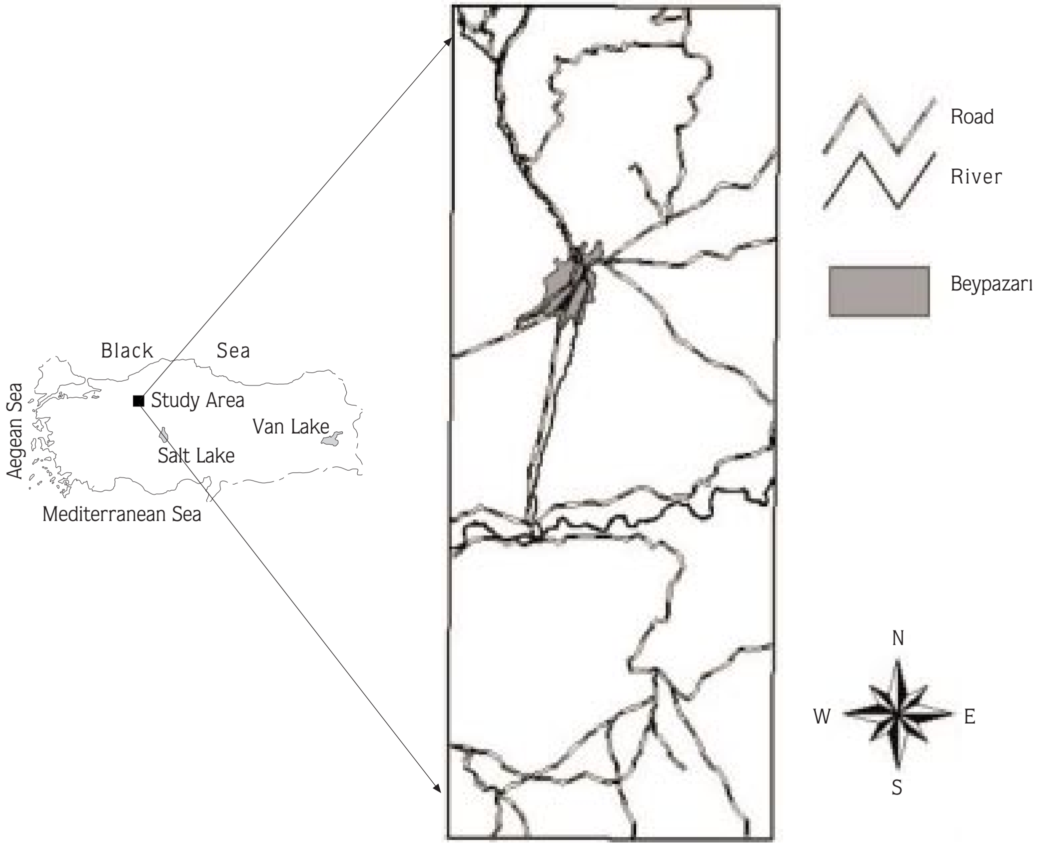

Figure 1. Location of the study area.

interpretation of land use and land cover categories, ground information was collected in the field with the aid of a Magellan Promax 5 global positioning system, and the classification system of the United States Geological Survey (Anderson et al., 1976) was applied.

Data Analysis

Each land mapping unit (LMU) was evaluated according to a set of relevant soil and vegetation characteristics. Entering the diagnostic characteristics (texture, slope, erosion, stoniness, depth, carbonates, organic matter and pH) for each LMU, a digital soil database was prepared. Suitability ratings were designated according to the FAO class levels (1977) (Table 1). A total of 19 different land use types (LUTs) were distinguished, and their land requirements were also determined. Digital soil map databases were examined for input data using ILSEN software for suitability ratings for agricultural uses (Table 2). Matching LUTs to LMUs is an essential step of land evaluation. The suitability of each identified LMU and LUT was assessed using the ILSEN computer model (Şenol and Tekeş, 1995) to generate a land utilization type suitability index (LUTSI).

All of the LUTs were automatically spread to land use groups (Table 3), using the ILSEN computer model for each kind of LMU to determine potential land use groups

Table 1. Suability ratings according to the FAO class levels (1977)

Symbol	Land suitability C.	Index
S1	Highly S.	1.00 – 0.90
S2	Moderately S.	0.89 – 0.75
S3	Marginal S.	0.74 – 0.50
N1	Currently not S.	0.49 – 0.25
N2	Permanently not S.	0.24 – 0.00

Table 2. Suitability Classes for agricultural use

Relative MU Index	Class
1.00 – 0.90 (C1)	Best
0.89 – 0.75 (C2)	Relatively good
0.74 – 0.50 (C3)	Problematic
0.49 – 0.20 (C4)	Restricted
0.19 – 0.00 (C5)	Non-agricultural

Table 3. Land use type groups distributed by ILSEN program.

Land use groups for rainfed agriculture (D)	
D1	Not suitable for this classification
D2	Chickpea, lentil
D3	Wheat, barley
D4	Wheat, barley, chickpea
D5	Wheat, barley, chickpea, cumin, lentil
Land use groups for irrigated agriculture (I)	
I1	Not suitable for this classification
I2	Sugar beat, sunflower
I3	Sugar beat, sunflower, corn
I4	Water melon - melon
I5	Water melon - melon, sugar beat, sunflower
I6	Water melon - melon, sugar beat, sunflower, corn
I7	Tomato, cucumber, water melon - melon, sugar beat, sunflower
I8	Tomato, cucumber, water melon - melon, sugar beat, sunflower, corn
I9	Onion, tomato, cucumber, water melon - melon, sugar beat, sunflower, corn
I10	Onion, spinach, cucumber, water melon - melon, sugar beat, sunflower, corn
I11	Onion, spinach, tomato, cucumber, water melon - melon, sugar beat, sunflower, corn
I12	Lettuce, onion, spinach, tomato, cucumber, water melon - melon, sugar beat, sunflower, corn
I13	Carrot, cucumber, water melon - melon, sugar beat, sunflower, corn
I14	Carrot, tomato, cucumber, water melon - melon, sugar beat, sunflower, corn
I15	Carrot, lettuce, tomato, cucumber, water melon - melon, sugar beat, sunflower, corn,
Land use groups for forage crops (Y)	
Y1	Not suitable for this classification
Y2	Vetch
Y3	Trefoil, vetch
Land use groups for non-agricultural uses (F)	
F1	Not suitable for this classification
F2	Rangeland
F3	Forest
F4	Forest, rangeland

(PLUG). In the final step, using the ILSEN computer model, a suitability map for agricultural use was obtained. The results, obtained from the ILSEN computer model, were added to the soil database for each LMU. These values were used to generate a rainfed agriculture suitability map, an irrigated agriculture suitability map, a forage suitability map, a non-agricultural use suitability map, a potential land use groups map and a suitability map for agricultural use using GIS. The suitability map for agricultural use is presented in Figure 2.

Results and Discussion

Twenty soil series, classified into seven sub groups, were described in the study area. The distribution of the soil series, the slope and depth phases are presented in Tables 4, 5 and 6. The distribution of these sub-groups was lithic xerorhents (13,193.5, 44.6%), typic xerorthents (5621.3, 19.0%), typic xerofluvents (1625.2 ha, 5.5%), typic haploxerepts (5464.1.3 ha, 18.5%), fluventic haploxerepts (1011.2 ha, 3.4%), typic calcixerepts (1844.0 ha, 6.2%) and gypsic haploxerepts (584.7 ha, 2.0%): 107 LMUs (a combination of 20 soil series and their slope - depth phases) were identified from soil maps (Figure 3).

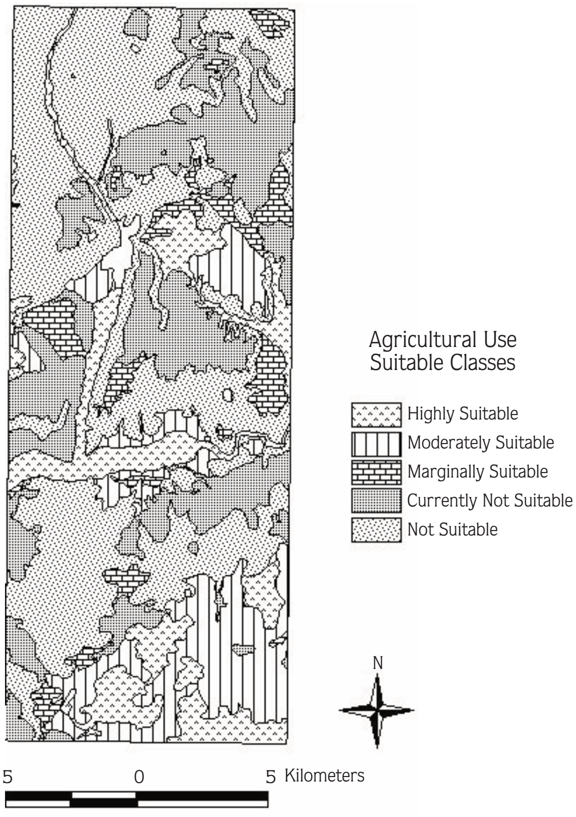

Figure 2. Agricultural land use suitability Map.

Table 4. Distribution of the study area soils.

Soil Series	Classification	Coverage ha	Coverage %	Parent material *	Landform **
Geyik Pınar S.	Lithic xerorthents	3771.6	12.8	LMOS	HMO
Sivrinin Deresi S.	Lithic xerorthents	985.8	3.3	LMOS	OPM
Ebehatun Kır. S.	Lithic xerorthents	1851.1	6.3	LMOS	HMO
Macun Deresi S.	Lithic xerorthents	1356.5	4.6	PYRO	HMO
Al Deresi S.	Lithic xerorthents	2927.0	9.9	GRA	HMO
Karaköy S.	Lithic xerorthents	256.4	0.9	META	HMO
Teke S.	Lithic xerorthents	2045.0	6.9	LMOS	OPM
Sopçaalan S.	Typic xerorthents	515.7	1.7	LMOS	OPM
Karakuyu D. S.	Typic xerorthents	1357.4	4.6	LMOS	OPM
Şarlayık Deresi S.	Typic xerorthents	993.7	3.4	GRA	OPM
Kozalay S.	Typic xerorthents	2754.3	9.3	PYRO	HMO
Kirmir S.	Typic xerofluvents	1625.2	5.5	ALU	PLA
Beypazarı S.	Fluventic haploxerepts	1011.2	3.4	ALU	PLA
Tacettin S.	Gypsic haploxerepts	584.7	2.0	LMOS	TAB
Topal Dik. D S.	Typic calcixerepts	278.4	0.9	LMOS	OPM
İn Deresi S.	Typic calcixerepts	1565.6	5.3	LMOS	OPM
Çamlıbağ Tep. S.	Typic haploxerepts	872.1	3.0	LMOS	OPM
Ortaboğaz Tep. S.	Typic haploxerepts	128.6	0.4	LMOS	OPM
Karlık Deresi S.	Typic haploxerepts	183.8	0.6	PYRO	OPM
Oymaağaç S.	Typic haploxerepts	4279.6	14.5	LMOS	TAB

* LMOS: lacustrine – marine originated sediments, PYRO: pyroclastic (volcanic) rocks, META: metamorphic rocks, GRA: granite-granodiorite, ALU: alluvial material

** PLA: plains, TAB: table lands, OPM: plains with open hill and mountains, HMO: high hill and mountains

Table 5. Distribution of the slope classes of the study area soils.

Slope Class	Coverage	
%	%	ha
0 – 2	12.1	3581.0
2 – 6	9.7	2853.5
6 – 12	18.1	5336.1
12 – 20	24.0	7088.1
20 – 30	18.3	5423.5
30 – 45	8.5	2499.2
> 45	8.7	2562.6
Settlements	0.7	216.5

Table 6. Distribution of the depth classes of the study area soils.

Depth Classes	Coverage	
cm	%	ha
0 – 20	9.8	2892.6
20 – 50	44.1	13039.2
50 – 90	15.8	4671.4
> 90	29.6	8740.8
Settlements	0.7	216.5

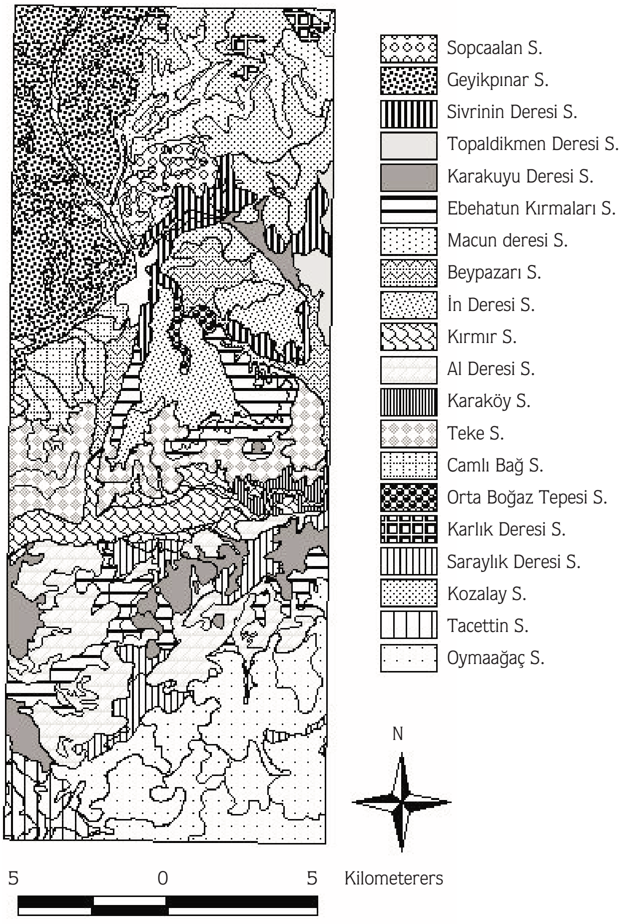

Figure 3. Soil map of the study area.

Georefenced Landsat Thematic Mapper data were classified using ground information, collected in the field with the aid of a Magellan Promax 5 global positioning system. The classification results were checked in the field using GPS at 176 control points and a 79.2% classification accuracy was obtained. Using Landsat Thematic Mapper data classification results and field observations, these LUTs were merged into four main groups: rainfed agricultural LUTs, irrigated agricultural LUTs, forage LUTs and non-agricultural LUTs. According to the field observations, 19 LUT: wheat, barely, chickpea, cumin, lentil (rainfed agriculture), vetch, trefoil (forage), carrot, lattice, onion, spinach, tomato-pepper, cucumber, water melon-melon, sun flower, maize and sugar beet (irrigated agriculture), forest and rangeland (non-agricultural uses), were determined for the study area.

The distribution of the rainfed agriculture suitability classes, non-agricultural use suitability classes, irrigated agriculture suitability classes, forage suitability classes, potential land use groups classes and suitability classes for agricultural uses are presented in Tables 7-12.

Table 7. Distribution of the land use groups for rainfed agriculture.

LUT	Coverage	
	ha	%
D1	21,892.2	74.1
D2	187.8	0.6
D3	894.1	3.0
D4	22.4	0.1
D5	6347.4	21.5

Table 8. Distribution of the land use groups non-agricultural uses.

LUT	Coverage	
	ha	%
F1	2887.9	9.8
F2	11,362.9	38.4
F3	3581.0	12.1
F4	11,512.2	38.9

Table 9. Distribution of the land use groups for irrigated agriculture.

LUT	Coverage		LUT	Coverage	
	ha	%		ha	%
I1	19,884.1	67.3	I9	1276.2	4.3
I2	202.5	0.7	I10	256.5	0.9
I3	15.0	0.1	I11	2960.7	10.0
I4	183.9	0.6	I12	318.7	1.1
I5	834.7	2.8	I13	78.5	0.3
I6	1453.4	4.9	I14	72.0	0.2
I7	308.8	1.0	I15	141.6	0.5
I8	1357.3	4.6			

Table 10. Distribution of the land use groups for forage crops.

LUT	Coverage	
	ha	%
Y1	14,596.6	49.4
Y2	7011.3	23.7
Y3	7736.1	26.2

Table 11. Distribution of the land use groups.

PLUF	Coverage		PLUG	Coverage	
	ha	%		ha	%
D1I1Y1F1	83.5	0.3	D3I3Y3F1	15.0	0.1
D1I1Y1F2	11,362.9	38.4	D3I4Y2F4	238.3	0.8
D1I1Y1F4	2907.1	9.8	D4I5Y3F1	22.4	0.1
D1I1Y2F1	55.1	0.2	D5I14Y3F1	72.0	0.2
D1I1Y2F4	5076.2	17.2	D5I1Y1F1	133.0	0.4
D1I11Y3F1	330.7	1.1	D5I12Y3F3	318.7	1.1
D1I11Y3F3	1907.6	6.5	D5I13Y3F3	78.5	0.3
D1I11Y3F4	111.5	0.4	D5I15Y2F1	141.6	0.5
D1I5Y2F4	394.2	1.3	D5I4Y2F4	183.9	0.6
D1I7Y3F4	308.8	1.0	D5I5Y1F1	87.7	0.3
D1I10Y3F1	256.5	0.9	D5I5Y4F4	92.1	0.3
D2I1Y2F4	187.8	0.6	D5I6Y1F1	186.3	0.6
D3I1Y2F1	146.8	0.5	D5I6Y4F4	1267.2	4.3
D3I2Y2F4	542.7	1.8	D5I8Y1F1	1357.3	4.6
D3I2Y3F4	202.5	0.7	D5I9Y3F2	1276.3	4.3

Table 12. Distribution of the suitability classes for agricultural uses.

LUT	Coverage	
	ha	%
C1	3759.0	12.7
C2	4122.6	13.9
C3	1831.6	6.2
C4	6981.7	23.6
C5	12,649.2	42.8

Settlements occupy 0.7% of in the study area. The distribution of the rainfed agriculture suitability map results showed that 74.1% of the study area soils were not suitable for any type of rainfed agricultural applications (D1). Most of these soils were classified as lithic xerorthents (58.1%) or typic xerorthents (22.9%). Only 21.5% of the study area soils were suitable for all of the rainfed agriculture land use types (D5). Typic haploxerepts (70.4%) and typic xerofluvents (20.4%) were typical soils for these land use applications.

The irrigated agriculture suitability map results showed that 67.3% of the study area soils were not suitable for any irrigation practices and that most of these soils (62.9%) were distributed on lithic xerorthents. The classes I6 (15.4%), I8 (14.3%), I9 (13.5%) and I11 (31.3%) were the major irrigation land use type groups. These soils are distributed on flat and nearly flat areas (alluvial plains and table lands) and classified as typic xerofluvents, fluventic haploxerepts, typic haploxerepts and typic calcixerepts.

According to the forage suitability map results, 49.4% of the study area soils are not suitable for any forage crops (Y0), and 23.7% of the land is suitable for vetch (Y1) and 26.2% is suitable both vetch and trefoil (Y2). Lithic xerorthents occupy 75.5% of the non-suitable areas. Major soils suitable for vetch (Y1) are lithic xerorthents (30.4%), typic xerorthents (37.0%) and typic calcixerepts (26.3%). Typic haploxerepts (61.8%) were the most common suitable soils for both forage crops (Y2).

The suitability map results for non-agricultural uses showed that only 9.8% of study area soils were not suitable for forest and rangelands (F0): 38.4% of the soils were suitable for rangelands (F1), while 12.1% of soils were suitable for forest (F2) and 38.9% were suitable for both rangelands and forest (F3). Lithic xerorthents were the major soils for rangelands with 97.0% area coverage. Typic xerorthents (32.2%), typic haploxerepts (44.5%) and fluventic haploxerepts were found as major soils for forest (F2) LUT. Typic xerorthents (45.6%) were major soils suitable for both rangelands and forest (F3).

Thirty different PLUG were calculated with the ILSEN computer model. Excluding the classes D0-I0-Y0-F1 (38.4%), D0-I10-Y2-F2 (9.8%), D0-I0-Y0-F3 (17.2%) and D0-I0-Y0-I0 (6.5%), the coverage rates of the classes were lower than 5%.

The suitability map for agricultural uses results showed that 42.8% of the study area soils were not suitable for agricultural uses (C5) and that 90.4% of these soils are classified as lithic xerorrthents. Only 12.7% of the study area soils were found to be employed in their best agricultural uses (C1). These soils were classified as typic xerofluvents (30.7%), typic haploxerepts (42.4%) and fluventic haploxerepts (26.9%). The distributions of the relatively good agricultural lands (C2), problematic agricultural lands (C3) and restricted agricultural lands (C4) were 13.9%, 6.2% and 23.6%, respectively. Most of the relatively good agricultural areas (C2) were found in the typic haploxerepts (69.8%). The major soils were lithic xerorthents (27.8%), typic xerorthents (32.5%) and typic haploxerepts (22.9%) for the problematic agricultural lands (C3). Finally, 57.0% of the restricted agricultural lands (C4) were found in the typic xerorthents.

Conclusion

The main objectives of this study were to assess the utility of GIS and RS techniques, to use the ILSEN computer model and to evaluate soils of the Beypazarı area. The soil database of the official soil maps in Turkey, the 1:25.000 scaled maps and soils classified according to the 1949 American soil classification system (Throp and Baldwin, 1938) were not adequate for scientific land evaluation. Official soil maps do not contain enough and scientific quality information for land evolution studies and they have to be upgraded with new classification techniques. RS is a very powerful tool for collecting and monitoring land cover and land use information at a very low cost and high accuracy. Developments in GIS technologies process large amounts of spatial data and provide more accurate and more accessible information about soils. In this research these technologies were successfully used to generate soil map and land evaluation assessments. ILSEN is very useful software for land evaluation studies. However, ILSEN has to be developed and integrated with GIS to consider spatial variability. One of the main limitations of the ILSEN software is that input values of the physical mapping unit index depend heavily on the user.

Detailed economic analyses have not been carried out in this research. Agriculture is one of the most important income sources for the people of Beypazarı. There are not enough land resource inventory data. This study was carried out to emphasize the necessity of land evaluation and will help and lead to the sustainable use of Beypazarı soils.

Acknowledgment

The authors wisch to thank the Scientific and Technical Research Council of Turkey (TÜBİTAK, project no: TARP 2097) and the Ankara University Research Foundation (project no: 20-7-11-02) for their support during the course of this research.

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