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Qualitative and Economic Land Suitability Evaluation for Tea (*Camellia sinensis* L.) in Sloping Area of Guilan, Iran

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ABSTRACT

In the present study and research work, land suitability evaluation (qualitative and economic classification) has been determined for tea in an area including 5000 ha in sloping lands of Guilan province in Iran. In the study area, eight soil series and three orders (Inceptisols, Entisols and Alfisols) were identified. The simple limitation method, the limitation method regarding number and intensity and the parametric methods including the Square root and the Storie methods were used for qualitative land suitability evaluation. Results of first and second methods showed similar marginally suitability classes (S3). According to these methods, the most important limiting factors were climate, topography and physical soil characteristics. Moreover, results of Storie method showed unsuitable condition for tea cultivation (N2), except one land unit, which had non-suitable but correctable conditions (N1). In addition, results of Square root method showed unsuitable condition for one and non-suitable conditions but correctable for six land units and just one land unit had marginally suitable land classes. Economic land suitability evaluation showed that four land units had marginally suitability, three land units had moderately suitability (S2), and only one of them had the highest class (S1) and the best gross benefits. Sloping area in Guilan used to be covered by forest, but regarding to the highly destruction of plant cover and deforestation in order to tea cultivation, an intensive erosion in the area is predict to happen in future.

Keywords: land suitability, qualitative and economic land evaluation, tea

INTRODUCTION

Land evaluation is the assessment of land performance when used for specified purposes. The principal objective of land evaluation is to select the optimum land use for each defined land unit (Sys et al. 1991). Determining land suitability for various efficiency is not only a way to prevent the destruction of agricultural lands, but one of the most important and most basic methods is to combat this problem. Agro ecological land evaluation predicts land behavior for each particular use, and soil quality evaluation predicts the natural ability of each soil to function. However, land evaluation is not the same as soil quality assessment, because biological parameters of the soil did not consider in land evaluation (Braimoh and Vlek 2008).

Many studies related to various aspects of land suitability for crop cultivation have been conducted on the basis of FAO framework in different countries (Chinene and Situmbanauma 1988; Embrechts et al. 1988; Oise 1993; Habruremа and Steiner 1997). Zang et al. (2004) conducted a system for the quantitative evaluation of soil productivity developed and deployed in Gaoyou County, China. The objective of their study was to develop a new quantitative method, within the framework of a GIS. Results of this study showed soils with a bleached layer in the soil profile in sloping areas were not suitable for rice and wheat, but suitable for tea plantations, fruit trees or other kinds of cash crops. Also in several parts of Iran land suitability evaluation for some of crops has been done by Sarvari and Mahmoudi (2001), Seyed Jalali (2001), Jafarzadeh and Abbasi (2006), Jafarzadeh et al. (2008), Rahimi Lake et al. (2009), Behzad et al. (2009).

Economic land evaluation is a method for predicting the micro-economic value of implementing a given land-use system on a given land area. This is a more useful prediction of land performance than a purely physical evaluation, since many land-use decisions are made on the basis of economic value (Rossiter 1995). Tea (*Camellia sinensis* L.) plant is an important source of different beverages, which is claimed to be the most widely consumed fluids after water, globally, and Iran as well. Lahijan region in Guilan province is considered as the major tea producing area in Iran. Tea is mainly cultivated in the hill slopes in the area (Khormali et al. 2007). The objectives of this study were land suitability evaluation (qualitative and economic classification) for tea in steep slopes of Lahijan and Langrud, as well as suitability maps within the framework of GIS.

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MATERIALS AND METHODS

Field description and Sampling

The research was conducted in province of Guilan in north of Iran. The study area is about 5000 hectare in sloping areas of Lahijan and Langroud, lying between 37º 7′ 50″ (4109809 m in UTM system) to 37º 11′ 36″ (4116814 m in UTM system) northern latitude and 50º 2′ 9″(414420 m in UTM system) to 50º 11′ 9″ (424770 m in UTM system) eastern longitude (Fig. 1). The study area is a mountain physiographic unit and cultivated by tea. The average annual precipitation and temperature of the region are 1312 mm and 16.5 °C, respectively. Annual air humidity and annual evaporation rate are 77.41% and 884 mm (estimation of potential evapotranspiration by Penman-Monteith method and CROPWAT software) respectively. Climatic data were prepared from Rasht synoptic weather forecasting data station and Lahijan climatology center. After interpretation of aerial photographs and output results obtain from DEM/GIS, sixteen profiles were dug. In order to obtain a reliable soil data, the soil survey reports from the profiles inspected and then eight profiles within different land units (Fig. 2) were chosen as representative for a more detailed investigation, where parent materials in pedons were granite and phyllite (Table 1). A brief morphological characteristic of horizons for the selected profiles (Schoeneberger et al. 2002) is presented in Table 2.

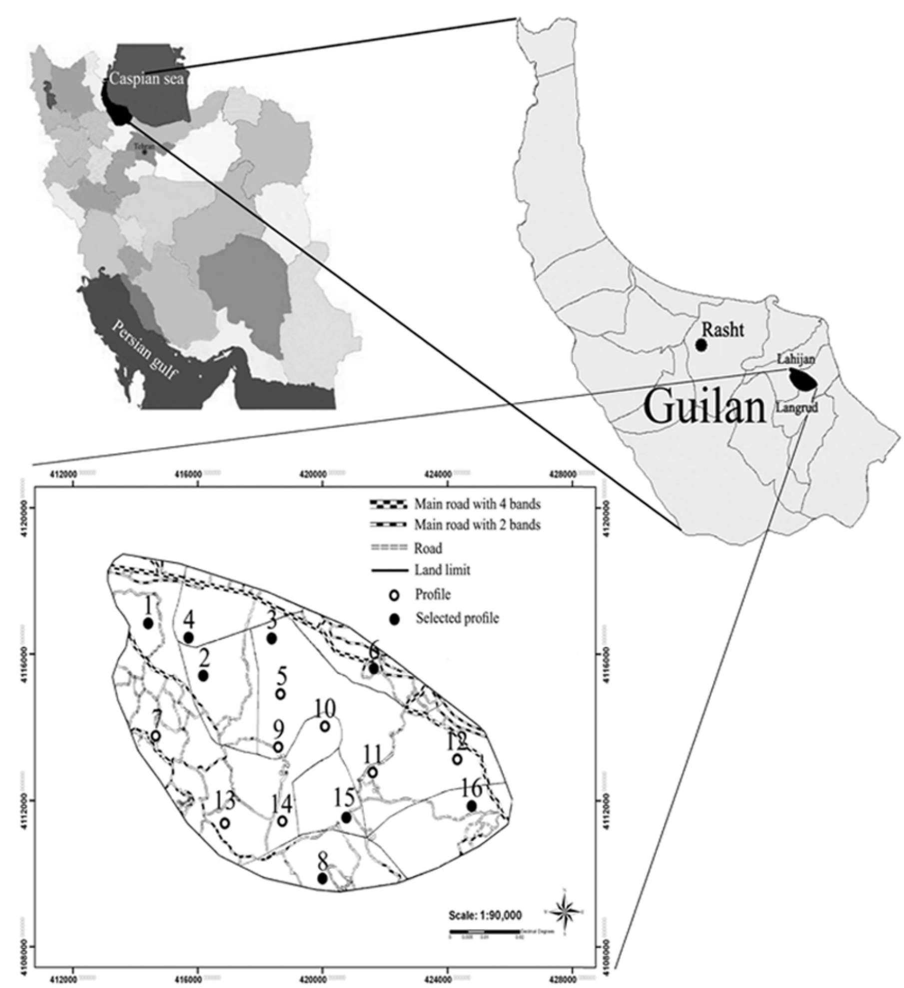

Figure 1. Study area in north of Iran (Guilan province)

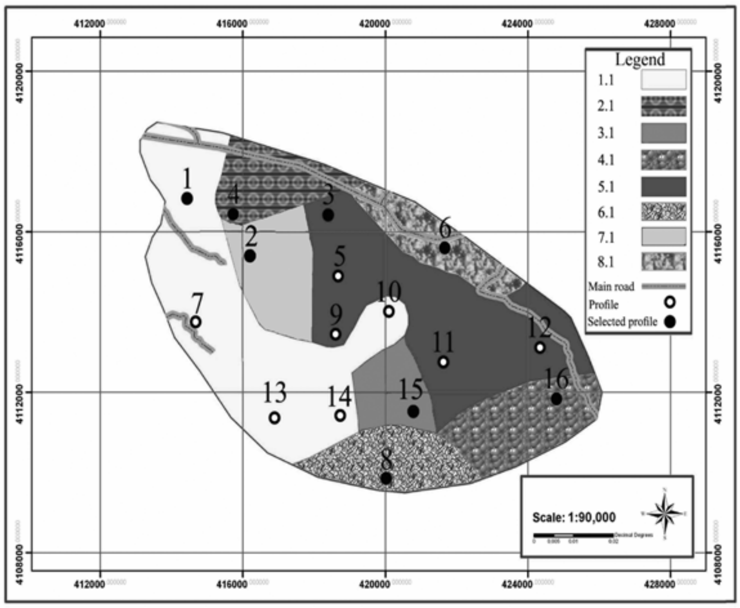

Figure 2. Study area based on land units

Table 1. Environmental information and classification of the eight soil profiles

Land unit	Profile number	Soil Series	Slope (%)	Elevation (m)	Solum thickness (cm)	Parent material	Soil classification	
							WRB systems [a]	Soil taxonomy [b]
1.1	1	Koh-Bijar	.5	99	50	phyllite	Alisols	Clayey (Fine), Mixed, Active, thermic Inceptic Haploudalfs
2.1	4	Kate shall (1)		113	75	phyllite	Alisols	Clayey (Fine), Mixed, Superactive, ThermicUltic Haploudalfs
3.1	15	Porush		162	90	phyllite	Alisols	Fine Loamy, Mixed, Superactive, Thermic Ultic Haploudalfs
4.1	16	Hajisara		43	57	granite	Cambisols	Fine Loamy, Mixed, Active, Thermic Typic Dystrudepts
5.1	3	Dizbon		298	100	granite	Cambisols	Fine Loamy, Mixed, Superactive, Thermic Typic Dystrudepts
6.1	8	Kore-kabijar		75	43	phyllite	Umbrisols	Sandy, Mixed, Superactive, Thermic Typic Dystrudepts
7.1	2	Kate shall (2)		71	25	phyllite	Regosols	Fine Loamy, Mixed, Superactive, Thermic Typic Udorthents
8.1	6	Divshall		83	25	granite	Cambisols	Coarse Loamy, Skeletal, Mixed, Superactive, ThermicTypic Dystrudepts

[a] IUSS Working Group WRB (2006).
[b] Soil Survey Division Staff (2006) classified in family level.

Table 2. Abbreviated morphological properties of horizons for the selected profiles

Horizon	Depth (cm)	Boundary [a]	Color		Texture[b]	Structure[c]	Consistenced		Pores[e]
			Dry	Moist			Moist	wet	
Profile 1									
Ap	0-25	aw	10YR3/6	10YR4/6	CL	2fgr	fr	s/p	2m
Bt	25-50	cs	7.5YR5/4	7.5YR5/6	C	1vfabk-2msbk	fi	s/p	2f
C1	50-84	cs	7.5YR5/6	7.5YR5/8	SCL	m	Fr	ss/p	1f
C2	84-125	-	7.5YR5/8	7.5YR5/8	C	m	Fi	s/p	1vf
Profile 4									
Ap	0-16	aw	10YR4/3	10YR6/3	C	2fgr	fi	s/p	1m
Bt1	16-38	gs	10YR4/6	10YR6/4	C	2mabk	fi	s/p	1vf
Bt2	38-75	gs	10YR4/4	10YR6/4	C	2mabk	fi	s/p	1vf
C	75-100	-	10YR5/4	10YR5/4	C	m	fi	s/p	-
Profile 15									
Ap	0-18	aw	10YR3/3	10YR5/6	C	2mgr	fi	s/p	2m
AB	18-54	cs	10YR4/4	10YR5/6	CL	2mabk-2mgr	fr	s/p	2m
Bt	54-90	gs	10YR5/4	10YR6/4	C	1mabk-m	fi	s/p	1f
C	90~	-	-	-	-	-	-	-	-
Profile 16									
Ap	0-30	aw	10YR3/4	10YR4/6	SCL	1fgr	fr-lo	ss/sp	2m
BC	30-57	gs	7.5YR4/6	7.5YR5/6	SCL	1fabk-m	fr-lo	ss/sp	1m
C	57-94	-	7.5YR5/6	7.5YR5/8	SCL	0	fr-lo	ss/sp	1m

[a] a = abrupt, c = clear, g = gradual; s = smooth, w = wave.[b] C= clay, L= loamy, SL= sandy loam, SCL= sandy clay loam, LS= loamy sand, CL= clay loam.[c] 0 = structureless, 1 = weak, 2 = moderate; vf = very fine, f = fine, m = medium; gr = granular, abk = angular blocky, sbk = subangular blocky, m= massive.
[d] lo= loose, vfr = very friable, fr = friable, fi = firm; s = moderately sticky, ss = slightly sticky, sp = slightly plastic, p = plastic. [e] 1= few, 2= common, 3= many; vf= very fine, f= fine, m=medium.

Table 2. Continued

Horizon	Depth (cm)	Boundary [a]	Color		Texture[b]	Structure[c]	Consistence[d]		Pores[e]
			Dry	Moist			moist	wet	
				Profile 3					
Ap	0-20	aw	10YR4/6	10YR5/6	SCL	2mgr	vfr	ss/sp	2m
AB	20-50	cs	10YR5/6	10YR6/6	SCL	2mabk-2mgr	fr-fi	ss/sp	1f
BC	50-100	cs	7.5YR4/6	7.5YR5/6	L	2mabk-m	fr-fi	ss/sp	1f
Cr1	100-130	cs	7.5YR4/4	7.5YR5/6	SCL	0	fr-fi	ss/sp	1f
Cr2	130-150	-	7.5YR4/6	7.5YR5/8	SCL	0	fi	s/p	1f
				Profile 8					
Ap	0-20	aw	10YR2/2	10YR3/3	CL	2mgr	fr	s/p	2m
Bw	20-43	cs	10YR3/3	10YR3/4	SL	2mabk-2msbk	vfr-lo	ss/sp	2m
C	43-68	-	10YR3/6	10YR3/6	LS	0	vfr-lo	ss/sp	2m
				Profile 2					
Ap	0-25	aw	7.5YR3/4	7.5YR4/6	L	1mgr	fr	s/p	2m
C1	25-50	cs	10YR5/8	10YR5/8	SL	0	fr	ss/sp	1f
C2	50-85	cs	10YR3/6	10YR5/8	SCL	0	fr	ss/sp	1f
C3	85-100	-	10YR4/6	10YR4/6	SCL	0	fr	ss/sp	1f
				Profile 6					
Ap	0-10	aw	10YR3/6	10YR5/8	SL	2fgr	fr	ss/sp	3m
BC	10-25	gw	10YR4/6	10YR6/3	SL	1msbk-m	fr	ss/sp	2m
C	25-75	-	10YR4/6	10YR6/4	SL	0	fr	ss/sp	2m

[a] a = abrupt, c = clear, g = gradual; s = smooth, w = wave.[b] C= clay, L= loamy, SL= sandy loam, SCL= sandy clay loam, LS= loamy sand, CL= clay loam.[c] 0 = structureless, 1 = weak, 2 = moderate; vf = very fine, f = fine, m = medium; gr = granular, abk = angular blocky, sbk = subangular blocky, m= massive.
[d] lo= loose, vfr = very friable, fr = friable, fi = firm; s = moderately sticky, ss = slightly sticky, sp = slightly plastic, p = plastic. [e] 1= few, 2= common, 3= many; vf= very fine, f= fine, m=medium.

Laboratory analysis

Physical and chemical properties of the sieved soil samples (<2mm) were determined after being air-dried. Particle size analysis by hydrometer method (Gee and Or 2002), and bulk density by clod method (Blake and Hartge 1986) were measured. The samples pH values was measured in the mixture of soil/deionized water (1:1) and in the mixture of soil/$CaCl_2$ (1:2) 0.01 M (Thomas 1996). Electrical conductivity (EC) was determined in a saturation extract of soil using conductivity meter (Rhoades 1996). Organic carbon (OC) content was measured by the Walkley–Black wet oxidation method (Nelson and Sommers 1996). Available phosphorus by Olsen method (Kuo 1996) and total nitrogen by Kjeldahl method (Bremner 1996) were determined. Cation exchange capacity (CEC) was determined using sodium acetate (NaOAc) at pH=8.2 (Sumner and Miller 1996). Exchangeable cations (Ca, Mg, Na and K) were extracted using 1 M ammonium acetate (pH=7.0) and were determined by atomic absorption and flame emission spectrometer (Suarez 1996; Helmke and Sparks 1996).

Land suitability evaluation

A wide range of limiting physical, economic and social factors can restrict suitability of the land for different kinds of use (FAO 2007). For qualitative land suitability investigation, simple limitation method, limitation regarding number and intensity method and parametric methods (Storie and square root) were used. Simple limitation method compares the plant requirements with its corresponding qualitative land and climatic characteristics and the most limiting characteristics defines land suitability class. The parametric land evaluation consists in numerical rating of different limitation levels of land characteristics according to a numerical scale between a maximum (normally 100) to a minimum value. Finally, the climatic index, as well as the land index, is calculated from these individual ratings. The calculation of these indices can be carried out following two procedures (Eq. 1 and Eq. 2);

1. The Storie method (Storie 1976):

$$I = A \times \frac{B}{100} \times \frac{C}{100} \times ... \qquad \text{(Eq. 1)}$$

Where:
I = index (%)
A, B, C etc. = ratings (%)
2. Square root method (Khiddir 1986):

$$I = R_{\min} \times \sqrt{\frac{A}{100} \times \frac{B}{100} \times ...} \qquad \text{(Eq. 2)}$$

where:
I = index (%)
R_{min} = minimum rating (%)
A, B, C etc. = remaining ratings (%)
Application of these methods implies that requirement tables have to be produced for each land utilization type. We compared the land characteristics with the plant requirements tables introduced by Sys et al. (1993). For determination, the limits of land classes we used pattern introduced by Sys et al. (1991). The land suitability classes are defined as follows:

- Lands having indexes >75 are in S1 (very suitable) class.
- Lands having indexes 50-75 are in S2 (moderate suitable) class.
- Lands having indexes 25-50 are in S3 (marginal suitable) class.
- Lands having indexes < 25 are in N (non-suitable) class.

Economic land evaluation calculated based on difference between gross income and variable costs. Variable costs like weeding, fertilizers, spraying and pouring herbicide and fertilizers, the cost of harvesting and collecting the yield, the cost of loading and transportation, unpredicted costs and etc were calculated (7302500 Rials in hectares-10000 Rials ~ 1 Dollar).
In addition, for determination of land classes in economic land evaluation, we used pattern introduced by FAO (1983) as mentioned below:

- Lands having >75 maximum gross benefit are in S1 class
- Lands having 50-75 maximum gross benefit are in S2 class
- Lands having 0-50 maximum gross benefit are in S3 class
- Lands having <0 maximum gross benefit are in N class

After determination of qualitative and economic land suitability classes, we presented the output results as georeferenced soil suitability maps using Arc GIS software version 9.2.

RESULTS AND DISCUSSION

Regarding to results obtained from description of the profiles and physical and chemical analysis of the samples (Table 3), soils were classified as Hapludalfs, Dystrudepts and Udorthents (Soil Survey Staff 2006) and Alisols, Cambisols, Umbrisols and Regosols in WRB system (IUSS Working Group WRB 2006). The most important feature observed, is the clay illuviation process shown as Bt horizon mainly in 1, 4 and 15 profiles. Sand content is higher in profiles with granite parent mater.

Table 3. Abbreviated physico-chemical properties of horizons for the selected profiles

Horizon	Depth (cm)	Texture ($g.kg^{-1}$) sand	silt	clay	BD[a] ($g.cm^{-3}$)	Gravel (%)	pH[b] H_2O	$CaCl_2$	ECe ($ds.m^{-1}$)	OC[c] ($g.kg^{-1}$)	N	P ($mg.kg^{-1}$)	CEC[d] ($Cmol.kg^{-1}$)	TEB[e]	B.S[f] (%)	ESP[g]
	Profile 1															
Ap	0-25	326	327	347	1.2	25.4	4.9	3.9	0.4	24	2	5.1	18.9	4.01	21.2	1.64
Bt	25-50	326	247	427	1.24	8.8	4.6	4	0.3	3.6	0.6	2.85	19.6	7	35.7	1.77
C1	50-84	486	167	347	1.32	18.9	4.6	4.1	0.5	3.5	0.5	2.82	18.4	8.02	43.4	1.89
C2	84-125	326	267	407	1.42	-	4.6	4.1	0.7	3.4	0.4	2.79	19.4	8.99	46.3	1.33
								Profile 4								
Ap	0-16	206	307	487	1.25	-	4.5	3.8	0.4	25.8	2.2	7.9	34.6	12.1	35	0.8
Bt1	16-38	166	207	627	1.55	-	5.2	4.3	0.1	1.79	0.05	7.8	37.4	16.6	44.4	0.7
Bt2	38-75	166	247	587	1.64	-	5.1	4.2	0.2	1.73	0.05	7.8	32.3	16.9	52.3	1
C	75-100	206	307	487	1.41	-	5.7	4.9	0.3	1.65	0.04	7.3	21	18.2	86.7	1
								Profile 15								
Ap	0-18	262	333	405	1.2	1.04	5.2	4.4	0.2	23.2	2.3	3.2	29.5	8.48	28.8	2.04
AB	18-54	272	412	345	1.6	2.07	4.9	4.1	0.2	22.6	2.2	3	28.8	7.78	27.2	1.35
Bt	54-90	102	293	605	1.7	0	5.5	4.8	0.1	3.5	0.4	2.28	43.7	15.37	35.1	1.59
C	90~	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
								Profile 16								
Ap	0-30	506	207	287	1.32	8.4	4.1	3.3	0.8	18.9	2	10.1	24.56	5.8	23.6	1.68
BC	30-57	486	187	327	1.4	8.4	3.9	3.4	0.6	17.8	0.5	9.3	19.12	6.7	35	2.44
C	57-94	606	127	267	1.47	10	4.4	3.8	0.4	17.4	0.5	8.4	15	6.78	44.7	2.98

[a] BD = Bulk density; [b] pH in 1:1 H_2O and 1:2 $CaCl_2$; [c] OC= Organic Carbone; [d] CEC= Cations Exchange Capacity; [e] TEB= Total Exchangeable Bases;
[f] B.S= Base Saturation; [g] ESP= Exchangeable sodium Percentage

Table 3. Continued

Horizon	Depth	Texture (g.kg-1)			BD[a]	Gravel	pH[b]		ECe	OC [c]	N	P	CEC [d]	TEB [e]	B.S [f]	ESP [g]
	(cm)	sand	silt	clay	(g.cm-3)	(%)	H2O	CaCl2	(ds.m-1)	(g.kg-1)		(mg.kg-1)	(Cmol.kg-1)		(%)	
							Profile 3									
Ap	0-20	518	273	209	1.24	22.5	4.1	3.5	0.8	13.6	1.7	5	19.34	4.3	22.2	2.6
AB	20-50	518	253	229	1.34	14	4.4	3.6	0.4	12.2	1.8	4.5	20.1	6	29.8	2.2
BC	50-100	438	233	329	1.36	10.6	4.8	3.8	0.18	6.5	0.5	4.5	17	5.5	32.3	3
Cr1	100-130	578	133	289	1.45	16.3	5	4.2	0.16	1.7	0.4	3.8	14.5	4.9	33.6	2.9
Cr2	130-150	538	173	289	1.52	18.7	5	4.1	0.16	1.6	0.4	3.4	14.56	4	27.5	2.6
							Profile 8									
Ap	0-20	406	267	327	1.33	-	5.4	5	0.5	18.9	0.9	3.3	19	5.4	28	5
Bw	20-43	566	147	187	1.46	-	5.9	5.1	0.3	14.1	0.7	2.7	14	4	28.1	4.5
C	43-68	806	87	107	1.52	-	5.9	5.1	0.2	1.4	0.3	1.3	7	2.7	38.9	4.4
							Profile 2									
Ap	0-25	489	313	198	1.3	-	4.8	3.8	0.1	9.2	2.2	3.5	16	3.76	23.5	3.7
C1	25-50	549	273	178	1.48	-	5.2	4.4	0.1	7.9	1.2	1.4	16	4.5	28.1	3.5
C2	50-85	509	253	238	1.45	-	5.2	4.3	0.09	1.9	0.6	1.4	20	6.01	30.1	2.3
C3	85-100	509	273	218	1.48	-	5.1	4.2	0.07	1.9	0.6	0.7	15	5.9	39.3	2
							Profile 6									
Ap	0-10	517	294	189	1.34	23.8	4.2	3.5	0.6	19.6	0.3	9.5	13	4.5	33.6	4.1
BC	10-25	578	234	189	1.31	34.7	4.5	3.7	0.7	18	0.3	3.8	11	3	27.3	4.4
C	25-75	737	174	89	1.5	47.4	5	4.3	0.7	17.4	0.2	3	7	2	28.7	2.3

[a] BD = Bulk density; [b] pH in 1:1 H_2O and 1:2 $CaCl_2$; [c] OC= Organic Carbone; [d] CEC= Cations Exchange Capacity; [e] TEB= Total Exchangeable Bases;
[f] B.S= Base Saturation; [g] ESP= Exchangeable sodium Percentage

Qualitative land suitability and climatic suitability classes for tea plantation in study area (Table 4) showed that all land units had severe climatic suitability class (S3). Main limitation in determining suitability classes were average minimum temperature in the coldest month. According to Simple limitation method, all land units had severe suitability class (S3), the most important limiting factors in whole land units were climate limitations; also 1-1, 3-1, 7-1 and 8-1 land units had topography limitations that caused by slope percentage. Only 8-1 land unit had physical soil characteristics limitation that caused by coarse fragments (high gravel percentage) (Fig. 3-a). High gravel percentage limitations comprise physical, chemical and fertility limitations. It decreased organic matter retention, number and intensity of microorganism activity, cations and anions in soil. All land units had moderate limitation levels (S2) too, for instance, 8-1 land unit had fertility limitation and the loss of nutrient caused by solum thickness and high gravel percentage in moderately suitable (S2) classes. Results of qualitative suitability class in limitation regarding number and intensity method accurately were similar to those of the simple limitation method (Fig. 3-b).

Table 4. Qualitative land suitability and climatic suitability classes for tea plantation in study area

Land unit	Area		Climatic suitability class	Qualitative suitability class					
	ha	(%)		Simple limitation	Limitation regarding number and intensity	Parametric (Storie)		Parametric (Root square)	
						Land index	Land class	Land index	Land class
1.1	2437	31.47	S3	S3ct	S3ct	5.74	N2	17.11	N1
2.1	520	6.7	S3	S3c*	S3c	13.12	N1	27.57	S3
3.1	379	4.9	S3	S3ct**	S3ct	5.93	N2	17.25	N1
4.1	698	9.06	S3	S3c	S3c	7.43	N2	21.85	N1
5.1	2015	26.07	S3	S3c	S3c	7.13	N2	21.37	N1
6.1	579	7.5	S3	S3c	S3c	9.53	N2	24.71	N1
7.1	604	7.8	S3	S3ct	S3ct	6.62	N2	19.45	N1
8.1	495	6.5	S3	S3cts***	S3cts	1.92	N2	9.99	N2

c* climate limitations, t** Topography limitations, s*** Physical soil characteristics limitations.

Results obtained by parametric methods (Storie) showed unsuitable condition for this cultivation (N2). Only 2-1 land unit had non-suitable but correctable (N1) land classes (Fig. 3-c). Results of square root method showed unsuitable condition (N2) for 8-1 land units and non-suitable but correctable (N1) for 1-1, 3-1, 4-1, 5-1, 6-1 and 7-1 land units. Only 2-1 land unit had marginally suitable (S3) land classes (Fig. 3-d). The accuracy of obtained results by the square root method was high and more realistic compared to limitation methods results, therefore according to the results of square root method cultivation of tea can be recommended only for soil profile 4 (2-1 land unit) where had marginally suitable (S3).

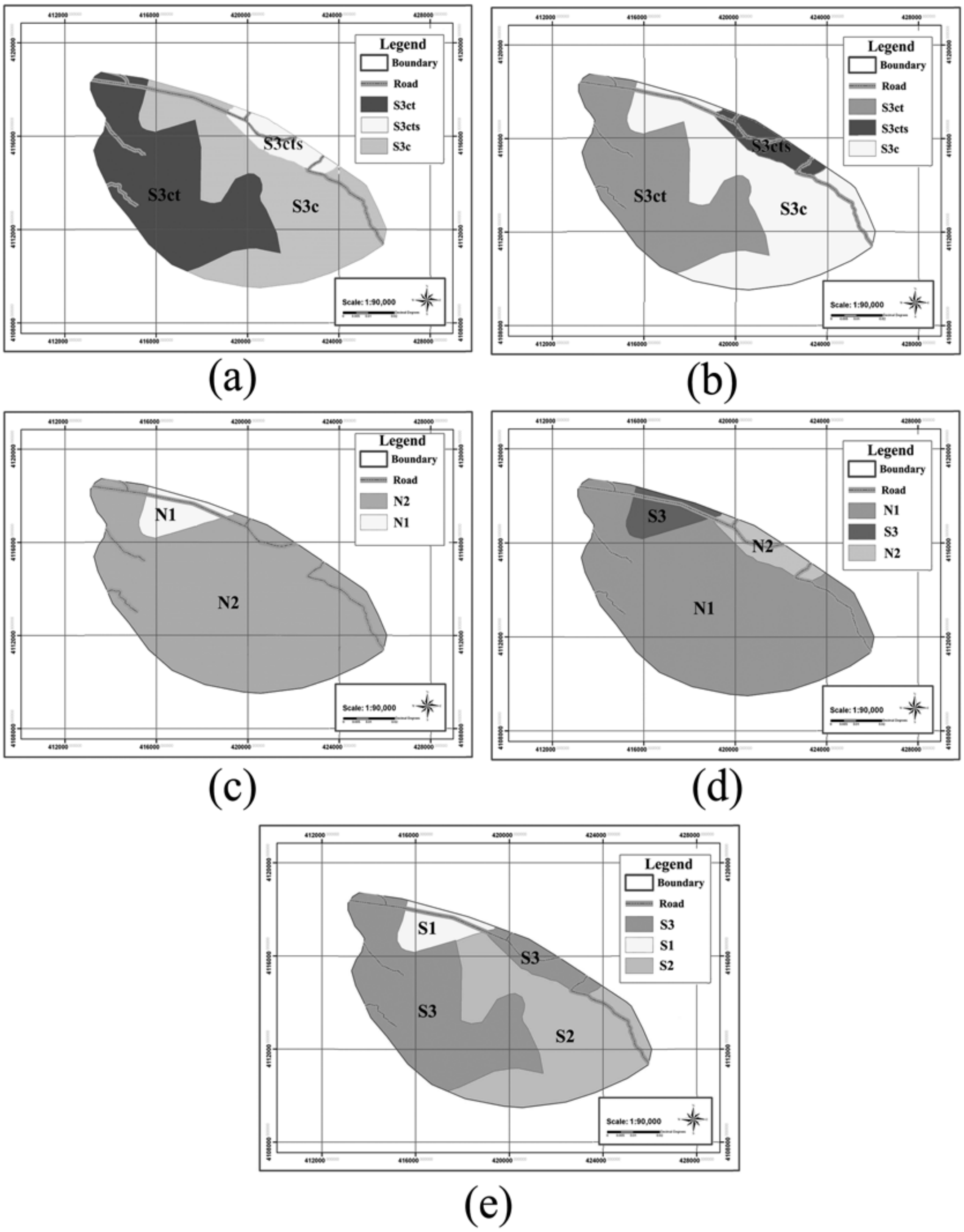

Figure 3. Qualitative land suitability evaluation maps of study area obtained from: (a) simple limitation method, (b) limitation regarding number and intensity method, (c) Storie parametric method, (d) Root square parametric method, and (e) Economic land suitability evaluation map (scale: 1:90000).

According to results obtained by maximum gross benefit in hectare (considering maximum observed yield) the limit of land classes in economic land evaluation can be determined (Table 5). Maximum yield was observed in 2-1 land unit (12 Mg hr $^{-1}$), so:

Table 5. Limit of land classes in economic land evaluation

Crop	Gross benefits (Rials in hectares)			
	S1	S2	S3	N
Tea	> 15088125	15088125–10058750	10058750–0	<0

Gross income = yield amount × price (the prices were calculated according to the 2008-2009 cropping season) of each unit

Gross incomes was obtained by tea price assessed by its quality (first class green leaves and second-class green leaves range: 3200 to 1980 Rials), as:
Maximum yield (kg hr^{-1}) × coefficient related to class green leaves × price of each unit
So, 12000 (kg hr^{-1}) × 0.25 × 3200 = 9600000 Rials
And 12000 (kg hr^{-1}) × 0.75 × 1980 = 17820000 Rials
Gross income = 27420000 Rials
Gross benefits = Gross income – Variable costs
Gross benefits = 27420000 – 7302500 = 20117500 Rials in hectares
Limit of land classes in economic land evaluation based on gross benefits were calculated.
So, 20117500 × 0.75 = 15088125 Rials in hectares
And 20117500 × 0.5 = 10058750 Rials in hectares
After determining the economic suitability class (Table 6), it was revealed that 1-1, 3-1, 7-1 and 8-1 land units had marginally suitability (S3) and 4-1, 5-1 and 6-1 had moderately suitability (S2), but 2-1 land unit lying Kate-e-Shall (1) has the highest class and the best gross benefits (Fig. 3-e). Comparison between qualitative and economic land suitability evaluation for tea showed that economic suitability class were in a higher levels.

Table 6. Gross benefits amount and economic suitability class

Land unit	Area		Gross benefits (Rials in hectares)	Economic suitability class
	ha	(%)		
1.1	2437	31.47	9149500	S3
2.1	520	6.7	20117500	S1
3.1	379	4.9	6407500	S3
4.1	698	9.06	13262500	S2
5.1	2015	26.07	10977500	S2
6.1	579	7.5	10063500	S2
7.1	604	7.8	8692500	S3
8.1	495	6.5	2980000	S3

With comparing climate information and product requirements, the results of this study showed that climatic suitability classes in three methods were S3. According to the high amount of annual rainfall in the region (>1312 mm), at the first look, it seemed that it was enough to fulfill tea water requirement and no irrigation was needed. A detailed study of the rainfall showed that it unequally distributed during the year, and mostly happens in non-cultivation months of the year in winter, when tea is in hibernation period. Considering that about 50 percent of tea production is in summer, so, water balance in this season is negative and the cultivation of tea in the time of the year needs supplementary irrigation. Since the severe topography problem that affects feasibility of effective irrigation system, obtaining a high yield was restricted. Sloping area in Guilan used to be covered by forest, but regarding to the highly destruction of plant cover and deforestation in order to tea cultivation, an intensive erosion in the area is predict to happen in future.

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REFERENCES

Behzad M, Albaji M, Papan P, Boroomand Nasab S, Naseri AA, and Bavi A (2009). Qualitative Evaluation of land suitability for principal crops in Gargar region, Khuzestan province, southwest Iran. Asian J. Plant Sci. 8: 28-34.

Blake GR and Hartge KH (1986). Bulk Density. In: Methods of soil analysis, Part 1-Physical and mineralogical methods, 2nd ed. Agronomy Monograph, vol. 9. (Ed. A Klute), ASA and SSSA, Madison, WI, pp. 363-375.

Braimoh AK and Vlek PLG (2008). Land Use and Soil Resources. Springer Inc. p. 253.

Bremner JM (1996). Nitrogen-total. In: Methods of soil analysis, Part 3- chemical methods. Agronomy Monograph, vol.9. (Eds. Sparks DL), ASA and SSSA, Madison, WI, pp. 1085-1121.

Chinene VR and Situmbanauma W (1988). Land evaluation of the proposed Musaba state farm in Samfya district Zambia. Soil Surv. Land Eval. 8: 176-182.

Embrechts J, Zulkanian P, and Sys C (1988). Physical land evaluation. Using a parametric method application to oil palm plantation in north-sumatra, Indonesia. Soil Surv. and Land Eval. 8: 111-122.

FAO (1983) Guidelines: Land evaluation for rainfed agriculture. Soil Bull, No. 52, FAO p. 237.

FAO (2007) Land evaluation towards a revised framework. Land & Water Discussion Paper 6. FAO, Rome, p. 124.

Gee GW and Or D (2002). Particle-size analysis. In: Methods of soil analysis, Part 4- Physical methods, 2nd ed. Agronomy Monograph, vol. 9. (Eds. JH Dane, GC Topp), ASA and SSSA, Madison, WI, pp. 255-293.

Habrurema E and Steiner K (1997). Soil suitability classification by farmers in southern Rwanada. Geoderma 75: 75-87.

Helmke PA and Sparks DL (1996). Lithium, Sodium, Potassium, Rubidium and Cesium. In: Methods of soil analysis, Part 3- chemical methods. Agronomy Monograph, vol.9. (Ed. DL Sparks), ASA and SSSA, Madison, WI, pp. 551-574.

IUSS Working Group WRB (2006). World reference base for soil Resources: 2nd edition. World Soil Resources Reports No. 103.FAO, Rome.

Jafarzadeh AA and Abbasi G (2006). Qualitative land suitability evaluation for the growth of onion, potato, maize, and alfalfa on soils of the Khalat pushan research station. Biologia 19: 349-352.

Jafarzadeh AA, Alamdari P, Neyshabouri MR, and Saedi S (2008). Land Suitability Evaluation of Bilverdy Research Station for Wheat, Barley, Alfalfa, Maize and Safflower. Soil & Water Res. 3: 81-88.

Khiddir SM (1986). A statistical approach in the use of parametric systems applied to the FAO framework for land evaluation. Ph.D. Thesis. State University Ghent.

Khormali F, Ayoubia Sh, Kananro Foomani F, Fatemi A, and Hemmati Kh (2007). Tea yield and soil properties as affected by slope position and aspect in Lahijan area, Iran. Int. J. Plant Prod. 1: 98-111.

Kuo S (1996). Phosphorus. In: Methods of soil analysis, Part 3- chemical methods. Agronomy Monograph, vol. 9. (Ed. DL Sparks), ASA and SSSA, Madison, WI, pp. 869-920.

Nelson DW and Sommers LE (1996). Total carbone, organic carbone, and organic matter. In: Methods of soil analysis, Part 3- chemical methods. Agronomy Monograph, vol.9. (Ed. DL Sparks), ASA and SSSA, Madison, WI, pp. 961-1010.

Osie BA (1993). Evaluation of some soils in south-western Nigeria for arable crop production. Commun. Soil Sci. Plant Anal. 24: 757-773.

Rahimi Lake H, Taghizadeh Mehrjardi A, Akbarzadeh A, and Ramezanpour H (2009). Qualitative and Quantitive land suitability evaluation for Olive (*Olea europaea* L.) production in Roodbar Region, Iran. Agric. J. 4: 52-62.

Rhoades JD (1996). Salinity: Electrical conductivity and total dissolved solids In: Methods of soil analysis, Part 3- chemical methods. Agronomy Monograph, vol.9. (Ed. DL Sparks), ASA and SSSA, Madison, WI, pp. 417-435.

Rossiter DG (1995). Economic land evaluation, Why and how. Soil Use Manage 11: 132-140.

Sarvari SA and Mahmoudi SH (2001). Qualitative land suitability evaluation for irrigated sugar beet in Ghazvin region. Iranian Journal of Soil and Water. Special issue on soil surv land eval pp. 66-75.

Schoeneberger PJ, Wysocki DA, Benham EC, and Broderson WD (2002). Field book for describing and sampling soils. Version 2.0.. Natural resources conservation service. National soil survey center, Lincoln, NE.

Seyed Jalali SA (2001). Comparison of land suitability classification methods for irrigated winter wheat. Iranian Journal of Soil and Water. Special issue on soil surv land eval pp. 56–65.

Soil Survey Staff (2006). Keys to Soil Taxonomy, (10th ed.), U.S. Dep. Agric., Soil Conserv. Serv., Washington, DC.

Storie RE (1976). Storie Index Soil Rating (revised 1978). Spec. Publ. Div. Agric. Sci. No. 3203, University of California, Berkeley.

Suarez DL (1996). Berylium, Magnesium, Calcium, Strontium, and Barium. In: Methods of soil analysis, Part 3- chemical methods. Agronomy Monograph, vol.9. (Ed. DL Sparks), ASA and SSSA, Madison, WI, pp. 575-601.

Sumner ME and Miller WP (1996). Cations exchange capacity and Exchange Coefficients. In: Methods of soil analysis, Part 3- chemical methods. Agronomy Monograph, vol.9. (Ed. DL Sparks), ASA and SSSA, Madison, WI, pp. 1201-1230.

Sys C, Vanranst E, and Debaveye J (1991). Land evaluation. Part I. Principles in land evaluation and crop production calculations. International training center for post graduate soil scientists. Ghent University. Gent. p. 237.

Sys C, Vanranst E, and Debaveye J (1993). Land evaluation. Part III: Crop requirement. International training center for post graduate soil scientists. Ghent university. Gent, p. 195.

Thomas GW (1996). Soil pH and soil acidity. In: Methods of soil analysis, Part 3- chemical methods. Agronomy Monograph, vol. 9. (Ed. DL Sparks), ASA and SSSA, Madison, WI, pp. 475-490.

Zhanga B, Zhanga Y, Chenb D, Whiteb RE, and Lib Y (2004). A quantitative evaluation system of soil productivity for intensive agriculture in China. Geoderma 123: 319-331.