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Qualitative and Quantitative Land Suitability Evaluation for Olive (*Olea europaea* L.) Production in Roodbar Region, Iran

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Abstract: Problems caused by immethodical and unsuitable using of lands, irregular development of urban areas and therefore reduction in cultivation zones have received widespread attention throughout the world. Using of optimum and suitable methods of lands is the main concern of policy makers for the sustainable planning and management most of the cultivation areas. Hence, studies related to land suitability evaluation will provide sustainable using agricultural lands. The objective of this study is to evaluate qualitative and quantitative Land suitability of the Roodbar region (Guilan province) of Iran on the basis of FAO model for olive plant. This study carried out in an area including 2200 ha in the south part of Roodbar city in the form of semi-detailed surveying level. The soils are classified on the basis of soil taxonomy system (2006). In study area, 6 soil series and 6 phases were identified and the soils were classified in two orders of Aridisols and Entisols. The various procedures of this investigation are site setting, sampling, qualitative and quantitative land suitability evaluation. Qualitative evaluation accomplished according to limitation and parametric methods. Quantitative evaluation was done on the basis of the observed yield level as well. The olive production according to cultivation area and yield values selected as a dominant utilization in Roodbar region. The results showed that the climatic characteristics of the region were very Suitable (S1) for olive plantation. Also, the most important limiting factors of land characteristics were topography, coarse fragment, shallow soil depth and salinity and alkalinity. Evaluation of land suitability using simple limitation method and limitation regarding number and intensity method distinguished that all separated units had moderate suitability to marginal suitability for olive cultivation (S_2-S_3). Based on Storie method, 4 units of separated units had marginal Suitability (S_3) and 2 units had corrigible non-suitability to Non-corrigible Non-suitability (N_1-N_2). Evaluating the land suitability using root square method indicated that 2 units of separated units were moderately Suitable (S_2), 3 units were marginal Suitable (S_3) and 1 unit was corrigible Non-suitable (N_1) for olive cultivation. Quantitative land suitability for olive based on observed yield level identified that three units of separated units had marginal Suitability (S_3) and 2 units were Non-suitable (N) for olive production as well.

Key words: Land suitability, olive, qualitative and quantitative land evaluation, roodbar region

INTRODUCTION

The growing rates of population and consumption and undervaluation of ecosystem services have caused irreversible losses and conversions of prime farmlands, alteration of biogeochemical cycles and pollution of water, air and soil. Proper recognition of land abilities and allocating of them to the best and most profitable and stable revenue operation system has special importance for preventing of ecosystem structure destruction. Sustainability of ecosystem productivity and biodiversity requires quantification of the quality and quantity of natural resources and their suitability for a range of land uses in the planning process of future rural, urban and industrial activities (Kilic *et al*., 2005). Land suitability evaluation often uses for determination of land compatibility values for a special land use. Also, it investigates revenue of an area for various usages before putting it into operation. Hence, this method will provide the exploiting of land with due attention to its ability and potential productivity. However, Land proportion identifies the suitability level of each land unit. Also, By means of investigations related to land evaluation we are able to identify the relationship between land and the type

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of its exploiting. Moreover, this relationship shows the type of proper use of land and hence, has a estimating of essential inputs and outputs levels. In principle, the main objective of land evaluation is the studding of land characteristics and economical conditions for achievement to optimum using of resources without soil degradation (FAO, 1976).

Many studies related to various aspects of land suitability for crop cultivation have been conducted on the basis of FAO framework in different areas (Alcantara *et al*., 1997; Donnollan *et al*., 1990; Friede and Stahr, 1999; Hassan *et al*., 2002; Mujica *et al*., 1995; Young and Goldsmith, 1997). Most of these studies confirm, the advantages and preferences of this method (Embrechts *et al*., 1988; Sys *et al*., 1991; Wilson, 1991). Osie (1993) used FAO guideline for evaluation of land suitability for dryland farming in south west of Nigeria. After qualitative evaluation he used simple limitation method for identification of classes. Ocanell (1975) conducted his investigation according to FAO guideline. He introduced land suitability classes for Oil palm cultivation on the basis of parametric method. His concerned parameters of land qualities were climate, topography, soil physical properties, soil depth, soil fertility and soil sodicity and acidity. Ogunkunle (1993) used FAO framework for evaluation of land suitability for coconut production in southern part of Nigeria. According to his method the most of climatic factors like temperature and precipitation were suitable for coconut production. Also, he introduced some of soil parameters such as Cation Exchange Capacity (CEC) and soil texture as major limitation factors for coconut production. Chinene and Situmbanauma (1988) showed that some of the soil parameters such as its fertility and root available oxygen can be limitation factors for crop production using FAO guideline. Menjiver *et al*. (2003) evaluated the land suitability for olive plant in the Spain. They selected 35 pedons in the study area and used 6 methods for land evaluation. Their results showed that on the basis of FAO guideline, the most limitation factors in the study area were the high level of soil moisture and the intensity of slope. In this system all of areas settled in the N_1 class (corrigible non-suitable). Also, they suggested that the mentioned limitations would reduce by the high expenditures. Bellinfonte *et al*. (2003) performed a study about land suitability evaluation in an area in southern part of Australia. They identified the land suitability for various plants including sylvan (wild), agricultural and garden crops. They used several models for determination of land suitability. They recognized 2 groups of soils including Calcisols and Luvisols in the study area. Their results showed that according to ALMAGRA and SIERRA models olive plant had moderate suitability to high suitability for these two groups of soils. Walia and Chamuah (1992) accomplished a land suitability evaluation for different types of crops in India. The soil of study area for cultivation of agricultural crops had moderate fertility and hence, was in S_2 class. Also, the soil moisture had Non-suitability (N) and soil erosion and acidity was in marginal Suitable (S_3) class for cultivation. Manrique and Vehera (1984) classified the land suitability into three levels in using of low, moderate and high agricultural inputs for potato plant in Hawaii. In using of low level of inputs, 87-94% of soils were non-suitable for potato production. In this case soil acidity, fertility and its moisture content was recognized to be the main limitation factors. Whereas, in using of high level of inputs, 99% of soil was suitable for tomato cultivation due to decreasing of these limitation factors. Similarly, Van Lanen *et al*. (1992) investigated the qualitative and quantitative methods for land suitability evaluation of potato production. They reported that the mentioned methods are able to economize the time of evaluation by approximately 50-70%.

Olive (*Olea europapea* L.) is grown extensively in the Mediterranean Basin, the subtropical regions of Australia, southern Africa and North and South America. Hence, most of the areas having Mediterranean climate may be suitable for olive cultivation. Roodbar region which is located on the south part of Guilan province bordering to the Caspian Sea in the northern Iran is considered as one of the areas having high potential for olive production because of its Mediterranean climate. Despite the economic importance of olive and its by-products, there is limited study about evaluation of the most suitable areas of this region for cultivation of this industrial plant. The present study was therefore, carried out with objectives: to evaluate the quantitative and quantitative land suitability for olive production in this area in order to determine the most proper areas for its cultivation according to land characteristics obtained from soil, climate and topography information and to determine the potential level of land productivity for olive plant and specify the olive yield value using soil index and actual productivity in land units of Roodbar region.

MATERIALS AND METHODS

The study area is located in the south direction of Roodbar city and by the side of Shahrood River in Guilan province of Iran. This study carried out in an area including 2200 ha between 36°41'11"-36°37'52" in northern latitude and 49°27', 20"-49°31' 3" eastern longitude in the form of semi-detailed surveying level for

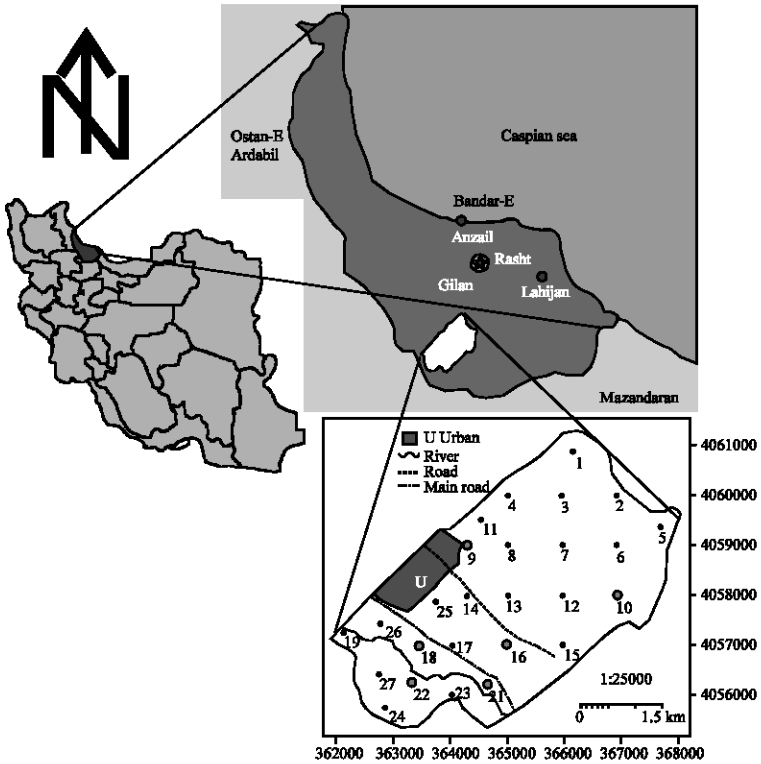

Fig. 1: Study area in North of Iran (Guilan province)

determination of soil characteristics and illustration of soil maps. After interpretation of aerial photographs the digging site of soil profile was identified. Twenty six pedons was selected and then was evaluated. Figure 1 demonstrates the position of the study area in north of Iran (Guilan province). Also, Fig. 2 illustrates the location of the representative pedons and soil characteristics map of the Roodbar region. Climatic data obtained from Manjil synoptic meterological station has been used for climatic evaluation. Soil moisture and temperature regimes of the region by means of Newhall software were arid and thermic, respectively.

We compared the land characteristics with the plant requirements tables introduced by Sys *et al.* (1991b) as well. Subsequently, in order to investigate the qualitative land suitability, simple method, limitation regarding number and intensity method and parametric methods (Storie and root square) were used. Also, based on these methods, land suitability classes were determined for olive crop. According to the results of measured land index in parametric method suggested by Sys *et al.* (1991), lands having indexes >75 are in S_1 (very suitable) class. Also, on the basis of this method land indexes of 50-75, 25-50 and <25 are in S_2 (moderate suitable), S_3 (marginal suitable) and N (non-suitable) classes, respectively.

For quantitative land suitability evaluation often methods which classify areas according to earth productivity values are used. For achieving to this issue, it was required that we delineate the boundary between two consecutive classes with high accuracy before land classification. For determinating of these limits we had to calculate the optimum yield or potential yield of olive primarily. We used Villalobos *et al.* (2006) model for estimating of olive productivity potential in our study that expressed as:

$$Y = R_{sp} \times Q_e \times \varepsilon_0 \quad (1)$$

where:

Y (g m^{-2})	=	Denotes the potential yield or radiation thermal production
R_{sp}	=	The annual incoming of Photosynthetic Active Radiation (PAR) (MJ m^{-2})
Q_e	=	The fraction of PAR intercepted by the canopy
ε_0	=	The Radiation-Use Efficiency (RUE) for above ground biomass production (g MJ^{-1})

Villalobos *et al.* (2006) reported the Radiation-Use Efficiency for above ground biomass production of olive plant (ε_0) about 0.44. Hence, they presented the Eq. (2) by using of this coefficient as mentioned:

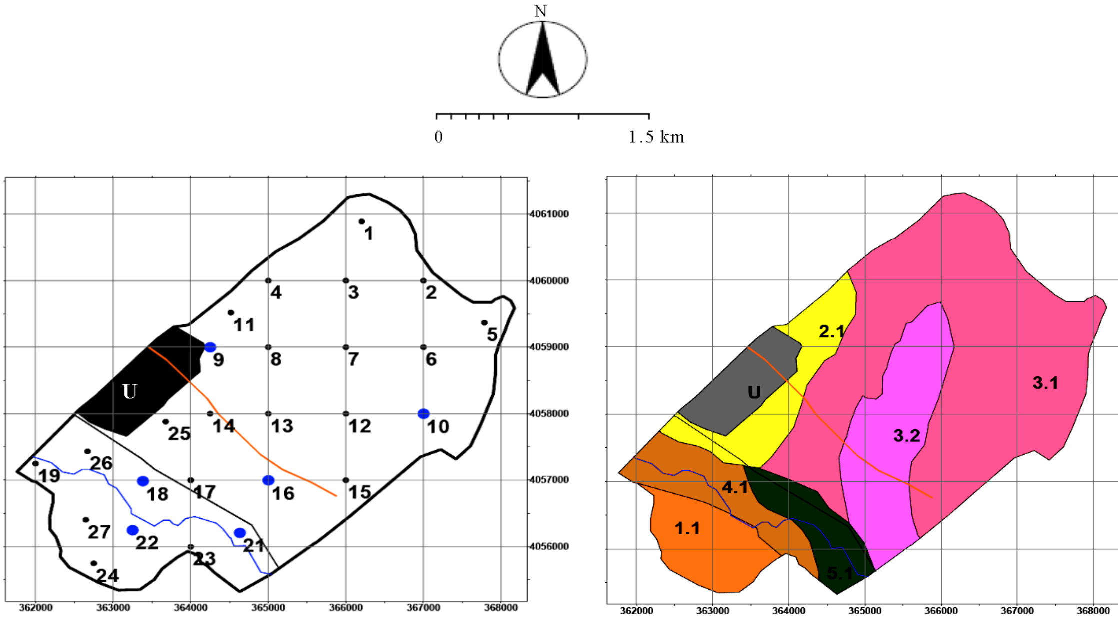

Fig. 2: a): The location of 26 soil profiles that were digged in the study area (we selected the profiles of 9, 10, 16, 18, 21 and 22 as representative pedons), b): Map of the soil characteristics and land units (Scale: 1:25000)

$$Y = 0.44 \times R_{sp} \times Q_e \quad (2)$$

Indeed, we used the class restrictions determination according to marginal yield as a method of quantitative land suitability evaluation in this study. Marginal yield shows the level of productivity that causes the total profit to be in equilibrium with the total expenses. Therefore, marginal yield can be showed by the Eq. 3:

$$\frac{\text{Total expenses}}{\text{Cost of yield}} \quad (3)$$

For measuring of marginal yield it was required that we estimate the essential expenses for production of a specific crop in each land unit. Hence, we collected the total information about current expenses including entire expenditures related to cultural practices in each land unit using specific forms. Consequently, total expenditures divided to total income are extractable. For determination the limits of land classes we used pattern introduced by Sys *et al.* (1991a) as mentioned below:

- The boundary between S_1 and S_2 classes is equal to the percentage of potential yield
- The boundary between S_2 and S_3 classes is equal to total marginal yield and its 40%
- The boundary between S_3 and N classes is equal to 10% of marginal yield and lower than marginal yield

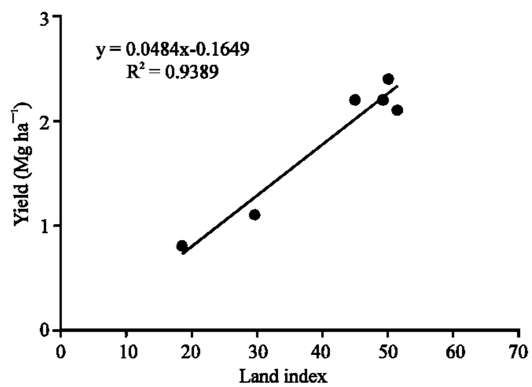

Fig. 3: Application of linear regression between land index and the observed yield for olive plant

First, we have to verify the accuracy of land evaluation. In this step, predicted yield will obtain using yield potential multipled by soil index. The presence of significant relationship between observed yield and predicted yield will prove the accuracy of selected land evaluation manner. After recognition of the accuracy of qualitative land suitability evaluation a linear regression among land index and observed yield for olive plant was applied (Fig. 3).

According to definition of the limits of various land classes, this regression equation will describe the boundaries between them using land index. Ultimately, just with measurement of land index in other land units or similar areas having this condition we are able to estimate the yield level by using these equations. Combination of this estimated yield with accomplished economical calculations can leads to the finding of beneficial advantages for each crop in each land unit.

After determination of qualitative and quantitative land suitability classes we presented the output results as georeferenced soil suitability maps using GIS utility.

RESULTS AND DISCUSSION

Qualitative land suitability: With regarding to results obtained from description of soil profiles and physical and chemical analysis of soil samples (Table 1), soils were classified as Entisols and Aridisols (2006) on the basis of soil taxonomy system. Also, in this area, 6 soil series and 6 phases were identified (Table 2). The results of climatic suitability evaluation showed that the climatic characteristics of the region according to that given by Sys *et al*. (1991) and our climatic data are very Suitable (S1) for olive plantation (Table 3). Hence, the climatic condition of this region had not any limitation for olive cultivation. Also, our results show that in the event of providing available water for olive plant, its vegetative growth will take about 365 days in this region or this period is throughout a complete year.

The results obtained from investigation of the influence of land characteristics on qualitative land suitability identified that the level of gravel, low depth of soil, Exchangeable Sodium Percentage (ESP) and slope intensity are the most limitation factors for olive plantation in this region. Therefore, these parameters will impress the yield value of olive plant. Table 3 illustrates the qualitative land suitability results for olive plant. This table indicates the range of changes of classes in different land units according to simple limitation method, limitation regarding number and intensity method, Storie parametric method and root square parametric method are S_2-S_3, S_2-S_3, S_3-N_2 and S_2-N_1, respectively. Also, Fig. 4 shows the qualitative land suitability evaluation maps of the region obtained from different methods.

Quantitative land suitability: In this stage of land evaluation by means of parameters such as land index, climatical potential yield, predicted yield and marginal yield, we developed the equations for estimating the yield values in the study area. Using of Villalobos *et al*. (2006) model and climatic data, potential yield of olive plant was estimated approximately 5.2 Mg ha^{-1} in this region. The high correlation between observed yield and predicted yield (potential yield x soil index) shows the accuracy of evaluation method. To develop this relationship we used soil index derived from parametric root square method. We introduce this equation as follows:

$$Y = 0.962, X-0.233 \qquad R^2 = 0.957 \qquad (4)$$

where, Y and X denote the observed yield (actual yield) and predicted yield, respectively. In the second stage for estimation of the yield value, a mathematical equation between land index and observed yield was developed:

Table 1: Some physico-chemical properties of representative pedons

Profile	Horizon	Depth (cm)	Silt (%)	Sand (%)	Clay (%)	Gravel (%)	S.P (%)	pHp	ECe (dS m^{-1})	TNV (%)	$CaSO_4$ (%)	OC (%)	Soil (Cmol kg^{-1}) CEC	TEB	B.S (%)	ESP (%)
22	A	0-30	50	15	35	35	40	8.01	1.38	19.5	0	0.86	22.6	15.45	92	17
	BK	30-55	51	10	39	35	35.3	7.97	2.16	16.5	0	0.6	23.1	19.8	93.9	18.7
	CK1	55-90	20	50	30	35	44	8.01	18.5	18.5	0	0.7	23.3	18.22	94	16.5
	CK2	90-130	19	49	32	35	42	7.9	17	19	0	0.6	22.5	19	94	16
9	A	0-28	57	10	33	35	41	8.15	0.87	22	0.5	0	23.7	21.7	93.7	3.2
	CK1	28-50	9	77	14	35	38	7.5	2.3	14.75	0.6	0	14.8	13.17	93.8	3
	CK2	50-83	10	77	13	35	37	7.6	2.5	2.57	0.7	0	14.7	13.2	93.7	3.9
10	A	0-30	50	15	35	40	40	7.8	1.77	13	0.13	1	23	21.42	96	9
	CK1	30-62	26	44	30	25	40	7.4	2.6	11.9	0.15	0.9	16.7	12.37	90.5	10
	CK2	62-94	27	55	18	25	43	7.3	4.1	12.5	0.15	0.9	20	16.15	94.6	10
	CK3	94-130	30	53	17	25	43	7.3	4.8	11	0.25	0.4	18	16	93	12
16	A	0-25	10	60	30	25	39	7.5	1.8	15	0	0.9	10.9	8.77	87.3	37
	CK1	25-58	11	55	34	25	39	7.5	4	17.5	0.15	0.9	13	11.9	98	44
	CK2	58-98	17	58	25	25	40	7.5	19.1	13.5	0.17	0.6	6.08	5.9	91.3	44
	CK3	98-139	15	60	25	35	42	8.5	18.9	16	0.15	0.5	5	4.5	95	44
18	A	0-25	12	70	18	35	50	7.9	2.4	20	0	0.5	22	18.44	93.6	16
	CK1	25-48	10	82	8	25	29	7.6	4.6	20	0	0.9	13	8.11	91.1	17
	CK2	48-82	6	89	5	35	32	7.8	3.9	18	0	0.7	10	6.7	90	17.3
21	A	0-20	46	15	39	15	33	8.1	1.22	21	0	2.3	24.1	20.96	94.2	31
	BCK	20-45	50	18	32	15	34	7.7	6.6	20.5	0.14	0.7	25.2	18.2	94.2	31.9
	CK1	45-84	51	19	32	35	29.4	7.5	4.6	19	0.15	0.7	23.9	19	92.3	30
	CK2	84-105	45	20	35	35	27	7.7	5	22	0.2	0.3	22	20	95	32
	CK3	105-145	45	19	36	35	25	7.9	5	24	0.4	0.1	20	18	96	34

Table 2: Morphological characteristics of representative pedons

Horizon	Depth (cm)	Color (moist)	Color (dry)	Texture	Structure	Boundary	Consistence D	Consistence W	HCl reaction
Profile 22 (trace or plateaux): Fine loamy skeletal, mixed, thermic Typic Haplocalcids									
A	0-30	5YR6/4	5YR4/4	SiCL	1fabk-ma	g.w	h	ss/p	esd
BK	30-55	5YR4/4	5YR3/4	SiCL	1mabk	a.w	h	s/p	esm2rss
CK1	55-90	7.5YR5/4	7.5YR4/4	SCL	ma	a.w	h	s/p	esm2rss
CK2	90-130	7.5YR4/4	7.5YR3/4	SCL	ma		h	s/p	esm2rss
Profile 9 (trace or plateaux): Coarse loamy skeletal, mixed, thermic Typic Torriorthents									
A	0-28	7.5YR6/6	7.5YR5/6	SiCL	1fabk-ma	g.w	sh-h	s/p	esd
CK1	28-50	5YR4/3	5YR3/3	SL	ma	g.w	sh-h	s/p	esf2rss
CK2	50-83	5YR4/4	5YR3/4	SL	ma		h	s/p	esm2rss
Profile 10 (trace or plateaux): Fine loamy, mixed, thermic Typic Torrifluvents									
A	0-30	7.5YR6/6	7.5YR5/6	SiCL	1fabk-ma	g.w	sh	s/p	esd
CK1	30-62	7.5YR4/4	5YR4/3	SCL	ma	g.s	sh	ss/p	esf2rss
CK2	62-94	5YR4/4	5YR4/3	SL	ma	g.s	h	ss/po	esf2rss
CK3	94-130	5YR4/4	5YR3/4	SL	ma		h	ss/po	esm2rss
Profile 16 (trace or plateaux): Fine loamy, mixed, thermic Typic Torrifluvents									
A	0-25	7.5YR5/4	7.5YR4/4	SCL	1fabk-ma	a.w	sh	ss/p	esd
CK1	25-58	7.5YR4/3	7.5YR3/3	SCL	ma-1fabk	a.s	sh	ss/p	esf2rss
CK2	58-98	5YR4/4	5YR4/3	SCL	ma	a.s	h	s/p	esf2rss
CK3	98-139	5YR4/3	5YR3/3	SCL	ma		h	s/p	esm2rss
Profile 18 (border of river): Coarse loamy skeletal, mixed, thermic Typic Torrifluvents									
A	0-25	7.5YR6/4	7.5YR5/4	SL	1fabk	a.s	sh	s/p	esd
CK1	25-48	5YR5/4	5YR4/4	LS	ma-1fabk	g.w	sh	s/p	esf1rss
CK2	48-82	5YR4/4	5YR3/4	LS	ma		h	s/p	esm2rss
Profile 21 (border of river): Fine loamy, mixed, thermic Typic Haplocalcids									
A	0-20	7.5YR4/6	7.5YR4/5	SiCL	2mabk	g.w	sh	ss/p	esd
BCK	20-45	7.5YR4/4	7.5YR4/3	SiCL	1mabk	g.w	sh	ss/p	esc2rss
CK1	45-84	7.5YR5/4	7.5YR4/4	SiCL	ma-1mabk	g.s	sh	s/p	esc2rss
CK2	84-105	5YR5/4	5YR4/4	SCL	ma	g.s	h	s/p	esf2rss
CK3	105-145	5YR4/4	5YR3/4	SCL	ma		h	s/p	esm2rss

(1) 1 = weak, 2 = moderate, m = medium, f = fine, abk = angular blocky, ma = massive, (2) SiCL = Silty Clay Loam, SCL = Sandy Clay Loam, SL = Sandy Loam, LS = Loamy Sand

Table 3: Qualitative land suitability and climatic suitability classes for olive plantation in the study area

Land unit	Area ha	Area (%)	Climatic suitability class	Qualitative suitability class: Simple limitation	Limitation regarding number and intensity	Parametric (storie) Land index	Parametric (storie) Land class	Parametric (root square) Land index	Parametric (root square) Land class
1.1	177	8.04	S_1	S_{2w}	S_2	34.5	S_3	50.4	S_2
2.1	358	16.27	S_1	S_{3S}	S_3	33.2	S_3	49.1	S_3
3.1	1059	48.13	S_1	S_{3t}	S_3	19.7	N_1	29.6	S_3
4.1	296	13.45	S_1	S_{3tn}	S_3	8.91	N_2	18.65	N_1
5.1	176	8.00	S_1	S_{3S}	S_3	33.6	S_3	51.4	S_2
6.1	134	6.09	S_1	S_{2wn}	S_2	29.9	S_3	45	S_3

$$Y = 0.048, X-0.168 \qquad R^2 = 0.939 \tag{5}$$

In the above equation, Y is the level of yield and X is the level of land index. Consequently, we determined the limits of land classes according to yield level. The amount of marginal yield in the study area according to the level of olive green yield in the 2005-2006 cropping season is obtainable using the following equation:

$$\frac{14000000\ (\text{Rial})}{7000\ (\text{Rial})} = 2\ \text{Mg ha}^{-1} \tag{6}$$

In this equation, Rial is the currency unit of Iran. Moreover, the results of economical investigations for determination the variable cost values of olive plant is presented in Table 4. The boundary between S_1 and S_2 classes is the 75% of potential yield for olive plant. This level is equal to:

The limit between S_1 and S_2:

$$0.75\times5.2 = 3.9\ \text{Mg ha}^{-1} \tag{7}$$

The limit between S_2 and S_3 classes is 75% more than the marginal yield level for olive plant. This level is equal to:

The limit between S_2 and S_3:

$$2 + (0.4\times2) = 2.8\ \text{Mg ha}^{-1} \tag{8}$$

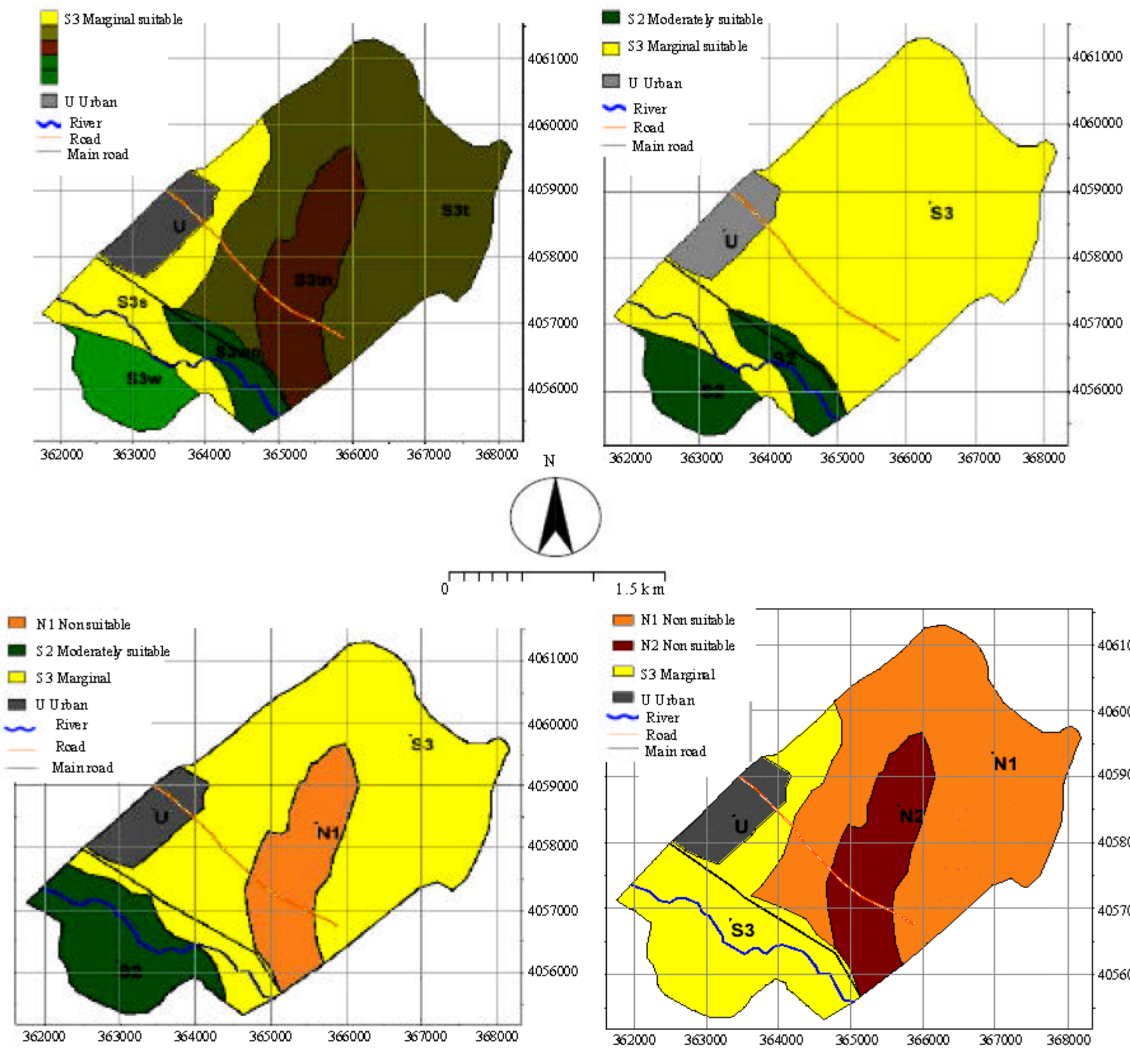

Fig. 4: Qualitative land suitability evaluation maps of the study area obtained from, a): Simple limitation method, b): Limitation regarding number and intensity method, c): Root square parametric method and d): Storie parametric method (Scale: 1:125000)

The limit between S_3 and N classes is 10% less than the marginal yield level for olive plant. This level is equal to:

$$\text{The limit between } S_3 \text{ and N: } 2-(0.1\times2) = 1.8 \text{ Mg ha}^{-1} \quad (9)$$

According to the calculated limit among S_3 and N and the definition of these 2 classes, the boundary between them have been considered the marginal yield or 2 Mg ha^{-1} in this study (Table 5). One of the most important advantages of this stage of land evaluation is that the obtained equation from estimation of yield level according to land index (land characteristics) can be useful in similar situations like other areas in the region or larger areas.

The next stage in quantitative land suitability is determination of classes for different land units of olive production by using of mathematical model or related nemograrh and the level of land index for each unit. Table 6 illustrates the results of quantitative land suitability evaluation for different land units. As shown in this table, the cultivation of olive in units of 1.1, 2.1, 5.1 and 6.1 has marginal Suitability (S_3). Also, the units of 3.1 and 4.1 are unsuitable (N) for olive plantation. Figure 5 shows the quantitative land suitability evaluation maps of the region.

According to the comparison of different methods of quantitative land suitability evaluation can be concluded that the parametric methods, spatially the Storie parametric method, will lead to more reasonable

Table 4: Economical investigations for determining the variable cost values of olive plant in 1 ha (we used this variables for measuring of the marginal yield level)

Operation kind and its description	Value	Unit/person/Mg/Kg/Li/ha/day	*Unit price (Rial)	*Total price (Rial)
Plough of the trees foot	10	Person	70000	700000
Summer pruning	2	Person	500000	100000
Winter pruning	1	ha	1200000	1200000
Dredging of channels in gravimetric irrigation	2	Person	50000	100000
Amortization and servicing of irrigation system	5%	ha	1200000	960000
Irrigation	5	Person	80000	400000
Purchasing and transportation of chemical fertilizers (N:P:K)	40	Kg	550	247500
Purchasing and transportation of manures (animal wastes)	10	Mg	900000	900000
Application of fertilizers for trees	10	Person	70000	7000000
Purchasing and spraying of poisons	1	ha	400000	400000
Spraying of microelements	1	ha	700000	700000
Instruments for transportation of harvested yield (boxes)	20	Number	35000	700000
The cost of harvesting and collecting the yield	-	Kg	-	3000000
The cost of loading and transportation	1	Service	35000	35000
Insurance of the yield	1	ha	1450000	1450000
Water-rate	1	ha	300000	300000
Electricity-rate	1	ha	100000	100000
Fuel-rate	1	ha	100000	100000
Amortization and repairing of machineries	12%	%	5500000	660000
Purchasing of horticultural gadgets	2	Series	250000	50000
Fighting against weeds	1	ha	450000	450000
Trapping for olive fly	1	ha	300000	300000
Unpredicted costs	5%	%	18267.5	9134000
Total price				14000000

*The prices are calculated according to the 2005-2006 cropping season

Table 5: The limits of land suitability class

	Marginal yield (Mg ha^{-1})				Land index			
Land class	S_1	S_2	S_3	N	S_1	S_2	S_3	N
Olive yield	>3.9	2.8-3.9	2-2.8	<2	>84.75	61.8-85.75	45-61.8	<45

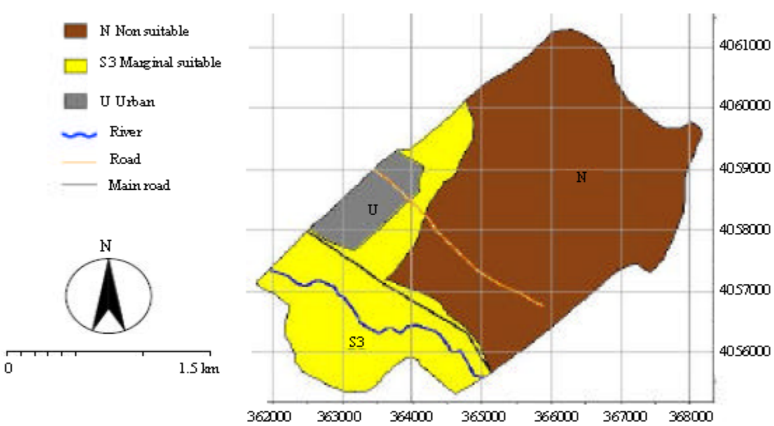

Fig. 5: Quantitative land suitability evaluation map of the study area (Scale: 1:75000)

results. Our results is in line with the work done by, Khormali *et al*. (2007). They indicated that using of parametric method (root square equation) instead of simple multiplication will provide realistic results. They also reported that the physical suitability classes determined by simple and number and intensity limitations methods had identical limitation degrees, whereas parametric methods (including Storie and square root) showed lower classes for tea production in all landscape positions due to the interaction among ratings of land characteristics. Similarly, Mandal *et al*. (2002) reported that land index calculated by khidir method (square root) was highly correlated with actual cotton yield in Nagpur district in India. Also, Seyed Jalali (2001) used 4 different land suitability methods for land suitability classification of irrigated winter wheat. He pointed out that simple limitation method, limitation regarding number and intensity of limitation and parametric method (square

Table 6: The results of quantitative land suitability evaluation for different land units

	Area				
Land unit	ha	(%)	Land index	Yield*	Land class
1.1	177	8.04	50.04	2.230	S_3
2.1	358	16.27	49.10	2.100	S_3
3.1	1059	48.13	29.60	1.250	N
4.1	296	13.45	18.56	0.722	N
5.1	176	8.00	51.40	2.290	S_3
6.1	134	6.09	45.00	1.990	S_3

*These yield values have been obtained from regression equations of land index (Mg ha^{-1})

root method) were closely related, but the application of Storie method led to a land suitability class which was one level lower, compare to other methods. Other similar conclusions have reported by the Manrique and Vehera (1984).

With regarding to our results and other studies, we recommend that simple limitation method or limitation regarding number and intensity of limitation are more appropriate for qualitative land suitability classification and parametric is more accurate for quantitative land suitability classification purposes.

For reaching to best results of land suitability evaluation, soil map have a fundamental role. An important difficulty for succeeding of this kind of studies in Iran is the scarcity of plant requirements tables and also, incoherence of these tables with Iran condition. The accuracy of the land suitability evaluation methods used in this study is confirmable for Iran. But, so much is adjustment and modification of these tables with different condition of Iran leads to more proper results.

Also, for eliminating the chief limitation factors in the study area there are many ways. We suggest several methods for solving of these limitation factors here: Because of the presence of intense topography in some parts of the region, terracing can mitigate this important limitation factor. But, this terracing should be performed with respect to the soil depth. Moreover, carrying out the tracing without consideration of soil depth by itself is a limitation factor.

The soil sodicity problem of the region can be reduced by the amendatory operations. Also, soil salinity can be removed by reclaiming these soils through leaching, especially by using the high quality of irrigation water and applied management programs, which can decrease the salinity.

For proper implementation of these operations more investigation must be accomplish in this area. In the case of resolving the soil depth which is an important limitation factor of the region for olive cultivation there are several methods. The best technique that we introduce here is using of dropping irrigation. The irrigation of olive plant with dropping method leads to growing the olive roots on the surfaces sectors of the soil profile. Also, alteration the cultivation type of the region with crops having exterior roots will alleviate this difficulty.

CONCLUSION

The results of this study showed that climatic characteristics of the region were very suitable for olive plantation. The largest parts of the study area were classified as moderate and marginal suitable to almost non-suitable for investigated olive plant due to physical and chemical soil parameters such as topography, coarse fragment and low soil depth.

Furthermore, the most limiting chemical factors being considered in this area is soil salinity and alkalinity. Also, the most suitable land units in the study area based on quantitative evaluation and according to actual yield of the region were 1.1, 5.1, 2.1, 6.1, 3.1 and 4.1, respectively.

These results are confirmed by the calculated land index for each land unit. Having superiority of predicted yield from actual yield in each land unit shows the accuracy of selected degrees in evaluation of different parameters. In general, quantitative land suitability classes for olive production in this region for each certain land unit had lower proportion than qualitative land suitability classes.

This result due to the amount of cultivation management in each land unit is also acceptable. On the other hand, the soil maps for agricultural suitability designed in this research can be helpful in carrying out the management processes. Also, the qualitative land suitability evaluation assists decision makers in ensuring that lands are used according to their capacities to satisfy human needs for present and future generations, thus, sustaining ecological and economic productivity of natural resources.

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