Land Suitability Evaluation of Bilverdy Research Station for Wheat, Barley, Alfalfa, Maize and Safflower

Ali Asghar JAFARZADEH, Parisa ALAMDARI, Mohamed Reza NEYSHABOURI and Siamak SAEDI

Department of Soil Science, Faculty of Agriculture, University of Tabriz, I.R. of Iran

Abstract: In the present study and research work, land suitability evaluation (qualitative classification) was made for the Bilverdy research station of the Islamic Azad University in East Azarbaijan for wheat, barley, alfalfa, maize and safflower. The Simple Limitation Method (SLM), the Limitation Method regarding Number and Intensity (LMNI) and the Parametric Methods (PM) such as the square-root and the Storie methods were used. The landscape, climate and soil and characteristics that influence suitability of the land for particular crops have been combined according to the adopted methodology. Economic factors were excluded and moderate level of management was assumed. The results of different methods show that the most important limiting factors are climate, pH, organic matter (OM), gravel, salinity and sodicity, taken either alone or in combination. For safflower, the cation exchange capacity (CEC) can be added to these factors. Evaluation by the SLM and LMNI methods result in similar suitability classes, which confirms previous findings by other researchers for the same crops. However, in many cases the use of parametric methods, especially the square-root method, turned to be more realistic in distinguishing separate suitability classes. This study not only compares different methods and their results but also evaluates the suitability of the study area for particular crops. According to the square-root method, the area can be recommended as marginally suitable for cultivation of wheat, barley, alfalfa and safflower and is expected to yield about 40–65% of optimal production.

Keywords: climate; pH; gravel; organic matter; cation exchange capacity; salinity; sodicity

Relatively scarcity of land resources for agriculture and insufficient food security of world's population require that the land be used in an optimum way. Based on FAO report (1991), 91% of developing countries (not including China) are potentially capable of dry farming on 2573 million ha which, in comparison with 757 million ha of irrigated land, is a considerable area. In arid and semiarid areas such as Iran, the problem of optimum land use is highly relevant. In Iran, 32 million ha of agricultural soils are suitable for crop cultivation, either rainfed or irrigated, provided that competent soil studies are carried out to indicate suitability of these soils for particular use under particular climate (Sys & Verheye 1974). The land suitability is assessed as a part of the rational cropping system (FAO 1976, 1983), in which the land use is optimised for a specific purpose (Sys *et al.* 1991a). Wheat, barley, alfalfa, maize and safflower are important crops commercially produced in major parts of Iran and also in the East & West Azerbaijan provinces, where their production depends very much on climate, soil, topography and water availability. These are the most important categories of environmental information required for judging land suitability. In different parts of Iran, land suitability was evaluated for some of these crops by Movahhedi

Naeni (1993), Ghasemi Dehkordi (1994), Sarvari and Mahmoudi (2001), Jafarzadeh and Atabakazar (2004), Jafarzadeh *et al.* (2005a, b), Jafarzadeh and Abbasi (2006), and Shahbazi and Jafarzadeh (2004), in order to find an optimum use for each land unit.

Purpose of this study is, first, to confirm the results of previous researchers as to the performance of different land evaluation methods and, second, to provide actual evaluation of the study area suitability for particular crops, based upon the Simple Limitation Method (SLM), the Limitation Method regarding Number and Intensity (LMNI) and two Parametric Methods (PM).

MATERIALS AND METHODS

Site and climate characteristics

Bilverdy research station with about 106 ha total area lies between 46°08' and 46°40' East latitudes and between 35°08' and 35°12' North longitudes. The altitude of the region is about 1550 m above sea level. The area is mainly used for wheat cultivation, while the rest is covered by native vegetation of acroption (*Compositae* L.), achillea (*Compositae* L.), chenopodium (*Chenopodiaceae* L.), alhaji (*Papilionaceae* L.) and salsola (*Chenopodiaceae* L.) (Alamdari 2004). The slope varies between 1% and 5%. There is no drainage problem in this area. The most important climate characteristics necessary for land suitability estimation (temperature, rainfall and relative humidity) were collected from the Ahar meteorological station (Table 1), where the average annual total rainfall is about 302.8 mm, with the mean and maximum annual temperatures being 4.8°C and 17.5°C, respectively.

Soil characteristics and land qualities

In order to obtain reliable soil data, the available soil survey reports were inspected and, based on this, nine representative soil profiles were chosen for a more detailed investigation within different land units with different average slope steepness. Soil profile descriptions (Table 2), samplings and analyses were made using standard terminology and procedures (Soil Survey Staff 1993). The soils were classified by Saedi and Jafarzadeh (2004) and Saedi *et al.* (2005) according to USDA classification system (Soil Survey Staff 2006) as belonging to the Aridisols order, Sodic Haplocambids and Typic Haplocambids suborders (Table 3). According to the map of soil temperature and moisture regimes of Iran (Banaei 1998), the soil temperature and moisture regimes of the area were identified as mesic and aridic, respectively. In the process of qualitative land suitability evaluation, it is the physical soil characteristics (texture, structure, stones, profile depth, $CaCO_3$ status and gypsum status), the fertility characteristics not easy to correct (apparent cation exchange capacity (CEC), sum of exchangeable base cations, pH in H_2O, organic matter) and the salinity and alkalinity that play an important role. The land qualities such as the moisture and oxygen availability and the foothold

Table 1. Climatic characteristics from the Ahar meteological station

Monthly temperatures (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max. mean	2.6	3	8.8	16.3	20.9	25.5	17.7	27.1	24.6	17.8	11.5	5.5
Min. mean	–5.5	–5	–0.8	2.3	8	11.8	15.2	14.9	10.8	6.3	1.6	–2.3
Absol. max	15.6	17.4	21	26.5	30.2	34.2	36.4	36.4	35	29	22.5	17
Absol. min	–19	–20.5	–17.5	–11	–4	6	8	7.4	4	–2.5	–16.6	–19
Mean monthly	–1.5	–0.6	4	10.3	14.5	18.7	21.5	21	17.7	12	6.6	1.6
Rainfall (mm)	18.44	19.2	38.9	42.7	14.4	29.4	5.3	9.1	9	33	31.1	22.2
Mean relative humidity (%)	68.7	69.7	67.4	60.7	59.8	56.3	51.4	55.8	56.1	62.1	61.5	67.5
Sunshine hours	4.74	5.15	5.13	6.29	7.57	9.1	9.59	8.82	8.08	6.16	5.36	4.36
Potential ET (mm)	26.7	35.6	55.8	95.6	131	171.8	191.4	179.6	138.2	85.6	50.6	34.3
½ ETp (mm)	13.35	17.8	27.9	47.8	65.5	85.9	95.7	89.8	69.1	42.8	25.3	17.15

Table 2. Analytical characteristics of representative soil profile for land units of the study area

Land unit	Horizon	Depth	C (%)	Si (%)	S (%)	Text. class	pH	OM (%)	$CaCO_3$ (%)	ECe (dS/m)	CEC ($Cmol^+$/kg)	Gravel (%)
1	A	0–25	3.36	22.7	41	SL	8.76	0.2	23.5	27.9	18.55	0.11
	C_1	25–55	9.33	27.8	39.3	SL	8.32	0.23	23.8	13.04	16.91	–
	C_2	55–120	43.1	15.9	41	C	8.46	0.25	20.5	0.61	23.05	–
	C_3	> 120	45	16	39	C	8.39	0.2	22.1	0.3	22.9	–
2	A	0–28	22.6	33	4.44	L	8.25	0.22	23.8	6.2	11.74	0.02
	BK	28–55	32	27	41	CL	8.46	0.23	23.9	5.72	16.46	0.05
	C_1	55–120	2.8	54.4	43.8	SL	8.85	0.24	21.5	5.48	1.88	0.15
	C_2	> 120	4	55	41	SL	7.98	0.25	22.7	5.6	2.5	0.2
3	A	0–25	16.4	25.5	58.1	SL	7.98	0.25	23.8	8.84	8.7	–
	B_1	25–55	13	37.4	49.6	L	8.14	0.19	24.9	1.95	6.88	0.02
	B_2	55–120	24.9	32.3	42.8	L	9.88	0.25	24.8	4.2	12.95	–
	C	> 120	33	27	40	CL	9.01	0.22	24.8	3.08	16.94	–
4	A	0–25	13	34	53	SL	8.11	0.25	24.9	8.9	7	2.86
	B	25–50	9.6	31.2	59.2	SL	8.14	0.23	24.7	5.25	5.26	0.22
	C	50–80	4.2	40	55.8	SL	9.2	0.18	24.4	5.7	2.46	32.35
	2AB	80–120	17.1	30.5	52.4	SL	10.03	0.26	24.8	5.5	90.07	0.19
	3C	> 120	14	28	58	SL	9.6	0.22	24.6	5.2	7.44	0.2
5	A	0–30	28.3	24.4	47.3	SCL	8.03	0.35	24.8	6.65	14.85	3.33
	B_1	30–60	21.5	26.1	52.4	SCL	8.82	0.22	24.8	6.7	11.19	0.9
	B_2	60–105	25.5	40.3	34.2	L	9.16	0.19	24.9	3.91	13.13	0
	C	> 105	5.1	52.2	42.7	SiL	9.33	0.2	23	1.9	2.95	0.79
6	A	0–35	30.6	31.8	37.6	SiCL	8.8	0.27	24.8	20.16	15.84	0
	B_1	35–80	25.5	42.5	42.5	L	10.07	0.2	24.9	4.42	13.15	0.12
	B_2	80–120	23.8	34	34	L	9.9	0.26	24.8	1.42	12.42	0.16
	C	> 120	24	35	35	L	9.98	0.23	24.8	2.92	12.46	0.14
7	A	0–9	33.4	28.9	38.7	CL	9.64	0.25	24.8	3.97	16.7	0.5
	B_1	9–22	31	32	37	CL	9.14	0.26	24.9	0.054	16.02	3.16
	B_2	22–64	18.2	2.3	79.5	LS	8.54	0.13	24.5	11.15	9.36	0.75
	C_1	64–120	34	27	39	CL	9.58	0.27	24.7	0.94	17.54	60.83
	C_2	> 120	32	25	43	CL	9.06	0.26	24.7	0.5	16.52	60.5
8	A	0–35	35	29	43	CL	8.45	0.26	24.9	14.53	18.02	0.6
	B_1	35–75	22.7	34.1	43.2	L	9.1	0.21	24.8	4.83	11.77	0.14
	B_2	75–120	30.5	40.5	29	CL	9.55	0.22	24.8	4.56	15.69	0.16
	C	> 120	17.9	29.9	52.2	L	10	0.24	24.9	3.41	9.43	0.15
9	A	0–15	35.3	43	21.7	LC	8.74	0.3	24.7	5.31	18.25	1.9
	B_1	15–35	31.6	45	23.4	LC	8.98	0.24	24.9	3.98	16.28	2.03
	B_2	35–75	19.8	22.1	58.1	LS	8.85	0.16	24.8	2.9	10.22	0.37
	C_1	75–120	30.3	44	35.7	LC	9.45	0.23	23.8	1.42	15.61	30.81
	C_2	> 120	34.4	30	35.6	LC	9.15	0.22	24.32	0.9	17.64	30.45

C (clay), Si (silt), S (sand); textural class (USDA textural class): L (loam), SL (sandy loam), CL (clay loam), LS (loamy sand), LC (loamy clay), SiL (silt loam), SCL (sandy clay loam), SiCL (silt clay loam), all estimated by the hydrometer method; OM (organic matter), ECe (electrical conductivity of saturated soil paste extract), CEC (cation exchange capacity) for root development depend to a large extent on the soil texture, the content of coarse fragments and stones, the soil depth and structure. The coarse fragments, present as gravel and cobbles at the surface and in the top 20 cm layer, influence tillage conditions and the capacity of the soil to retain nutrients and water. Experience has shown that most crops produce excellent yields with an effective root zone depth of 90 to 100 cm. Therefore, for annual crops, the dense root system is usually assumed to occur within the upper 100 cm, while most tree crops have a dense to moderate root system up to the 150 cm depth.

The textural classes to be used for land suitability evaluation were recalculated using depth-weighting factors up to the depth 1 m for annual crops and up to 1.5 m or up to an impermeable layer for perennial crops. When the content of gypsum in the root zone is higher than 25% and the mean lime and gypsum content decreases with depth within the top 30 cm layer, then the lime and gypsum content in the soil was evaluated for this upper 30 cm only. In the other cases, the recalculated lime and gypsum content, using depth-weighting factors, was taken. The apparent CEC (ACEC) of the B horizon, or at 50 cm depth for A–C profiles, or just at the lithic or paralithic contact if this was present within 50 cm from the surface, was calculated as the weighted average of the sum of the exchangeable Ca, Mg and K, taking into account pH and organic matter (OM) in the upper 25 cm of the soil. In the irrigated land, salinity and alkalinity evaluation was made for the 100 cm depth from the soil surface, while the salinity evaluation for annual crops with shallow root systems was calculated as a weighted average of the upper 50 cm only.

Land suitability evaluation

The crop requirements with respect to climate, landscape and soil were summarized in separate tables according to Sys *et al.* (1993). With the help of these tables, the qualitative land suitability evaluation was done for wheat (*Triticum* spp. L.), barley (*Hordeum vulgare* L.), alfalfa (*Medicago sativa* L.), maize (*Zea mays* L.) and safflower (*Carthamus tinctorius* L.) by comparing the actual soil characteristics and qualities with the crop requirements. The lands were classified using the Simple Limitation Method (SLM), the Limitation Method regarding Number and Intensity (LMNI) and two Parametric Methods (PM), namely, the square-root and the Storie methods (Sys *et al.* 1991a, b).

Simple limitation method (SLM)

The simple limitation method implies that the crop requirement tables are made for each land utilisation type. For each characteristic, the tables define the class-level criteria. The methodology suggests that, in the first place, an evaluation of the climatic characteristics is made, with an aim to determine a climate class level to be used in the following evaluation. The climate class level is determined by the lowest class level among those found for particular climatic characteristics. Then, similarly, the land class is determined by the lowest class level among those found for particular soil characteristics. The SLM was used, for example,

Table 3. Families of representative soils in the study area (Saedi & Jafarzadeh 2004; Saedi *et al.* 2005)

Soil family (soil taxonomy)	Representative profile in land unit
Fine mixed, superactive, mesic, Sodic Haplocambids	1
Loamy mixed, active, mesic, Typic Haplocalcids	2
Loamy mixed, active, mesic, Sodic Haplocambids	3
Loamy mixed, active, mesic, Sodic Haplocambids Coarse	4
Loamy mixed, active, mesic, Sodic Haplocambids	5
Loamy mixed, active, mesic, Sodic Haplocambids	6
Loamy mixed, active, mesic, Sodic Haplocambids Coarse	7
Loamy mixed, active, mesic, Sodic Haplocambids	8
Coarse loamy mixed, active, mesic, Sodic Haplocambids	9

by Osie (1993) for qualitative land suitability determination of five soil series in South-Western Nigeria for crops such as maize, rice and cassava, cultivated under rainfed conditions.

Limitation method regarding number and intensity of limitations

This method defines land classes according to number and intensity of limitations. The crop requirement tables are requested which define limitation levels for each characteristic. The methodology evaluates, in the first place, the climatic characteristics, regrouped according to radiation, temperature, rainfall and humidity. For each climatic characteristic group, the most severe limitation determines the climatic suitability class, which is then used as the corresponding limitation level for the total land evaluation. The evaluation is carried out by comparing the actual land characteristics with the limitation levels defined by the crop requirement tables. This method is more difficult than SLM, but the approach is more accurate, because it considers the land with several limitations of the same level as belonging to a lower-class land than that with only a single limitation of the same level.

Parametric methods (PM)

The parametric land evaluation consists in numerical rating of different limitation levels of land characteristics according to a numerical scale between the maximum (normalised as 100%) and the minimum value. Finally, the climatic index, as well as the land index, is calculated from these individual ratings. In our case, the indices were calculated following two alternative procedures:

The Storie method (Storie 1976):

The index was taken as a product of individual ratings:

$$I = A \times \frac{B}{100} \times \frac{C}{100} \times \ldots \quad (1)$$

where:
I – index (%)
A, B, C etc. – ratings (%)

Square-root method (Khiddir 1986):

$$I = R_{\min} \times \sqrt{\frac{B}{100} \times \frac{C}{100} \times \ldots} \quad (2)$$

where:
I – index (%)
$R_{\min}$ – minimum rating (%)
A, B, C etc. – remaining ratings (%)

RESULTS AND DISCUSSION

According to Vink's (1960) report, the suitability is largely a matter of producing crop yield with relatively low inputs and also a matter of crop needs

Table 4. Land suitability classes in the study area for barley, wheat and alfalfa based on different methods

LU	Barley				Wheat				Alfalfa			
	SLM	LMNI	Storie	Square root	SLM	LMNI	Storie	Square root	SLM	LMNI	Storie	Square root
1	N_{2fn}	N_{2fn}	N_2	N_2	N_{2fn}	N_{2fn}	N_2	N_2	N_{2fn}	N_{2fn}	N_2	N_2
2	S_{3sf}	S_{3sf}	N_1	S_3	S_{3s}	S_{3s}	N_1	S_3	S_{3sf}	S_{3cf}	N_2	N_1
3	S_{3sf}	S_{3sf}	N_1	S_3	S_{3s}	S_{3s}	N_1	S_3	S_{3sf}	S_{3sf}	N_2	N_1
4	S_{3f}	S_{3f}	N_1	S_3	S_{3s}	S_{3s}	N_1	S_3	S_{3f}	S_{3f}	N_1	S_3
5	S_{3f}	S_{3f}	S_3	S_3	S_{2cf}	S_{2cf}	S_3	S_3	S_{3f}	S_{3f}	N_2	S_3
6	N_{2fn}	N_{2fn}	N_2	N_2	N_{2fn}	N_{2fn}	N_2	N_2	N_{2n}	N_{2n}	N_2	N_2
7	N_{2f}	N_{2f}	N_2	N_2	N_{2f}	N_{2f}	N_1	N_1	N_{2f}	N_{2f}	N_2	N_2
8	S_{3sfn}	S_{3sfn}	N_2	N_1	S_{3sfn}	S_{3sfn}	N_2	N_2	S_{3sfn}	S_{3sfn}	N_2	N_2
9	N_{2f}	N_{2f}	N_2	N_1	N_{2f}	N_{2f}	N_2	N_1	N_{2f}	N_{2f}	N_2	N_2

SLM – simple limitation method; LMNI – limitation method regarding number and intensity; LU – land unit; f – fertility limitation; n – salinity and alkalinity limitations; s – soil limitation; c – climate limitation

Table 5. Land suitability classes of the study area for maize and safflower based on different methods

LU	Maize				Safflower			
	SLM	LMNI	Storie	Square root	SLM	LMNI	Storie	Square root
1	N_{2fn}	N_{2fn}	N_2	N_2	N_{2fn}	N_{2fn}	N_2	N_2
2	S_{3csf}	S_{3cf}	N_2	N_2	S_{3f}	S_{3f}	N_1	S_3
3	S_{3csfn}	S_{3cfn}	N_2	N_2	S_{3f}	S_{3f}	N_2	N_2
4	S_{3csfn}	S_{3cfn}	N_2	N_1	S_{3f}	S_{3f}	N_2	N_1
5	S_{3cfn}	S_{3cfn}	N_2	N_1	S_{3f}	S_{3f}	N_1	S_3
6	N_{2fn}	N_{2fn}	N_2	N_2	N_{2fn}	N_{2n}	N_2	N_2
7	N_{2fn}	N_{2fn}	N_2	N_2	N_{2f}	N_{2f}	N_2	N_2
8	N_{2n}	N_{2n}	N_2	N_2	N_{2f}	N_{2f}	N_2	N_2
9	N_{2fn}	N_{2fn}	N_2	N_2	N_{2f}	N_{2f}	N_2	N_2

SLM – simple limitation method; LMNI – limitation method regarding number and intensity; LU – land unit; f – fertility limitation; n – salinity and alkalinity limitations; s – soil limitation; c – climate limitation

and the influence of soil and site characteristics upon the crop. The identification and delineation of land with desirable attributes are two important stages in finding a land suitable for a specific crop. In this study, after analyzing soil samples, the requirements of wheat, barely, alfalfa, maize and safflower, summarised by Sys *et al.* (1993) were used. Then the simple limitation method (SLM), the limitation method regarding number and intensity (LMNI), and the parametric methods (the Storie and the square-root methods) were employed. The classes of land suitability were determined (S_1 or highly suitable with production of 80–100% of optimum, S_2 or moderately suitable or 60 to 80% of optimum, S_3 or marginally suitable or 40–60% of optimum and N or non suitable (N_1 & N_2)). Economic factors were excluded and moderate level of management was assumed. The evaluations based on SLM and LMNI resulted in similar land suitability classes, which, however, differed from those obtained with the parametric square-root method, if the levels of limitations were high. The results obtained by the parametric square-root method are probably more realistic, as suggested by comparison with other reports (Movahhedi Naeni 1993; Ghasemi Dehkordi 1994; Sarvari & Mahmoudi 2001; Jafarzadeh & Atabakazar 2004; Jafarzadeh *et al.* 2005a, b; Jafarzadeh & Abbasi 2006; Shahbazi & Jafarzadeh 2004) in which different methods were applied in different parts of country for the same crops. The parametric square-root method suggests that the region of the Bilverdy research station possesses optimal climatic condition for irrigated barley and safflower, indicating for this case a high suitability class (S_1), while the climatic conditions during the growing cycle make the region only moderately (S_2) or marginally (S_3) suitable for wheat, alfalfa and maize. The soil attributes such as pH, organic matter, gravel content, salinity and alkalinity, taken either alone or in combination, have an influence on the land suitability for barley, wheat, alfalfa, maize and safflower. The results of evaluation of soil properties suggest that the lands in the regions belong to land classes between marginally suitable (S_3) and non-suitable (N_2). This result can be obtained by either of the two limitation methods (SLM or LMNI) and also by the parametric square-root method. The Storie method suggests that practically all lands belong to the non-suitable (N_1–N_2) classes (Tables 4 and 5), which, however, is an unrealistic result. The square-root method indicates that the lands are non-suitable (N_1–N_2) for maize only. Based on the results (especially those from the square-root method), the priority crops for the area studied turn to be wheat (first), barley (second), alfalfa and safflower (third), for which the region belongs to the marginally suitable class. These crops can yield 40–65% of their optimal production.

CONCLUSION

In general, the area is highly suitable (S_1) from the climatic point of view (c) for safflower, moderately suitable (S_2) for wheat, barley and alfalfa and marginally suitable (S_3) for maize. However, the soil fertility characteristics (f), the salinity and alkalinity conditions (n) and, in some cases, the soil physical characteristics (s) make the lands in the area marginally suitable (S_3) or even non-suitable. Based on these results (especially on those obtained with the parametric square-root method, which seems to be the best), the cultivation of irrigated wheat and barley can be recommended, but the majority of the region is non-suitable for maize and alfalfa with safflower. Limitations are posed mainly by the high gravel content, high pH, low organic matter and high salinity and alkalinity, either alone or in combination. The picture is principally same for all soil suborders (Cambids or Calcids) and great groups (Haplocambids or Haplocalcids) in the area.

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Corresponding author:

Dr. Ali Asghar Jafarzadeh, University of Tabriz, Faculty of Agriculture, Department of Soil Science, 51664 Iran

tel: + 98 411 339 20 20, fax: + 98 411 334 53 32, e-mail: ajafarzadeh@tabrizu.ac.ir