Land Suitability Evaluation for Winter Wheat in Tiaret Region (Algeria)

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Abstract

A land resources analysis was carried out in the Tiaret Region, one of the most important cereal growing areas (especially durum wheat) of Algeria. The principal aim of the work was the assessment of land suitability for rainfed winter wheat.

The primary source of information was Landsat TM imagery, which was utilized to obtain a Land Unit map (scale 1:200,000). After preliminary image interpretation, the whole area was surveyed in a multidisciplinary and integrated way, following a holistic approach to the analysis of land.

All data were processed integrating different hardware/software resources. The land suitability assessment has been conducted according to the Guidelines for Land Evaluation for Rainfed Agriculture (FAO, 1983).

Most land units showed physical limitations, in terms of climate, soil, topography and erosion risks. Only about 2% of the entire study area was evaluated "very suitable", mainly in the northern and central alluvial plains, while 56% was evaluated "not suitable", because of climate and/or morphology.

Résumé

Cet article va présenter une étude intégrée des ressources naturelles réalisée dans la région de Tiaret qui est l'une zone des plus importantes pour la culture des céréales (blé dur en particulier) en Algérie. L'objet principal de ce travail était l'évaluation de l'aptitude des terres pour la culture du blé dur sans irrigation.

La première source d'information était constituée par des images Landsat TM qui ont été utilisées pour obtenir une carte des Unités de Terres (échelle 1/200 000). Après

l'interprétation préliminaire des images, toute la région a été relevée d'une manière multidisciplinaire et intégrée, suivant un approche holistique pour l'étude des terres.

Tous les données ont été élaborées à travers l'intégration de différentes ressources informatiques. L'évaluation de l'aptitude des terres a été réalisée selon les Directives pour l'Evaluation des Terres pour l'Agriculture Pluviale (FAO, 1983).

Plusieurs unités ont révélé des limitations physiques, liées au climat, au sol, à la topographie et aux risques d'érosion. Seulement 2% de la région étudiée ont été évalués « très aptes », surtout dans les plaines alluviales du nord et du centre, tandis que 56% de la surface a été évaluée « inapte » à cause de limitations liées au climat et/ou à la morphologie.

Presentation and objectives

The knowledge of land resources is a general need, as it concerns the man's capability to make a sustainable use of them. This is particularly true in developing countries, where resources are often scarce or have a fragile environmental equilibrium.

Remote Sensing techniques and GIS are not any more new tools in the field of land resources assessment and evaluation, and their potential in thematic mapping is well known to environmental scientists (ZONNEVELD, 1979); land resources assessments at regional or national scale are now possible in a reasonably short time and low cost, but a common methodological approach is needed to allow data interchange and comparison (Aa.Vv., 1993).

A land resources analysis was conducted in Tiaret region (Algeria) as part of a bi-lateral project of agricultural development financed by Italy and Algeria. Italian Ministry of Foreign Affairs committed to IAO (*Istituto Agronomico per l'Oltremare* of Florence, Italy), in collaboration with ITGC (*Institut Technique des Grandes Cultures*, Algeria) its organization and management.

The first aim of study was the basic analysis of land resources, both from a physical and from an agro-economical point of view in order to assess the land suitability for rainfed winter wheat.

The agro-economic part of this study was developed separately and it is not treated in this paper.

This article presents a brief description of procedures utilized for analysis of land resources and results obtained.

Study area

The survey area extended for about 30,000 km² including four provinces (*wilayata*): Mostaganem, Relizane, Tiaret and Tissemsilt. It is located in the northwestern part of Algeria (Fig. 1) between the Mediterranean sea and Saharian Atlas chain.

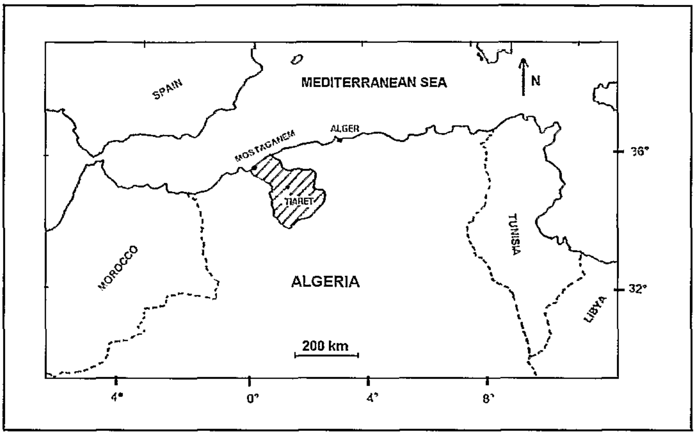

Figure 1. Location of study area.

Very different landscapes can be found in the area, due to influence of several topographic factors (latitude, elevation, distance from sea) on climate and consequently, on geomorphological and pedological processes: coastal zone, flat in the west and mountainous in the east; river Cheliff valley with the sebkha of Ben Ziane, the mountains of Tellian Atlas with connected piedmont formations, the Sersou plateau and, south of it, the Hauts Plateaux. Both mountains and valleys have a SW-NE axis, parallel to the coastal line.

Methods and material

Land resources analysis was conducted using an holistic approach (Fig. 2).

Remote sensing plays an important role in this methodology. Four Landsat TM scenes (acquisition: November 1989; path/row: 196/35, 196/36, 197/35, 197/36) were digitally processed at IAO laboratory: geometric correction, colour enhancement, contrast stretches were applied and a false colour composition (bands 7,4,1) was realised to obtain 24 photographical prints at about 1:110,000 scale.

A Digital Elevation Model (grid size: 180 x 180 m) has been calculated, digitizing contour lines (100 m interval) from topographical maps (scale 1:50,000 and 1:200,000).

Together with other information sources, Landsat TM photographical prints were used for image interpretation of preliminary landscape units. Preliminary satellite image interpretation served as a basis to stratify field sampling: 132 surveying sites were identified, with higher surveying intensity on arable land. Two multidisciplinary teams of surveyors have been working in the area for four months.

Detailed fieldwork was carried out by surveying, for each site, the most important ecological factors (geomorphology, soil, vegetation and land use) affecting natural resources management; field forms, previously prepared, were filled in, soil profiles were described and samples were taken for laboratory analysis.

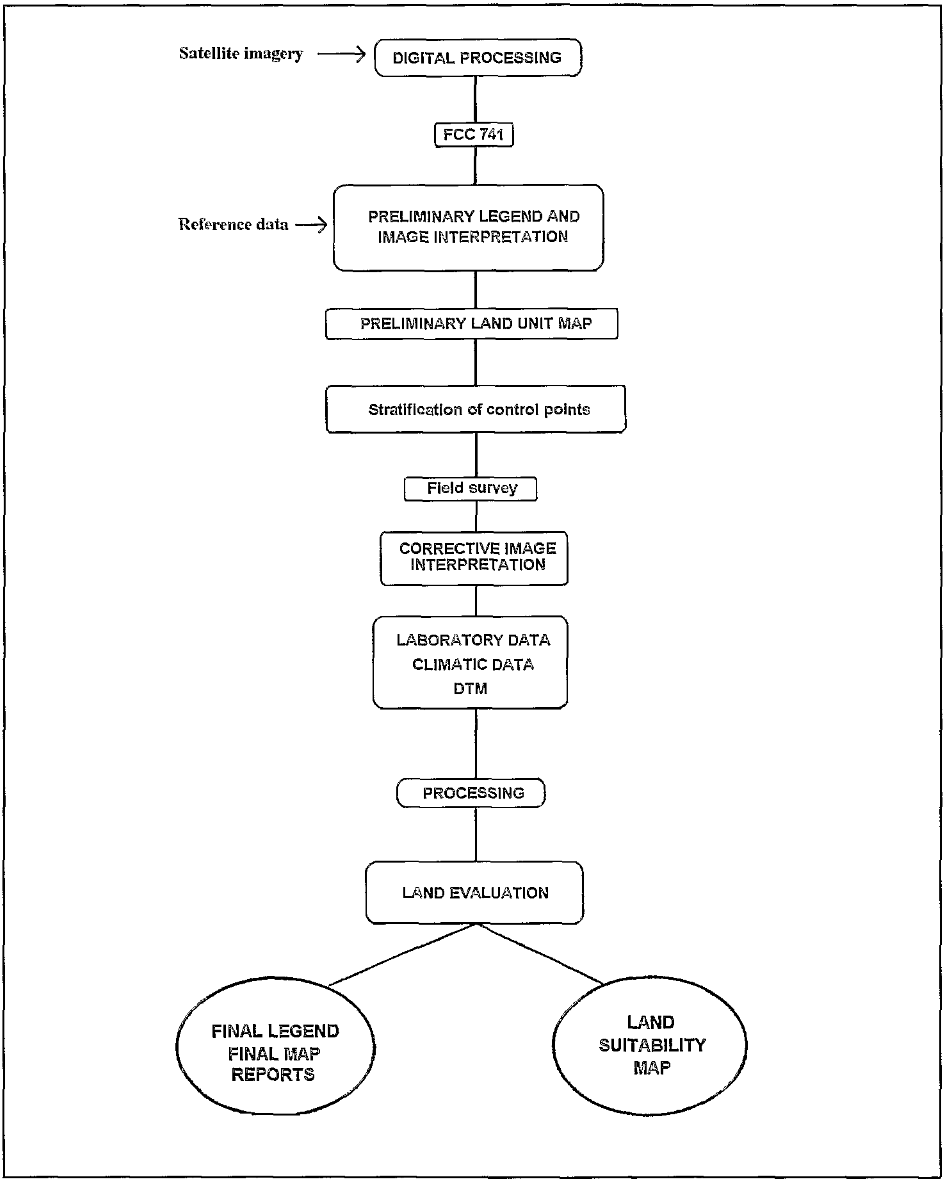

Figure 2. Flow diagram of methodology.

A field form was designed in order to register data about the site and cartographic unit. After corrective satellite image interpretation 118 distinct units were identified.

The data processing for land mapping and evaluation was performed using different hardware/software resources integrated in a local network. Several automated procedures and *ad hoc* software were developed to exchange data among various systems so we could collect, edit and process geographical and alpha-numeric data within a Geographic Information System.

Five main modules composed our processing system:

a) image processing module
b) natural resource inventory;
c) climatic data processing module;
d) land evaluation module;
e) geographic CAD.

A land unit map (1:200,000) with a legend in tabular form and a land suitability map for rainfed wheat cultivation (1:500,000) were the final result of the study.

Land resources analysis

Land resources surveyed were climate, geology and geomorphology, soil distribution, vegetation and land use.

Climate

The study area presented a basic scarcity of climatological data (BALDY, 1974; ITGC, 1976; ONM, 1989), both in term of spatial and temporal distribution; moreover there were reliability problems. Seven thermometric and 46 rainfall stations, having a sufficient amount and reliability of data, were chosen. Statistic elaboration, such as spatial interpolation and multiple linear regression, were used to estimate precipitation and temperature for the whole surface starting from available data. Mean temperatures in the hottest month (July) are around 26-27°C (from north to south), while those of the coldest one are between 5 and 10°C (from south to north). The total annual precipitation varied from 183 mm (southern steppes) to 650 mm (Ouarsenis mountains); a partial influence of topography, latitude and sea on rainfall distribution was recognised.

Climate may be considered typically Mediterranean, with rainy winter and dry summer.

Geomorphology

Tiaret area can be subdivided in several physiographic regions quite homogeneous with regard to geomorphologic origin and actual landscape forming processes (SARI, 1977; MATTAUER 1958).

Aeolian deposits of the coastal zone (*zone littorale*), fluvial and alluvial plains (*oueds*), plateaux (*Mostaganem, Sersou* and of *Ain D'Eheb*), mountain chains (*Tell littoral, Ouarsenis, Saida, Nador*), piedmonts (*septentrional* and *méridional*), and endoreic depressions (*chotts* and *sebkhas*) are the main geomorphological regions which can be distinguished in the area under study.

Soils

Soil distribution in the study area was obtained through the digging of 132 soil profiles, each described, classified and sampled (FAO-ISRIC, 1990; SANESI, 1977; Soil Survey Staff 1981). The purpose of the study was not a soil map, but a general characterisation of soils for each land unit in order to evaluate land suitability for the selected land evaluation type.

FAO classification for the soil map of the world (1988) was considered the most suitable for both output scale (1:200,000) and general scope of this study.

Although there is a great soil variability (BOULAINE, 1957; DURAND, 1954), in general we can distinguish 4 main zones on a pedological basis:

- Coastal zone, characterised predominantly by the presence of ancient reddened dunes with hardly any soil development (Arenosols and Luvisols);
- Sebkhas, chotts and alluvial plains, with salinity problems, ranging from slight to very severe, depending on superficial water table or irrational use of irrigation; Fluvisols, Vertisols and Solonchaks are prevalent. They have a distribution in the whole area;
- Central zones, with prevalence of undulated areas; they show several types of soils, Vertisols, Luvisols and Calcisols on marls. These areas are characterised by intense water erosion;
- Southern zones, characterised by flat or almost flat surfaces and isolated low mountains (*djebel*); Calcisols are prevalent because of a very frequent petrocalcic horizon near to the soil surface. Vertisols and Luvisols can also be found. In the southern zone of the study area (plateau of Ain D'Eheb) soils are often covered with recent aeolian deposits.

Vegetation

A floristic analysis and physiognomic description of vegetation structure was also carried out for each land unit. 114 surveys were realised and some main classes of land cover were distinguished:

- Steppe vegetation found in southern part of study area;
- Halophytic vegetation, found close to chotts, sebkhas and alluvial plains with soils degraded by excess of salinity;
- Mediterranean maquis, generally degraded by overgrazing and agricultural activities;
- Forest, in particularly secondary forest of *Pinus Halepensis*, mainly located on Ouarsenis mountains;
- New plantations, not very wide, present as a protection from erosion risk;
- Riparian vegetation bordering oueds;
- Rangeland, mainly Mediterranean maquis degraded and not cultivated over a long period or recently abandoned lands;
- Cultivated lands, cereal areas prevailing.

Land evaluation

The steps involved in this phase follow the procedural scheme of FAO (1976, 1983). Our evaluation is fundamentally based on physical aspects, not taking into account social, economic and infrastructural conditions which have been subject of a separate study. Statistical data concerning wheat yields have been used to calibrate limits between classes, following methods suggested by FAO: this means that the results of this classification give us information about present land suitability, as they don't consider the effects of any improvement in crop management or energy inputs.

Only one land utilization type was considered because the purpose of the project was specifically the evaluation of lands for wheat cropping.

A brief description of the proposed LUT is given:

- Cropping: wheat;
- Market orientation: mainly commercial production with subsidiary subsistence;
- Capital intensity: the level of capital investments is medium, higher than traditional farms but lower than commercial farms;
- Labour intensity: it is low, less than 0.25 man-months per hectare;
- Technical knowledge and attitudes: farmers have good level of general and agricultural education; they show receptiveness to innovation and change, depending on results obtained;
- Power and mechanisation: motor-driven machinery are largely used for main farming operations;
- Land holding size: it is very variable, decreasing from flat to sloping areas;
- Land tenure: mixed system of state, communal or private farms;
- Infrastructures: they are sufficiently available in terms of road transport, distribution centres of improved plant material, pesticides, machinery etc..;
- Material inputs: medium level, using improved techniques and materials on the basis of agricultural service advices;
- Cultivation practices: all appropriate practices needed, land preparation, fertiliser applications, seeding, weeding, pest control, harvesting, land protection against water erosion hazards by contouring;
- Crop rotations: the basic arable rotation is pulses-cereal-yearly fodder-cereal;
- Yields and production: under a good management, the potential yield of wheat in the best conditions is about 2,000 kg/ha per year.

The next step was to define the land use requirements and to take into account which land qualities and characteristics were relevant to the evaluation; 11 land qualities and 19 land characteristics were identified.

Table 1 shows the land qualities and characteristics list with factor ratings proposed.

Some characteristics initially considered, for instance pH and base saturation, were left aside because of their scarce variability, while others like frequency of damaging flood or frost/storm hazard were omitted because of absence of data.

LAND REQUIREMENTS		FACTOR RATING				
LAND QUALITIES	LAND CHARACTERISTICS	Unit	S1 Highly suitable	S2 Moderately suitable	S3 Marginally suitable	N Not suitable
MOISTURE AVAILABILITY	Total rainfall during growing period	mm	350 - 1250	> 250 < 1500	> 200 < 1750	< 200
OXYGEN AVAILABILITY TO ROOTS	Soil drainage class	class	Well to excessively drained	Imperfectly	Poorly	Very poorly
NUTRIENT RETENTION CAPACITY	Organic matter of top horizon Cation Exchange Capacity	% meq/100 g. clay	> 1.0 > 16	1 - 0.5 < 16	< 0.5	
ROOTING CONDITIONS	Soil depth	cm	> 60	60 - 40	40 - 25	< 25
CONDITION AFFECTING GERMINATION	Mean monthly temperature of germination period	°C	10 - 20	> 6 < 25	> 2 < 37	< 2
FLOWERING AND RIPENING CONDITIONS	Mean monthly temperature during flowering period Mean monthly temperature during ripening period Mean monthly rainfall during flowering period Mean monthly rainfall during ripening period	°C °C mm mm	12 - 26 14 - 30 30 - 120 30 - 120	> 10 < 32 > 12 < 36 15 - 30 > 10 < 150	> 8 < 36 > 10 < 42 10 - 15 < 10 > 150	< 8 > 36 < 10 > 42 < 10
EXCESS OF SALTS	Salinity (EC) Sodicity (ESP)	mmhos/cm %	< 8 < 25	8 -12 25 - 35	12 - 16 35 - 45	> 16 > 45
TOXICITY	$CaCO_3$	%	< 30	30 -40	40 - 60	> 60
SOIL WORKABILITY	Texture/Structure	SYS seq	from C+60 to SCL	SL + LfS	Cm-SiCm-LS	from LcS to cS
POTENTIAL FOR MECHANIZATION	Slope Stoniness Rockiness	% % %	< 1 < 2	< 25 1 - 5 2 - 10	5 - 15 10 - 50	> 25 > 15 > 50
EROSION HAZARD	Water erosion Aeolian erosion	Field observations	ABSENT SLIGHT-NEGLIGIBLE SLIGHT-LOCALIZED MODER.-NEGLIGIBLE	SEVERE-NEGLIGIBLE MODER.-LOCALIZED SLIGHT-WIDESPREAD	SEVERE-LOCALIZED MODER.-WIDESPREAD	SEVERE-WIDESPREAD

Table 1. Land requirements and factor rating for land evaluation (wheat) - Soil control section = 0-50 cm.

Soil workability was assessed according to a sequence proposed by SYS (1993) where 22 classes are identified in terms of a combination of soil structure and texture.

The erosion hazard assessment was obtained by field observations about intensity of phenomena and surface affected; the synthetic scheme showed in table 1 was used, both for water and aeolian erosion.

This method was calibrated comparing geomorphological and pedological aspects of each land unit with the results obtained: we verified a good accuracy of results, better than the one obtained by an alternative method first checked (GIORDANO *et al.* 1991).

Measured or estimated land qualities and characteristics were matched with land use requirements and the suitability class was assigned to each land characteristic.

With the help of graphical displaying, spatial distribution of considered land characteristics was analysed: seven distinct classifications were obtained through the selection, for each characteristic, of different ranges of conditions and different classification procedures on the basis of FAO guidelines indications.

Finally, a mixed method of "limiting conditions" and "arithmetic procedures" was adopted for the evaluation.

A parametric value was assigned to each land quality (Table 3); in case of more than one land characteristic the suitability class of the correspondent land quality was considered equal to the class of its most limiting land characteristic.

Table 2. Evaluation table for erosion hazards.

Surface affected	Intensity Slight	Moderate	Severe
Negligible	S1	S1	S2
Localized	S1	S2	S3
Widespread	S2	S3	N

Table 3. Parametric values of suitability classes of land qualities.

S1	S2	S3	N
0	0.5	0.8	1.0

An overall parametric value was calculated multiplying the parametric values of land qualities. Results of multiplication were converted back to an overall suitability class (Table 4).

Table 4. Suitability classes of parametric values of land units.

> 0.8	0.4-0.8	0.2-0.4	< 0.2
S1	S2	S3	N

In order to check the accuracy of outcome, potential yields were calculated for each land unit, assuming a maximum yield of 2,000 kg/ha in the best conditions (see table 5) and compared with yield records collected during agro-economic survey.

Table 5. Potential wheat yield for each suitability class.

Suitability Class	Degree of limitation (%)	Yield (kg/ha)
S1	> 80	> 1.600
S2	40-80	800-1.600
S3	20-40	400-800
N	< 20	< 400

A map at scale 1:500,000 showing the results of land evaluation results was finally produced.

Table 6 shows a synthesis of evaluation; it substantially indicates that there are few highly suitable land units, about 2% of the entire surface under study. Because topographic and climatic conditions are the most important limiting factors in the area, units close to the sea and at lower altitudes are the most suitable for the LUT considered. Mountainous areas and continental plateaux are predominant and they are generally not suitable.

"Not relevant" is referred to water bodies, urban areas etc.., while "not assessable" was given to units homogeneus for every ecological factor but spatially distributed all over the area (azonal units).

Table 6. Results of land evaluation.

Class	Evaluation	Surface (ha)	Surface (%)
S1	Very suitable	60.128	1.97
S2	Moderately suitable	229.348	7.52
S3	Marginally suitable	879,039	28.81
N	Not suitable	1.733.350	56.81
NR	Not relevant	55,112	1.81
NE	Not evaluable	93,956	3.08

Conclusions

The general approach to land resources analysis and the evaluation methodology adopted allowed us to investigate a very large area in a relatively short time, obtaining sufficiently accurate data, useful for land conservation and land use planning.

The land evaluation methodology proposed by FAO Guidelines has revealed a great potential for practical applications: simplicity, objectivity and the possibility to develop automated procedures, using the most common software packages, seem to be its main advantages. Nevertheless, it usually needs some adjustment, depending on the characteristics of the area under study, in order to select, for each land quality, the most appropriate set of parameters to be used for evaluation.

Furthermore, a geographical and alphanumeric database of land resources, which is now available, could be used for further analysis and evaluations and could be improved, updated and enriched with other data, representing a starting-point for subsequent investigations.

Results obtained will be better analysed in the light of the agro-economic survey results, when they will be available.

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