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Comparative Study of Three Land Evaluation Systems by using a Geographic Information System (GIS) under Mediterranean Condition

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ABSTRACT

Background: The purpose of this work consists of doing a comparative study of three Land Capability Classification (LCC), Storie, National Institute of Irrigation and Drainage Institute (INSID) by applying them to the region of the Oriental Mitidja (Rouiba-Algeria). **Methods:** A geographic information system for the region in question was carried out, with a view to developing different thematic maps and allowing the comparison of these three evaluation systems, thanks to a database that has been created for this purpose. **Result:** The system adapted by INSID has given rise to lower evaluation results compared to the two other systems, because 99.99% of the total agricultural ability by the LCC, 97% Apt for agriculture. By Storie while only 48% of the total area is fit for agriculture according to INSID. Statistical results have shown the existence of a significant difference between the three land evaluation systems. However, the correlation is significant between the INSID and STORIE system.

Key words: Comparison, Geographic information system (GIS), INSID, Land evaluation systems, LCC, STORIE.

INTRODUCTION

The use of land resources is becoming more common in order to fulfill the needs of the world's rising population. The urgent need for land resource optimization is required to meet rising food demand and resource utilization trends (Kutter *et al.* 1997; Yonas, 2022).

In Algeria, the useful agricultural area does not exceed 3% of the total area of the country. It is a very constrained physical factor. As there are other problems of a technical nature which essentially boil down to the irrational use of agricultural land, these deficiencies explain our country's dependence on foreign food. Land valuation has become a necessary parameter for proper land use.

As a result, many studies have addressed this problem through various approaches (Erqi Xu and Hongqi, 2013; Yaolin Liu, 2013; Michelle *et al.*, 2021; Atul Kumar, 2021).

Furthermore, FAO (1976) defined a new approach to land valuation, called "Framework for land valuation", which allowed the development of practical methods for this valuation, as there are other systems of evaluation, such as that of the U.S.D.A. (1962) called "Land Capability Classification" and the evaluation system of STORIE (1976).

The National Institute of Soils, Irrigation and Drainage of Algéria (INSID) (INSID, 2001) adopted an agricultural land evaluation system inspired by the parametric method of STORIE (1976) and the FAO method (1976), which represents, in a way, a "hybrid" approach.

The purpose of this work is to make a comparison between the system adopted by INSID (2001) and the two American systems STORIE (1976) and the Land Capability classification of the USDA (1962) by using a geographic information system (GIS). By applying these three evaluation systems to the region of Mitidja Orientale (Rouiba-Algiers) in order to see if these evaluation results are similar or very different and in the end, some proposals would be made to the INSID to improve their agricultural land evaluation system.

Different sectors in national development have adopted Geographic Information Systems (GIS), but little has been done to support decisions for development in agriculture (Kuria *et al.*, 2011) recommended the use of these technologies to improve quality of life. Previously, GIS has been applied under different scenarios. For instance, Faostat (2019) assessed the suitability of growing wheat and the application of GIS in land evaluation and development of suitability by Michelle *et al.* (2021).

MATERIALS AND METHODS

Study area

It should be emphasized that the plain of Mitidja is one of the largest sub littoral plains in Algeria. The climate of this region is Mediterranean in type, the rainfall is between 600 and 800 mm. The maximal summer and winter temperatures are respectively 36°C and 7.7°C.

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The soils studied are located in the region of (Rouiba - Algiers), in Mitidjaorientaleplains (Fig 1).

The comparison of the land evaluation results, obtained by the three systems in question, was carried out by a geographical information system for the region of Rouiba (Algiers), in order to produce thematic maps for a graphic presentation of the results of land assessments.

This study was conducted at the Ecole Nationale Supérieure Agronomique, El-Harrach, Algeria. January, 2005.

The methodology adopted for carrying out this work was as follows:

Cartographic support

The soil coverage of the study area (Rouiba) in digital format has been produced.

Descriptive and analytical sheets of the profiles which represent the cartographic units produced by the national study and rural development office (BNEDER) for INSID. These sheets allowed us first to make the evaluation of the land and, secondly to create the database for the GIS, the latter was introduced by data entry.

Data acquisition

The acquisition of the data was done by digitization that is to say by a process which allows the transformation of the graphic data into digital data (settings and digitization).

It is necessary to recall the principle of the land evaluation system adopted by INSID. The method consists in classifying the soil properties according to their degree of constraint or limitation, a six-level scale is then proposed (0, 1, 2, 3, 4, 5).

When the property constitutes a very severe constraint, it is assigned a minimum score. -When the property does not constitute any constraint, it is optimal and its score is maximum (INSID, 2001).

The rating scale varies from a maximum equal to 100 to a minimum greater than 0. These constraints are classified as follows:

0 represents no constraint, 1 represents a low constraint, 2 represents moderate stress, 3 represents a fairly severe constraint, 4 represents severe constraints and 5 represents a very severe constraint. The soil factors are noted according to their degree of constraint for agriculture, the main indices obtained will be multiplied.

$$It = PR \times (CC/100) \times (TX/100) \times (Is/100) \times (CT/100) \times (CEC/100) \times (pH/100) \times (CE/100)$$

It: Land index.
PR: Useful soil depth (cm).
CC: Stony load (%).
TX: Texture (Class).
Is: Structural stability index.
CT: Total limestone (%).
CEC: Cation exchange capacity [cmol(+)kg^{-1}].
EC: Electrical conductivity (dS m^{-1}) and pH.

The data processing was carried out using the MAPINFO 6.5 software, which is a GIS-type software and which has a number of advantages, such as possibility of spatial analysis and querying using SQL (Structured Query Language).

The methodology adopted for carining out this work was as follows:

Application of the three land evaluation systems, STORIE, LCC and INSID; in the region of Mitidja Orientale (Rouiba - Algiers).

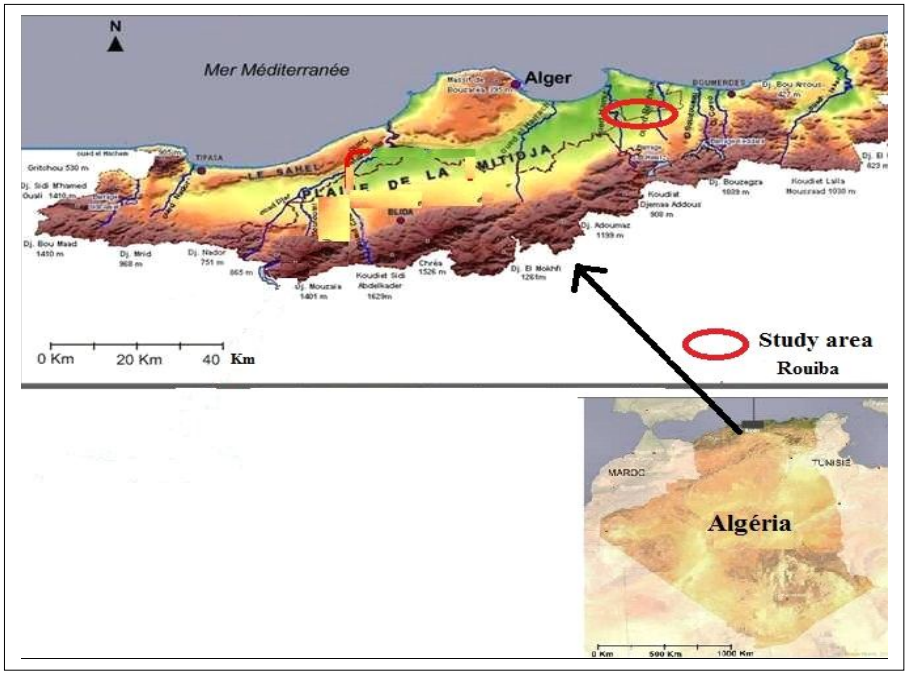


Fig 1: Location of the study area of Ruiba (Mitidja Orientale plains). Source (PAC, 2006).

In addition, the STORIE and LCC evaluation systems are recognized by international competence.

The analytical and morphological data used for the evaluation were provided to us by INSID. The land evaluation of the region was done manually, following an evaluation guide for each system to evaluate the soils of the region. (STORIE, 1976; LCC, 1962; INSID, 2001).

The USDA land capability classification (LCC) is one of several interpretive soil grouping systems developed specifically for agricultural purposes. This method is classified in the first group *i.e.* constraint approach methods. The properties or criteria used by LCC for land valuation are as follows:

1: Effective depth (cm).
2: Texture.
3: Permeability (cm h^{-1}).
4: Drainage class (state).
5: Available water retention capacity (cm of water/cm of soil).
6: Slope (%).
7: Erosion (state).
8: Flood (frequency, duration and intensity).
9: EC (dS/m).
10: Alkalinity.
11: Toxic substance.

The system includes two major categories of soil grouping: Suitability class and suitability subclass.

Soil properties are tested first against the criteria for the best soil class and if all the criteria are not met, the soil automatically moves to the lower class.

The types of constraints are represented by the subclasses: e, w, s and c.

e: Risk of erosion.
w: Excess water, drainage, flooding.
s: Depth texture, rooting constraints.
c: Climatic constraints.

The STORIE system is a soil notation method, known as the STORIE index, based on the characteristics (properties) of the soil that influence the potential use of land and its productive capacities. Percentage values (%) are attributed to soil properties, including the development of the soil profile and its depth (factor A); surface texture (factor B); the slope (factor C) and the conditions of the soil other than those of the three factors mentioned above (factor X). These factors are drainage, alkalinity, nutritive state, and erosion.

The most favorable or ideal conditions concerning each factor are noted at 100%. The values of each factor or rating are then multiplied with each other. The result between O and 100 will be the index of Storie lands.

STORIE land index =

$$A \times (B/100) \times (C/100) \times (X/100) = [0\text{-}100]$$

The STORIE land index should make it possible to classify the soil in suitability grade, there are six grades: grade 1 (excellent), grade 2 (good), grade 3 (average), grade 4 (poor), grade 5 (very poor) and the grade 6 (non-agricultural soil).

It should be remembered that the three evaluation systems evaluate the soil in a general way without taking into consideration the type of land use.

After obtaining the results, it is proceeded to:

1: Comparison of the land indices obtained by the three land evaluation systems;
2: The use of the geographic information system that installed for the Rouiba region, in order to carry out a graphic representation of the evaluation results using the thematic analysis using the MAPINFO software.

For the realization of the GIS, it is proceeded to the creation of a Table (Fig 2).

RESULTS AND DISCUSSION

The results obtained by the three land evaluation systems (INSID, LCC, STORIE), allowed us to make a comparison between the three systems in question. For the Rouiba region, the GIS helped us to appreciate the distribution of land suitability classes by making requests and evaluation maps.

Results of the evaluation of cartographic units (land index), comparison between the three systems

For INSID and STORIE systems, the evaluation was noted on a scale of 100, for the LCC system, the results were classes of aptitude and hence, they have been converted into numbers (Table 1), in order to produce a graph.

The statistics of the results obtained from the three land evaluation systems are shown in Table 2.

Statistics showed that the average of the STORIE, INSID and LCC land valuation indices is 50.8, 24.81 and 80.95, respectively. However, the coefficients of variation indicate a fairly heterogeneous distribution of STORIE (CV=40%) and LCC (CV=53%) rating systems. On the other hand, the

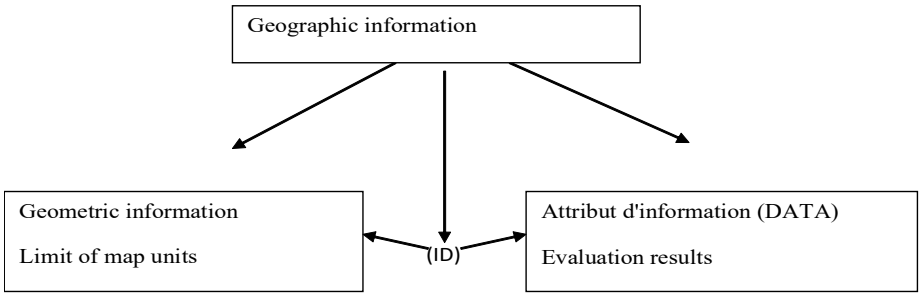


Fig 2: Table structure.

Table 1: Numerical conversion of each LCC classes. (LESA, 1997).

Classes	Notation/100
I	100
IIe	90
IIs,w	80
IIIe	70
IIIs,w	60
IVe	50
IVs,w	40
V	30
VI	20
VII	10
VIII	1

Table 2: Statistical parameters of the indices of the three evaluation systems.

	STORIE	INSID	LCC
Minimum	12	6	40
Maximum	90	64	100
Mean	50.8	24.81	80.95
S-D	20.3	13.15	8.73
CV (%)	40	53	11.0

distribution of the indices obtained by LCC is very little variability (CV=11%).

The results were obtained from the existence of a significant difference between the three land evaluation systems.

Furthermore, the Kruskal-Wallis non-parametric statistical test was used to confirm the existence of a significant difference between the three systems. The test results are shown in Table 3.

At the significance level α=0.05, it can reject the null hypothesis of no difference between the three systems. This clearly shows that the difference between the three evaluation systems is significant. This is proven to be explained by the fact that the three systems are based on soil parameters that are different.

Table 3: Results of the Kruskal-wallis statistical test.

H (observed value)	164.82
H (critical value)	5.99
Df (degree of freedom)	2
p-value	<0.0001
α	0.05

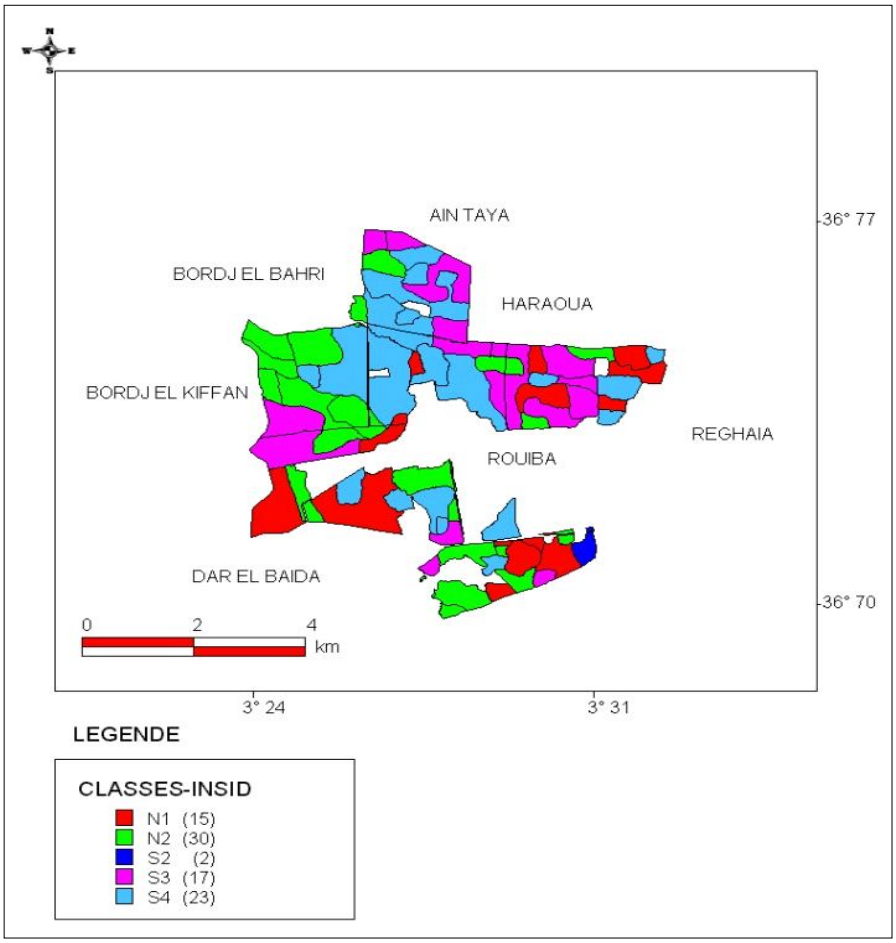


Fig 3: Map of soil suitability classes of obtained by the INSIDE system.

According to the results obtained it noticed that:

1: INSID rating system yielded lower results than the other two rating systems.

2: LCC evaluation system made superior results compared to the other two evaluation systems.

3: STORIE evaluation system gave intermediate results when compared to the other two evaluation systems.

In order to highlight this difference using GIS, illustrations were made.

Table 4: Comparative presentation of the distribution of soil suitability classes obtained by GIS.

E.S	Classes	Area (ha)	Total area (%)	Area (ha)	Total area (%)	Suitability
LCC	I	246,82	9,32			
	II	2334	88,13	2648,16	99,99	Suitable for
	III	29,94	1,13			agriculture
	IV	37,4	1,41			
STORIE	1	500	18,89			
	2	411,63	15,55			Suitable for
	3	1486,51	56,13	2648	97,46	agriculture
	4	182,62	6,89			
	5	67,16	2,53	67,16	2,53	Unsuitable for agriculture
INSID	S2	23,22	0,87			Suitable for agriculture
	S3	598,9	22,61	1488,22	56,18	
	S4	866,1	32,7			
	N1	499,85	18,87	1159,96	43,79	
	N2	660,11	24,92			Unsuitable for agriculture

E.S: Evaluation system of land.

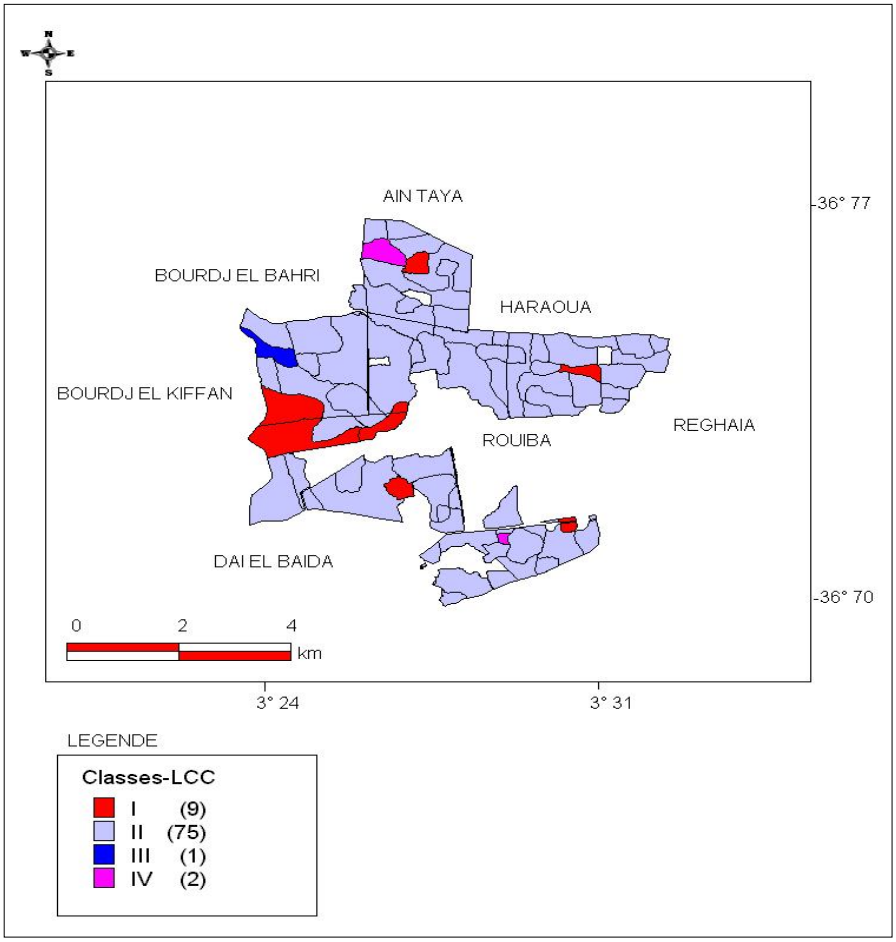


Fig 4: Map of soil suitability classes obtained by LCC system.

Map of the convenience classes of the INSID system are shown in Fig 3.

Regarding the map of soil suitability classes, which was obtained by applying the INSID evaluation system, it is noted that the convenience classes S4, N2, S3, N1, S2 are the most represented, respectively with values of 32.77%, 24.92%, 22.61%, 18.87%, 0.87%, (Fig 3).

Table 5: Subclasses distribution of LCC capability obtained by GIS.

Subclasses	Area (ha)	Total area (%)	Contraints
S	2204.66	83.2	Texture
W	183.6	6.93	Drainage

Table 6: Relations between indices of LCC, STORIE and INSID.

Relations	df	r
INSID-ICC	84	0.19
INSID-STORIE	84	0.64
LCC-INSID	84	0.19
LCC-STORIE	84	0.17

Note. *Significant at probability P<0.05; r: Coefficient of correlation; df: Degree of freedom.

Moreover, the study area is 56.18% suitable for agriculture represented by the three classes (S2, S3, S4) and 43.79% represented by the classes (N1, N2) which are unsuitable for agriculture (Table 4).

Map of LCC suitability classes (Fig 4)

Based on the distribution of suitability classes of the soils of the study region that were obtained by applying the LCC land evaluation system, it is able to bring out the following remarks.

1: Aptitude classes II, I, IV, III are the most represented: with respectively 88.13%, 9.32%, 1.4%, 1.13%, (Fig 4).

2: The study area is 99.99% suitable for agriculture represented by four classes (II, I, IV, III), according to the results obtained by the LCC evaluation system (Table 4).

The aptitude subclasses (S, W) are the most representative of the study region, with 83.1%, 6.9% respectively. It should be recalled that the subclass indicates the constraints that are responsible for the downgrading of soils. It should also be noted that the class “I” has no subclass because it is excellent (Table 5 and Fig 5). The findings of this study would therefore be useful to farmers, county governments and stakeholders in their decision making and planning and to other researchers for further (Michelle *et al*., 2021).

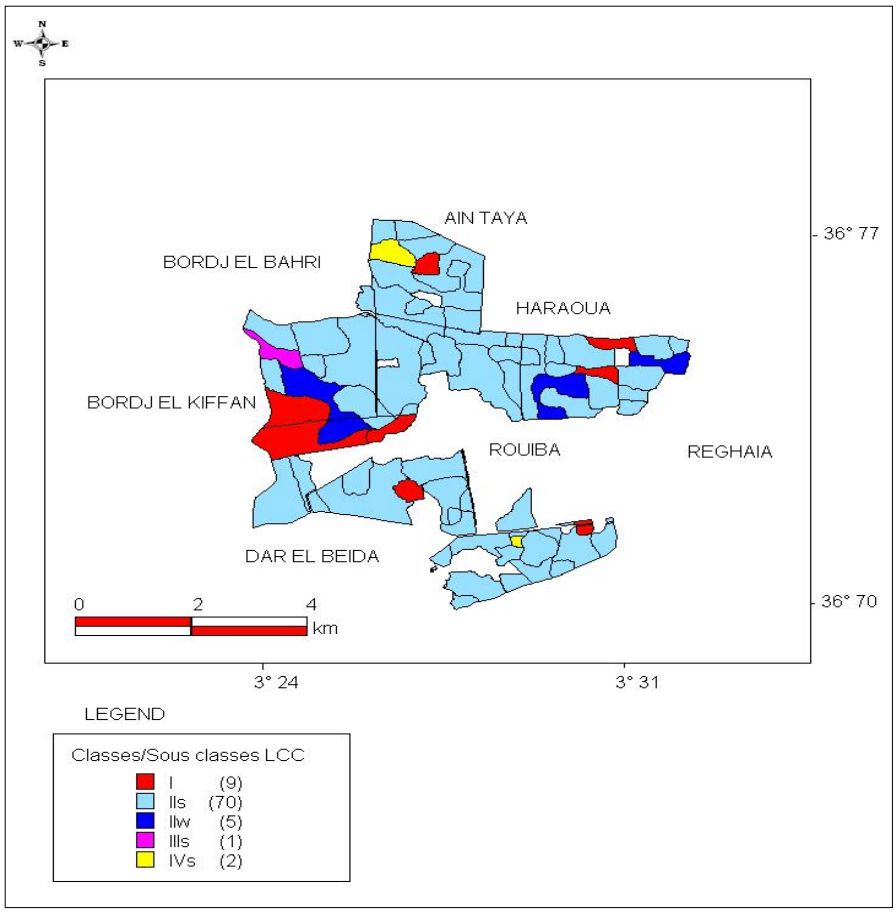


Fig 5: Map of the aptitude subclasses of soil (LCC).

According to the grades of notation of the soils of the region of study, which were obtained by the application of the system of evaluation STORIE, it is noticed that the grades of notation 3, 1, 2, 4, 5, are the most represented, with respectively 56.13%, 18.89%, 15.55%, 6.89% 2.53%, (Fig 6). However, the study area is 97.46% suitable for agriculture, represented by the four grades 1, 2, 3, 4, while 2.53% is unsuitable for agriculture, represented by grade 4 (Table 4).

The results of the correlation test between the three evaluation systems are shown in Table 6.

Data analyses showed a value of 5, that the relationships between the three indices of land evaluation were non-significant at $P<0.05$ between INSID-LCC. Similarly, the correlation remains non-significant at the $P<0.05$ level between LCC-STORIE (Table 6). On the other hand, the correlation is very highly significant at the $P<0.001$ level between INSID-STORIE by Fig 7. This is explained by the fact that the STORY and INSIDE evaluation system are based on the parametric method by weighting (Hadj Miloud, 2005).

From the results of the evaluation of the three evaluation systems, it could be inferred that there is a difference between LCC, STORIE and INSID, as the thematic maps and the distribution of the classes of each system show quite well.

The INSID system performed lower than the other two systems; this is explained by the fact that this system takes into account certain soil properties such as the CEC (cation exchange capacity), the gravel load, the total lime content, the IS (the structural stability index) and the pH, whereas these variables are not taken into account by the two other evaluation systems.

Furthermore, the constraints that were noted during the evaluation are the pH, which is quite high, the CEC and the IS, which are noted with 60 or 80/100, which causes a downgrading of the soil towards classes inferior, without forgetting other constraints such as texture. The rating scale of the latter differs from the other two rating systems; there was an under-rating by the INSID system.

When it comes to the STORIE and LCC systems, there is a difference between the results of the three rating systems. However, there is a connection between the results of STORIE and those of the LCC, because the properties of the soil which have been evaluated are virtually the same, except that the water retention capacity is only taken into consideration by

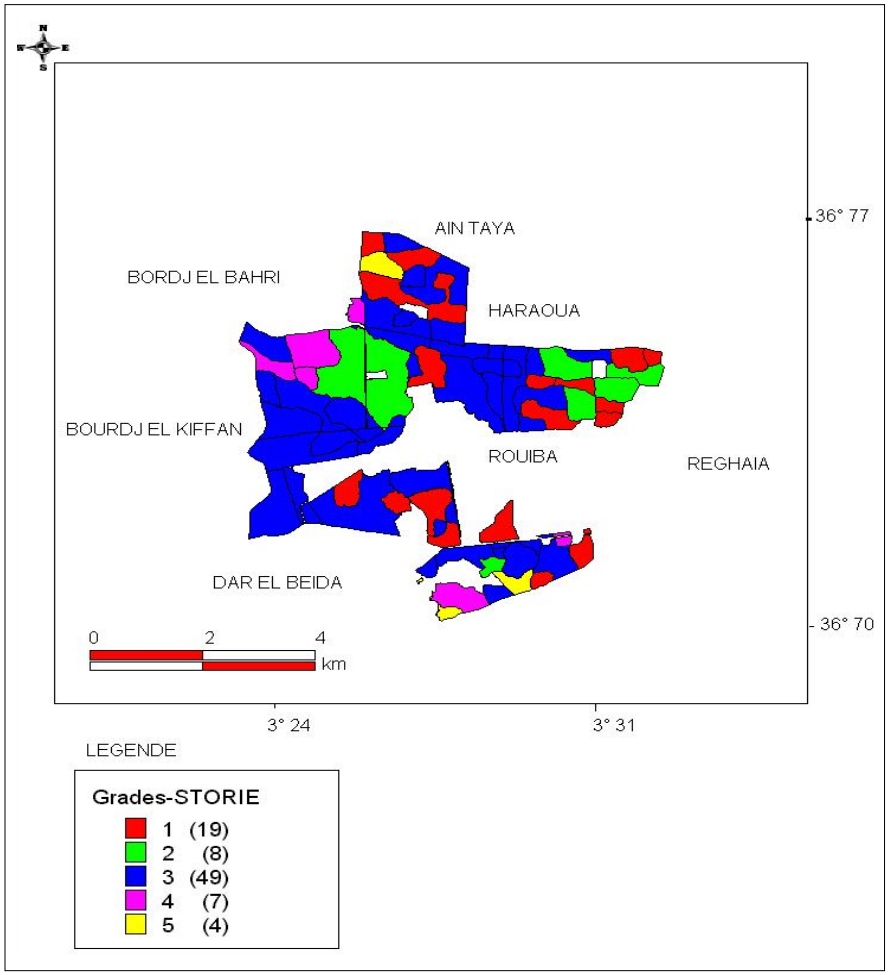


Fig 6: Map of soil rating grades obtained by the STORY system.

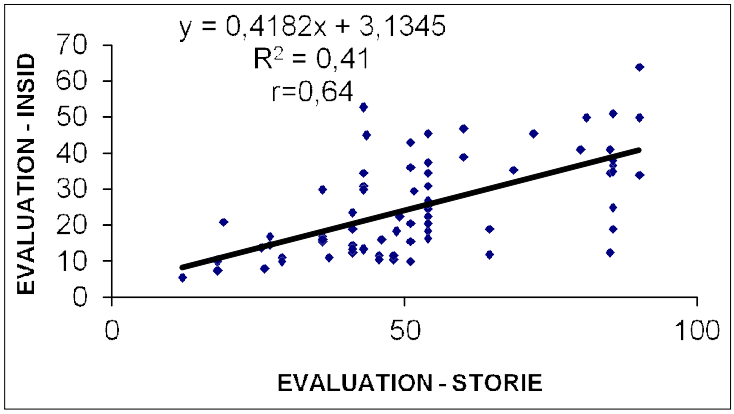


Fig 7: Correlation between INSID and STORIE.

the LCC system. Moreover, according to the results of the GIS, 99.99% of the total area of the study region is classified as suitable for agriculture by the LCC system and 97% is classified as suitable for agriculture by the STORY system; but when LCC ability classes and STORIE ranks were compared, some difference were observed.

It should be noted that all three evaluation systems rate soil in a general way without taking into consideration the type of land use.

When applying the INSID rating system, it was found that INSID offers soil assessment scales without specifying the methods of analysis for most edaphic properties. This seems very important to us for the interpretation of the results and even for a possible evaluation like the present case: As an example, for the evaluation of salinity, the INSID proposes a scale without indicating the method of analysis, which is actually that of "saturated paste" according to USSL (1954) standards, but in our case it is the method of "diluted extracts ratio 1/5" which was used. According to the latter, the soil is considered salty from 1.4 dS/m while for that of the "saturated paste" the soil is considered salty from 4 dS/m, as a result, the two methods differ significantly.

It is suggested that INSID specify the name of the analysis methods for each scale used for the evaluation of soil properties.

On the other hand, it is important to reduce the number of certain variables, in particular those concerning the interdependent properties. As an example, it is cited the case of pH and total limestone; if a soil has a high rate of limestone it will affect its pH, the soil will then has been penalized twice by a single property. There is also the CEC and the texture: in Algeria, the CEC is primarily determined by clay due to the low organic matter in the soil.

On the other hand, to refine the results of the evaluation, it is interesting to apply fuzzy logic for the classification of the suitability of the lands. This makes it possible to have more precision on the use of agricultural land, as shown by Hadj-Miloud and Djili, 2022; Hadj Miloud *et al*., 2018; Hadj Miloud, 2019).

CONCLUSION

A comparative study of the three land evaluation systems (STORIE, LCC and INSID) was carried out in the Rouiba region (Mitidja Orientale). A GIS was createdfor the same region, which allowed us, from its various sources, to gather, organize, manage, analyze and combine geographic information data.

The GIS enabled us to highlight the distribution in percentage and in hectares of the classes of aptitudes and subclasses of the LCC, at the same time the classes of the INSID and grades of STORIE and to represent them by thematic maps. Thanks to a database that has been created for this purpose.

The evaluation results obtained by the three systems revealed the existence of a difference between LCC, STORIE and INSID. According to the results of the GIS 99.99% of the total area is suitable for agriculture by the LCC, 97% suitable for agriculture by STORIE while only 48% of the total area is suitable for agriculture according to INSID. This INSID land rating system gave lower rating results than the other two systems, but there is more of a similarity to STORIE than to LCC when comparing the classes of the two systems.

In addition, the STORIE system gave intermediate evaluation results between LCC and INSID.

Through the use of GIS, it has been highlighted with maximum objectivity the performance and limits of each evaluation system. Further research in this direction could lead to an improvement in the method adopted by INSID and thereby improve the quality of the work of evaluating land and its use.

The final objective remains the increase of their productivity within the framework of reasoned sustainable agriculture.

Conflict of interest

All the authors declare that they have no conflicts of interest.

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