ZIBELINE INTERNATIONAL PUBLISHING

ISSN: 2521-5035 (Print)
ISSN: 2521-5043 (Online)
CODEN: ESMACU

Earth Sciences Malaysia (ESMY)

DOI: http://doi.org/10.26480/esmy.01.2020.08.14

CrossMark

RESEARCH ARTICLE

ASSESSMENT AND MAPPING OF SOIL SENSITIVITY TO EROSION USING GIS IN MELLEGUE CATCHMENT, NORTHEAST OF ALGERIA

Kamel Khanchoul[a]*, Mahmoud Tourki[b]

[a]Department of Geology, Laboratory of Soils and Sustainable Development, Badji Mokhtar University-Annaba, P.O. Box 12, Annaba, Algeria
[b]Department of Hydraulics, Laboratory of Soils and Sustainable Development, Badji Mokhtar University-Annaba, P.O. Box 12, Annaba, Algeria
**Corresponding author Email: kamel.khanchoul@univ-annaba.dz; kam.khanchoul@gmail.com*

ARTICLE DETAILS

Article History:

Received 09 January 2020
Accepted 17 February 2020
Available online 24 February 2020

ABSTRACT

In Algeria, there is an urgent need for cartographic zones touched by erosion and also to target priority risk areas to improve the consistency of erosion prevention actions. Such a mapping must be able to display the areas at sensitivity to erosion and must take into account the developments to be undertaken. It is in this perspective that this study is carried out for (a) to map the sensitivity to erosion in the Mellegue catchment by relying on three factors of erosion namely topography, lithology and land use; and (b) to propose a management plan for vulnerable areas. This study is conducted using a Geographic Information System, which has allowed to characterize different areas of the study catchment and its sub-basins by producing a synthetic map of degrees of susceptibility to erosion.The results has shown that the basin has dominant areas of medium to high sensitivity to erosion, despite the existence of a considerable low sensitive area, corresponding to 47% of the basin area and observed mainly at the Meskiana sub-basin. The integration of the results into three levels of sub-basins has allowed identifying the most susceptible areas to erosion. This study provides sufficient data for a prioritization of the study basin according to their degree of erosion, making possible to the different actors, the management of the territory.

KEYWORDS

Erosion, erosion factors, catchment, mapping, GIS, sensitivity.

1. INTRODUCTION

Soil erosion is a natural and dynamic process that affect all landforms causing there environmental degradation with decreased soil fertility and destruction of agricultural ecosystems (Bayramin et al., 2003). Soil erosion can be defined as a systematic washing away of soil plant nutrient from the land surface by various agents and processes of denudation which occur in several parts of Algeria under different soil, climatic and geologic formations (Samson et al., 2017). Natural erosion can be a slow process that continues relatively unnoticed and is usually of little concern from soil quality point of view because its rate is low and soil loss can be naturally compensated by soil formation. Erosion can occur at an alarming rate, causing serious loss of topsoil where human actions such as deforestation, overgrazing, over tilling, and shifting cultivation have accelerated soil erosion beyond the tolerance limit.

The sensitivity of an area to erosion is highly dependent on some factors such as intensity of rainfall, nature of the soil, vegetative cover, topographic characteristics, and land use practices. These factors vary considerably at the catchment scale or at the regional scale. Identifying factors of erosion and areas vulnerable to soil erosion could be very useful in assessing the spread and degree of risks and, ultimately, developing conservation measures and management plans. In Algeria, soil erosion is a serious problem that arises because of land use changes. It is known that overgrazing, improper management and expansion of settlements accelerate land loss, reduce agricultural production and increase sedimentation in the next catchment areas (Halefom et al., 2018). Since independence, Algerian agriculture has had short-term strategies that have not solved the problems of the sector, which has resulted in an imbalance between rural and urban areas. This precarious situation is the result of a lack of concordance of agricultural policies and self-management of agricultural lands.

Algerian farmers are more dependent on the availability of water from rainfall and irrigation system. In the highlands, with the local topography, there is a reduction of the productivity of agricultural land through soil erosion. This problem occurs, thus, through both anthropogenic and natural activities such as poor land use practices, luck of soil protection measures (Hurni, 1989; Halefom and Teshome, 2019). Studies on soil erosion have been carried out in many parts of the world. Soil erosion is a wide spread problem in both developing and developed countries. The problem has far reaching economic, political, social and environmental implication due to both on site and off site damages (Grepperud, 1995; Pandey et al., 2007; Udokporo et al., 2015). In an overview of global erosion and sedimentation, in a study stated that more than 50% of the world's forestland and about 80% of agricultural land suffer from significant erosion (Pimentel and Burgess, 2013). Different authors has stated in their studies that the problem of erosion is more severe in the country related with steep topography, overgrazing and long cultivation history with outdated technology (Nyssen et al., 2004; Tahiri et al., 2016). It is considered to be the main treat to the national economy, national food supply and sustainability of agricultural production in the country (Fazzini et al., 2015; Mekuriaw et al., 2018; Molla ans Sisheber, 2017). In addition, soil erosion can be influenced by local climate, topography, population,

Quick Response Code	Access this article online	
	Website: www.earthsciencesmalaysia.com	**DOI:** 10.26480/esmy.01.2020.08.14

Cite the Article: Kamel Khanchoul, Mahmoud Tourki (2020). Assessment and Mapping of Soil Sensitivity to Erosion Using GIS in Mellegue Catchment, Northeast of Algeria. *Earth Sciences Malaysia, 4(1): 08-14.*

soil susceptibility, agricultural practices and agro-ecology (Belayneh et al., 2019). In this regard, quantitative and qualitative methods of soil erosion have been employed to infer the extent and magnitude of the problem and identification of more vulnerable sites. Different model-based methods have been developed for soil erosion spatial assessment and quantification (Rejani et al., 2016; Semwal et al., 2017).

In Algeria, such studies, even though less frequent, have been able to show various aspects of accelerated erosion (particularly around the northwestern part of Algeria) and to map soil erosion vulnerability areas at basin scale. They include those of have conducted soil degradation on the scale of a micro basin in the northwest of Algeria to follow the variation of the soil potential sensitivity to water erosion (Meddi and Mosli, 2001; Anteur et al., 2014; Bouguerra and Bouanani, 2016; Benguerai and Benabdeli, 2016; Benguerai and Benabdeli, 2017; Bouguerra et al., 2017 ; Souidi et al., 2017; Touaher et al., 2017; Khanchoul and Boubehziz, 2019; Kessaissia et al., 2017). Moreover, recent studies on the vulnerability of soil to erosion also indicate a trend towards increased aridity which accelerating water erosion (Djoukbala et al., 2018; Benchettouh et al., 2017). It is worth mentioning that these studies alert for the negative impacts of certain land use changes on soil losses and soil fertility. In addition to these is the work of the ministry of Agriculture and Rural Development in Algeria. In the study conducted so far in this area, the researchers have not been aware of studies on soil erosion vulnerability mapping at basin scale. Furthermore, analysis of geographical information is becoming an emerging approach which is capable of acquiring, managing and analyzing complex problems of river basins watersheds (Stathopoulos et al., 2017). In recent years, GIS linked with simple erosion models has shown to be a good alternative to identify the most erosion sensitive areas in the region, so that serving as a better decision support tool for conservation measures and planning of prevention practices (Setegn et al., 2017). Consequently, the integration of multi-criteria evaluation within a GIS context could help users to improve decision making processes.

The Mellegue catchment is an area which knows an enormous deficit of water. To mitigate this problem, the State is following a political of great hydraulics consisting of the creation of infrastructures such as the dam. Meanwhile, a study of erosion has to be undertaken prior to the hydraulic Ouldjet Mellegue dam project to estimate the threats of future reservoir silting from its site and to manage the area that can be subjected to intense erosion. Therefore, this study attempts to: (1) assess the spatial variability of soil erosion caused by water; (2) to prioritize hotspot areas and sub-catchments for conservation measures in the semi-arid Mellegue catchment. Relative to this purpose, a cartographic approach based on Multi-criteria evaluation in a GIS is going to be integrated to show the influencing factors of erosion such as slope, nature of the outcropping material and plant cover. Thus, this study constitutes a reference document for land management to be developed in this study.

2. Study Area

The study area covers two main sub-basins in Mellegue River Basin. The first sub-basin originates from Meskiana Wadi in the West and the second sub-basin from Chabro Wadi in the East; the union of the two wadis drains the Mellegue River (Figure 1). The selected Mellegue catchment has an area of 4570 km^2 at the gauging station of Ouenza. The elevation ranges from 1622m in eastern part to 492m in northern most part of the catchment.

The Mellegue River basin is characterized with basically two seasons: dry and wet seasons where the dry season runs for June to September and the wet season is between October to May. The mean annual rainfall ranges from 245mm to 351mm (related to 13 rainfall stations) with estimated temperature ranging between 11 and 22°C. Abundant rainfall values occur from March to May but storm events, exceeding 30 mm.day^{-1}, are frequent in September, October and April.

The major forested vegetation region is to the south and east with forest and shrub land. Agriculturalfarmland is found in most zones suitable for cultivation within the basin, covering more than 30% of the study basin area. Steppes and grassland tend towards the north. The soil is predominantly marl-clayey typewith important percentages of recent soils, alluvium and loam along the major streams. The soil permeability ranges from deep to very shallow to moderately deep well drained soils.

The geology of the study area is characterized mainly by calcareous crusts and weathered limestone that occupy essentially the western part of the basin (at Meskiana sub-basin) (Figure 2). Marl and marly limestone tend to be abundant towards the East at Chabro sub-basin. The sandstone outcrops are mainly presented at the Chabro sub-basin. The weak rocks as marl formations are to be considered which are abundantly found in the Mellegue sub-basin. More than 60% of the basin has slopes with gradients lesser than 3° (Selmi and Khan, 2016). The slopes greater than 15° are less frequent, occupying the south-eastern part of the basin.

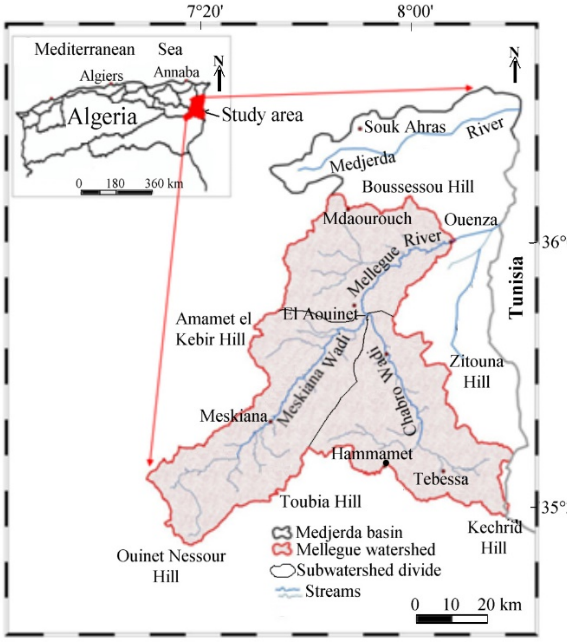

Figure 1: Location map of Mellegue catchment

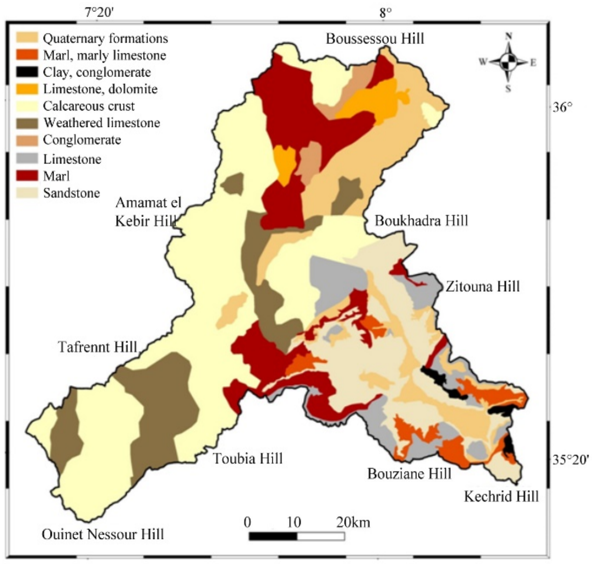

Figure 2: Lithological map of Mellegue catchment

3. Methods

The erosion sensitivity map produced is a basic tool for decision-making and management plans. The methods are going to focus on:

- knowing the current state of the land;
- identify and determine areas susceptible to erosion;
- allowing optimal use of agricultural land;
- requesting watershed management tools available to decision-makers, planners.

The first step of our approach consists in selecting the most representative factors involved in erosive phenomena. These are topography, characterized by the criterion "slope", the nature of the soil, represented by the lithology, and the land use described by the vegetation cover. The interest of the approach is based on the contribution of digital data by using a GIS program, in order to integrate spatial mapping and characterize the degree of sensitivity of soils to erosion over the entire study area.

The method used, shown in Figure 3, consists of integrating the previously mentioned data in the form of information layers into a GIS. These layers are then qualitatively reclassified as a sensitivity indicator according to their contribution to the erosion phenomenon (Chevalier et al., 1995; Soti, 2003). The sensitivity thresholds are chosen according to the studies undertaken about soil erosion in northeast of Algeria. Thus, based on the collectedinformation, three classes related to erosion are selected and which determine increasing levels of soil sensitivity to erosion.

For each erosion factor, a potential sensitivity map is produced. The method is based on the weighting of the factors of erosion then on the superposition of the three thematic maps. Thus, the soil fragility is obtained by the superposition of the lithological map with the map of land cover and the soil sensitivity to erosion is obtained by the superposition of fragile maps with map of slope land (Kessaissia et al., 2017). Finally, the actual soil erosion vulnerability map is classified into three classes; (1) low, (2) medium, (3) high. Meanwhile, the climatic factor is not taken into account in the development of the erosion model. Precipitation is therefore considered to be constant in the used approach.

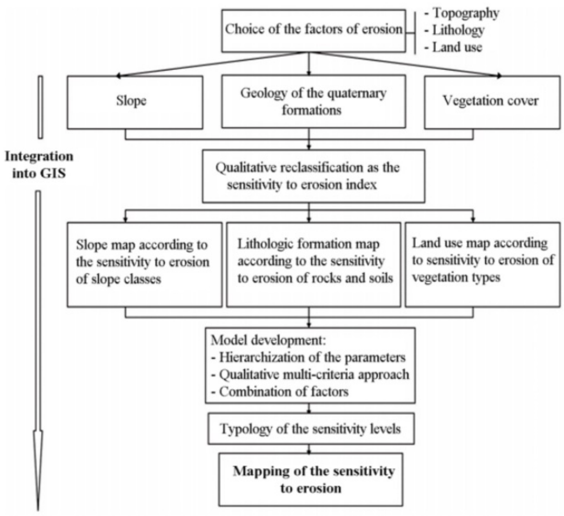

Figure 3: Flowchart presenting the steps of sensitivity mapping

The first factor involved in the sensitivity of soil erosion is the slope in percent. From the digital elevation model (DEM), the slope variable is calculated (first derivative of elevation) from the generation of slope map using Arcgis 10.4. A hierarchy in three classes according to its influence on erosive phenomena is defined: a slope of 0 to 3% represents a low sensitivity to erosion, from 3 to 10%, a medium sensitivity, and more 10%, a high sensitivity (Khanchoul et al., 2007).

The lithological nature of the basin is the second factor that can contribute to generate land eroded surfaces by different geomorphic processes. Lithology represents one of the layers, of providing information, necessary for the creation of the erosion sensitivity map. The simplified lithological map locates the main geologic layersthat are classified according to their resistance to erosion. These rocks, grouped into homogeneous units, give the classification shown in Table 1. Thus, the information can allow us to assign a qualitative erodibility index to each type of a geological formation. Three classes of rock sensitivity to erosion by water are applied as low, medium and high.

Table 1: Classification of rocks according to their resistance to erosion

Lithology	Degree of erodibility
Limestone	Low
Limestone and dolomite	Low
Sandstone	Low
Calcareous crust	Medium
Weathered limestone	Medium
Conglomerate	Medium
Marl, marly limestone	Medium
Clay, conglomerate	Medium
Marl	High
Quaternary formations	High

In addition, a priority is carried out in order to obtain qualitative information on the effect of vegetative cover by assigning an erosion sensitivity index to the different land use classes (Table 2). Bare soils, representing the greatest sensitivity to erosion, receive the highest index, while dense forest cover, strongly limiting the erosive process, is assigned the lowest index. Thus, three classes determine the degree of land use protection against water erosion as seen in Table 2.

Table 2: Sensitivity index of land use in Mellegue catchment

Land use	Sensitivity index
Cultures	Slightly protective
Steppes and grassland	Protective
Sparse forest and shrubs	Protective
Bare soils	Slightly protectrice
Dense forest	Strongly protective
Humid zones	Slightly protectrice

The mapping and assessment of soil erosion is an important step in the study. It allows taking into account the global adequacy of the model to the studied problem, to display local particularities and present the results to local deciders. However, prioritization of areas for management actions has to be undertaken. Management actions are selected from field-proven options and are applied to the appropriate combinations of soil erosion process and priority area.

4. Results and Discussion

In order to give at the local administration some cartographic instruments to fight against soil degradation in the catchment area of Mellegue River and to plan basin management with specific policies, three types of maps are developed. The processing of vulnerability database is performed with the professional software ArcGIS 10.4 for map creation and digitalization.

4.1 Mapping the sensitivity of soils to erosion

The slope map (e.g Figure 4) is one of the basic elements for the analysis of the physical characteristics that determine the suitability of the various zones.It shows that most Mellegue catchment area is characterized by low slopes (0 to 3%), located along the Meskiana and Chabro wadis and downstream of Mellegue River. These areas have a low sensitivity to erosion and occupy 39% of the basin area (Table 2).

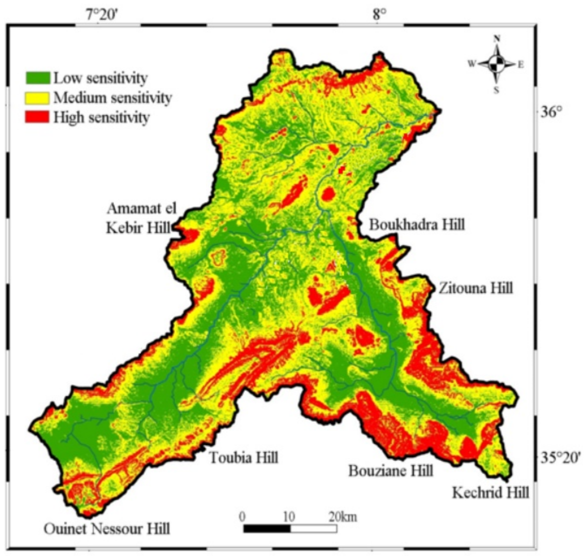

Figure 4: Slope sensitivity map to erosion of Mellegue catchment

The zones with medium sensitivity to water erosion occupy 43% of the basin area and are mainly located at glacis surfaces of both Meskiana and Chabro wadis. On the other hand, areas with steep slopes (> 10%) are less dominant and occupy mainly the hillslopes of the Meskiana and Chabro sub-basins (Table 3).

Table 3: Slope sensitivity to erosion distribution

Sensitivity	Basin area	
	km²	%

Low	1792,9	39,2
Medium	1952,2	42,7
High	829,9	18,1
Total	4575,0	100,0

Concerning the lithological nature of the basin; the map in Figure 5 and Table 4 show that the medium erodibility of rocks dominates (with 52% of basin area). This vast area is mainly composed of calcareous crusts and friable limestone, located in the west of the Mellegue catchment and covers almost the entire Meskiana sub-basin. While Chabro sub-basin includes a large part of low erodibility rocks such as sandstone and limestone, which occupy 21.3% of the study area. The class which represents a high erodibility is distinguished mainly by marl outcrops and quaternary formations in the Mellegue sub-basin and Hammamet area.

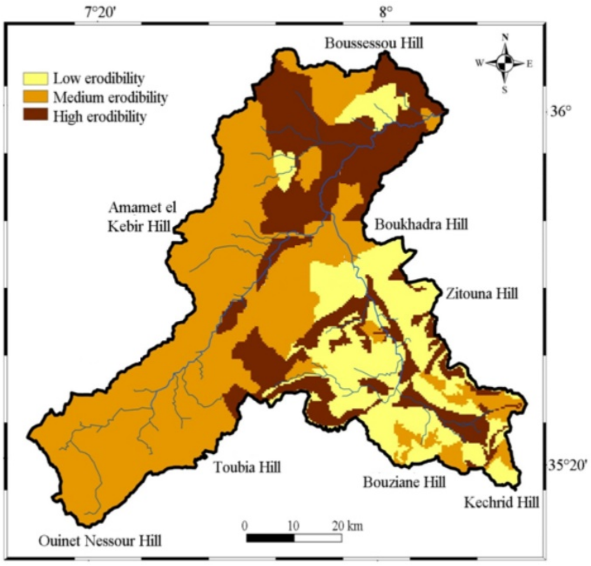

Figure 5: Lithology classification according to rock resistance to erosion

Table 4: Rock resistance to erosion distribution in Mellegue catchment		
Erodibility	**Basin area**	
	km²	**%**
Low	974.7	21.3
Medium	2360.3	51.6
High	1240.0	27.1
Total	4575.0	100.0

Table 5 show that the Mellegue catchment is considered protected by a vegetation cover where strongly protected to protected areas are highly dominant with a contribution of 55.4%.The class most sensitive to erosion is found along Meskiana and Chabro valleys (Figure 6). The system of valleys extends through plains and glacis of gentle slopes. They are extensive areas cultivated with rainfed crops, very sensitive to erosion (with almost 45% of basin area). Meanwhile, the protected areas are distinguished mainly by steppes, grassland, and insignificant sparse forest and shrubs occupation; they are essentially observed at Mellegue sub-basin. The most protective vegetation cover (dense forest) that could protect soil against sheetwash and rill erosion occupies only an area of 325.7 km² (with 7% of basin area).

Table 5: Land use sensitivity distribution in Mellegue catchment		
Land use	**Basin area**	
	km²	**%**
Slightly protective	2040.60	44.60
Protective	2208.70	48.30
Strongly protective	325.70	7.10
Total	4575	100

The superposition of the concerned layers (slope, lithology, land use) has allowed identifying the areas sensitive to erosion. The most areas affected by the erosion processes and those most preserved can thus be distinguished. The resulting map from the multi-criteria combination, shown in Figure 7, is distinguished by a pronounced dichotomy between the alluvial plain less subjected to erosive processes, in general, and the mountain system marked by more or less high degrees of sensitivity. This situation is of course the result of the superposition of factors of high sensitivity to erosion. Thus the areas characterized by steep slopes, an erodible substrate and poor plant protection show a high potential for soil loss.

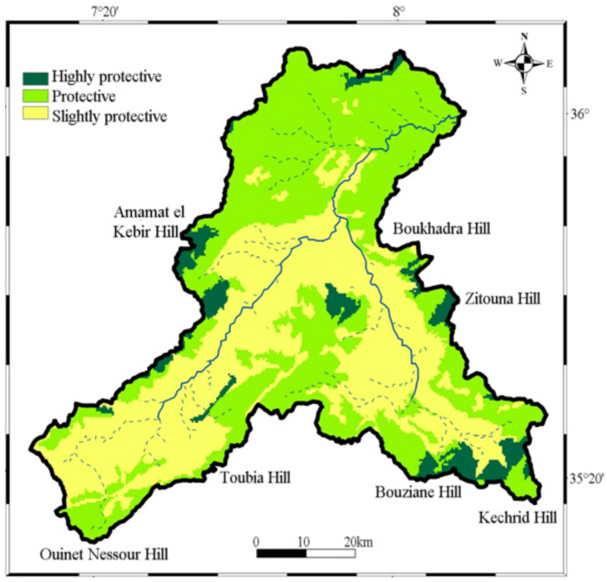

Figure 6: Land use sensitivity map of Mellegue catchment

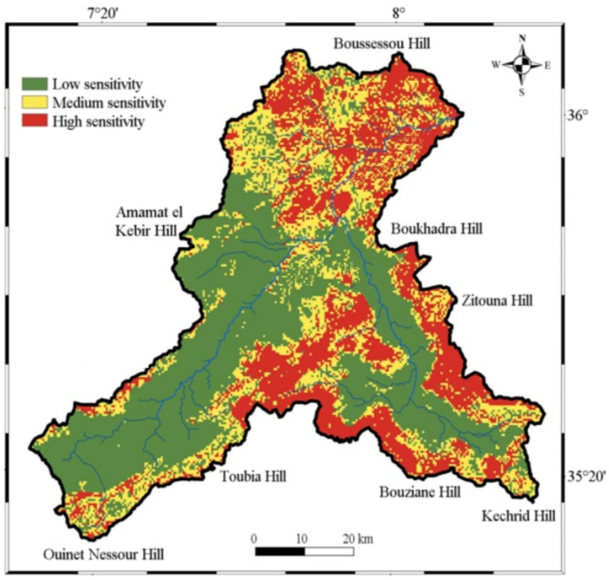

Figure 7: Potential sensitivity map of Mellegue catchment

For the Mellegue catchment, the class which represents a low sensitivity to erosion occupies almost half of the study basin with a rate of 47% of its total surface (Table 6). This class is mainly located in the south of the Mellegue basin; it occupies almost the entire Meskiana sub-basin and a good part of Chabro sub-basin. This is explained by the low slopes (<3%) of these areas comprising extended alluvial plains. However, it seems that the Meskiana sub-basin is characterized by low erosion compared to its neighbor, the Chabro sub-basin.

The zones with medium sensitivity to erosion are mainly located at the Mellegue sub-basin, along the common divide surfaces of both Meskiana and Chabro sub-basins, and along the hillslopes from Boukhadra Hill to Bouziane Hill (at Chabro sub-basin). Their total area is estimated to 1470 km², which corresponds to 32% of the basin area.

The class which symbolizes a high sensitivity to erosion covers an area 955.5 km² (21%). The zones where this class dominates are generally associated with those of the medium sensitivity areas but are spatially distributed at higher elevations, where the hillslopes are steeper developed on marly and clayey geologic formations.

Table 6: Areas of potential sensitivity to erosion at Mellegue catchment and its sub-basins

	Basins	Mellegue sub-basin		Chabro sub-basin		Meskiana sub-basin		Mellegue basin	
Sensitivity to erosion	Area	Km²	%	Km²	%	Km²	%	Km²	%
	Low	212	18.12	645	41.35	1336	72.41	2150	46.99
	Medium	603	51.54	443	28.40	381	20.65	1470	32.13
	High	355	30.34	472	30.26	128	6.94	955	20.87
	Total	1170	100	1560	100	1845	100	4575	100

Furthermore, the Mellegue and Chabro sub-basins are both aggressively affected by erosive processes and thus are highly prone to erosion by mass wasting, sheetwash and rill erosion; they belong to the high sensitive lands to erosion, with an extension of 30% for each. The Chabro is also characterized by incised alluvial fans. The steep slopes have a greater impact on soil conservation. The minerals and organic content present in the soil moves down toward the slope, due to heavy rainfall. Soil erosion is usually experienced higher in slope with less vegetation. Sparse shrubs and plants can't prevent successfully the top soil from eroding. We find that the high erosion risk in these two sectors clearly explains that the vegetation cover factor plays a protector role. Moreover, the C-factor decreases the erosive risk to 0.01 under perennial vegetation associated with herbaceous cover (Roose et al., 2012). In order to optimize the allowance of the resources intended for the short-term reduction of the silting of the future dam, of Ouldjet Mellegue, we propose that only the areas included in the category of high sensitivity to erosion receive a special attention as regards to conservation measurements. These contiguous sectors will have a significant impact on a silting proportion of this dam. These sectors represent mainly agricultural lands.

In contrary, the Meskiana sub-basin is the most stable zone with low erosion surfaces, corresponding to 72.41% of its basin area. Nevertheless, it is important to note that an area which presents a low erosive hazard according to the model is an area which potentially will not produce runoff. On the other hand, if it is located downstream of cultivated lands, it will be exposed to significant damage (Souadi et al., 2000). Overall, since water is the prime limiting factor of productivity in this terrestrial ecosystem, when soil-water availability for agriculture is reduced, productivity is depressed. Particularly, in semiarid areas vegetation suffers longer periods of water deficit, determining the vegetation structure and complexity, and thus soil protection and water conservation.

4.2 Advantages and limitations of the model

The method implemented leads to a better understanding of the spatial distribution of erosion in the Mellegue catchment; it could also constitute the starting point for applying a feasible basin management to fight against land degradation. However, this work constitutes the first step towards a more precise estimation of this hazard. The approach presented in this study can be applied in any sector for which the input data necessary for the model are available. It should be noted that this model does not allow calculation of exported volumes of land. Thus, we cannot estimate the amount of soil transported to the rivers. Likewise, this model gives more importance to the occurrence than to the intensity of the erosive hazard, and it underestimates the damage caused by extreme climatic events. In the future, some uncertainties in the results could be removed by improving the accuracy of the model or by developing the model. To contribute to the development of the model, one could, on the basis of the obtained results, make simulations on the influence of changes in climate or land use.

4.3 Anti-erosive measures proposed for land management

The anti-erosion measures proposed for land management of the Mellegue catchment are determined according to the combinations of land use classes and slope classes associated with the sensitivity map. Indeed, the slope, which imposes or excludes the application of certain measures, is a determining factor in the choice of the measures to be applied. The conservation of soil on sloping surfaces becomes necessary, since these surfaces are always exposed to erosion by generating runoff. On low slope surfaces (<10%), the land management is limited to conservative farming techniques (plowing in contour lines, mulching, etc.), but when the slope is steep (> 10%), they become insufficient, therefore other solutions are possible, such as benches, dry stone walls and barriers, in order to reduce the length of the slope, and slowing runoff (Figure 8).

The construction of dry stone or vegetation barriers is to be favored because the latter are less expensive and more easily implemented. The benches on stone walls can be preferred for steep slopes because they allow the correction of more sloping surfaces using barriers. This can be done on surfaces having considerable lengths in some Meskiana and Chabro agricultural lands.

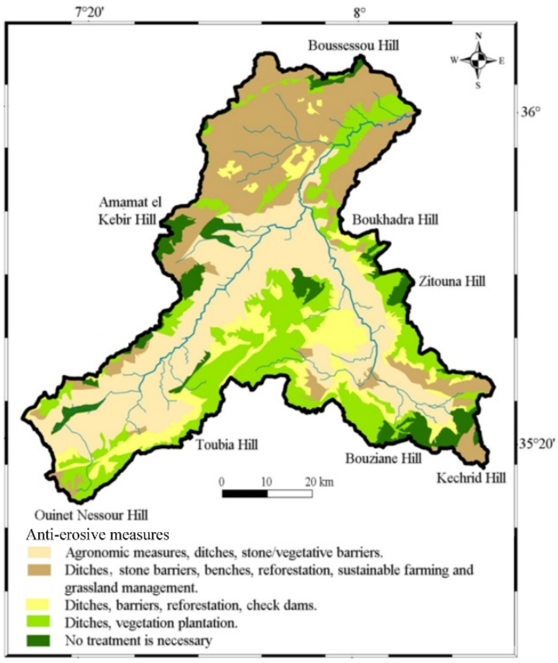

Figure 8: Map of management plan of Mellegue catchment

For the hydraulic correction of gullies, contour diversion ditches are also recommended as seen in Figure 8. They can allow a good stabilization of gullies in marly lands and a good recovery of vegetation. Sediments captured by the ditchesare able to be re-transported as suspended load and to continue their movement if they are not fixed quickly (Combes, 1992). So, we must think about the stabilization of the sediments retained by a biological fixation. Species with strong roots are envisaged, their role is to improve the infiltration of water into the soil and dissipate the energy of runoff and its transport capacity.

Agronomic measures and agricultural development are applicable to crop areas and grassland and steppes. They have two objectives of fighting against erosion and improving agrarian systems by limiting soil degradation and improving water conservation. For the grasslands and steppes with slopes greater than 10%, it is proposed to convert the livestock areas to reforested ones because of increasing erosive risk on that lands. In areas with natural vegetation such as the steppes, the existence of plant cover is an acquired procedure. It is therefore proposed to promote spontaneous colonization by reducing the pressure of grazing and by building dry stone barriers where natural vegetation can be developed on slopes less than 10%. For slopes greater than 10% re-vegetation and in particular reforestation have to be intensified in order to increase soil protection and plant fixation, suitable measures for soil conservation.

In areas with bare soils, the presence of inexpensive stabilizing structures such as stone barriers is recommended in addition to re-vegetation. Those of rare vegetation particularly in Chabro sub-basin, re-vegetation and reforestation in particular are the preferred solutions, whatever the slope steepness. The reforestation should relate to the choice of xeric forest species adapted to the edapho-climatic conditions of the study area. Plantation of Acacia saligna (Acacia cyanophylla), Lambert cypress (Cupressus macrocarpa), Aleppo pine (Pinus halepensis) and Umbrella pine (Pinus pinea) is recommended. In addition, the introduction of fruit and agroforestry trees is recommended, since fruit trees, such as Olive tree (Olea europea L.) and almond tree (Prunus amygdalus), play a role in protecting the soil while providing income for the local population. The erosion control benches reduce both the length of slope susceptible to runoff and the runoff velocity, which remains below the critical threshold of gully erosion. They are proposed sparingly for land management in the Mellegue catchment in areas of rare vegetation developed mainly on marly, marly limestone formations and having slopes exceeding 10%.

5. Conclusion

The knowledge of the spatial distribution of erosion by water at the catchment scale is still a real challenge to the scientific community. Spatial analysis of the erosive hazard is becoming thus a very useful tool for locating the areas most likely to be subject to water erosion. This study aims to answer to this question in the Mellegue catchment, northeast of Algeria. The determination of the sensitivity to erosion is successfully used under Geographic Information System (GIS) environment.

The study basin is divided into three category areas; higher to medium which dominate the sparse steppes, grasslands and shrubs; and the lower category is distributed on plains with crop. Nevertheless, these three categories of areas require intervention measures at different degrees to control the pace of soil erosion because the presence of erosion and heavy runoff on gentle slopes indicates that this phenomenon can occur without any need for a steep slope, where the action of rain is enough to generate runoff.

In addition, to optimize the allocation of resources for the reduction silt up of the dam Ouldjet Mellegue in a short and long term, it is necessary to manage only the priority areas with special attention in terms of anti-erosion control. Erosion control interventions suggested in these areas are reforestation, planting fruit trees and some resistant species to increase plant cover on slopes. Also, to reduce the effect of sensitive areas to erosive runoff, these areas also require the establishment of stone walls, barriers, benches and drains, on the slopes and gullies.

The assessment of soil erosion is thus very important to fight against the different erosive processes and that in order to minimize erosion risk and to standardize conservation measures for sustaining agricultural productivity. Furthermore, land use plans should be practiced for the management and utilization of fragile and marginal areas. Agricultural policy can further reduce soil loss rates in arable lands. The management plan should be coupled with a rural development project to ensure the sustainability of anti-erosion measures and the implementation of suitable agricultural practices.

References

Anteur, D., Khalladi, M., Gliz, M., 2014. Contribution à l'évaluation et à la cartographie de la sensibilité à l'érosion hydrique des sols du sous bassin versant de l'Oued de Saida (ouest de l'Algérie). European Scientific Journal, 10(27), 142-153.

Bayramin, I., Dengiz, O., Baskan, O., Parlak, M., 2003. Soil erosion assessment with ICONA model: Case study, Baypazari area. Turkish Journal of Agriculture and Forestry, 27, 105-116.

Belayneh, M., Yirgu, T., Tsegaye, D., 2019. Potential soil erosion estimation and area prioritization for better conservation planning in Gumara watershed using RUSLE and GIS techniques. Environmental Systems Research, 8(1), 2-17.

Benchettouh, A., Kouri, L., Jebari, S., 2017. Spatial estimation of soil erosion risk using RUSLE/GIS techniques and practices conservation suggested for reducing soil erosion in Wadi Mina watershed (northwest, Algeria). Arabian Journal of Geosciences, 10(4), 1-14.

Benguerai, A., Benabdeli, K., 2017. Assessment of soil vulnerability to water erosion using GIS and remote sensing in the watershed of Fergoug, North-West of Algeria. Journal of Applied Environmental and Biological Sciences, 7(3), 166-172.

Bouguerra, H., Bouanani, A., Khanchoul, K., Derdous, O., Tachi, S.E., 2017. Mapping erosion prone areas in the Bouhamdane watershed (Algeria) using the Revised Universal Soil Loss Equation through GIS. Journal of Water and Land Development, 32, 13-23.

Bouguerra, S., Bouanani, A., 2016. Cartographie qualitative de la sensibilité du sol à l'érosion hydrique: cas du bassin versant oued Boukiou (nord ouest de l'Algérie). Etude et Gestion des Sols, 23, 91-100.

Chevalier, J.J., Pouliot, J., Thomson, K., Boussema, M.R., 1995. Systèmes d'aide à la planification pour la conservation des eaux et des sols (Tunisie). Systèmes d'information géographiques utilisant les données de télédétection. Actes du Colloque Scientifique International, Hammamet, 4-12.

Combes, F., 1992. Les plantations RTM. Bulletin Réseau Érosion,12, 52-56.

Djoukbala, O., Mazour, M., Hasbaia, M., Benselama, O., 2018. Estimating of water erosion in semiarid regions using RUSLE equation under GIS environment. Environmental Earth Sciences, 77(9), 1-13.

Fazzini, M., Bisci, C., Billi, P., 2015. The climate of Ethiopia. In: Billi P (ed) Landscapes and Landforms of Ethiopia. World geomorphologic landscapes. Springer, Dordrecht.

Grepperud, S., 1995. Soil conservation and governmental policies in tropical areas: does aid worsen the incentives for arresting erosion. Agricultural economics, 12,129-140.

Halefom, A., Teshome, A., 2019. Modelling and mapping of erosion potentially watersheds using AHP and GIS technique: a case of Alamata Watershed, South Tigray, Ethiopia. Modeling Earth Systems and Environment, pp.1-13. DOI:10.1007/s40808-018-00568-6.

Halefom, A., Teshome, A., Sisay, E., Dananto, M., 2018. Erosion sensitivity using GIS and multi-criteria decision approach in Ribb watershed Upper Blue Nile, Ethiopia. International Journal of Energy and Environmental Science, 3(6), 99-111.

Hurni, H., 1989. Soil for the future. Environmental Research for Development Cooperation. University Press 62, University of Berne, pp. 42-46.

Kessaissia, A., Mazour, M., M'hamedi Bouzina, M., Nabed, A., 2017. Spatiotemporal variation of the soil potential sensitivity to water erosion. Case of the Tifiles micro basin of the North West Algerian. Applied Journal of Environmental Engineering Science, 3(4), 321-332.

Khanchoul, K., Boubehziz, S., 2019. Spatial variability of soil erodibility at El Hammam catchment, northeast of Algeria. Environment and Ecosystem Science, 3(1), 17-25.

Khanchoul, K., Jansson, M.B., Lange, Y., 2007. Comparison of suspended sediment yield in two catchments, northeast Algeria. Zeitschrift für Geomorphologie, 51(1), 63-94.

Meddi, M., Morsli, B., 2001. Etude de l'érosion et de ruissellement sur basins versants expérimentaux dans les monts de Beni Chougrane (Ouest d'Algerie). Zeitschrift für Geomorphologie, 45(4), 443-452.

Mekuriaw, A., Heinimann, A., Zeleke, G., Hurni, H., 2018. Factors influencing the adoption of physical soil and water conservation practices in the Ethiopian highlands. International Soil Water Conservation Research, 6, 23-30.

Molla, T., Sisheber, B., 2017. Estimating soil erosion risk and evaluating erosion control measures for soil conservation planning at Koga watershed in the highlands of Ethiopia. Solid Earth, 8, 13-25.

Nyssen, J., Poesen, J., Moeyersons, J., Deckers, J., Haile, M., Lang, A., 2004. Human impact on the environment in the Ethiopian and Eritrean highlands - a state of the art. Earth Science Reviews, 64, 273-320.

Pandey, A., Chowdary, V.M., Mai, B.C., 2007. Identification of critical erosion prone areas in the small agricultural watershed using USLE, GIS and remote sensing. Water Resource Management, 21, 729-746.

Pimentel, D., Burgess M., 2013. Soil Erosion Threatens Food Production. Agriculture, 3, 443-463.

Rejani, R., Rao, K.V., Osman, M., Srinivasa Rao, C., Sammi Reddy, K., Chary, G. R., Pushpanjali, Samuel, J., 2016. Spatial and temporal estimation of soil loss for the sustainable management of a wet semi-arid watershed cluster. Environmental Monitoring Assessment, 188(3), 2-16.

Roose, E., Sabir, M., Arabi, M., Morsli, B., Mazour, M., 2012. Soixante années de recherches en coopération sur l'érosion hydrique et la lutte antiérosive au Maghreb. Physio-Géo, 6, 43-69.

Samson, S.A., Ayanlade, A., Alabi, O., Alaga, A.T., Oloko-oba, M.O., Ogunyemi S.A., Badru, R.A., 2017. Soil erosion vulnerability mapping and implication on vegetation in parts of Oshun River Basin, Nigeria. International Journal of Scientific Research in Science, Engineering and Technology, 3(1), 82-91.

Selmi, K., Khanchoul, K., 2016. Sediment load estimation in the Mellegue catchment, Algeria. Journal of Water and Land Development, 31, 129-137.

Semwal, P., Khobragade, S.D., Nainwal, H.C., 2017. Modelling of recent erosion rates in a Lake Catchment in the North-Western Siwalik Himalayas. Environmental Processes, 4, 355-374.

Setegn, S.G., Srinivasan, R., Dargahi, B., Melesse, A.M., 2009. Spatial delineation of soil erosion vulnerability in the Lake Tana Basin, Ethiopia. Hydrological Processes, 23, 3738-3750.

Soti, V., 2003. Apport de la télédétection spatiale à la gestion intégrée du 'lagon' de Saint-Gilles / La Saline à l'île de la Réunion : Un exemple d'application : cartographie et suivi des zones susceptibles à l'érosion entre 1995 et 2002 par intégration des données SPOT. Montpellier, Mastère SILAT (Engref-Ensam-INAPGIGN), pp. 35.

Souadi, T., King, C., Le Bissonnais, Y., Bourguignon, A., Souchere, V., Denis, L., Lecour, A., Maurizo, R., 2000. Atlas régional de l'Aléa érosion en Haute Normandie. BRGM Report RP50454-FR.

Souidi, Z., Hamimed, A., Zaagane, M., Donze, F., 2017. Cartographie des zones à risqué d'érosion hydrique: Application au basin versant d'Oued Fergoug dans les monts des Beni-Chougranes en Algérie. SAGREN, 1(1), 1-8.

Stathopoulos, N., Lykoudi, E., Vasileiou, E., Rozos, D., Dimitrakopoulos, D., 2017. Erosion vulnerability assessment of Sperchios River Basin, in East Central Greece - A GIS based analysis. Open Journal of Geology, 7, 621-646.

Tahiri, M., Tabyaoui, H., Tahiri, A., El Hadi, A., El Hammichi, F., Achab, M., 2016. Modelling soil Erosion and sedimentation in the Oued Haricha Sub-Basin (Tahaddart Watershed, Western Rif, Morocco): risk assessment. Journal of Geoscience and Environment Protection, 4, 107-119.

Touahir, S., Khenter, K., Remini, B., Saad, H., 2017. Prediction of soil water erosion risk within GIS – case study of Beni Amrane dam catchment (North of Algeria). 3rd International Conference on Water Resource and Environment, 82, 1-13.

Udokporo, E., Ngozika Anikwe, M.A., Chukwu, K.E., 2015. Assessment and mapping of the vulnerability of soils in Imo State, Nigeria to erosion hazard using geographic information system. International Journal of Environmental Monitoring and Analysis, 3(5), 245-259.