Open Access Library Journal
2023, Volume 10, e9888
ISSN Online: 2333-9721
ISSN Print: 2333-9705

Evaluation of Soil Erosion by RUSLE Model in Mount Guera

Issa Justin Laougué[1]*, Djebé Mbaindogoum[1], Mahamat Ali Mustapha[2]

[1]Department of Geography, Adam Barka University, Abeché, Chad
[2]Ecole Normale Supérieure de Bongor, Bongor, Chad
Email: *issa_laougue@yahoo.fr

How to cite this paper: Laougué, I.J., Mbaindogoum, D. and Mustapha, M.A. (2023) Evaluation of Soil Erosion by RUSLE Model in Mount Guera. *Open Access Library Journal*, **10**: e9888.
https://doi.org/10.4236/oalib.1109888

Received: February 17, 2023
Accepted: March 28, 2023
Published: March 31, 2023

Abstract

The Mount Guera is a particularly fragile environment undergoing soil degradation due to its rugged terrain, the violent nature of the types of precipitations that occur there and its geographical location which places it in the sahelian zone. Also, this environment constitutes the most populated part of the center of Chad, which makes it more vulnerable due to the anthropic action undertaken by men to satisfy their needs. This work aims to assess soil erosion in the region using the RUSLE model which quantifies the rate of erosion which varies in this region on average between 0.01 and 2967.09 t/ha/year. To spatialize this phenomenon, the RUSLE parameters have been implemented in ArGis. In view of the data obtained, there is reason to wonder about the future of this fragile environment which is likely to experience environmental problems in the short term.

Subject Areas

Soil Science

Keywords

Evaluation, Erosion, RUSLE, Guera, Factors

1. Introduction

Space technologies, and more particularly earth observation systems, are now essential tools in the problem of the physical degradation of soils. The growing interest in multi-kilometer scale studies and the associated environmental issues have stimulated the use of remote sensing [1]. Our approach is based on the use of remote sensing data for a spatial knowledge of erosion factors (land use, importance of plant cover, etc) and on the use of geographic information system (GIS) for analysis of operations and the stimulation of erosion processes.

It is the fact admitted that the choice of a model is consecutive to certain number of criteria which must guide the researcher. In our case, we choose the RUSLE model for various reasons including the availability of data to apply in this region which is a controversial subject. Also, its flexibility to be used constitutes the second reason for choice because the RUSLE is a model that can be regularly supplemented and adapted according to the bioclimatic environment, environment sometimes totally different from that within which the equation was designed [2]. Similarly, the RUSLE has been successfully used in regions of Africa with physical characteristics similar to our study region such as northern Cameroon, Burkina Faso, Niger, Mali, etc. The results obtained from the application of this equation seem to be satisfactory because "the RUSLE model provides interesting information on the risk of erosion" [3]. For this group of authors, as the RUSLE is an empirical model, its application to a given study area can be the source of biases or errors in the evaluation of the factors, but its integration into GIS presents many advantages, especially those related to the large number results relating to the factors involved in the water erosion. These various findings have been summarized by these terms, the most encountered model, the RUSLE has often been used outside its application context; the derived equations allow it to be deployed in regions of different climatic and geological conditions as well as to poorly informed countries whose data are scarce or non-existent (developing countries, intertropical, mediterranean, …) [3]. It is therefore on the basics of these various observations that we have opted for this model. The Revised Universal Soil Loss Equation (RUSLE) model is inbuilt on the equation of the form [2]:

$$A = R * K * LS * C * P$$

where:

A = soil loss rate in tons per hectare per year (t/ha/year);

R = erosivity of rainfall in megajoule millimeter per hectare hour (MJ·mm/ha·h);

K = soil erodibility in tonne hours per megajoule millimeter (th/MJ.mm);

LS = length of slope and inclination (unitless);

C = vegetation cover factor;

P = factor taking anti-erosion practices into account.

This model allowed us to map areas with high or low potential for soil degradation.

2. Study Methodology

To achieve the objective of the study which is to identify the variables describing the nature and extent of physical soil degradation factors in order to spatialize the loss of land at the scale of our study (region, we have opted for the following approaches:

- creation of thematic layers describing the various factors retained for soil erosion using remote sensing images and others available data;

- integration of these layers in a database and their combination according to the selected calculation model;
- creation of loss maps and vulnerability of soils;
- In this work, we used satellitee images from sources:
- Shuttle radar topography images Mission (SRTM) resolution at our disposal by P-SIDRAT. These data, which are presented in raster form (GEO Tiff= tagged image Files format), provide, information for each pixel on the altimetry. These previously decompressed images were exported in Arcview and, thanks to the topographic wetness index tool in terrain analysis, we were able to generate the Digital Elevation Model (DEM). For factors such as rainfall erosivity R or soil erodibility K, the data comes from eitter thz modeling data posted online by worldclim after interpolation or data archived in digital form in the IRD (Institut de Recherche pour le Développement, http://www.cartographie.ird.fr/sphaera/tableaux/scripts/search_tbl.php?Tbl=/sphaera/tableaux/assemblage/MDG6.html&Num=2652). The factor P was determined from surveys and observations made in the field. The value corresponding to the different anti-erosive practices have been entered in the appropriate field. Then, the latter was resterized at 90 m resolution through conversion tools module.
- Images from the TM (Thematic Mapper) sensors of the Landsat-5 Satellite and the ETM+ (Enhanced Thematic Mapper) of Landsat 8. Indeed, these images, archived by USGS on its site, are accessible by download. The images obtained (three scenes per year to cover the study region) from composition of certain bands of afore mentioned satellites made it possible to establish land use maps over a time step of years (1999 and 2019) by color comparison. In addition, we wanted to get 2 to 3 images for each year so as to highlight the main characteristics of the different factors according to the seasons, but the constraints of image availability forced us to use only the images from November 1999 and December 2019. Even if the different images of the years studied were not recorded in the same month, it is possible to carry out a diachronic analysis of the dynamic of vulnerability since the difference is of the order of a week and these two months belong to the same season. These images were already arthorectified by the USGS (WGS 1984 UTM) and resampled to base resolution. These Landsat images have undergone some minor pretreatment ranging from geometric correction to automatic classification, georeferencing and mosaiking.

Once the satellite images are available and put in a adequate form, we proceeded to their implementation under the Argis software in order to in one hand to create thematic layers of the selected erosion factors and on the other hand integrating these layers in a database in order to combine them with in view of their application in the global soil loss model chosen, the RUSLE model. More specifically, we retained the following factors; rainfall regime, slope, plant cover, soil erodibility and anti-erosion practices. The various factors entering in the establishment of the RUSLE were also evaluated from the specific variables. Thus, the R INDEX was determined from the formula applied by Roose in the West Africa which evaluates $R = 0.5 \times P \times 1.735$ with P presenting the annual precipitation in mm; or K factor, depending on the grain size or texture of soil, the organic content, the structural stability, the porosity, the permeability; was determined from formula $K = 2.8 \times 10^{-7} M^{1,14} (12\text{-MO}) + 4.3 \times 10^{-3} (b - 2) + 3.3 \times 10^{-3} (c - 3)$

$$\text{With } M = (\%\ \text{silts} + \%\ \text{sands})\ (100 - \%\ \text{clays})$$

OM = Percentage of organic matter,

b = soil structure code

c = profile permeability class

It is therefore the crossing of the different factors carried out in our GIS (Arcgis) through the spatial analyst tools option which allowed us to have an idea of the spatialization of the phenomenon of water erosion and the different values according to the topographic landscape positions. To calculate the slope of the study area, we used the digital terrain model (DTM) taking as slope length the resolution of the slope maps (i.e. 10 m) given that each pixel has relatively, homogeneous slope characteristics and appropriate for the pixel in question. Indeed, this mesh allows a better estimate of the slopes for the marked hilly areas and offers a greater precision, better highlighting the small variations of the hilly area which can be at the origin erosion. Thus, in order to generate the map of slopes, the slope patterns we digitized before proceeding to group them into five classes ranging from very low to very steep slopes. Also, it seems to us interesting to carry out the mathematization of this factor in order to have an average value which could enter into the calculation of the loss of the grounds of the area.

To do this many others have tried depending on the objectives of their studies, to develop mathematical formulas more or less able to predict the situation in their area of study.

Thus, this factor (LS) is calculated from the length of the slopes (L) and their inclination (S), determined from the SRTM image previously decompressed then exported in Arcview, the topographic index

Enter into the calculation of the loss of the grounds of the area.

To do this many others have tried depending on, the objectives of their studies, to develop mathematical formulas more or less able to predict the situation in their area of study.

Thus, this factor (LS) is calculated from the length of the slopes (L) and their inclination (S), determined from the SRTM image previously decompressed then exported in ArcView, the topographic index was generated thanks to the topographic wetness index tool in terrain analysis; which allowed us to have the map of the values of the index of the region studies. For our part, the formula that caught our attention is:

$$L = \lambda^{0.5}\left(0.0076 + 0.005 * \alpha + 0.00076 * \alpha^2\right) \quad [4]:$$

With λ the length of the plot (in feet) and α the slope (in %).

3. Results

The elevation of land loss is related to different factors since each method used is most often perceiver, as better by its promoters. However, there is consensus on measures with characteristics that can be adapted to the different natural regions of the globe.

Thus, from experimental measurements that are more costly in terms of time and investment, we now come to the all-round use of cartographic modeling which does not reflect the actual measurements exactly but which gives an indication of the extent of this process of degradation of the soils.

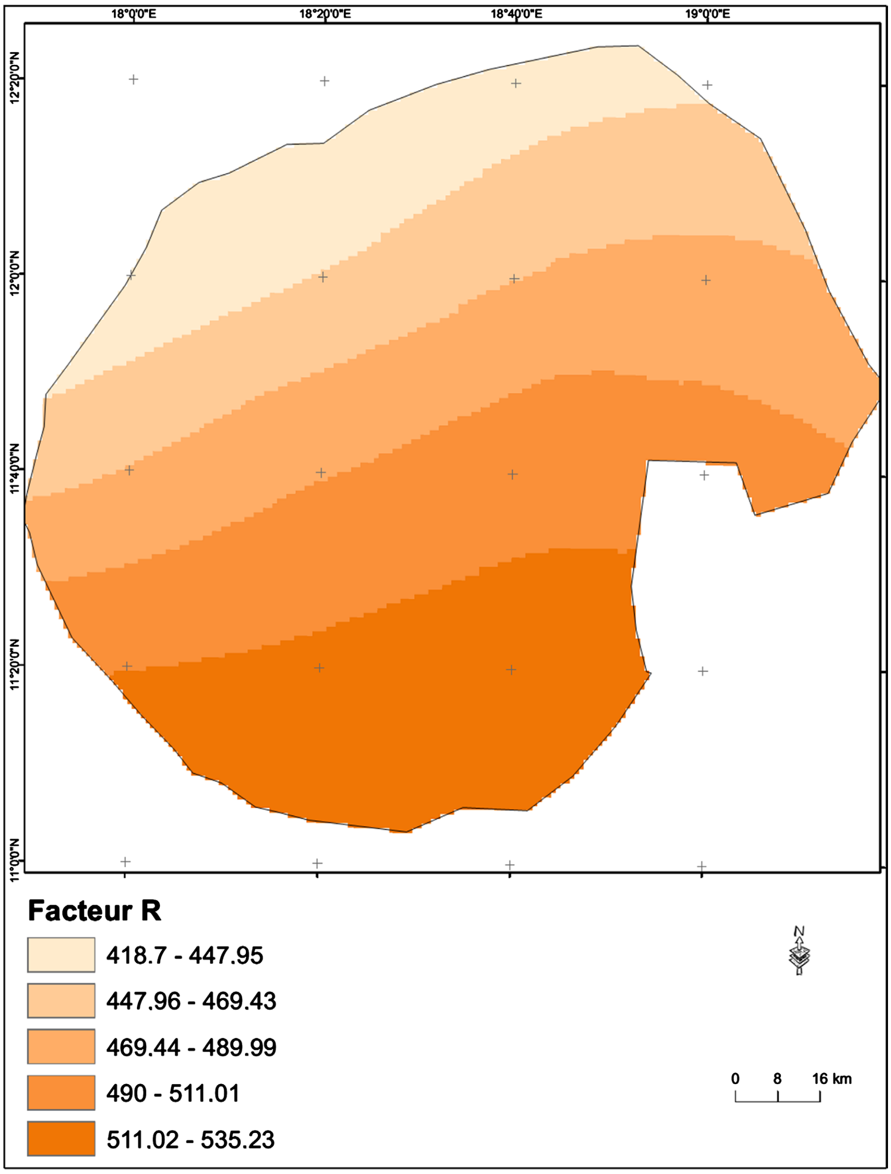
3.1. Rainfall Source of Erosion

The Rain is one of the main factors of physical soil degradation (because without it we cannot speak of water erosion [5]. For our study, not having rainfall data at each rainfall event and data covering the area sufficiently, we were led to interpolate rainfall data to cover the spatial distribution of rainfall through ranges. Then, to determine the rainfall erosivity index, we proceeded in to same way. Indeed, so that the whole zone is covered by the indices, the point interpolation method has applied. In this case, the probabilistic or kringing approach is used.

Kringing is an interpolation that estimates values at sampled points by combination of data. The sample weights are weighted by a structure function that is derived from the data. Distances, values and correlations are thus taken into account. The function is not fixed a priori but following the analysis of the estimated value at a point is the product of an underlying process, it provides an estimation variance unlike other approaches. It makes it possible to apprehend the spatial structure of the phenomenon studied. Kriging is therefore part of a process of analysis of a geostatistical data. To do this, we first created a table in Excel and attached to each station its geographical coordinates X and Y as well as the value of its erosivity index. Subsequently, the table obtained was exported in Arc map and the kriging interpolation method of spatial analyst, the various points representing the erosivity index were interpolated then rasterized as shown in **Figure 1** relating to the distribution of the erosivity index as an isoline. The rain erosivity factor reflects the aggressiveness of the rains on the soils; in other words, it is a question of determining the impact of the rains on the soil. This factor is determined from the kinetic energies (E) and the maximum intensity (I30) over thirty consecutive minutes of the raindrops of each downpour [4] and would be written with:

$$R_i = E_c * I_{30} \text{ and } E_c = 11.9 + 8.73 \log I_{10}$$

where: E_c = Kinetic energy of the downpour ($J/m^2/mm$), I = Average intensity of the rain (mm/h).



Source: SRTM 90; P-SIDRAT, 2011; Terrain, 2019.

Figure 1. Répartition spatiale du facteur R dans le Guéra.

I = number of downpour and n = Total number of annual downpours.

The main difficulty in our area is that the rainfall data collection devices work too less well and the only data available for a few rare station are either monthly or annual data. This difficulty means that we are forced, for the purposes of this study, to use the revised version of this equation which determines the erosivity index of rainfall [6] by:

$$R = 0.5 * P * 1.735 \quad (1)$$

where: P represents the annual precipitation in mm.

This formula is applied to the annual precipitation values after precalculation in Excel; then, the data are spatialized. In a practical way, we first calculated the average precipitation of anormal (30 years) for each pluviometric station. Then the roose formula was applied to the value obtained in order to determine the erosivity index of each station. Thus, by considering the rainfall at Bitkine and Mongo stations and the values obtained after krining, it appears the R factor varies from 419.15 to 539.24 MJ·mm/ha·h year depending on whetter one is going from the north to the south. In fact, this work of interpolation by krining allowed us to obtain five different regions which decreases from north to south, there by respecting the logic of the distribution of rainfall over the whole territory which decreases from south to north and this suggests that the importance of the R factor depends on the amount of rainfall.

Also, these values agree well with the sketch of the distribution of the annual climatic aggressiveness index in west and central Africa situation drawn up from the erosion plots [6].

3.2. Variable Erodibility According to the Nature of Soils

The erodiblity of the soil measures soil sensitivity to erosion taking into account the texture, organic matter content structure and permeability of the soil. From their observations, Wischmeier and Smith have created a norm graph to calculate erosivity according to the fine silt and sand content, the percentage of sands and ($1 < b < 4$ and of the permeability structure $1 < c < 6$) (**Table 1**).

The data used in the determination of the K factor come from the analysis of the soil, water and plants Laboratory (LASEP) after a collection made by us on a few sites in the study area for a better consideration of all the parameters entering in to the determination of the erodibility factor of the soils, we were led to determine.

The value of permeability and of the structure of the soils from respectively the triangle of evaluation based on the permeability soil texture and from ground contact when digging soil profiles. Starting from the aforementioned elements, we classified, then codified, the possible to draw up an erodibility map.

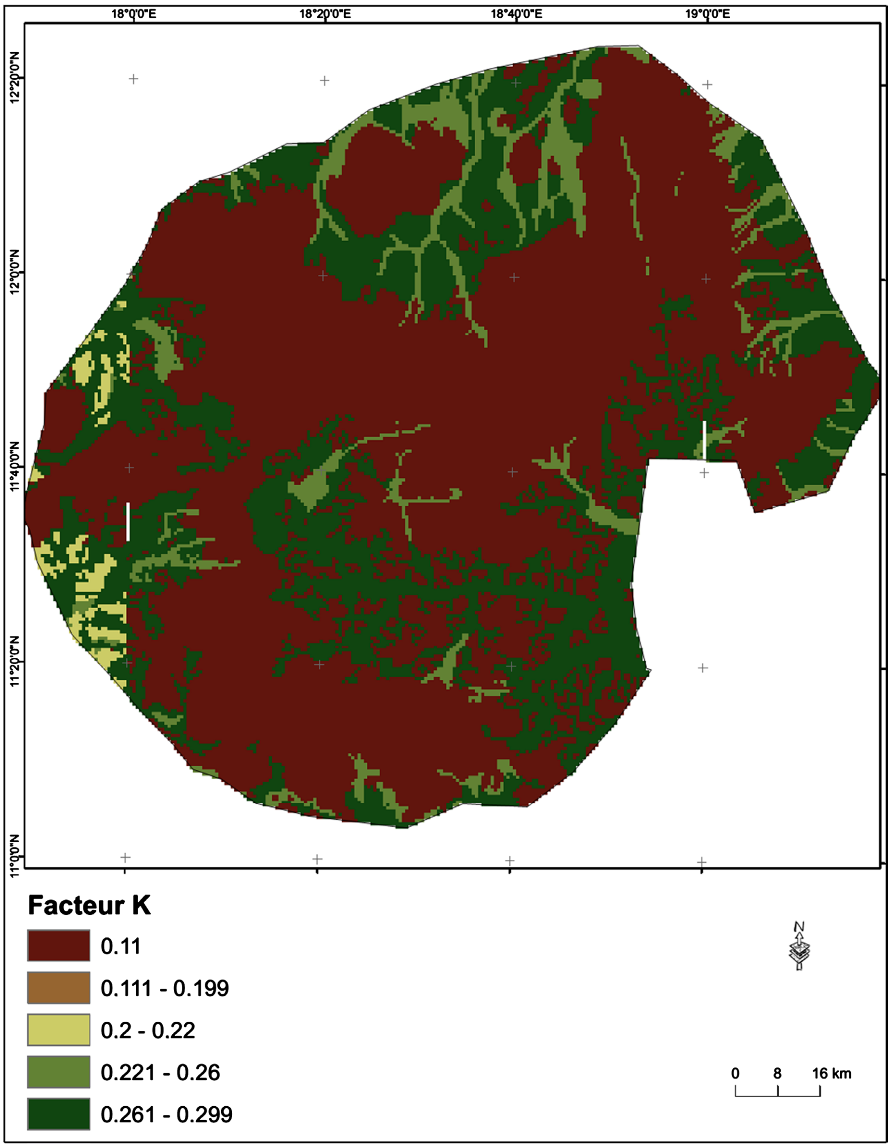
It is apparent from **Figure 2** that the sensitivity of the soils to erosion is variable depending on the nature of the latter, depending on whether or not, or that their structure s massive or five.

Considering the similarities and/or proximity of soils, we grouped them in to

Table 1. Meaning of codes for soil structure and permeability.

Code	Perméabilité	Code	Structure du sol
1	Rapide	1	Très fine
2	Moyenne à rapide	2	Fine
3	Moyenne		
4	Lente à moyenne	3	Moyenne ou grossière
5	Lente		
6	Très lente	4	Massive

Source: Wischmeier et Smith, 1978.



Source: SRTM 90; P-SIDRAT, 2011; Terrain, 2019.

Figure 2. Distribution of the soil erodibility factor.

five units to facilitate reading on the map and then analyzes.

Table 2 completes the figure relating to podology and it is undeniable that the erodibility factor is closely dependent on the characteristics of the soil.

From our sample made from 14 soil/pits, it appears that there are five major soil units whit a few variations and these units have various characteristics that make them more or less vulnerable to erosion. However, erodibility is not necessarily linked to these characteristics since field observations have shown that the edges of hills and other inselbergs are the most exposed to gullying.

While considering the intrinsic characteristics of the soils in our study area, some soils are more vulnerable than others, but the majority are sensitive or even very sensitive to erosion. Indeed, we note the dominance of lithosols and regosols, evolved soils (brown soils, red soils), as well as sandy soils (hydromorphic

Table 2. Granulometric analysis extract of the soils of Guéra.

Unités	Composition granulométrique						Code_c	Code_b	Texture estimée	Perméabilité	Structure
	A	LF	LG	SF	SG	MO					
Unité 1	447	200	163	101	91	10	3	5		Imperméable	Compacte
Unité 2	347	148	116	212	116	9.33	3	4		Perméable	Peu structurée
Unité 3	171	75	77.3	167	449	6.8	3	3		perméable	
Unité 4	218	69	66.9	203	447	6	2	4		Perméabilité moyenne	
Unité 5	446	144	118	125	167	7.5	4	5		Perméabilité moyenne	

Sources: LASEP, 2019.

Table 3. Spatial extension of K value in Mount Guéra.

K factor	Area in m²	Proportion
0.043	96,385,131.12	0.571241403
0.0541372	4,754,055,215	28.17564433
0.137303	1,881,800,243	11.15278051
0.20184	10,140,683,981	60.10033376
Total général	16,872,924,570	100

Source; Extract to the factor's carte K, 2019.

or leached) developed on granite or clay.

Table 3 is the perfect illustration of the extent of erodibility in the region because over more than half of the territory (*i.e.* 60.1%) erodibility is present at 0.20 th/MJ·mm against 0.043 th/MJ·mm on a portion representing only 0.5% of the study area.

3.3. Foothills and Glacis, as the Sector Most Vulnerable to Erosion

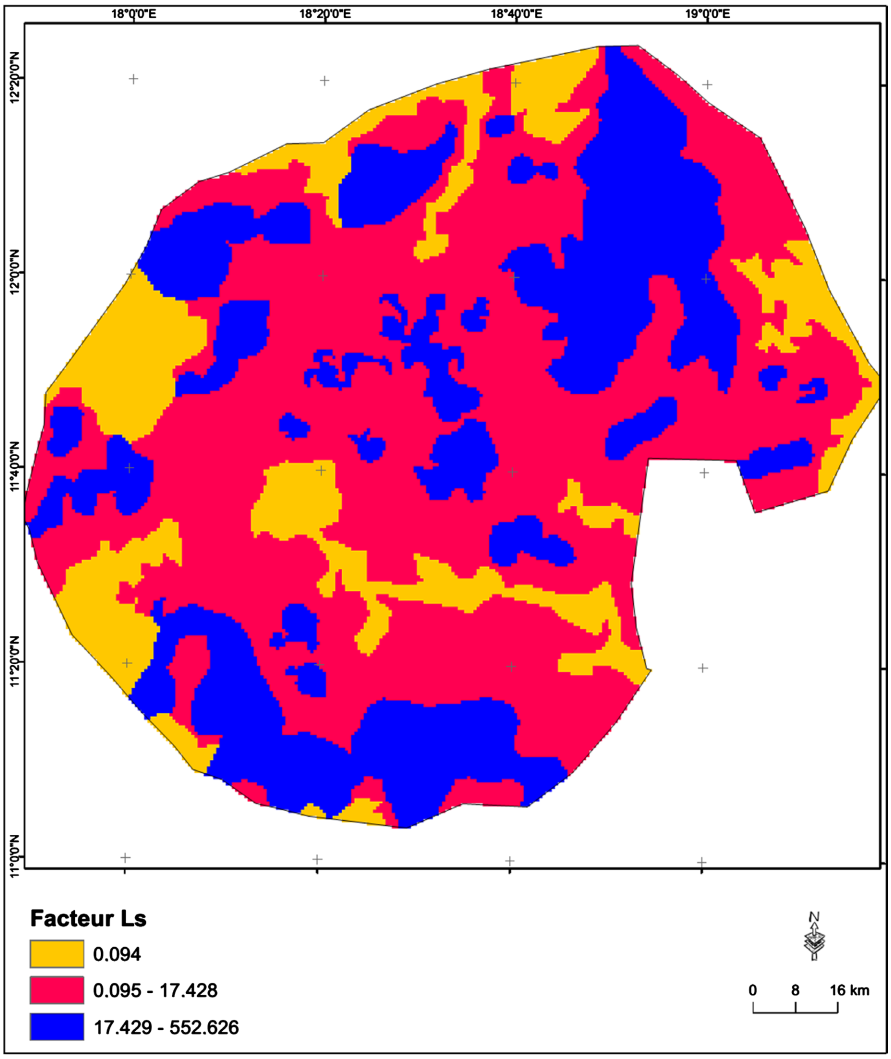
The topographic factor combines both the length Land the inclination S. The two factors L and S are combined in a single topographic factor, which makes it possible to globally evaluate the influence of the slope on the rate of erosion. (Figure 3)

The application of the RUSLE model gives LS values varying from 0/09 to 17.42 with a few isolated and rare cases whose values are abnormally high and turn around 55.62 (Table 4).

The highest values are observed on foothills and glacis, where the slopes are steep and the concentration of runoff water is maximum. As there is accumulation of water and where the slopes are increasingly steep.

3.4. A Disparate Vegetation Favors an Erosive Influence

The risk of erosion increases when the soil has little vegetation cover or residues. The residues and vegetation protect the soil from the impact of raindrops and



Source: SRTM 90; P-SIDRAT, 2011; Terrain, 2013.

Figure 3. Carte de répartition du facteur LS du Mont Guéra.

Table 4. Statistics of the distribution of the LS factor at Mount Guéra.

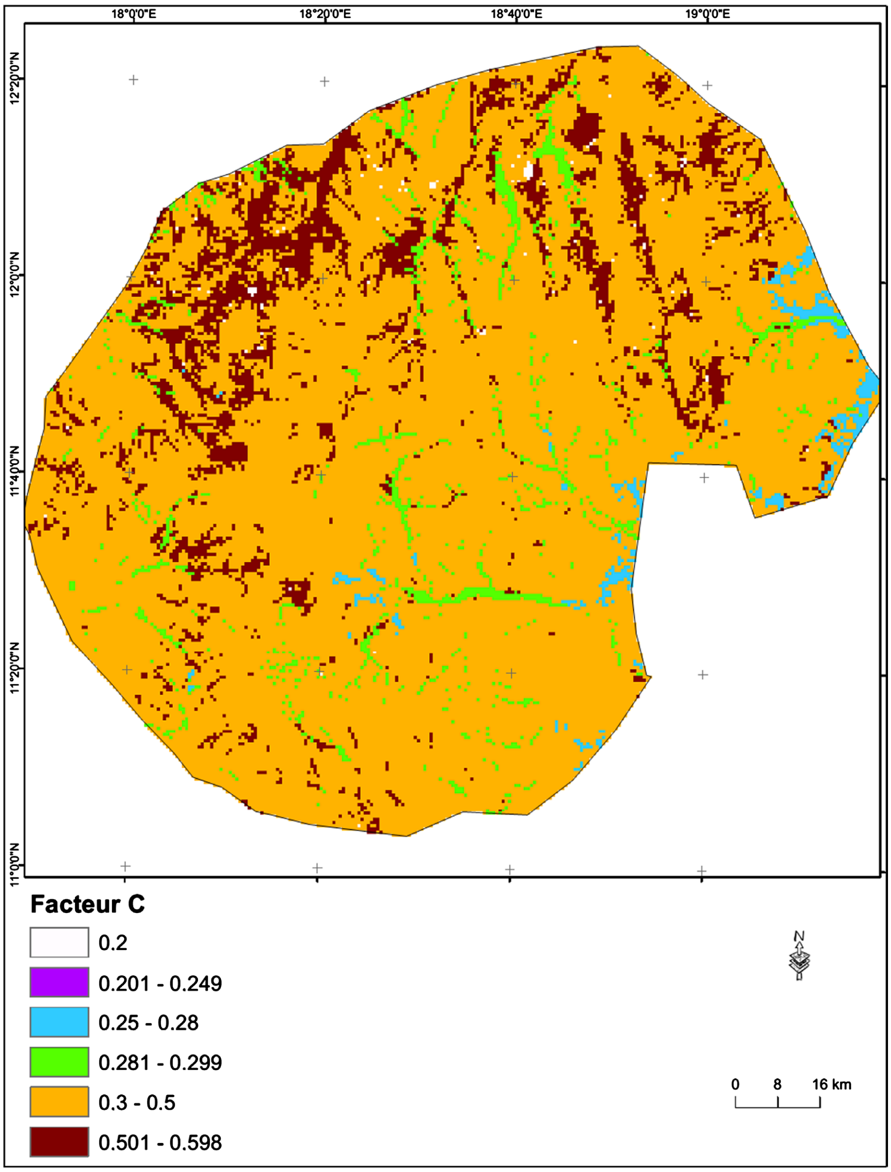
Objected	LS	Area
1	0.09384319275	2,527,786,887, 33,000,000,000
2	0.16575942540	4,200,682,095, 63,000,000,000
3	0.46646212186	4,459,007,351, 12,000,000,000
4	17.90248735600	4,006,492,422, 46,000,000,000
5	552.62630998300	652,572,341, 84,500,000,000

Source: Extract from the LS factor map. 2019.

splashing. They slow down the speed of runoff water and allow better infiltration. Thus, for low vegetation, soil loss decreases with the increase in plan cover [7]. The factor C is defined as the ratio between the losses in bare soils under specific conditions and the losses in soils corresponding to the soils under the operating system [4] [8]. C varies from 1 to, on bare soil, that is its maximum value in terms of efficiency of erosive processes, 1/1000th under forest, 1/100th under grassland and cover crops 1 to 9/10th under hoe cultivation. For our study region, we have defined the typology of the different types of occupation from the BD.

The distribution map of factor C (Figure 4) shows the sensitivity of the different types of land use to erosive processes. Even though the savannahs occupy the biggest part of the study area (Table 5), a plan caver which appears in the form of islands and is distinguished from this by a bushy cover laid out in islands of dense vegetation separated by bare beaches whose density is low.

Heavily vegetated areas of the forest type are associated with the lowest coefficient (0.1), and the highest coefficient (1) corresponding to bare soils (Table 5).



Source: SRTM 90; P-SIDRAT, 2011; Terrain, 2019.

Figure 4. Repartition of the Factor C.

Table 5. Statistics of the distribution of the factor C according to the landscape units.

Soil occupation	Area sum in ha	Factor C	% in proportion
Forest	150,518.319	0.1	1.30
Mangrove	107,505.048	0.28	0.93
Mosaick of culture	196,614.282	0.58	1.70
Water body	7.802	0	0.00006
Savannahs	11,049,030.29	0.6	95.85
Built area	3955.889	0.2	0.30
Sparse vegetation	18,962.67	0.18	0.16

Source: Extract from the C factor map, 2019.

The often degraded grassy savannahs rest on tropical ferruginous soils and represent the type of plant cover most sensitive to erosion processes. Indeed, even though savannahs constitute vegetation, the C factor seems to be higher (0.6) whereas it is 0.1 under forest. Also, in terms of extension, these savannahs occupy 95.85 against 1.30% for heavily wooded areas; which suggests that protection by vegetation remains very weak in the region.

3.5. Localized and Effective Anti-Erosive Practices

The P factor expresses the influence of conservation methods on erosion. Stone barriers, living hedges, diversionary micro-dams or permeable micro-dams, terraces, contour crops and plantations, rotations, and manure, alternating strips, infiltration ditches, Zai, half-moons, etc. are so many effective soil conservation practices. However, the determination of this factor has some limits in the sense that management practices are only carried out where man practices his production activities and especially when these activities have weaknesses in terms of yield. Also, the slope remains the region because anti-erosion practices are only carried when the words, when the right to deploy wasted energy because if in these is a drop in yield, this can be explained by either the low productivity of the soils or by their nature. However, in Mount Guéra, the lowlands (with low slopes) have been increasingly disputed for farming in recent years for their agricultural value, but also for their ability to retain humidity when there is edaphic drought, added to this are the uncultivated marginal spaces which are not exploited for agricultural purposes. These two elements lead us to say that the developments only concern certain fringes of the region studied and therefore cannot expand to the entire territory studied. However, the justification of their presence in all sectors studied, confirm their extrapolation to the entire region studied. That is why we believe that it is a determining factor in the same way as all the other factors and their influence on the physical degradation or not of the soil remains essential. In the region, there anti-erosion practices exist and are even rooted in the tradition of certain villages, especially Bitkine, where villages like Arengha and Moukoulou have become models in the practices even if its dissemination came from an NGO of foreign origin, the CARA.

The test has the advantage of having an idea of the spatial variation of the parameter under study. The values of (P) are less or equal to (1) [4].

The value (1) is assigned to land on which there are no anti-erosion practices. The value of (P) varies according to practices adopted and according to the slope of the land. Therefore, to determine the factor (P) and for modeling purposes, we were interested in four villages in which traditional anti (erosion practices were combined with modern practices popularized by the NGO NAGDARO since 1982. (**Table 6**) This choice is explained by the fact that we could not cover the whole region for lack of means. This allowed us to design a CES development map of these villages that we then proceeded to an evaluation in relation to the value assigned by studies in particulars that [9] (table: 28). It appears that in the sites selected, this factor varies between 0.1 and (**Figure 5**).

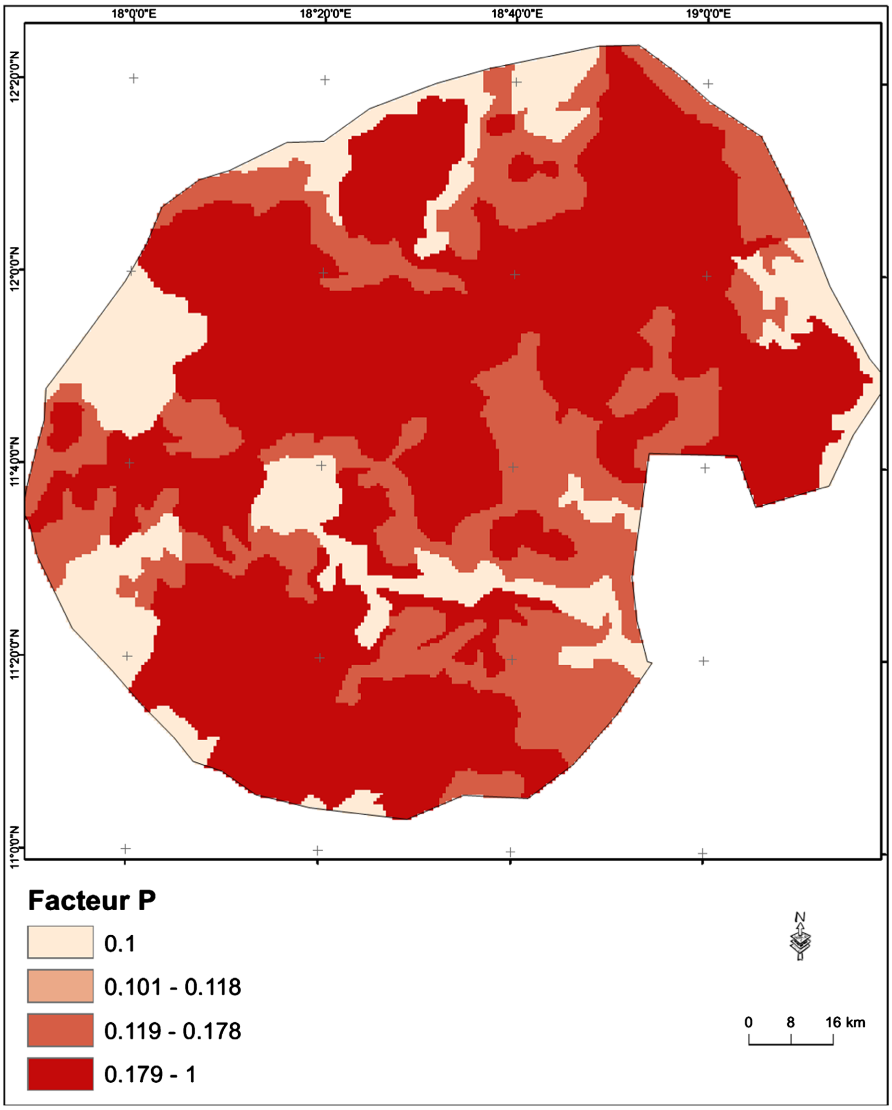
A first agricultural zone developed by dry stone cordons which are development made on the slopes level curves like benches. The variation in the value of the factor (P) in this unit, in addition to the latter being defined by the SWC development used (dry stone cords), it depends on the value of the slope already established in n˚ 16, using the spatial analysis functions of ArcGis (Raster Calculator) in order to assign the value of (P) to the classes of slopes which correspond to it.

A second agricultural zone happens to be devoid of anti-erosion practices, but surveys have revealed that farmers there say they plow their land on contour lines, information relatively denied by some locals stakeholders. Here, in order to facilitate estimates, it was assumed that the plowing was done in contour lines. The variations in the value of the factor (P) in this unit; in addition to the latter being defined by plowing in contour lines, are conditioned by the values of the slope. It was therefore necessary to divide this zone by also using the classes of slope already established in the previous table via the same Arcgis analysis function as before (Raster calculator) and thus assign the appropriate value of (P) to the classes of slopes. Indeed, the values corresponding to the letter various anti-erosion practices have been entered in the appropriate field. The latter was then rasterized to 90 m resolution through the conversion tools > to Raster > polygon to Raster.

Table 6. Variation of (P) according to anti-erosion practices.

Types of anti-erosion arrangements	Slope value	P value
Seating arrangement	2 à 7	214
	8 à 12	120
	13 à 18	121
	19 à 24	210

Source: Roose (1994).



Source: SRTM 90; P-SIDRAT, 2011; Terrain, 2019.

Figure 5. Facteur P dans le Mont Guéra.

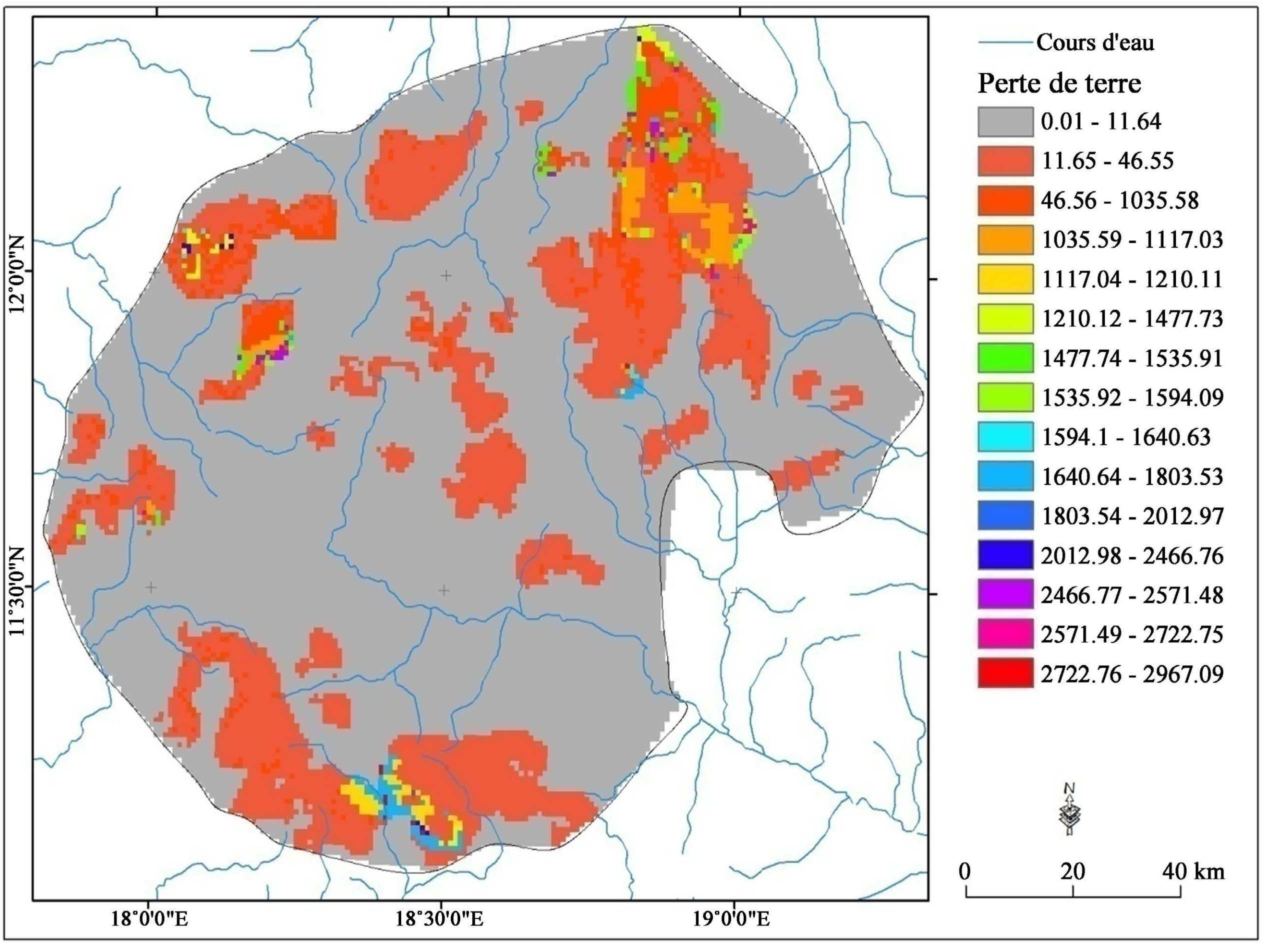
A third zone is constituted by sylvicultural units that ensure the maintenance of soils by the root system of forest essences and at the same time break the speed of the runoff (departing the tearing force of the soil particles). These units have therefore been considered as if they had been arranged by vegetation and received the lowest value, 0.1.

A fourth zone includes pastoral, but degraded units, completely stripped in places, in general in places marked by strong slopes and without any layout of these. We assigned them the value of 0.9.

3.6. A Variable Soil Loss in Space

After calculating and spatial zing the various factors of the universal soil loss equation, degradation and/or the estimated soil loss in t/ha/year is calculated by multiplicative superposition of these factors in a GIS. Map derived from the summaries of the factors discussed above shows a clear spatial variability of the risk of water erosion within the studied zone. It is certainly proven that the phenomenon is everywhere present but the critical character remains very localized and limited to a few localized and limited to a few areas whose extension is low. The sensitivity of Mount Guéra to the physical degradation of soils is perceptible throughout the region but the magnitude is different. The multiplicative superposition of the thematic layers representing the erosion factors in raster format, allowed to obtain the erosion map, expressing the potential erosion value in t/ha/year per spatial unit.

In fact, the crossing of the various useful factors for our model has been done by introducing in ArcGIS the product of these different parameters obtained (R, K, LS, C and P) through the spatial analyst tools > Map algebra > Raster calculator: "R" * "K" * "LS" * "CX" * "P". The result obtained, which corresponds to our region exposed to soil water erosion, is the equation of our rolling model. The map obtained from this equation, Figure 6 shows erosion rates varying between 0.01 and 2967.09 t/ha/year spread over the entire study area. According a very low erosion varies between 0 and 11 t/ha/year, a moderate erosion between



Source: SRTM 90; P-SIDRAT, 2011; Terrain, 201ç.

Figure 6. Perte de terres dans le Mont Guéra.

11 to 22 t/ha/year, white beyond 22, erosion is strong (22 to 23 t/ha/year) with very strong (>33 t/ha/year) [10].

In this work, we have classified the soil loss map into 15 classes for a better spatial visualization of the results will take into account the thresh holds mentioned above. This estimate therefore in no way gives a prediction of the contribution to the various wadis and rivers, but provides information on the quantity of materials potentiality supplied by erosion and therefore reveals its current alteration the statistical distribution shows that more of the large half of the area of the region reveals a low to moderate sensitivity to erosion white about 12% a very high Sensitivity.

In addition, lower soil losses are associated with low topography such as lowlands or depressions on clay soils where grassy vegetation dominates; conversely, higher values are assigned to glacis on less compact, intensely exploited sandy soils. This is particularly true, due to the generalization of the degradation of forest ecosystems favored by human settlement and the toposequential situation of poorly evolved soils on the glacis.

The results provided as part of this study highlight the dynamics of sheet erosion in the region. The RUSLE model provides a potential average estimate of soil loss, provided for each sub-watershed of Mount Guéra.

Generally speaking, degraded steppes, bare soils, fragile soils (lithosols and ferruginous soils), steep lowlands and aggressive precipitation strongly contribute to increasing the influence of water erosion. Analysis of the results obtained that soil degradation in the study region varies from 0.01 to 2967.09 t/ha/year (strong). These areas of arable land depletion are located at the level of poorly evolved soils.

4. Discussion

The evaluation of soil degradation is not a new practice as several authors have noted it in their manuscripts and the variation in the methods used comes from the fact that the factors involved vary according to the environment but also according to the costs of the operations and data availability. With regard to factors, several authors question the fragility of soils, which has long been demonstrated as the main factor in soil degradation [11] [12]. Some authors focus instead on the devastating effects of drought [13] [14] [15] [16], while others simply place the Man and his activities at the heart of the destruction of land capital (especially arable land), considering natural factors as simple catalysts [17]. However, much of the information so far provided about the causes of the phenomenon is unverified conjecture. For our part, in the Guéra region, the demographic weight is relatively low, it is the natural factors that are more responsible for this accelerated soil degradation; hence the interest shown in analyzing the extent of physical soil degradation. The aim is in fact to produce an integrated understanding of the causes of physical soil degradation and their biophysical and socio-economic impacts. Indeed, authors attested through their writings that in fragile Sahelian regions, soil degradation is preponderant because of the fragility of the environment and anthropogenic factors only come exacerbate the trend [18] [19] [20] [21].

These authors are based more on a physical evaluation, in particular through the determination of the soil surface states. This assessment based on the observation of surface conditions can be biased when we know that an objective assessment must set verifiable parameters and indicators [22] [23] [24] [25]. Other authors used a quantification method based on measuring the characteristics of the artifacts left by erosion or their density on the affected land to estimate the quantity of particles torn from the soil. With the development of spatial analysis tools, the RUSLE method has become a powerful tool for modeling this soil degradation even if it has certain limits, because indices on the conditions and the scale of application are not similar to those of countries that have developed the method. However, its flexibility in being able to be integrated into the model, makes it possible to modify the parameters of several factors and then implement them in the chosen analysis model. For this study, the model chosen is the ArGis software and given the unavailability of rainfall data at the scale of a rainfall event, the absence of frequent soil analyses, we had to adapt global data. It appears that the trend of the data obtained under this software is similar to practical measurements made in the field; which makes it possible to affirm that Guéra is prey to a degradation of the grounds which is variable according to the state of parameters of each factor. It also appears that the factors cited are variable at the station level even though the factors studied are the same. Ultimately, in Guéra, the presence of soil erosion is underpinned by various factors. Thus, the erosivity reflecting the aggressiveness of the climate depends on the following parameters and can be reduced by the plant cover within a range of rainfall erosivity ranging from 419.15 to 539.24 MJ·mm/ha·h. year, by the slope in a ratio of 1 to 17.42, by the type of soil in a proportion of 0.11 to 299, of vegetation cover between 0.2 and 0.6 and finally, by the cultivation techniques which can divide its intensity by 10. Given the role that these elements can play in favoring or not the physical degradation of the soil, it is important to see to what extent these factors intervene to favor such a process.

5. Conclusion

The evaluation of land loss by erosion approached through the RUSLE equation can easily be applied to Geographic Information Systems by the compatibility between the parameters of the targeted factors and the map algebra. The GIS makes it possible to manage in a rational way, a multitude of data, with spatial reference, relating to the various factors of soil degradation, which enabled us to conclude that these main factors influence water erosion. The application of the model may include biases but gives details on the overall trend of soil degradation and gives results that can provide valuable assistance, at very low cost, to decision-makers and land planners with the aim of simulating evolution scenarios and then target priority areas that require conservation and erosion control actions. The potential erosion risk maps show that the Guéra is a region at risk of erosion whose annual soil loss values vary between 0.11 and 2967.09 T/ha/year with a relatively high average annual loss of 400.8 t/ha/year.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Bonn, F. and Escadafal, G. (1996) La télédétection appliquée aux sols. In: Bonn, F., Ed., *Précis de télédétection*, Vol. 2 (Applications), Puq/Aupelf, Paris, 91-135.

[2] Renard, K.G., Foster, G.R., Weessies, G.A., McCool, D.K. and Yoder, D.C. (1997) Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). U.S. Department of Agriculture, Agriculture Handbook No. 703.

[3] Nguemhe, F.S.C., Etouna, J. and Hakdaoui, M. (2014) Apport de l'OT et du SIG à la cartographie des zones à risque d'érosion hydrique dans le bassin versant productif de Sanguéré, Nord-Cameroun, Afrique Centrale. *International Journal of Innovation and Applied Studies*, **9**, 449-479.

[4] Wischmeier, W.H. and Smith, D.D. (1978) Predicting Rainfall Erosion Losses: A Guide to Conservation Planning. United States Department of Agriculture, Agriculture Handbook No. 537, 58.

[5] Le Bissonnais, Y., Thorette, J., Bardet, C. and Daroussin, J. (2002) L'érosion hydrique des sols en France. INRA, IFEN, 106.

[6] Roose, E. (1977) Erosion et ruissellement en Afrique de l'Ouest: Vingt années de mesures en petites parcelles expérimentales. Collection Travaux et Documents No. 78, ORSTOM, 108.

[7] Soutter, M., Mermoud, A. and André, M. (2007) Ingénierie des eaux et du sol: Processus et aménagements. Presses Polytechniques et Universitaires Romandes, Lausanne.

[8] El Garouani, A., Merzouk, A., Jabrane, R. and Boussema, M.R. (2003) Cartographie de l'érosion des sols dans le bassin versant de l'Oued Jemâa (Pré-rif, Maroc). *Géomaghreb*, **1**, 39-46.

[9] Wall, G.J., Coote, D.R., Pringle, E.A. and Shelton, I.J. (2002) RUSLE-CAN: Équation universelle révisée des pertes de solpour application au Canada. Manuel pour l'évaluation des pertes de sol causées par l'érosion hydrique au Canada. Direction générale de la recherche, Agriculture et Agroalimentaire Canada, Numéro de la contribution AAFC/AAC2244F, 117.

[10] Dubois, J. (1948) Esquisses des différents types de sol dans la moitié sud du Sénégal. *Proceedings of Comptes rendus de la Conférence africaine des sols*, Goma, 8-16 Novembre 1948, 575-626.

[11] Maignien, R. (1965) Carte pédologique du Sénégal AU 1/1000 000. ORSTOM, Paris, Série Notices et cartes No. 24, 3-63.

[12] Boivin, P., Loyer, J.-Y., Mougenot, B. and Zante, P. (1986) Sécheresse et évolution des sédiments fluvio-marins au Sénégal: Cas de la Basse Casamance. ORSTOM, Dakar.

[13] Barry, B., *et al.* (1988) Sécheresse et modifications des ressources hydriques en Basse

Casamance: Conséquences pour le milieu naturel et son aménagement. ORSTOM, ISRA, 22.

[14] Sene, M. and Perez, P. (1994) Contraintes et possibilités de valorisation des ressources naturelles dans le sud du bassin arachidier (Sine Saloum, Sénégal). In: Reyniers, F. and Neloyo, L., Eds., *Bilan hydrique agricole et secheresse en Afrique tropicale*, Aupelf-Uref, John Libbey Eurotext, Montrouge, 217-234.

[15] Ndione, J.-A. (1999) Contraintes et evolution climatique récente: Impact sur le milieu physique. Thèse de Doctorat, Université Cheickh Anta Diop, Darkar.

[16] Dancette, C.L. and Sarr, P.L. (1985) La dégradation des sols dans les régions centre-nord du Sénégal (Cap-Vert, Thiès, Diourbel et Louga). Travaux et documents No. 2, ISRA, Dakar.

[17] Néboit, R. (1991) L'homme et l'érosion: L'érosion des sols dans le monde. 2ème Edtion, Press Université Blaise-Pascal, Clermont-Ferrand.

[18] Mietton, M. (1998) Les processus élémentaires d'érosion hydrique à l'échelle du versant. In: Veyret, Y., Ed., *L'érosion entre nature et société*, DIEM Dossiers des images économiques du monde, No. 22, Sedes, Paris, 57-67.

[19] Roose, E., Chebbani, R. and Bourougaa, L. (2000) Ravinement en Algérie. Typologie, facteurs de contrôle, quantification et réhabilitation. *Sécheresse*, **11**, 317-326.

[20] Bertrand, R. and Gigou, J. (2000) La fertilité des sols tropicaux. Edition Maisonneuve et Larose, Collection Le technicien d'agriculture tropicale No. 40, 397.

[21] Hauchart, V. (2005) Culture du coton et dégradation des sols dans le Mouhoun (Burkina Faso). Thèse de Doctorat, Université de Reims.

[22] Affanou, K.C. (1996) Dégradation de l'environnement et aménagement urbain à Lokossa. Mémoire de maîtrise de géographie, FLASH/UNB, 105.

[23] Eténé, C.G. (2005) Hydrologie urbaine d'Allada: Impacts sur les infrastructures Socioéconomiques. Mémoire de DEA, EDP-FLASH/UAC, 77.

[24] Biaou, S., Houeto, F., Gouwakinnou, G., Biaou, H.S.S., Awessou, B., Tovihessi, S. and Tete, R. (2019) Dynamique spatio-temporelle de l'occupation du sol de la forêt classée de Ouénou-Bénou au Nord Bénin. *Proceedings of Conférence OSFACO: Des images satellites pour la gestion durable des territoires en Afrique*, Cotonou, 13-15 March 2019, 1-20. https://hal.archives-ouvertes.fr/hal-02189367

[25] UNEP (2007) Fourth Global Environment Outlook—Environment for Development. United Nations Environment Programme (UNEP).