WATER EROSION RISK EVALUATION BY CARTOGRAPHIC APPROACH IN AMBOHITSARA – FARAVOHITRA-MADAGASCAR

RANDRIANARISOA Aronantenaina (1), RAMIANDRISOA Njจararivelo Louisa (2), RAKOTONDRAZAFY Raymond (3)

1.Doctorate in Sciences and Technology, STE Doctoral School, Geology Department, Faculty of Sciences, University of Antananarivo-Madagascar, BP 101

2. Doctor-HDR and Head of the Earth and Environmental Sciences Department of the Science, Faculty of Sciences the University of Antananarivo-Madagascar, BP 101

3. Professor in Sciences and Technology, STE Doctoral School, Geology Department, Faculty of Sciences, University of Antananarivo-Madagascar, BP 101

Abstract

Water erosion of soils is not just soil that goes into the waterway. This takes with it many other elements that can deteriorate the quality of the water. It brings many environmental and socio-economic disadvantages. It is therefore necessary to establish a detailed assessment of this process before any development. These areas are already eroded by erosion. In addition, the activities out by the local population and the bushfire only further accelerate the erosion in this part.

Based on the results of the empirical estimate study, the soil loss in the Ambohitsara-Faravohitra area is ranked among the most alarming.

The use of the USLE model leads to more reliable results which can provide invaluable help, at very low costs, to decision-makers and land planners, with the aim of assessing the evolution and consequently targeting the priority areas which require actions conservation and erosion control. The results obtained, in the form of an erosion risk map, show that the study area has soil losses that vary from 0 to 300 t / ha / year with an average annual loss of 34.57 t / ha / year, so erosion is classified among the very strong in Madagascar.

In order to spatially and quantitatively estimate the disguises of soil erosion in order to cope with this phenomenon and provide the best strategies for land control, conservation and development; the universal soil loss equation USLE was used, coupled with a GIS.The spatialization and quantification of erosion were carried out in the Urbain Commune of Tritriva in Betafo District, Vakinankaratra Region.

Keywords: *erosion, SIG, USLE, Tritriva, Madagascar*

1. Introduction

Tritriva is an Urban Commune located in the south-central part of the Vakinankaratra Region, at 19° 55’ 00’’ South latitude and 46° 56’ 00’’ East longitude. It is bordered to the north by Faratsiho, to the east by Antsirabe II, to the south by Ambositra and to the west by Betafo. The study area is located in Faravohitra-Ambohitsara, belonging to the Faravohitra and Ambohitsara districts, Tritriva Commune, Betafo District, which covers an area of 11.11 km2.

To maintain productivity in this area, ensure long-term habitability and contribute to the protection of biodiversity, sustainable land management is necessary. Thus, research on erosion risk mapping is important for land use planning and resource conservation to achieve sustainable development goals in the Tritriva territory. Several approaches are used in erosion risk mapping. As per Cox, R. et al., 2009, there are empirical, semi-empirical and physical approaches [1]. As per Ganasri and Ramesh, 2015, the direct measurement approach is the most reliable, but requires a huge cost in terms of time and money for data collection [2]. Thus, in the absence of permanent soil loss monitoring stations due to erosion, as per Tamene et al., 2017; Tadesse et al., 2017, the spatial modeling approach using the Geographic Information System (GIS) can provide a first approximation of the erosion risk at the scale of a watershed or a larger territory by identifying the areas at first risk [3]. As per Singh and Kumar, 2017; Gashaw et al. 2017, this approach also contributes to the prioritization of areas for conservation [4].

In the Tritriva territory, some studies have combined GIS and remote sensing to determine the silting factors of the Mangorokoba River sub-basin. These studies only cover limited areas due to the lack of field hydrometeorological data (meteorological data, river flow and sediment flow data) which are necessary to determine the different factors over large areas and for a long period. However, there is a lack of information at the territorial scale to guide the decision-maker's choice when planning the Tritriva territory. It is in this context that this work attempts to show how the integration of multi-source data through the use of a GIS (QGIS, ArcGis and SAGA GIS) and the Universal Soil Loss Equation (USLE) of Wischmeier and Smith (1978) offer a possibility to assess by rapid and low-cost mapping the risk of water erosion at the territorial scale. This approach will make it possible to determine areas at high risk of erosion and priorities for soil conservation.

2. Materials and Methods

2.1. Location of the area

2.1.1. Geographical situation

The study area is located 125 km as the crow flies south of Antananarivo, following the national road RN7 to Antsirabe (170 km), then turn left towards the RN34 road for 12 km, then turn left following the dirt road for 500m.

2.1.2. Administrative situation

Tritriva is an Urban Commune located in the south-central part of the Vakinankaratra Region, at 19° 55’ 00’’ South latitude and 46° 56’ 00’’ East longitude.
The study area is located in Faravohitra-Ambohitsara, belonging to the Faravohitra and Ambohitsara districts, Tritriva Municipality, Betafo District, which covers an area of 11.11 km2. The entire study area is delimited by the following geographical coordinates (see Table 1) according to the Mercator Labored projection system.

Table 1: Geographic coordinates of the study area

X	Y
450 296	692 960
454 295	692 960
450 296	688 492
454 295	688 492

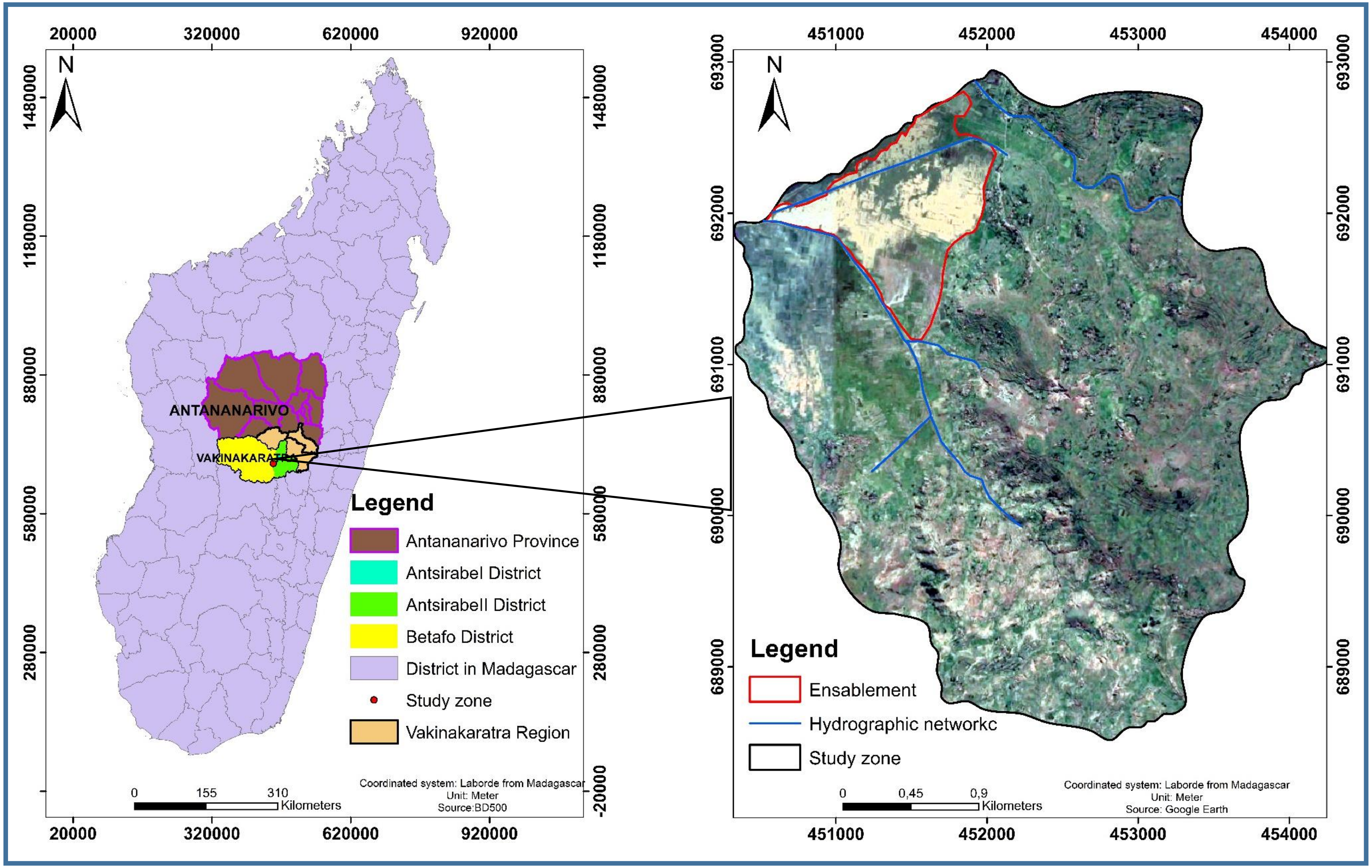

Figure 1: Location map and delimitation of the study area (BD 500)

2.2. Materials

Some materials and tools were useful for the preparation and analysis of data, including GIS (Geographic Information System), used from software, such as ArcGis 10.3.1, QGIS 2.18.24, and Google Earth 1.3 and Google Engine. These software allow the acquisition, management, analysis, as well as the presentation of geographically located information for mapping. In addition, remote sensing with ENVI (Environment for Visualizing Images) is used to have a better visualization, analyze and process images to extract data; similarly, GPS (Global Positioning System) is useful for taking geographic coordinates on the ground.

2.2.1. Data

The data used (see Table 2) are from different sources and have been projected into the Labored Madagascar system. These are climate data from the Google Engine database, soil data from the Madagascar Soil Database, SRTM (Shuttle Radar Topography Mission) data and Landsat 7 images from April 25, 2012 and August 15, 2022 from the USGS site, to see the evolution of the density of the vegetation cover over a period of 10 years. These data were used to estimate the parameters of the Universal Soil Loss Equation (USLE) by Wischmeier and Smith (1978). This model makes it possible to calculate the possible long-term average annual soil losses (A) through water erosion based on climatic, topographic, soil parameters and the mode of land use and conservation.

Table 2: Data used/ Used Data

Data Types	Associated Factor	Format	Scale/Pixel Size	Data Sources
Climate	R	Raster (ESRI grids)	1km	http://googleengine.gov
SRTM	LS	Raster (Géo Tif)	30 m	http://earthexplorer.usgs.gov
Soil Map	K	Vector (Shape)	1/100 000	Soil Map of Madagascar
Landsat 7	C	Raster (Shape)	30 m	http://earthexplorer.usgs.gov
Slopes	P	Raster (Shape)	30 m	http://earthexplorer.usgs.gov

ESRI (***E**nvironmental **S**ystems **R**esearch **I**nstitute*)

2.3. Methodology

First, the documentation: a significant amount of documentation work was done to collect the essential information needed to carry out the project. The general recognition of the study area is done through bibliographic reviews (books or works, dissertations, theses and online sites), mastery of the manipulation of computer tools using different software in order to obtain reliable and realistic results.

Afterwards, the reconnaissance phase: before going to the field, it consists of gathering all the general data and information on the study area to better understand and analyze the factors and processes of the erosion phenomenon.

Then, the field: the field trip took place in Ambohitsara and Faravohitra for (15) days in the Urban Municipality of Tritriva. We identified and verified the areas subject to and at risk of erosion.

Then, data processing: the processing of the data and information collected consists of their assembly, that is to say acquisition and integration of geographic information on the factors and parameters of erosion.

Subsequently, cartographic processing: its purpose is to process spatial digital images to obtain spatially referenced databases and to delimit the study area. The three types of cartographic processing are: Preprocessing, import of satellite image, visualization, superposition of two images, cutting of the area of interest; processing, non-superimposed and supervised classification; post-processing, image change detection, interpretation and analysis.

Quantitative mapping of erosion risk by GIS/USLE approach: As per Smith and Wischmeier, 1978, the Universal Soil Loss Equation (USLE) was chosen to assess soil loss caused by erosion [5]. This model allows to calculate the possible long-term average annual soil losses (A) by water erosion depending on the climatic, topographical, pedological parameters and the mode of use and conservation of the land. This equation is defined by:

$A = R * K * LS * C * P$, A (in t/ha.year)

• R: rainfall erosivity index (MJ.mm/ha.h.year),

• K: soil erodibility index (t.ha.h/ha.MJ.mm),

• LS: topographic factor (dimensionless),

• C: vegetation factor (dimensionless),

• P: support practice factor or protection factor (dimensionless).

The constitution of data on the factors (see fig.2) consists of digitizing the orography and hydrography from the topographic map, allowing the production of the Digital Terrain Model (DTM) and its derivatives, as well as the hydrographic network; digitizing the soil and geological maps in order to develop the soil erodibility layers; digital processing of the satellite image giving the land use map. The integration of these data into the Geographic Information System (GIS) is driven by ArcGis software. This involves quantifying the solid materials resulting from soil erosion, expressed in tonnes per hectare per year. The erosion map expresses the slices of land lost on an annual average.

2.3.1. Potential erosion (PA)

As per Wischmeier et al., the erosive potential is determined by the combination of the following factors [6].

- Rainfall aggressiveness factor, R;

- Soil erodibility factor, K;

- Physiographic factor related to slope and slope length, LS.

The erosive potential (Ap) is determined according to the following formula: Ap = R . K . LS

The R factor is obtained from the analysis of rainfall data over several years. The values of the R factor are determined for the study area using the following formula:

R = 0.0483[p1, 610]

Where: R: rainfall aggressiveness.

P: Interannual precipitation of the area

The R factor was calculated separately for each station, then the results were interpolated by the IDW interpolation method, to obtain the erosivity factor map of the study area.

The erodibility factor of a soil K is its resistance to two energy sources, the beating of raindrops on the soil surface and the notch of runoff between clods in claws or gutters. Some authors, including Wischmeier (1978), have found a correlation between this factor and parameters related to soil structure. Wischmeier et al., (1971) proposed a model to calculate the K factor according to the equation:

1000 K = 2.1 M1, 4 . 10-4 (12 - a) + 3.25 (b - 2) + 2.5 (c – 3)

Where: K: erodibility factor

a: percentage of organic matter

b: structure code

c: permeability class

M: (% fine sand + % silt) (100 - % clay).

In our case, the value of K is determined by recoding according to the bibliographic values (explanatory note of the Antsirabe soil sheet) and the visualization of the Wischmeier charts to estimate the erodibility index of soils to water erosion and the soil texture triangle and the USDA Soil Texture Class table as per FAO, 1974 [7].

The LS factor is the product of two sub-factors, namely the slope length sub-factor and the slope gradient sub-factor. They come from the Digital Terrain Model (DTM). The slope length (L) is defined as the distance traveled by a drop of water from the runoff source to a given point in the basin. Computer software, such as ArcGis, has greatly facilitated the calculation of certain parameters, such as the case of the topographic factor, which were calculated from the DTM, the slope class map and the flow map according to the following expression:

LS=[(Flow.Acc*Resolution)/22.1]m*[(sin(slope)*0.01745)/0.0896]1.4*1.4

We took the value of m = 0.5 because more than 80% of the slope map has a value of > 5% (see Table 3). The whole will be divided by 100 because we used slopes in % as the unit for the LS calculation.

Table 3: Values of the m factor

Percentage of slope (%)	Factor m
≥ 5	0.5
$3.5 \leq e \leq 5$	0.4
$1 \leq e < 3.5$	0.3
< 1	0.2

2.3.2. Current erosion

Current erosion is defined as the soil loss resulting from the interaction of the factors R, LS and P. The calculation expression is: Aa = R . K . LS . C . P = Ap . C . P
It is therefore a function of potential erosion (Ap), the cropping method (C) and the slope's anti-erosion features (P), as per Wischmeier et al., 1971 [5].

The cropping factor C is a simple ratio of soil losses in a production system to the losses of the same soil treated in continuously worked bare fallow. It takes into account the fact that rain acts proportionally on bare soil as on covered soil: plant cover, its production level, the associated cropping techniques, the quality of the cover and root growth, water use by growing plants and the method of residue treatments. The determination of this factor is based on land use and using the tool (google.earth.pro) for better visualization of the satellite image. As per Roose, 1994, the values of C vary from 1 for bare soils to 0.001 for dense forests and abundantly mulched crops [8].

Table 4: Table of soil coefficient C according to the type of land use

Type of land use	**Factor C**
Bare soil	1
Degraded forest	0.7
Degraded grassland savannah	0.6
Cultivation mosaic	0.5
Tree and shrub savannah	0.3
Mangrove	0.28
Built-up area	0.2
Reforested area	0.18
Rice field	0.15
Dense forest	0.001
Water body	0

The anti-erosion factor P is determined from the map of existing developments. It varies depending on the development carried out on the slope and the value of the slope itself.

The mapping of existing developments in the study region is done on the basis of aerial photos followed by a validation survey on the ground. Once the developments have been mapped, the development map is combined with that of the slope in order to determine on which level of slope the development in question has been carried out or will be carried out. The cartographic representation of what the current erosion (Aa) could be is done by combining the three factors AP, C and P according to the expression:

Aa = AP. C. P

After mapping, let's move on to technical observation and prospecting of erosion phenomena, the observation and identification points of areas disturbed by soil erosion and water erosion are: within a few meters of human presence, building foundations, mining activities, proximity of hedges or paths on the upstream slope, accumulation of fine particles marking the old pond, on solum truncations (break in slopes at the edge of a plateau, top of a vineyard, cultivated land), on various trenches, river bank, erosion ravine, on cultural anomalies or special forestry station, on massive and prolonged contributions of amendments, especially organic. The location of the different soil degradations is linked to factors such as: nature and state of the parent rock, mesoclimate, and topographic position, aspect of facies or pedological features, classification of slopes, classification or denomination of horizon and solum structures, qualitative evaluation of pedological covers, diagnostics relating to water access or water reservoir.

Finally, inventory and approximate monitoring of erosion to develop mitigation measures. Remote sensing is the set of knowledge and techniques used to determine the physical and biological characteristics of objects by measurements taken remotely, without physical contact with them. It covers all the information required from the satellite platform by sensors. The signals obtained will be processed, classified, and interpreted directly or indirectly by resolutions. Erosion rates can be monitored and limited using the GIS/USLE approach and remote sensing.

3. Results and interpretations

Before arriving at the soil erosion rate assessment map in the study area, several maps of soil erosion risk factors are obtained using a GIS/USLE approach.

Altitude of the study area

The study area is made up of different types of relief with a variation in altitudes between 1510 m and 1709 m. The average altitude is 1593.57 m.

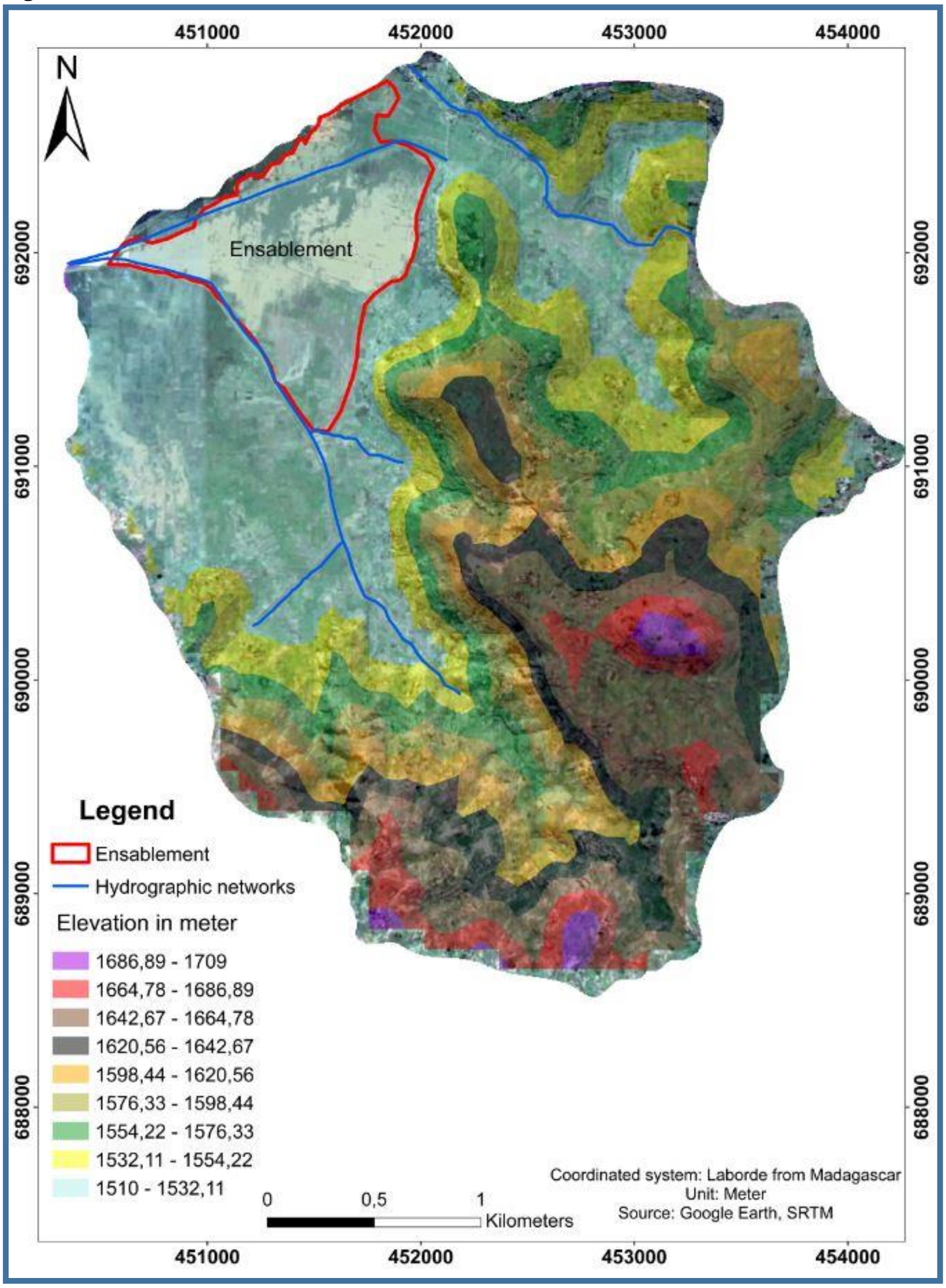

Figure 2: Elevation map of the area (Google Earth, SRTM)

The slopes in the study area are varied depending on the shape of the relief. The gentle slopes are found in the northwestern part of the territory. On the other hand, the steep slopes are in the center of the area and in the slope of the area.

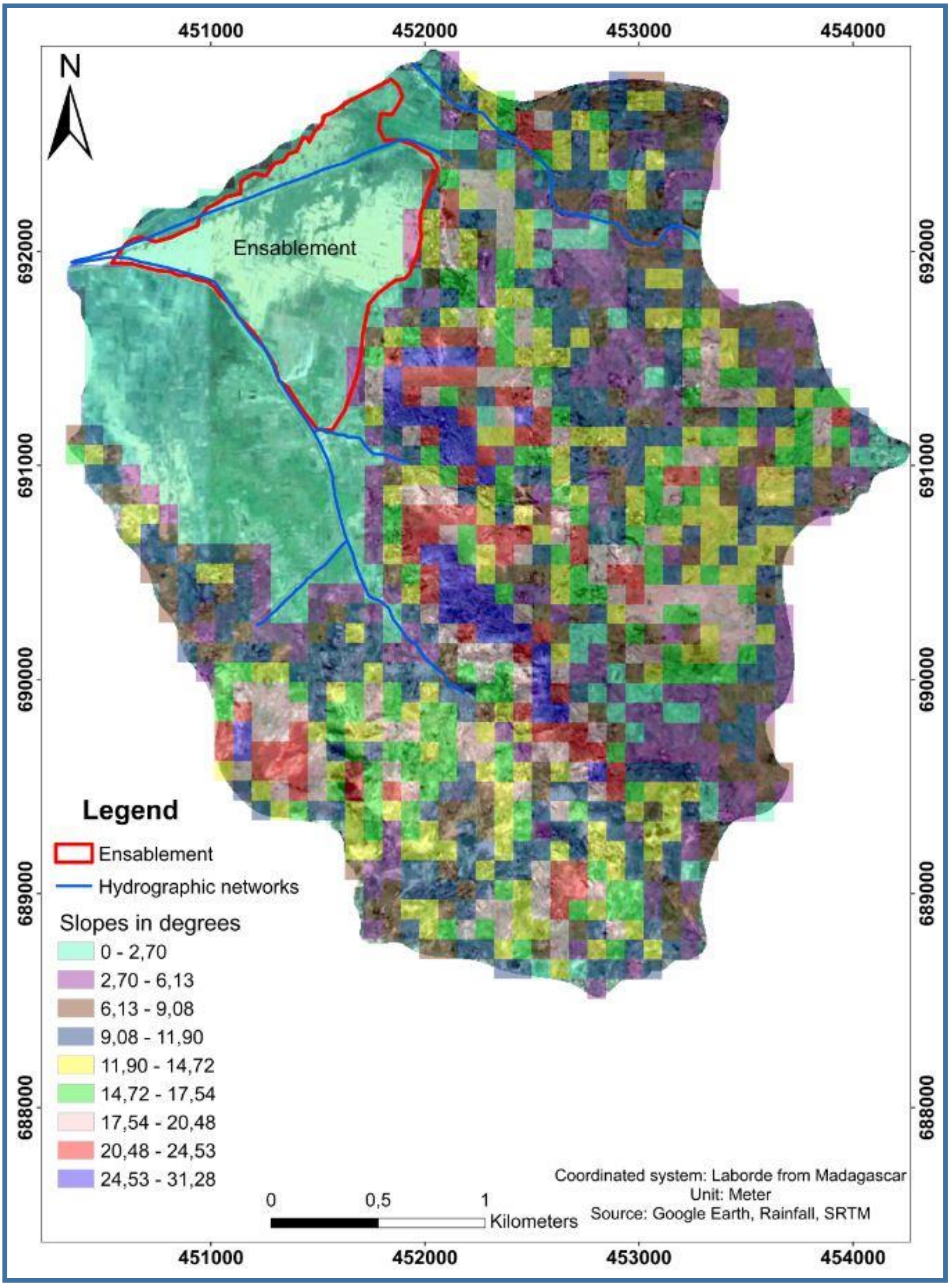

Figure 3: Map of slopes in degrees (Google Earth, SERTM)

3.1. Evaluation of USLE factors

The USLE equation is a multiplication of the five erosion factors, namely rainfall erosivity R, soil erodibility K, slope inclination and length LS, vegetation cover C and anti-erosion practices P. Each of these factors was expressed in the form of a thematic map.

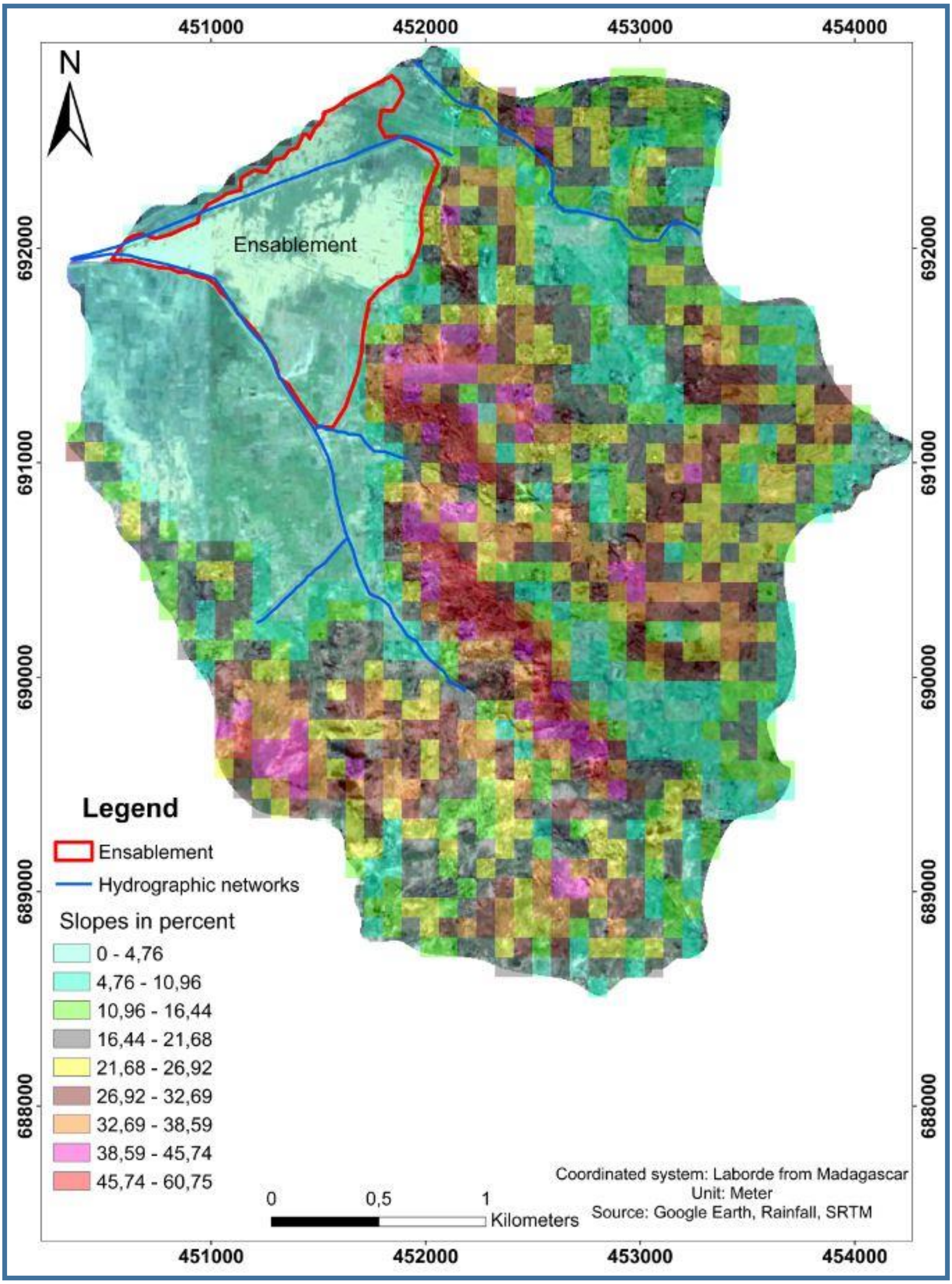

Figure 4: Map of slopes in percent (Google Earth, SRTM)

3.1.1. Rainfall aggressiveness factor (R)

The rainfall of the area

The study area enjoys a tropical climate which is contrasted by the relief. Precipitation varies according to altitudes and soil types. It ranges from 1251.69 to 1326.79 mm. The average annual precipitation is 1287.58 mm.

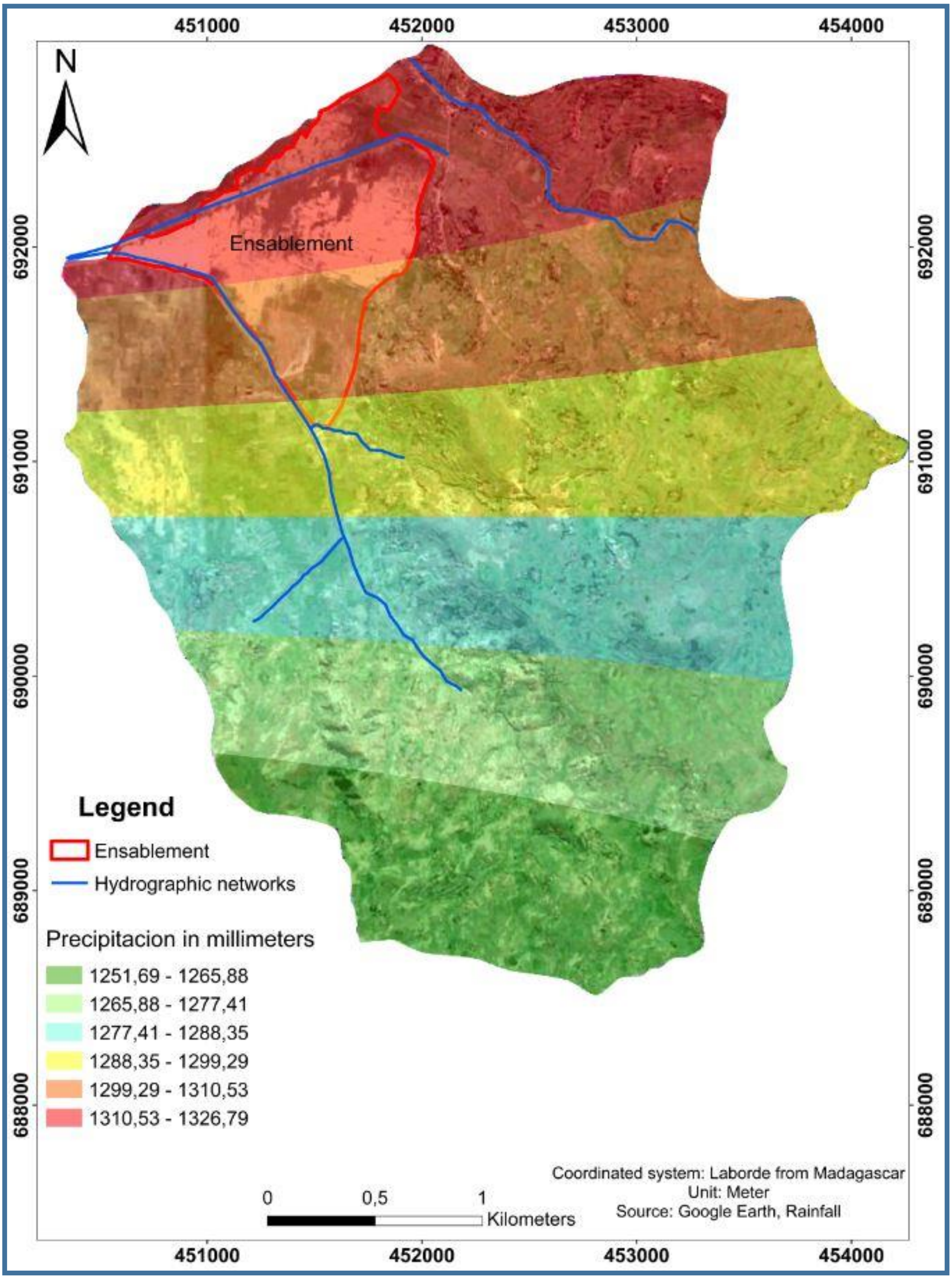

Figure 5: Map of precipitation factor in the study area (SRTM, Google Earth)

Aggression factor R

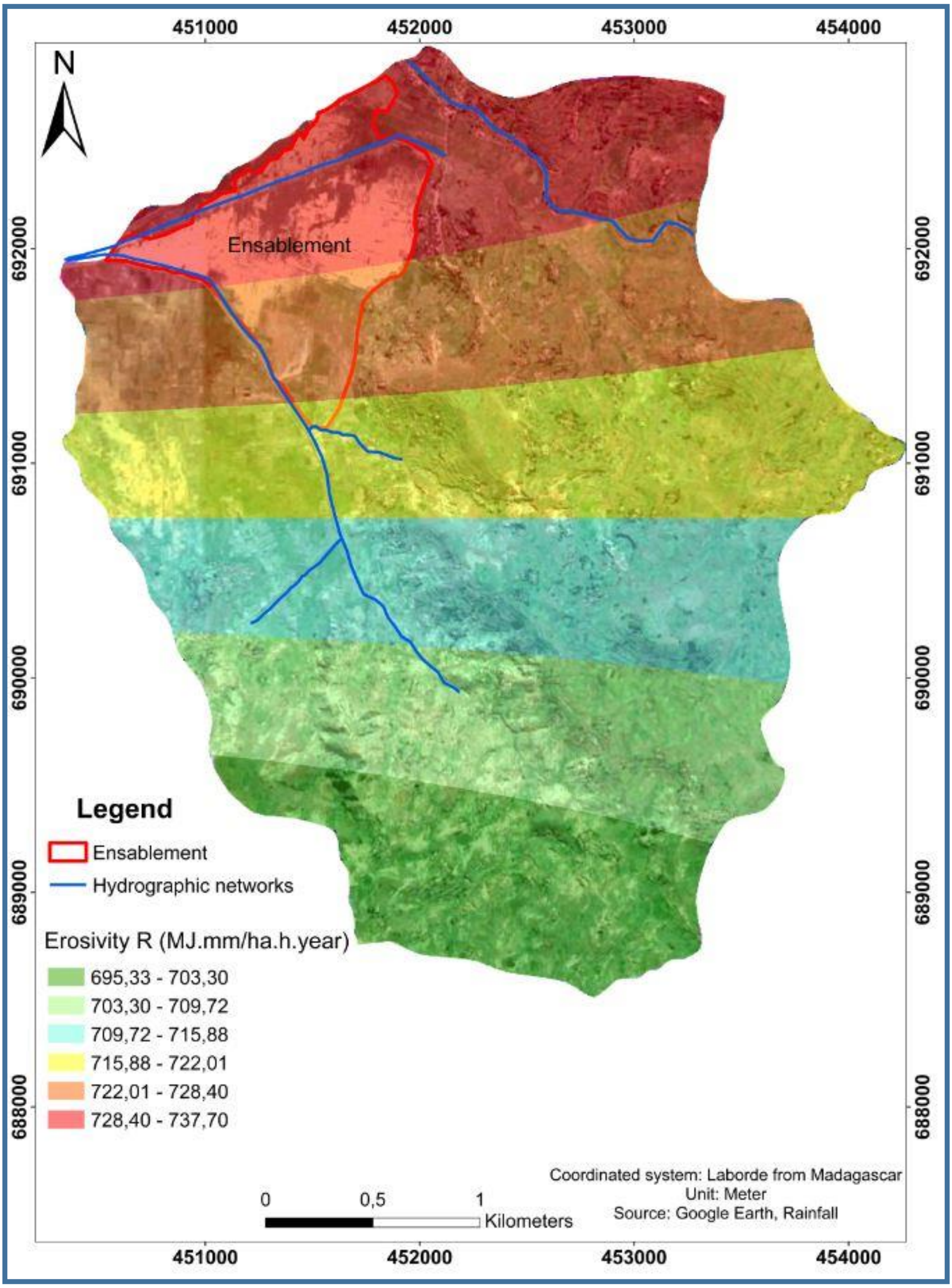

Figure 6: Map of the rain aggressiveness factor R in the study area (SRTM, Google Earth)

The figure above is the map of the rain erosivity factor R (see Fig. 7) in the study area, with values ranging from 97.33 to 103.20 megajoule millimeter per hectare per hour per year. The rain erosibility factor (R) depends on the soil texture and topography of the area, i.e. when rainwater can no longer infiltrate into the soil and tear off particles and carry them away.

3.1.2. Soil erodibility factor (K)

Characterization of soils in the study area

As per Bourgeat, F. et al. 1995, soil classification is based on a combination of criteria, such as the degree of evolution, the type of alteration linked to climatic and edaphic factors, and situational physicochemical characteristics. There are four (04) soil types in the study area [9].
Thanks to the use of GIS, it is possible to form databases which allow storage of information provided by the soil map of the Antsirabe sheet and the explanatory note.

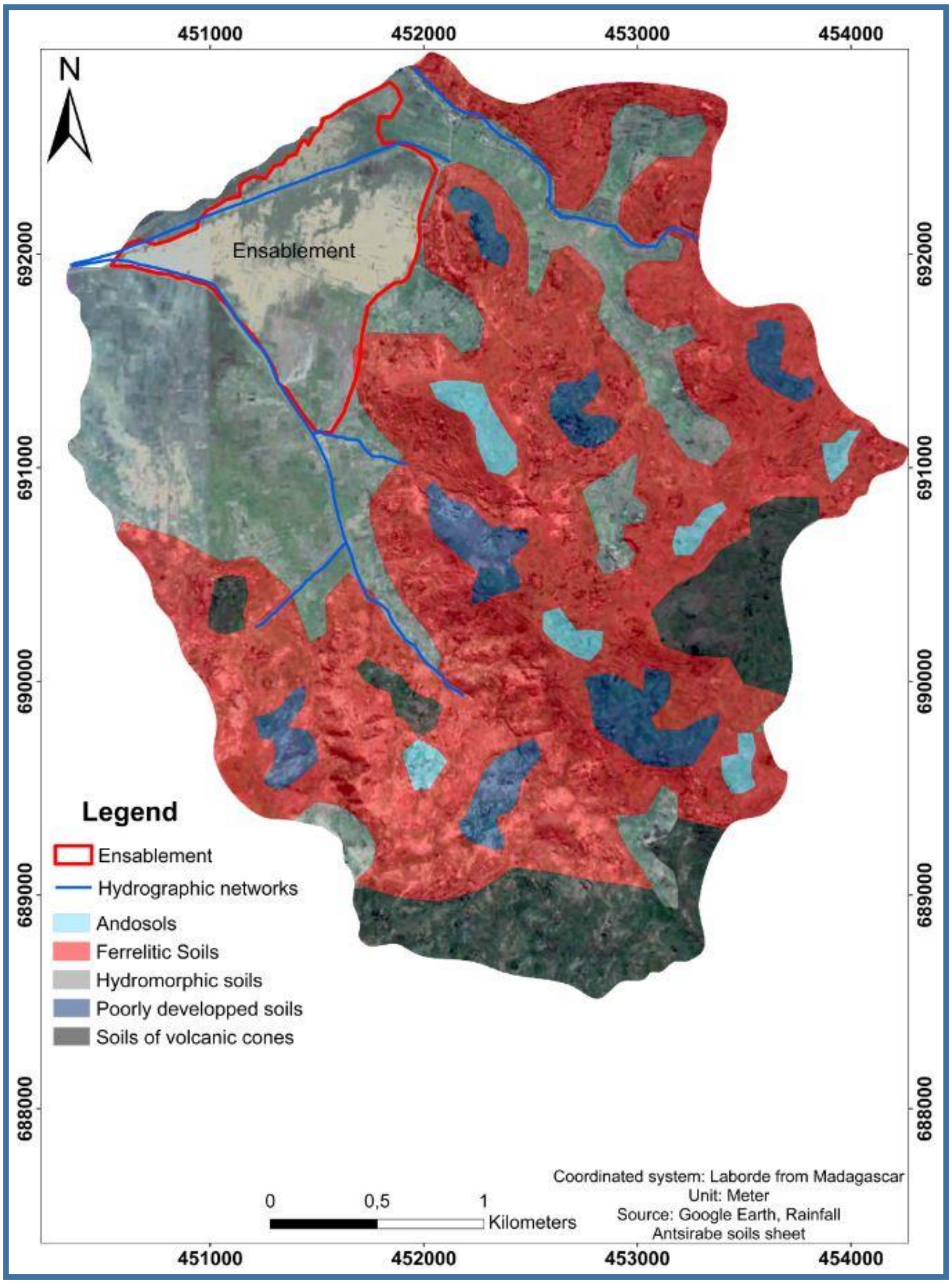

Figure 8: Soil map of the study area (Antsirabe soil map, Google Earth)

The map below (see Fig. 9) shows the spatial classification of the different classes of the soil erodibility factor K in the study area. The values of the erodibility index are between 0.02 and 0.28 and are distributed over the study area according to the different homogeneous units. Our area generally has low erodibility (0.02 - 0.04) covering 5.81% of the study area with an area of 644714 m2, followed by medium erodibility (0.04- 0.21) with 12.50% of the area or 1.39 km2 of the area and high erodibility (0.21 - 0.28) with 81.69% of the total area or 9.07 km2 of the area.

Soil erodibility (K)

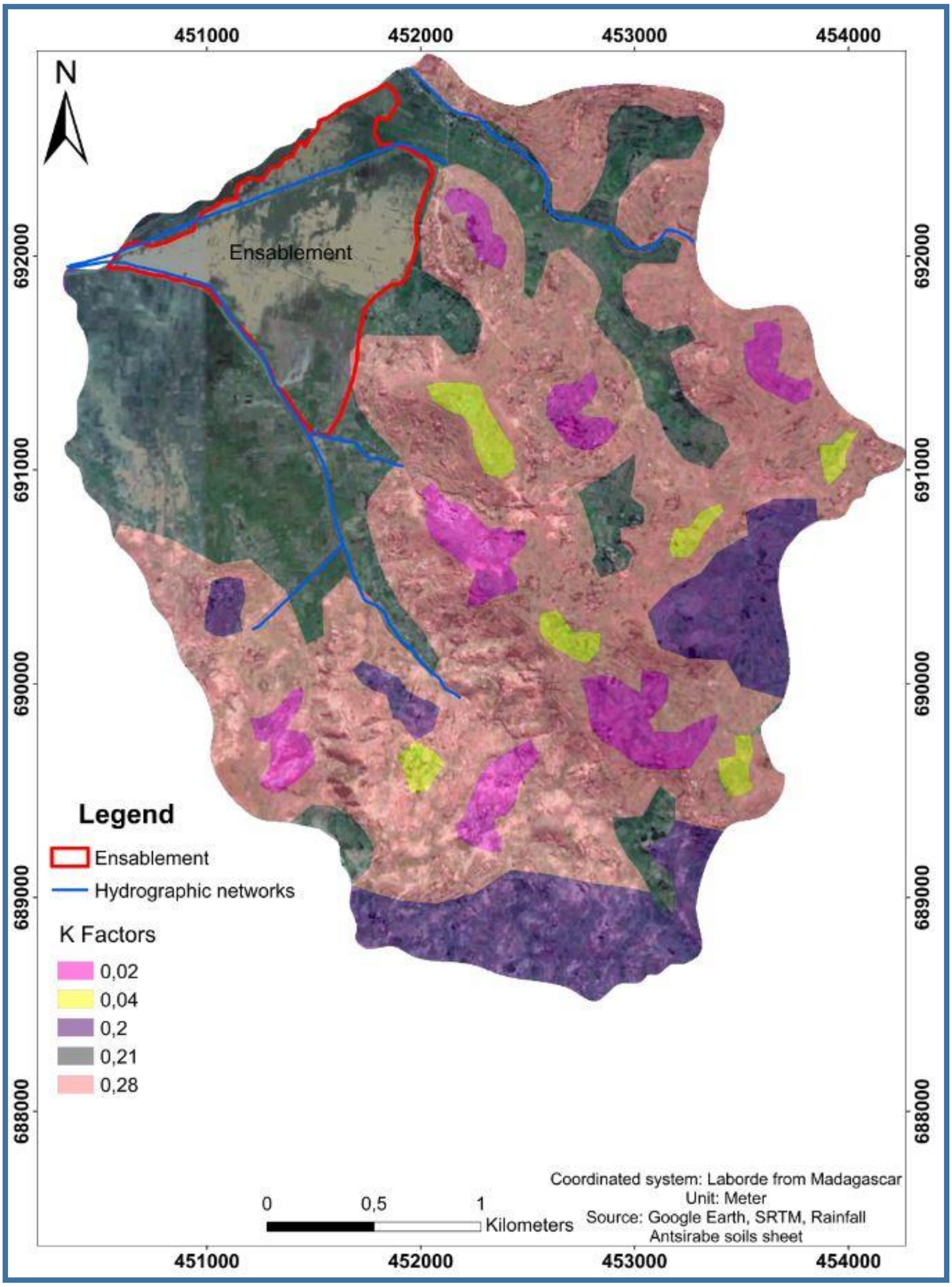

Figure 9: Map of the classification of the values of the erodibility factors K of the study area (Antsirabe soil map, Google Earth)

3.1.3. Topographic factor (LS

The topographic factor LS is classified according to values ranging from 0 to 3.99. Reading the map (see Fig. 10) generally reflects the topography of the terrain. The minimum values (0-0.11) cover 58.09% of the total area of the study area, i.e. 6.44km2 of the area with slopes less than 17.54°. Values between 0.11 and 0.34 are distributed throughout the area with an average slope between 17.54° and 20.48°. The remaining 10.91% of the area correspond to values greater than 0.34 generally coinciding with areas at high altitudes and high slopes (greater than 30°).

The topographic factor (LS) depends on the degree of slope in the study area, and there is a relationship between the topographic factor (LS) and the erosion action, that is, the higher the slope, the more intense the erosion.

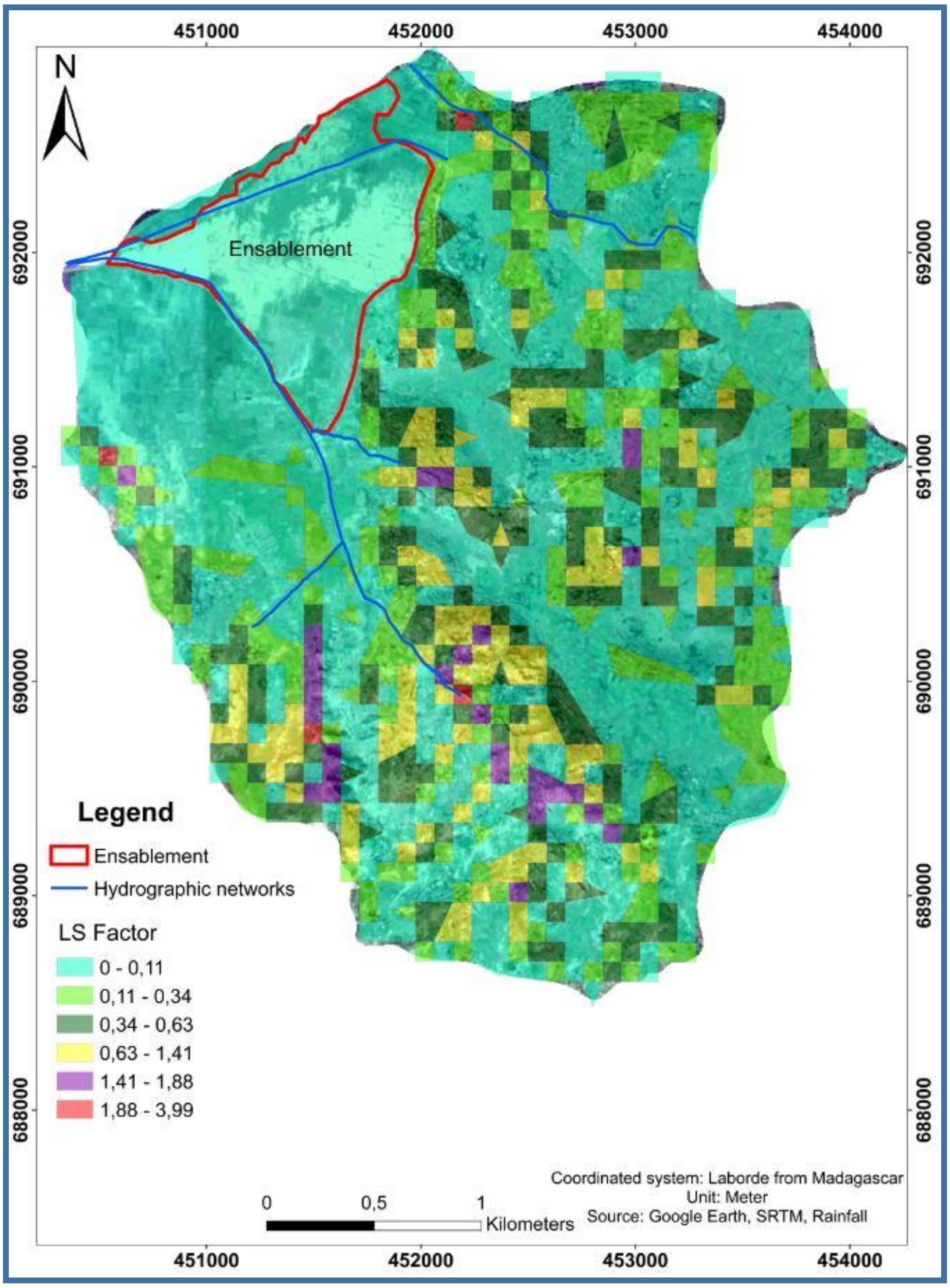

Figure 10: Map of the LS value classification of the study area (Rainfall of the area, Google Earth)

3.2. Potential erosion (PA)

The multiplicative superposition of the three thematic layers R, K, LS, representing the erosion factors in Raster format, made it possible to obtain the potential erosion map, expressing the potential erosion value in t/ha/year per spatial unit. The map obtained (see Fig.11) shows erosion rates varying between 0 and 85 t/ha/year distributed over the entire study area. As per Jean Nacishali N., 2020, the Table 5 presents the distribution of erosion classes at the level of the study area. In this work, we have divided the soil losses into 5 classes for better spatial visualization, however, the discussion of the results will take into account the following thresholds: if the erosion rate is between 0 and 57.28 t/ha/year, it is an average erosion class, covering 39.49% of the study area; for the area where erosion rates are found between 57.28 to 259.29 t/ha/year, this area is considered to be highly eroded, 7.90% of the study area is occupied by this type of erosion; and the higher erosion rate of 259.29 t/ha/year is classified as very high erosion, it is dominated in the study area, 52.61% is occupied by this type of erosion [10].

Table 5: Distribution of potential erosion classes (AP)

Soil loss class	Class Severity	Area in m^2	Area in %
0 – 10	Small	8652000.65	79.24
10 – 20	Moderate	1430925.03	13.11
20 – 30	Elevated	561464.10	5.14
30 – 50	Severe	249932.37	2.29
50 – 603	Very severe	24187	0.22

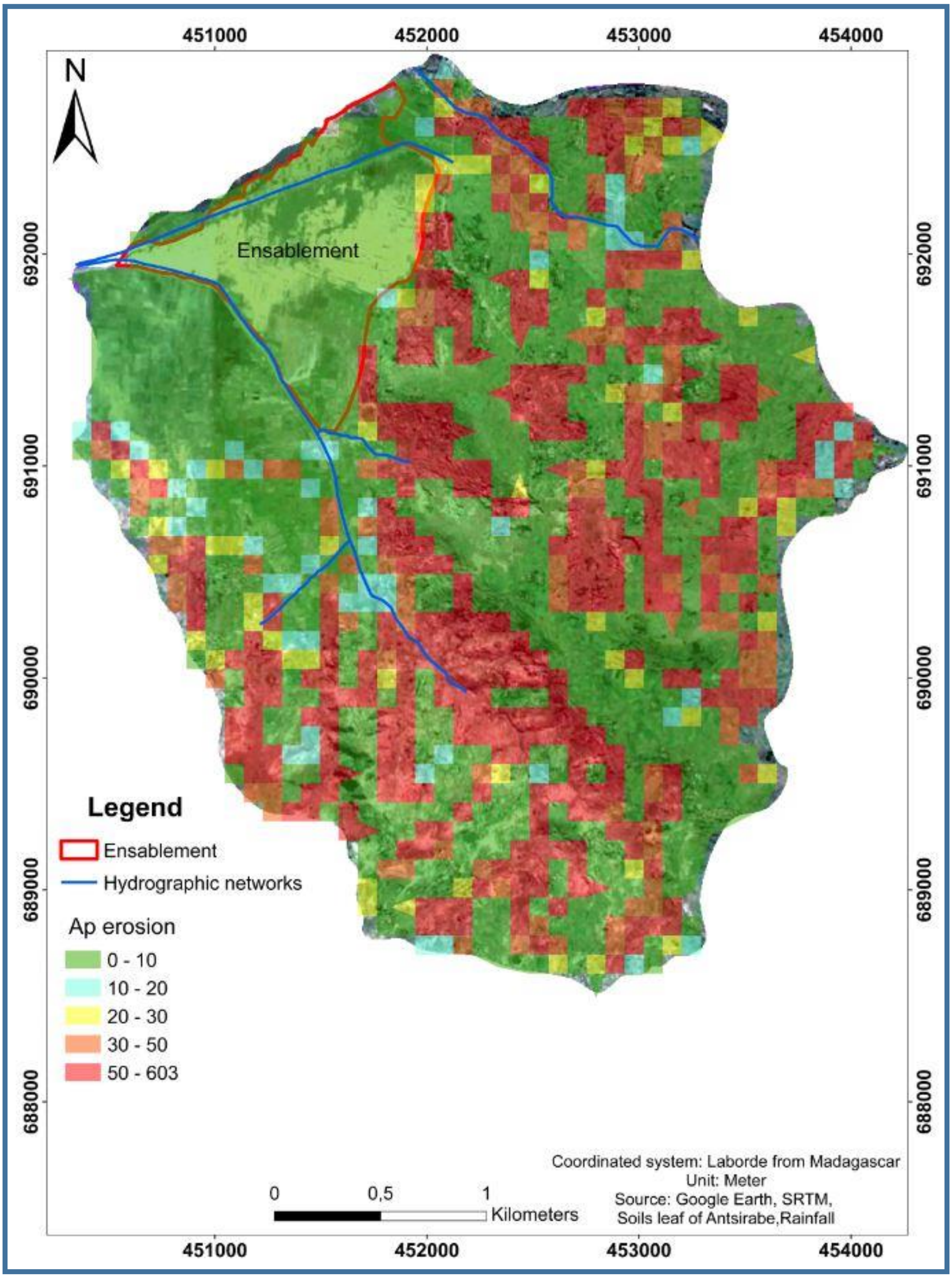

Figure 11: Potential erosion rate Ap of the area (Antsirabe soil map, Google Earth, Rainfall data)

4. Conclusion

The Tritriva area is located in the crystalline basements. It is marked by vast volcanic areas of almost black volcanic soils. These areas are already eaten away by erosion. In addition, the activities carried out by the local population and the bush fire only accelerate the erosion in this part.

According to the results of the study on the empirical estimate, the soil loss of the Tritriva area is classified among the most alarming.

The use of the USLE model leads to more reliable results that can provide valuable assistance, at very low costs, to decision-makers and land planners, in order to assess the evolution and consequently target priority areas that require conservation and erosion control actions. The results obtained, in the form of an erosion risk map, show that the study area has soil losses that vary from 0 to 85 t/ha/year with an average annual loss of 32.8 t/ha/year, so erosion is classified among the very high in Madagascar.

As per Gashaw, T., Tulu, T. and Argaw, M., land use is a better way to control the increase in the erosion rate [11]. It has a huge effect on erosion rates: soil losses on bare land or with highly degraded vegetation are probably higher than those on surfaces with permanent vegetation, even on steep slopes. On these lands, erosion is controlled mainly by the topographic factor.

Finally, this approach helped to better estimate potential erosion rates at the scale of the study area. It greatly contributed to the classification of erosion risks. Furthermore, following this classification, environmental provisions are also classified according to risks. From this study, my perspective is the use of the USLE and GIS method for other areas or land use planning in Madagascar.

6. Bibliography

[1]. Bourgeat, F. et al. 1995. Pedomorphological units in Madagascar, factors of pedogenesis, regional potentialities and constraints. ORSTOM, pp 40-49.

[2]. Cox, R. et al., 2009. Erosion Rates and Sediment Sources in Madagascar Inferred from Be Analysis of Lavaka, Slope, and River Sediment. The Journal of Geology, vol. 117, pp 363-376.

[3]. FAO, 1974. Pedological map of Madagascar.

[4]. Jean Nacishali N., 2020. Mapping of soil water erosion and prioritization of conservation measures in the territory of Uvira (Democratic Republic of Congo). The electronic journal in environmental sciences, Department of Geology, Faculty of Sciences, Official University of Bukavu (UOB), BP 570, Bukavu, DR Congo.

[5]. Ganasri, B.P., Ramesh H., 2015. Assessment of soil erosion by RUSLE model using remote sensing and GIS - A case study of Nethravathi Basin, Geoscience Frontiers

[6]. Gashaw, T., Tulu, T. and Argaw, M., 2017, Erosion risk assessment for prioritization of conservation measures in Geleda watershed, Blue Nile basin, Ethiopia, Environmental Systems Research.

[7]. Singh, S., and Kumar, P.R., 2017. Grid-cell based assessment of soil erosion potential for identification of critical erosion prone areas using USLE, GIS and remote sensing: a case study in the Kapgari watershed, India, International Soil and Water Conservation Research [Online], 5, pp. 202-211.

[8]. Tadesse, L., K.V. Suryabhagavan, G. Sridhar and G. Legesse, 2017, Land use and land cover changes and Soil erosion in Yezat Watershed, North Western Ethiopia, International Soil and Water Conservation Research [Online], pp. 85-94.

[9]. Tamene, L., Z. Adimassu, E. Aynekulu and T. Yaekob, 2017. Estimating landscape susceptibility to soil erosion using a GIS-based approach in Northern Ethiopia, International Soil and Water Conservation Research [Online], 5, pp. 221-230.

[10]. Roose, E., 1990. Erodibility of some tropical soils Twenty years of measurement in erosion plots under natural rainfall. Fig09-Tab08, 27p.

[11]. Smith and Wischmeier, 1978. Factors of soil formation, a system of quantitative pedology.

[12]. Wischmeier et al., 1971. Factors of soil formation, a system of quantitative pedology

7. Webography

1- Geography of Madagascar (March 15, 2022)

http://fr.wikipedia.org/wiki/G%C3%Geographie de Madagascar.

2- Google Earth (March 20, 2022)

http://www.googleearth.exe

3- Lachainemeteo (April 05, 2022)

http://www.lachainemeteo.com.

4- Larousse (May 27, 2022)

http://www.larousse.fr/encyclopedie/divers/pédogenèse/77823.

5- Hydric wrestle (June 10, 2022) http://www.ma.auf.org/erosion/chapitre/VI.Lutte.html 6- FAO (June 19, 2022) http://www.erosion hydrique.fao.org/3/t1765f0v.htm 7- Assessment of soil erosion by RUSLE (March 12, 2023) http://dx.doi.org/10.1016/ j.gsf.2015.10.007 8- Erosion risk assessment for prioritization of conservation measures (April 17, 2023) https://doi.org/10.1186/s40068-016-0078-x

9- Estimating landscape susceptibility to soil erosion (May 2 2023)

http://dx.doi.org/10.1016/j.iswcr.2017.05.002

10- Land use and land cover changes and Soil erosion (10 May 2023)

https://doi.org/10.1016/j.iswcr.2017.05.004

11- Grid-cell based assessment of soil erosion potential (11 June 2023)

https://doi.org/10.1016/j.iswcr.2017.05.006

12- Climate factor (25 July 2023)

http://googleengine.gov

13- Topographic factor (25 July 2023)

http://earthexplorer.usgs.gov