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Evolution of Silting: Case of Alaotramangoro Lake - Madagascar

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ABSTRACT

The Lake Alaotra region is the first granary in Madagascar, it had problems of agricultural production because of silting. The work provides granulometric and morphoscopic analysis of sand sediments. These analyzes allowed the different forms of quartz grain, angular to subarrondi. The sediments are of fluviatile origin with short transport that is plowed towards the flood plain and rice fields.Image processing led the sand silting results of the Imamba-Ivakaka watershed during the years 1993 through 2018 to the use of SIG and remote sensing. Following the determination of silted surfaces and the loss of soil. Indeed, we proposed measures to learn to fight against the degradation in the watershed in order to mitigate the silting of the rice fields.

Keywords: Erosion –Silting -Soil Loss - Watershed – SIG – Alaotramangoro

1-Introduction

The Alaotra region, Madagascar's first granary, is experiencing difficulties in rice production, which is getting worse every year. This scourge has its origins on the one hand in the population explosion and on the other in the reduction of arable land due to the erosion of the watersheds of the silting of rice fields and other infrastructures linked to rice farming.It is precisely with this in mind that studies of the silting up of part of the affected paddy land have been carried out by the filling of the bottom caused by this degradation of the surrounding catchment area. This phenomenon plays the main factor of all environmental problems throughout the Alaotra-Mangoro region, especially in the study area which is the sub-watershed of Imamba-Ivakakasedimentary soils.

As far as agricultural production is concerned, arable land does not correspond to the rate of population increase.In 2014, the area cultivated by rice farmers and normally irrigated by dams averages 135,000 ha and only 19,700 ha is used for rainfed rice cultivation on the sides of the watershed (Randriamanarivoarison Z.H., 2015).

The overall objective of this study is to understand the evolution of silting in the Imamba-Ivakaka watershed. The specific objectives relating to this objective are to:

- map the evolution of silting in the Imamba-Ivakaka sub-watershed,
- determine the area of silting by the use of the Geographic Information System (GIS) and remote sensing,
- calculate the earth loss volume,
- consider and recommend solutions for combating degradation in the basin with a view to reducing silting of rice fields

2. Geomorphological Context

The relief is characterized by rugged terrain (figure 1), on a slope of the multiconvex shape. It is weakened by erosion and becomes sensitive, by the phenomenon of lavaka. This area is most threatened by lavaka, hence the morphology shaped residual form.

Multiconvex or "half-orange" reliefs on gneiss and migmatites characterize the most specific landscapes in the western and southwest parts of Lake Alaotra (Raunet, 1984). Moreover, Rabezandrina says that the «lavaka», are formed on the mother rock of gneiss or micaschist which easily altering gives a loamy zone, micaceous, even friable.

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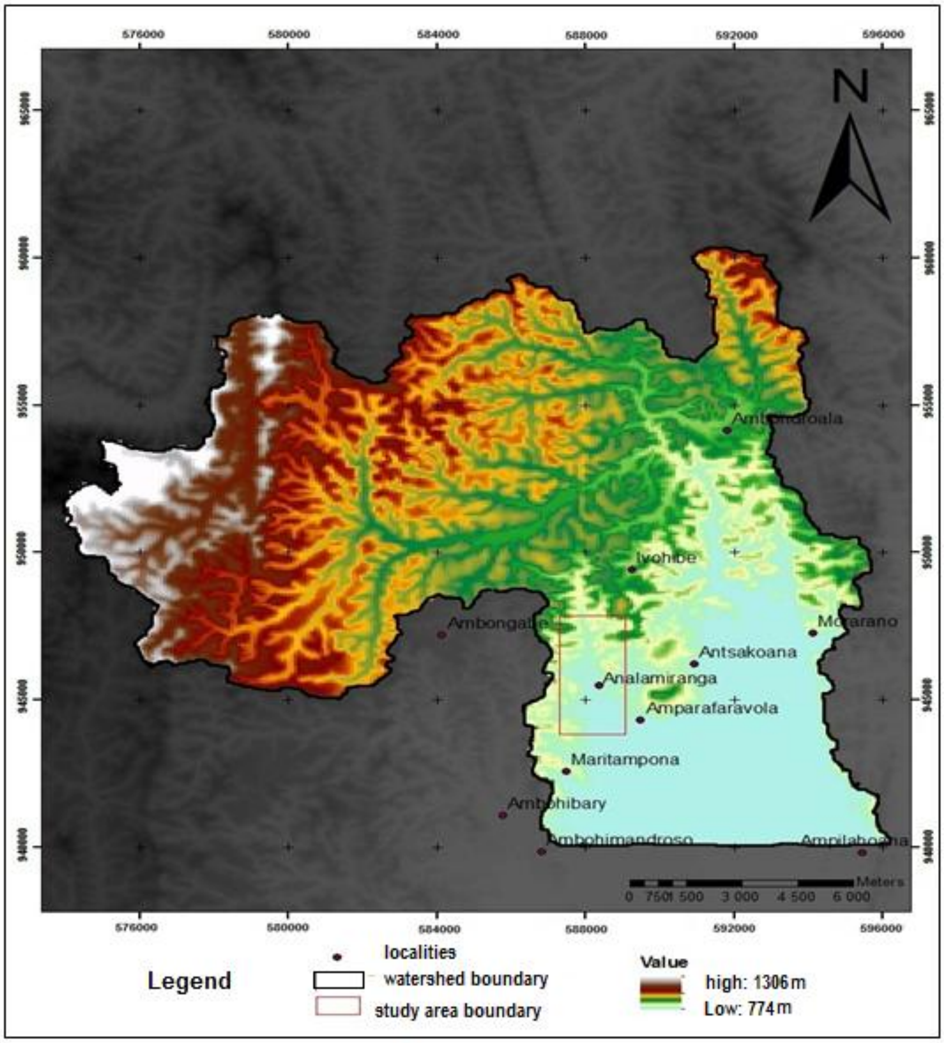


Figure 1: delimitation of the watershed

From the SRTM data, the watershed boundary was extracted by applying a "watershed" tool in Arc Gis 10.3.1

3. Geological Context

The Lake Alaotra Region is part of the Malagasy Precambrian Base Area. The Alaotra basin, of Plio-Quaternary age (Besairie, 1960) depression of the Akay-Alaotra rests discordantly on the crystalline base. It is composed of migmatite, gneissic rock in the western part of the lake (Raunet 1984).

The Imamba-Ivakaka watershed consists of the following formations:

- alluvial and sands,
- volcanic tufts with ankaratrite blocks,
- ankaratrite,
- migmatites,
- migmatite granitoids and migmatitic granites.

4. Materials and Methods

Based on the USLE Universal Soil Loss Equation (Stone et al, May 2000), the Soil Loss Equation is used to calculate the volume of soil removed by erosion. It is made up of five factors that govern the phenomenon of erosion and the simulations represent annual average values of soil loss. As a result, erosion is translated as a function of rainfall and runoff patterns; soil type in the field; slope of the land; vegetation cover or cultivation and soil conservation practices.

The annual land loss was made by the following formula:

A=2.24 R K LS C P

A= loss of land (tonne/hectare/year)

2.24: coefficient allowing the use of the metric system for soil losses.

Factor R:

R is the rainfall factor collected by the weather station near the study area. The erosivity index R can be calculated in the previous two years (2016 and 2017). Details of the calculations are in Appendix II.

R=(And I30)/100 Gold And= E I30

I30: rainfall intensity for 30min

E: Kinetic energy (Tm/ha/cm)

A: Erosivity Index (expressed in US units), Rusa

Table 5: Erosion Index in 2016 and 2017

Annual erosion index	R_A (2016)	R_B(2017)
Numerical calculations	$R_A=\frac{825,64}{100}$	$R_B=\frac{2281,42}{100}$
Results	R_A=8,26	R_B=22, 81

Erodibility factor k:

The k-factor can be found using the soil type that characterizes the study area. In 1975, ROOSE made the experiment in Africa, drawing the standards of the value of K according to soil types, these values are found in table 2.

Table 2: Erosion value K by soil type, according to Roose in 1975

Types of soils	Erodibility factor (K)
Ferralitic soils	0,01 à 0,18
Ferruginous soils	0,20 à 0,30
Leached soils	0,20 à 0,70

Factor C: vegetation cover

This factor depends on certain type of crop or vegetation, we are in the type of savanna vegetation, burned prairie or grazed; then C=0.1(table 3).

Table 3: Influence of vegetation cover on erosion in West Africa (Roose 1973)

Plants and cultivation techniques		**Valeurs du facteur agronomique (C) annuelles moyennes (sans unité)**
Baresoil		1
Dense forest or extensive mulching		0,001
Savanna and meadow in good condition		0,01
Savanna and meadow burned and/or grazed		0,1
Fast-growing cover plants and planting early in the first year		0,3 à 0,8
But, sorghum, millet (depending on yield)		0,01 à 0,1
Rice under intensive cultivation		0,4 à 0,9
Cotton, tobacco (second cycle)		0,1 à 0,2
Peanut (depending on planting date)		0,5
Cassava (1st year), yam (depending on planting date)		0,4 à 0,8
Palm tree, coffee, cocoa with cover plants		0,2 à 0,8
Flat pineapple (depending on slope) slope 4 to 20%	- Residues burned	0,1 à 0,3
	-Landfilled tailings	0,1 à 0,5
	- Surface residues	0,1 à 0,3
Pineapple on partitioned billon (slope 7%)		0,01 à 0,1

5. Results and Interpretation

The descent in field made it possible to obtain the photo (figure 1 and figure 2) of the silted rice fields in the site.

Here is the evolution of silting maps obtained in 1993, 2005 and 2018 with the use of the satellite image (landsat 5, landsat 7 and sentinel 2)

In 1993: Landsat 5

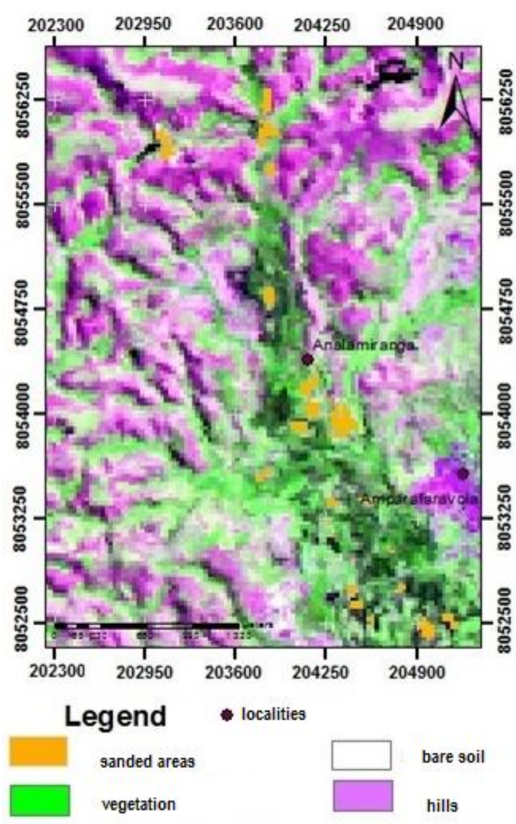


Figure 2: Sand map in 1993 ***(Source : Image LANDSAT 5)***

The silt-covered area in 1993 is in the southern part of the study area. The sand comes from the uprooting of the unstable upstream slope and which is diverse in the rice field by the river transport agent which causes the silting up of some cultivated rice fields.

In 2005 : Landsat 7

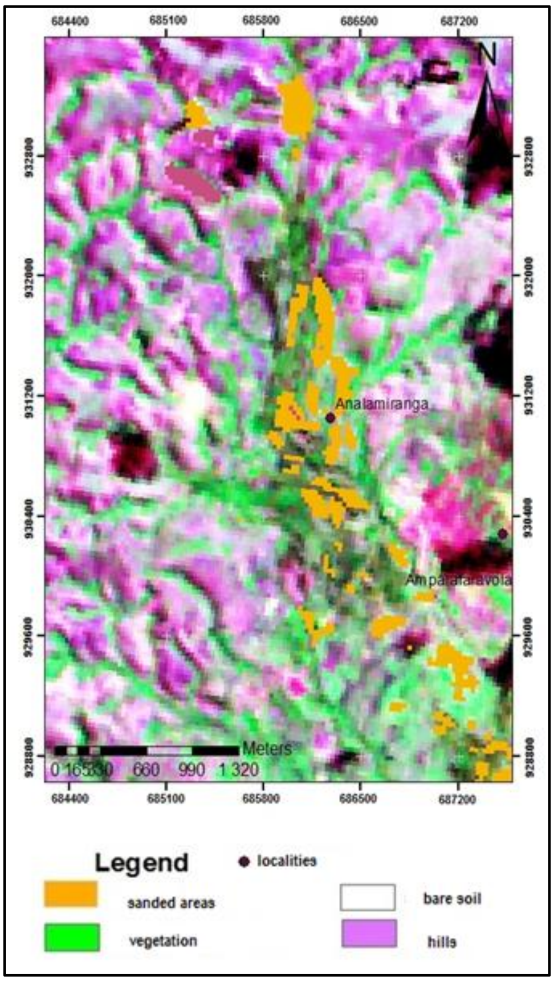


Figure 3: Sand map in 2005 (Source : Image LANDSAT 7)

For 2005, the silted surfaces are accentuated towards the south and south-east of the study area.

In 2018 : Sentinelle 2

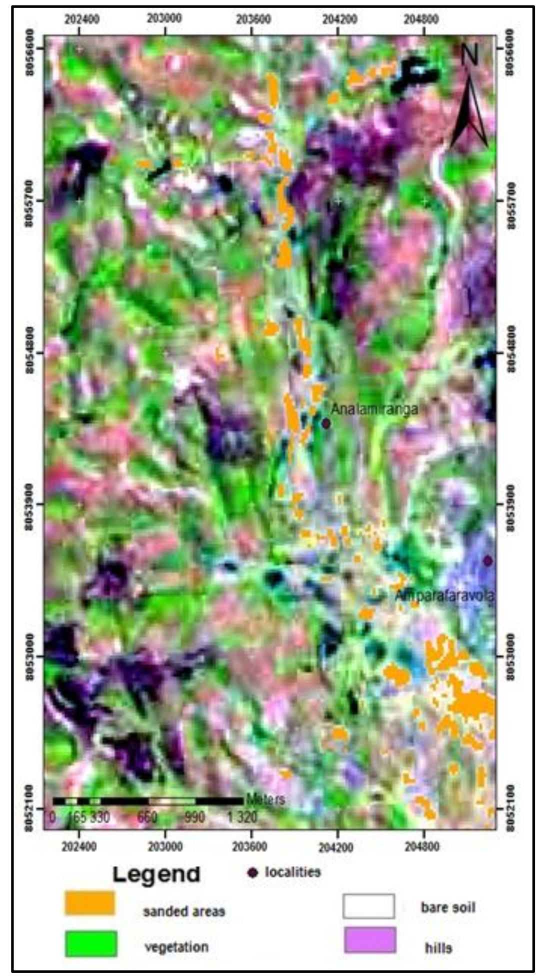


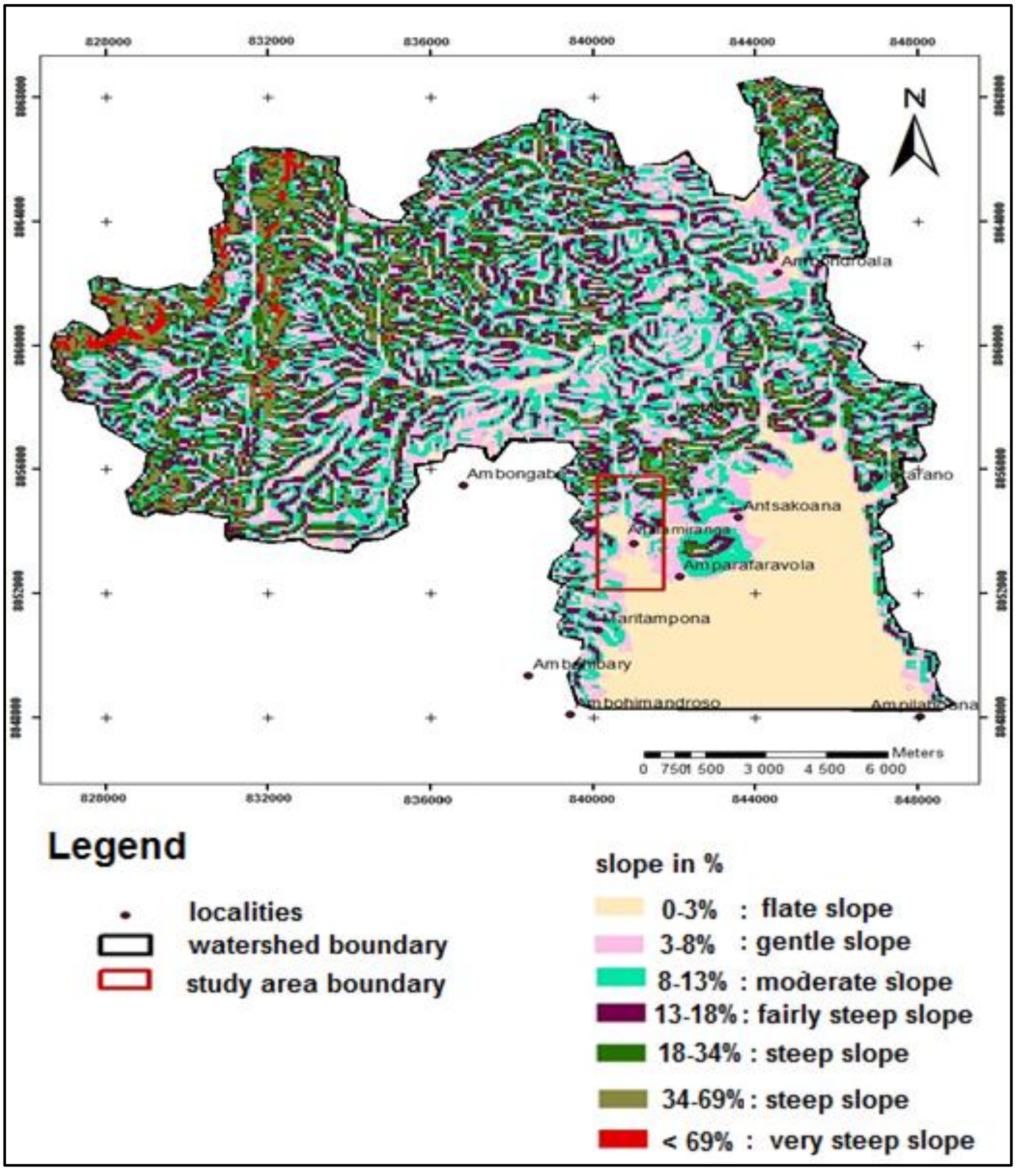
Figure 4:Sand map in 2018 (Source : Image SENTINELLE 2)

In 2018 the North and the South-East part of the study area is in the silting.

The use of MNT data made it possible to know the nature and values of slopes; the latter are expressed in percent (%).

Slope Map

The use of MNT data made it possible to know the nature and values of slopes;the latter are expressed in percent (%)



6. Discussions

Morphoscopic analysis makes it possible to study sand grains, the majority of these grains are generally composed of quartz minerals with a varied shape and size, most of the shapes are predominantly angular and sub-angular: that is, - say unworn. The transport time is short and they are not deposited far, with low speed. The observed sediment is of fluvial origin, which is carried to the floodplain.

The results obtained show the silted areas for each year, using multidate satellite image processing and Geographic Information System (GIS) processing and remote sensing. Consequently, these sandy surfaces change differently because of the constant climate change and the phenomenon of erosion: the lavaka which is found on the hilly areas.

7. Conclusion

Satellite images taken during the dry season and the same period should be used. Image processing is the only way to determine the surfaces of silted areas using GIS processing software and Remote Sensing. The application of the Tabulate area function in the Arc Gis 10.3.1 software allowed to deduce the silted surfaces for the three years (1993, 2005 and 2018) with these areas respectively of 18.44 ha and 67.23 ha and 42.04 haThe cyclonic passage with a strong aggressiveness brings destruction in the watershed, because of the heavy and very frequent showers; erosion becomes more accentuated; what result is considerable quantities of sediment carried by runoff water, the latter accumulated in low points and fill the areas of concavity as well as the bottom of hydrographic networks for example: rice fields from where silting up rice fields and streams

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