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Incidence of Spatio-Temporal Impact of Runoff in the Spontaneous Subdivision of the Kindele District Located in the Watershed Funa in Kinshasa

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ABSTRACT: The organization of space and its occupation requires preliminary studies including spatial analysis and physical arrangements The objective of this study is to highlight the characteristics of the watershed which are the detonator of the erosions in the Kindele district in the commune of Mount Ngafula in Kinshasa.

To do this, IKONOS satellite and Google Earth images covering the study area from 2001 and 2015 were used to monitor and map the different areas using ArcGIS.10 software.

The runoff coefficient calculations to highlight the water flow rates likely to cause water erosion considering a normal rain of 25mm for 30mn were carried out on Excel. The results obtained after the analyzes reveal that the 2001 situation has a runoff coefficient of 0.12 and a runoff rate of 14m3/S, while that of 2015 has a runoff coefficient of 7.18 and a runoff rate of 1222m3/S.

The difference in flow is 1208m3 /s in 14 year intervals with slopes of a statistical average of 25% which greatly exceeds 6% as provided for in the town planning code.

KEYWORDS: Subdivision, watershed, sealed area, satellite image, runoff coefficient, soil erosion.

1. INTRODUCTION

The world continues to urbanize. The developed countries are very largely urbanized, three quarters of their inhabitants living in cities with 64% for the countries of Asia and Oceania, 15% for Africa against 61% for Europe and 21% for Latin America (Anonymous, 2005).

Although the urbanization rates of developing countries are much lower, they are home to more than two billion city dwellers, out of the approximately three billion on the planet (Anonymous,
2010). According to the United Nations, almost 400 cities in the world have a population of at least one million inhabitants and 284 of these cities are in developing countries (Anonymous, 2005).

The fastest urban growth is currently occurring in Africa. The rate for the period 2000 – 2020 is estimated at around 4% per year. The highest annual additional urban population rate is, however, found in Asia, due to the masses of population concerned. One billion additional city dwellers are expected between 2000 and 2020, including 500 million for China and India (Veron, 2010).

In the Democratic Republic of Congo, the dysfunction of the institutional structures of land and urban management has often favored anarchy in land management and the creation of housing estates. This anarchy is reflected in the lack of respect for urban development master plans and urban planning standards. In this anarchy, some people have been allocated land belonging to others or settled on land already assigned to other uses. The extensions of the cities of the DRC made without a master plan or even a regulatory layout today represent 77.5% of the urban fabric and are home to 83.5% of the urban population (Anonymous, 2000, p.2).

2. Issue

The visits we made in the field enabled us to identify a set of problems for which precise and urgent solutions had to be provided. Without this, the population of this neighborhood risks living in perpetual fear of erosion which threatens to wash away their homes in the near future.

The entire part located upstream of the new district is the subject of significant heads of soil erosion which have been photographed and presented (see photos in Annex 1) showing the seriousness of the situation which can even affect the site of the campus of the alma mater of Kinshasa and the Higher Institute of Medical Techniques of Kinshasa (ISTM/K).

3.Assumptions

This study is based on the following assumptions:

- the occupation of these lands presents a risk of gully erosion in the near future;
- the increase in impermeable surfaces due to land use increases runoff water which causes soil erosion and flooding.

4. Objectives

The general objective of this work is to understand the erosive process of the watershed by studying the mechanisms of runoff development in order to protect the population against the risks of soil erosion and flooding in the FUNA watershed more precisely. in the Kindele district. Specifically, it aims to:

- carry out a spatial analysis, an inventory of impermeable areas, areas with high density of vegetation, low density of vegetation and the assessment of the risks represented by runoff water over the entire extent of the catchment area;
- highlight the environmental impacts due to the occupation of these lands;
- determine the runoff coefficient for the study area in 2001 and 2015 in order to know the quantities of water likely to run off after a recurrent rain.

5. Interest of the subject

The interest of this work is to fully manage the rainwater in the FUNA watershed.

6. Organization of work

This work comprises three chapters apart from the introduction, the conclusion and the suggestions. The first chapter deals with the literature review, the second is devoted to the description of the study environment, materials and methods while the third presents, correlates and discusses the biophysical and socio-human results.

I. MATERIALS AND METHODS

This chapter describes the study area in general and in particular the extent of the area exposed to risks, as well as presenting the methodology followed to carry out this work.

The analysis of the site is based on the bibliographic synthesis and the collection of certain data in the field. Its objective is to know the characteristics of the biophysical and human environment as well as the sensitive elements of the environment in order to be able to subsequently assess the risks of occupying this site.

I.1. DESCRIPTION OF THE STUDY ENVIRONMENT

I.1.1. Geographic location

The section selected for this study is located in the Funa watershed at Kindele/Mont Ngafula, Selembao, Lemba and Makala at 4° 25′ 35″ de South latitude et 15° 17′ 44″ de longitude East.

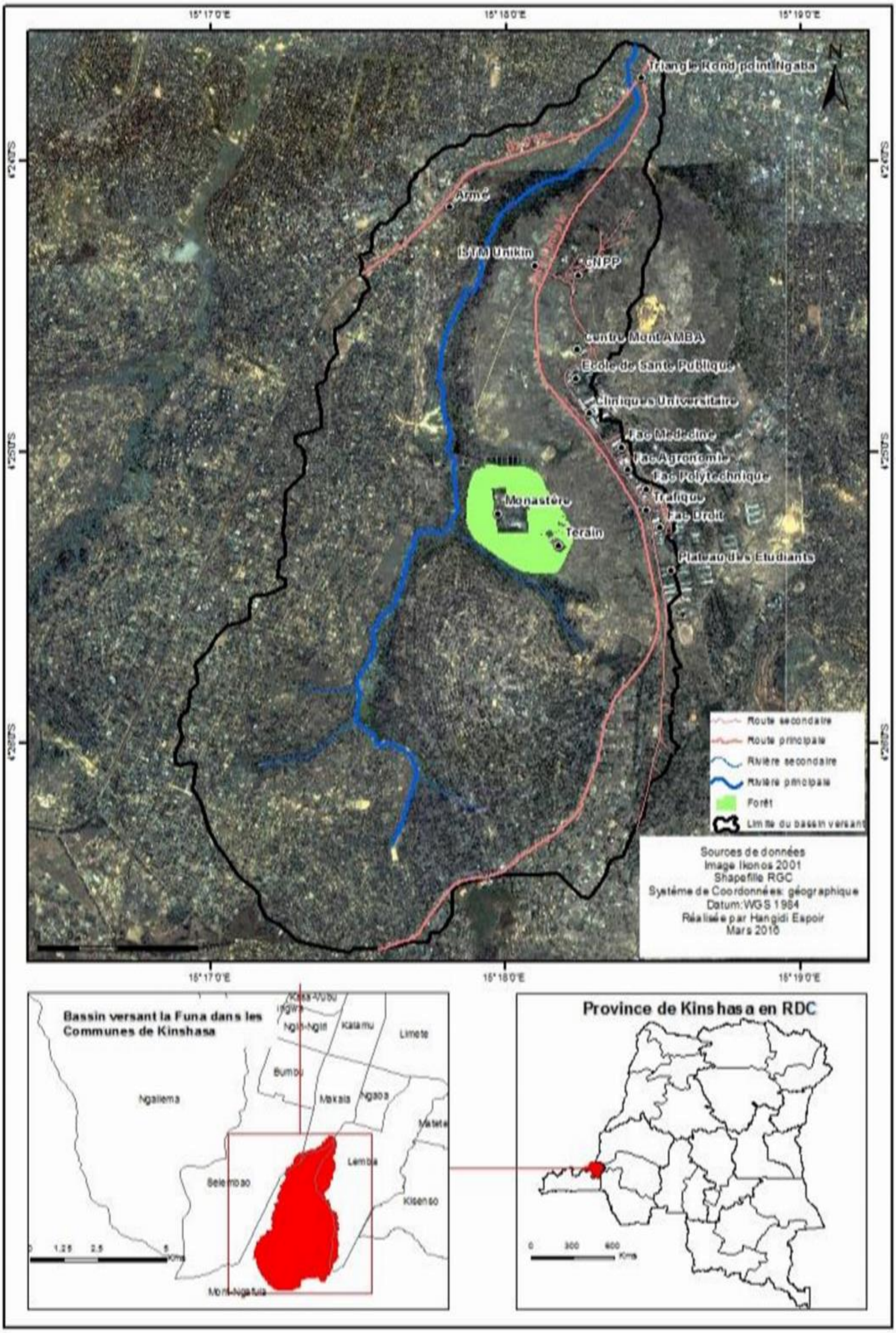

Fig.1. FUNA watershed

I.1.3. Historical

The district takes its name from the name of a former Professor of the Zootechnics Department of the Faculty of Agronomic Sciences of the University of Kinshasa, the late Prof. Dr. Ir.

KINDELE who was the first great influential personality to live there.

When the district has evolved in space, it keeps the Kindele connotation and according to the space it occupies, it will be called Kindele, Kimwenza, Kindele Gare, Kindele Mabanga, Kindele Bayoka and Kindele Monastère.

Ten years ago, the space occupied by these last two neighborhoods was an almost empty space. The influence of its green space will begin to attract market gardeners there and revivalist churches sometimes held prayer retreats there, and later they began to set up their tents to spend the night there.

Day after day, these men of faith began to erect walls there, each in his anarchically occupied corner. Despite some eviction initiatives taken by the provincial government in 2003, these men quickly returned to their spaces and have taken up residence there to this day (Oral Comm., Office of the neighborhood chief).

I.2. Presentation of the environment

Our study area consists of an area of 1,150.5 ha which represents an area of 11.5 km2. This area constitutes the FUNA watershed in the communes of Mont Ngafula, Lemba, Makala and Selembao. For the part located in Mont Ngafula, we find the KINDELE district, BAYOKA district, part of the campus of the University of Kinshasa and the site of the Higher Institute of Medical Techniques (ISTM). The characteristics of the zone are explained in the paragraphs below.

I.2.1. Site description

The topographical survey which was carried out and shown in Figure 2 and includes the following parts:

- the FUNA watershed, in its part of the Monastery up to the By Pass-Avenue Kimwenza triangle;
- upstream of the district, there is part of the campus of the University of Kinshasa and downstream of the ISTM whose slopes are of the order of more than 6%.

A topographic map is produced on a scale of 1/1000, the equidistance of these contour lines being 1m.

I.2.2. Characteristic of the watershed

The total area of the watershed is 11.50 km2.

I.2.3. Biophysical characteristics

I.2.3.1. Climate

With an annual rainfall of about 1500mm, and an average annual temperature of 24°C, the Kinshasa region is characterized by a hot and humid climate with:

- a dry season with practically no precipitation, which extends over almost four months between May and September, and
- a rainy season which takes over from October to May with a slight dip in rainfall from December to February.

Precipitation is of short duration and of high intensity. It rains a total of more than 100 days a year. The average annual thermal amplitude is low, around 35°C. The monthly average relative humidity is always greater than or equal to 78%. The winds blow north-east (N.E) in the rainy season and south-west (S.W) in the dry season (Anonymous, 2005).

I.2.5.2. Hydrography

The hydrological network of the district includes streams and groundwater.

For the calculation of the flows, we used the American rational method which gives the maximum runoff flow in a catchment area and which is:

$$Q = \psi * C_r * i * A$$ Where:

i = Intensity of precipitation recorded on the intensity-duration-frequency curves;

A = Area of the watershed (Km^2)

C_r = Average runoff coefficient depending on the state of the soil.

Ψ = Reduction coefficient taking into account the spatial distribution of rainfall over

watershed: $- 0{,}005\sqrt{\frac{4*A}{\pi}}$[1 . (π= 3,14)].

The study area is drained by the Funa River which, moreover, has its source even upstream of this watershed following an East-West direction and branches off at the triangle with the KEMI River.

I.2.5.3. Pedology

The Kindele district is characterized by clay-sandy soil (Kasongo et al. 2010). In the marshy and flood-prone areas of the district, the soils are made up of fine to very fine and coarse elements, more or less clayey, brown or blackish in color.

On the slopes, there is a cover of fine sand, slightly clayey, brownish in color, which is particularly sensitive to erosion. The slopes are generally made up of more or less coherent sands which give rise to a hill morphology with pronounced slopes and convex summits.

I.2.5.5 Relief

The relief of the Kindele district is marked by slopes of the hills characterized by very steep slopes which we represent in table 5. But also by a valley which extends from the source of the Funa river passing all around the islet forest where the Notre Dame de la Rédemption cathedral stands, a former monastery to the triangle of the Ngaba roundabout.

The reliefs of the earth are represented on a flat map by contour lines and side points. Level curves are imaginary lines that join points of land located at the same altitude (Stampfli, 2007). They are isolines so they are also called isohypses.

If we represent a hill cut into horizontal plates of equal thickness, the contours of these plates - seen from above - draw the level curves, which follow the shape of the relief. The layout of the contour lines on the map provides information on the shape of the relief. For a hill with steeper sides, the level curves are closer together, a gentler slope is represented by more spaced lines (Philibert, 2001). As part of this work, below are the curves that represent the relief of our study area.

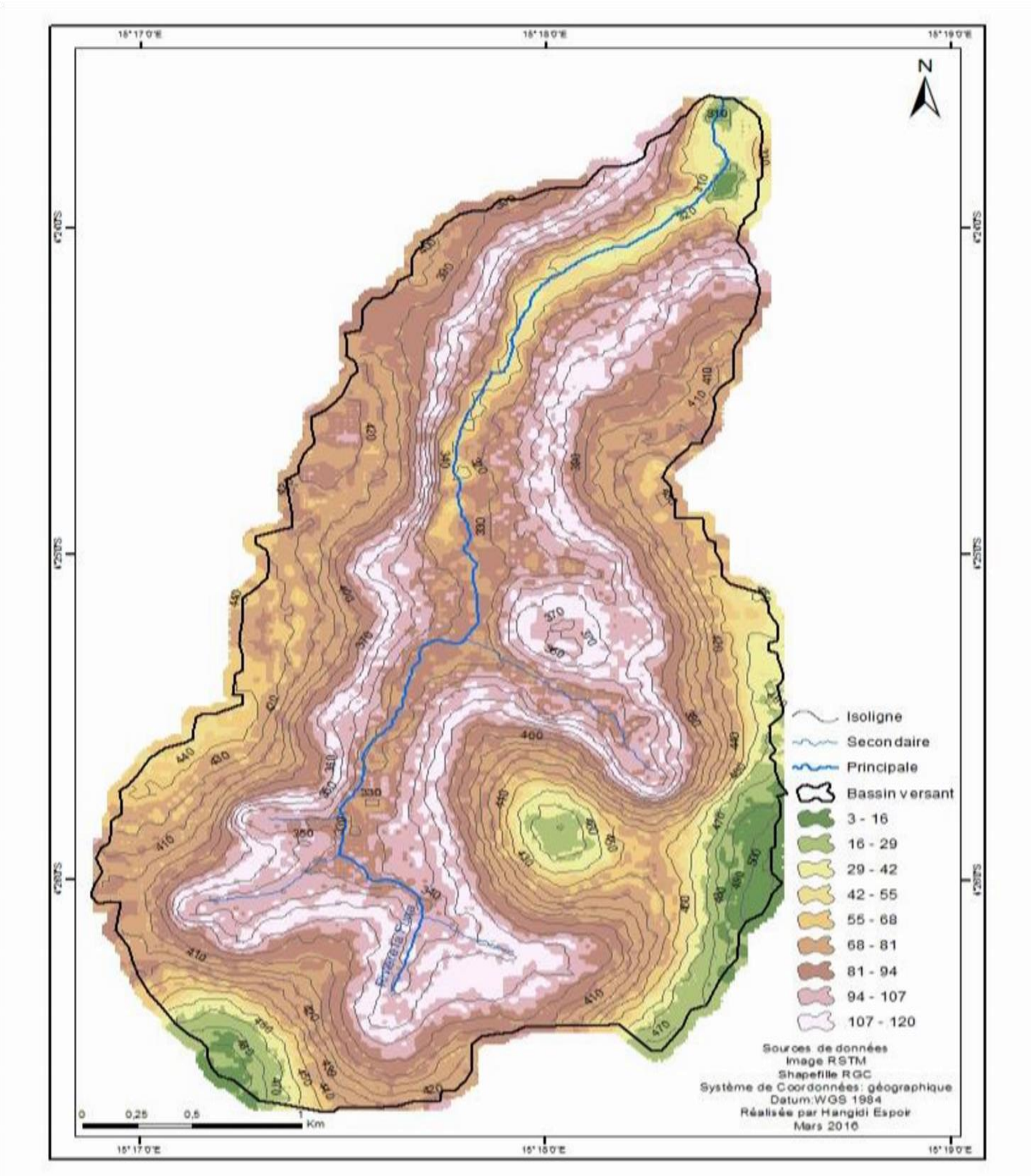

Fig.2: Contour of the study area

II. RESULTS AND DISCUSSION

We gather and present here the results of this research and their discussion. These results are presented in the form of plates and tables.

II.1. Presentation of results

The results of this study are presented in two parts. In a first part, they present the different situations of sealing of the catchment area in 2001 and 2015; the individual and total runoff coefficients of different areas including the situation in 2001 and 2015, and presents the runoff rate in the watershed concerned.

In the second parts, it presents the slopes and the spatial distribution of constructions in the different classes of slopes in the catchment area concerned through maps.

II.1.1. Spatial distribution of sealed areas

The plates below illustrate the spatial distribution of sealed areas in difference of 15 years apart, i.e. from 2001 and 2015, in the watershed:

a) The undivided FUNA watershed

The sealed areas as shown on this plate are those detected in 2001 in the FUNA watershed.

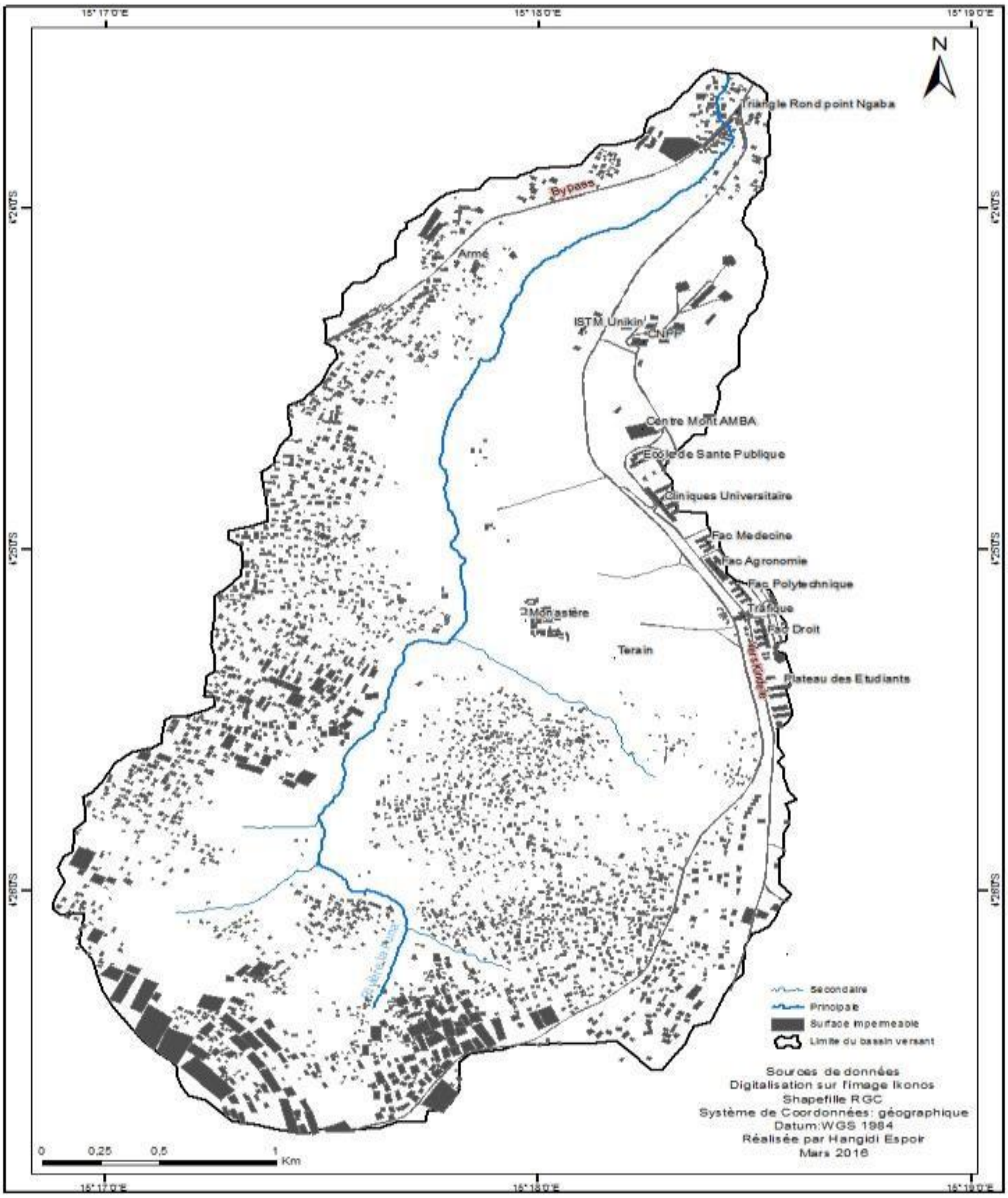

Plate 1: Type of land use in the FUNA watershed in 2001

Table 1 : Runoff coefficient and rate in the study area in 2001.

A_i (m^2)	Coefficient (C_r)	individual Coefficient (C_i)
Permeable Surface Area with High Vegetation Density		
285238,6599m²	**0,35**	**238,6599 x 0,35 =34941,7358**

Permeable surface Low Vegetation Density = A-$\sum SupImp - \sum Sup.Gv$

676109,05202m² 0,7		**'6109,0520 x 0,7 =473276,3364**
Surface Waterproofed		
961347,712m² 1		**961347,712 x 1= 961347,712**

Cr= $\frac{\sum Ci}{\sum Ai} = \frac{1469565,78}{11,5050Km^2} = \mathbf{0,12\%}$

Rain intensity (i)= 25mm pour 30mn.

Total basin area (A) =$\mathbf{11505018,8451}$ m²

Flow rate (Q) =ψ $* C_r *$ **i** $*$ **A** = $14\boldsymbol{m^3/S}$

The precedent Table above, presents the results from Calculation of runoff flow for the year 2001; considering the average precipitation intensity of a normal rain of 25mm/30mn which is
25.10^{-6} with a runoff coefficient of 0.12; a Reduction coefficient taking into account the spatial distribution of rainfall over the catchment area of 0.98086 and a total area of the catchment area of 11505018.8451m².

Calculation of runoff flow for the year 2001.

By taking the average precipitation intensity of 25mm for a time of 30 minutes, we have:

$$i = \frac{25mm}{1800} = \frac{25.10^{-6}}{1800}$$

Cr= 0, 12

Ψ = 0, 98086

$$Q = \frac{0,12 * 0,98086 * 11,5050 * 25.10^{-6}}{1800}$$

= 0, 014.$10^{-6} km^3$/s

⟹ $1km^3 = 10^9 m^3$/s

Q = 0, 014. 10^{-6} . $10^9 m^3/s$

= 0,014. $10^3 m^3$/s

Q = 14 m^3/s

a) The randomly occupied FUNA catchment area

The figure below shows the impermeable areas in land that has not been urbanized for the most part, detected during the year 2015, i.e.

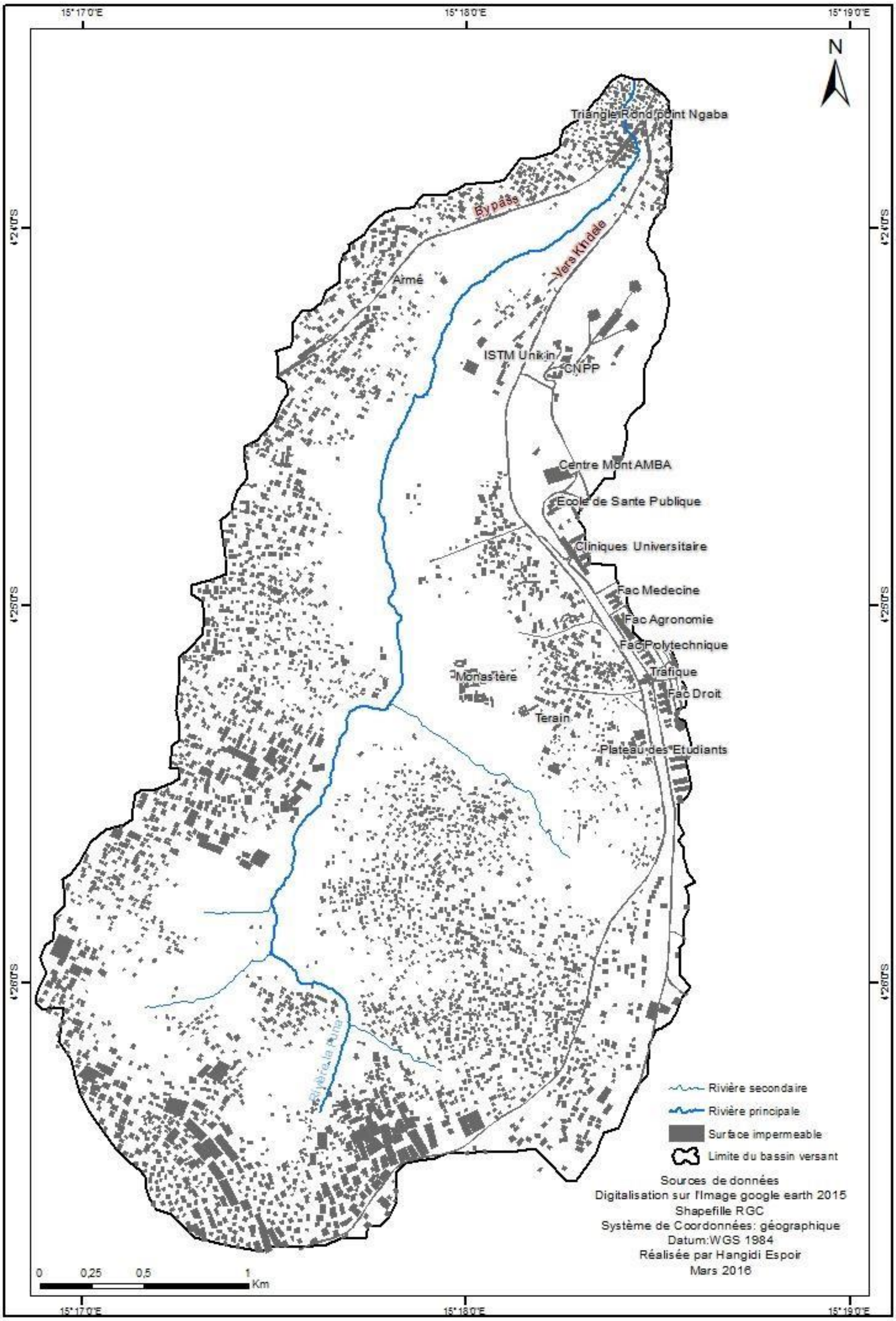

Plate 2: Type of land cover in the FUNA watershed in 2015

Table 2: Runoff coefficient and water flow rate in the catchment area for the year 2015

A_i (m^2)	**Coefficient (C_r)**	**individual Coefficient (C_i)**
Permeable Surface Area with High Vegetation Density		
281702,4489	**0,35**	**281702,4489 x 0,35 =98595,8571**
Permeable surface Low Vegetation Density =A-$\sum SupImp - \sum Sup.Gv$		
10174134,2461	**0,7**	**10174134,2461 x 0,7 =7121893,9723**
Surface Waterproofed		
1049182.15m^2	**1**	**1049182.15x 1= 1049182,15**
Cr=$\frac{\sum Ci}{\sum Ai}=\frac{8269671,97945289335}{11505018,8451554} = 7,18\%$		
Rain intensity (i)= 25mm pour 30mn.		
Total basin area (A) =**11505018, 8451 m²**		
Flow rate (Q) =$\psi * C_r * i * A$ =**1222m³/S**		

The table above presents the results from Calculation of coefficients and runoff flow for the year 2015; considering the average precipitation intensity of a normal rain of 25mm for 30 minutes which is worth at 25.10^{-6}; a runoff coefficient of 7.18; a reduction coefficient taking into account the spatial distribution of rainfall over the catchment area of 0.98086; and a total catchment area of 11505018, 8451 m². Calculation of runoff flow for the year 2015

By taking the average precipitation intensity of 25mm for a time of 30 minutes, we have:

Cr= 7, 18

Ψ = 0, 98086

$$i = \frac{25\,.\,10^{-6}}{1800}$$

$$Q = \frac{7{,}18\,.\,0{,}98086\,.\,11{,}5050\,.\;25.\,10^{-6}}{1800}$$

$= 1{,}222.10^{-6} km^3/s$

⇒ $1km^3 = 10^9 m^3$

$Q = 1{,}222\,.\,10^{-6}\,.\,10^9$

$Q = 1{,}222\,.\; 10^3 m^3/s$

$Q = 1222\; m^3/s$

c) Topography, urban structure, anarchic occupation of slopes and risk of gullying and flooding in the FUNA watershed.

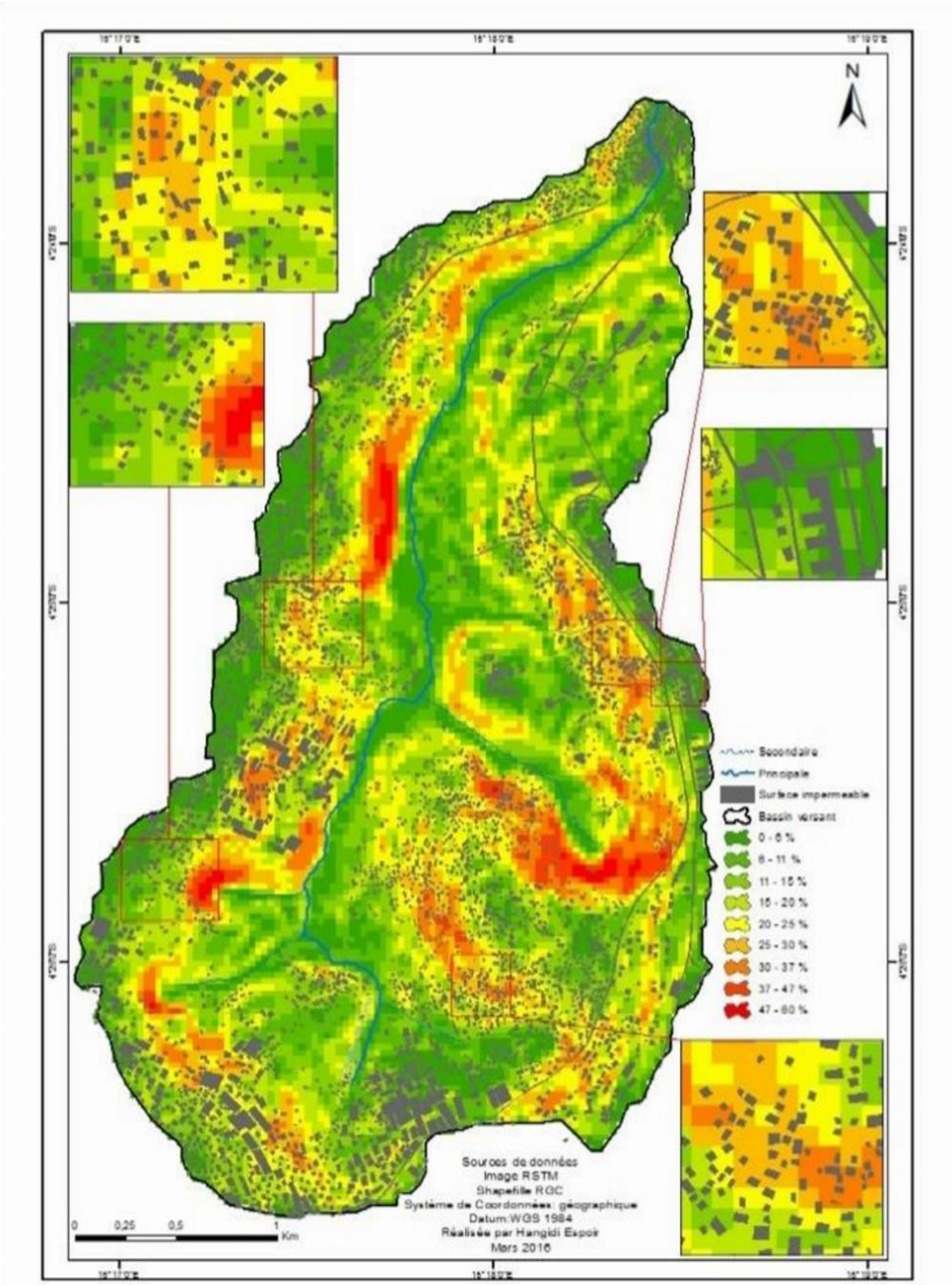

Plate 3: Spatial distribution of impermeable areas of the watershed in 2015.

DISCUSSION

Ikonos and Google Earth satellite images allow us to report daily on the extent of urbanization all over the world, particularly in the city of Kinshasa and precisely in the watershed studied.

On the basis of these data provided in the form of polygons, the various spatial analyses, and calculations of the coefficients and runoff flow were carried out to highlight the zones and periods at high risk of soil erosion and flooding. It savors that the year 2015 presents a great risk of erosion with a runoff rate of 1222m3/S against 14m3 for 2001.

The results illustrated in plates 3 and 4 above on the spatial dispersion of impermeable surfaces also provide information on the rate of modification of the urban fabric of the FUNA catchment area in the space of 14 years.

Indeed, the runoff coefficients and flow rate calculated for each year of study show that the years most exposed to so-called ravine soil erosion generally correspond to the range from 2015 or beyond.

The most representative year in terms of maximum percentage of site occupancy is 2015 with a runoff coefficient of 718%.

With regard to the slope in the two cases of 2001 and 2015, Figure 6 shows that the waterproofing of surfaces in high-risk areas is not homogeneous and varies from one year to another. The highest occupancy peaks are observed in 2015.

In accordance with urban planning standards which stipulate that: any occupation of land with slopes beyond 6% is prohibited (Anonymous, 2012).

Indeed, Table 5 and Plate 5 prove that the Funa watershed was occupied in an anarchic manner in defiance of the land use master plan of the city of Kinshasa. This reality is also noted in other neighborhoods of the city.

CONCLUSION AND SUGGESTIONS

The general objective of this study was to make an analysis in order to be able to control the erosive process of the watershed by studying the mechanisms of development of runoff in order to protect the population against the risks of soil erosion and flooding in the watershed of the FUNA more precisely in the KINDELE district.

The analysis of the surfaces impermeable by the elaboration, on the basis of the satellite images of the tables and plates relating to the coefficients and flow of runoff and spatial distributions of the impermeable surfaces, enabled us to highlight the risk of flooding and gullying of the study area and the most risky places for dwellings on the other hand.

It is evident that these ravines are caused by the high concentration of water coming from impermeable surfaces and urban infrastructure such as roads, clogged gutters/sewers and destroyed collectors, as well as footpaths.

By sealing the soil and concentrating large quantities of runoff water, in increasingly steep slopes, urbanization modifies the natural drainage of the soil and increases the hazard in this area where it already existed. It would therefore be the main cause of the erosion that threatens the sandy slopes of the FUNA basin at Kindele / Mount Ngafula.

All this information would allow the public authorities of the city of Kinshasa to be able to plan the subdivision before selling plots in risk areas.

For the proper management of risks in these spaces, the solution is to make better decisions in terms of urban planning and land use in the city of Kinshasa.

Plate 3 produced for the case of the year 2015 shows exactly the growing threats suffered by the inhabitants of neighborhoods in the face of erosion and flooding. This constitutes a danger for the biophysical and socio-human environment. These maps could be used to locate impermeable areas built on slopes that do not meet town planning standards and to relocate and compensate occupants or operators so as to preserve sensitive areas and plan construction activities. layout.

However, urban development efforts in these neighborhoods must start from the base of the social pyramid because the success of the management of these neighborhoods depends on the protection that the populations of the neighborhood will find. Therefore, it is of interest to promote urban subdivision and urban development projects in the municipality of Mount Ngafula.

From all the above, we recommend to the institutions in charge of the management of urban planning in the country:

- Develop a program for monitoring and implementing the land use plan and the national strategy for managing natural disasters.
- Establish an effective surveillance service for the protection of green spaces in the city. A fairly high number of eco-guards would be essential to enforce the legislation protecting public spaces against uncontrolled construction. As such, adequate equipment will allow them to monitor and roam all of these spaces;
- Set up a monitoring and evaluation system through a geographical information system (the remarkable possibilities offered by GIS and remote sensing) for the effective analysis of data on the detection of anarchic constructions and the evaluation of their impacts on the environment ;
- Finally, it would be desirable for this study to be supplemented by an increase in the number of hours of field observations in order to precisely determine the environmental problems so as to accurately assess the real impacts of runoff water on the population. neighborhood.

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