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A Study of Erosion in the Mfuti Watershed for the Sanitation and Protection of the Zamba-Telecom Road in Kinshasa/DR Congo

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ABSTRACT

Zamba-Telecom is a road that has suffered erosion for a long time, more particularly gullying, due to poor drainage of runoff water and uncontrolled urbanization of the area in which it is located. We carried out a hydrological study throughout the watershed in which this road is located, in order to best size a canal attached to the road, which will effectively drain rainwater upstream. According to our calculations, to better manage this water, this road must be attached to a free surface canal, with a base of 1.3 m and a height of 1.4 m to thus evacuate a total peak flow of 7.462 m^3/s to the Mfuti river. However, after carrying out a field trip, we sampled the soil from this watershed and passed it to the laboratory. It turns out that the soil of the basin is mainly made up of fine sand, the grain size of which is 0.05 to 0.4 mm. For our different samples taken, the Atterberg limits gave the average value of the Plasticity Index: 8.8; the liquidity limit: 14.79 and a plasticity limit of 6, this watershed has solid, moderately plastic soil. Therefore, to protect the road from possible erosive phenomena, we should already limit urbanization in this area to limit runoff and instead encourage the infiltration of rainwater. We need to plant enough trees downstream of the watershed and develop best soil conservation practices.

Keywords: Erosion, Gullying, Drainage, Urbanization, Mfuti watershed

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1. INTRODUCTION

The transport sector constitutes an essential factor in the development of a country because it facilitates its economic growth by allowing the transport of economic goods as well as population mobility [1]. As for roads, they are excellent vectors through which this development can take place. Peri-urban areas, neither totally urban nor totally rural, therefore represent most of the surface area of large urban agglomerations. With increasing urbanization, these spaces are and will be subject to increasing pressure and controlling their development and planning is an important issue for the management of rainwater and polluting discharges. [2]. Most of the city of Kinshasa is covered in a mantle more or less thick sandy and sandy-clay materials of yellow, light brown and sometimes reddish [3]. In summary, the lithostratigraphy of the city of Kinshasa and its immediate surroundings is made up of Inkisi sandstone, marly sandstone, soft sandstone, coarse sands and kaolin sands [4].

There are hydrological risks to which a slope is exposed during an increase in runoff [5]. Water erosion results from the detachment, under the effect of the kinetic energy of raindrops, and the transport of fragments or particles of soil or rocks from their initial location by water, degrading water quality and soil fertility and reducing reservoir capacity [6]. The phenomenon of erosion modifies the shape and hydrology of environments, and sometimes causes land movements. The consequences can be serious for biodiversity as well as for the safety of everyone in the direct vicinity of the environment. Erosion also leads to a degradation of water quality, caused by suspended solids. Sometimes people or even heavy objects are swept away by the current. It is a known fact that runoff can concentrate along roads and create gullying problems [7].

Water erosion in general and in particular gullying constitutes a major problem in the upper city of Kinshasa, but it should also be noted that the consequences of erosion are not limited only to the loss of land values eroded, they have extremely serious repercussions on elements of general interest [8]. The correlative problems are the deposits and silting in the valleys and in the lower town due to the floods of larger rivers which previously did not reach such magnitude. The upper town is heavily dissected by deep (30m) and wide (40m) ravines several hundred meters long. Thus, the urban site is locally transformed into bad land. These mega-ravines isolate and separate inhabited neighborhoods into islands, thus jeopardizing any harmonious development of the city. On the hillsides and slopes, torrents shape the relief and landscape of Kinshasa.

The phenomenon of silting is accentuated by the addition of household waste and other garbage. This accentuates the phenomenon of flooding in the neighborhoods of the Kinshasa plain (Bandalungwa, Lingwala, Ngiri Ngiri, Kasa Vubu, etc.), this sometimes disrupts the electrical supply otherwise causing cases of electrocution [9]. There are different types of flooding in Kinshasa; notably river flooding (N'djili and Pool Malebo due to rain falling upstream), backwater flooding of the N'djili due to flooding of Pool Malebo following high water from tributaries such as the Oubangui and full-bank flows of local watercourses due to local rainfall. Thus, despite a sufficient slope (2.3 - 7%) of the hydrographic network to evacuate the heaviest rains within a period of time estimated at 24 hours [10], we very often record during rains of a certain intensity flooding in the lower town in November and December.

2. METHODS

For this study, we proceeded as follows:

- Literature review: the literature review allowed us to sufficiently document our subject as well as the area of our study. The synthesis of books, theses, dissertations, articles, scientific journals, as well as the use of the Internet constituted the first stage through which we went in order to constitute the background of this work and also, the very understanding of our subject of study;

- Field investigation: in order to understand how to proceed and situate our study, we carried out a field trip, where we had to discuss with the occupants of the area, in order to identify the erosion problems in the region and thus better guide our work;

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- Laboratory: after the soil sampling phase, they are sent to the laboratory to be subjected to various analyzes and tests.

Study area

The "Zamba-Telecom" road is located in the City-Province of Kinshasa, more precisely in the commune of Mont Ngafula (figure 1a). It is located in the Musangu district, Antenne (in the North), Kimbondo (in the South-West), Mitendi (in the South-West) and Sans-fil (in the South-East). Taking the Béliar firm stop as a reference point (figure 1b), the road is geolocated under the coordinates: 15.22°E and 4.45°S.

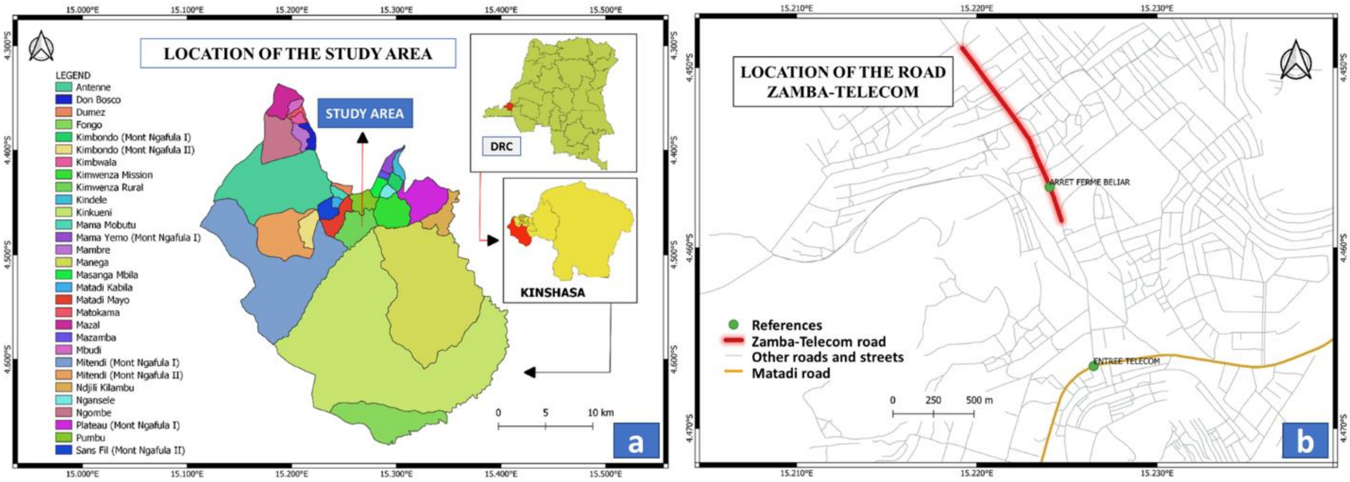

Fig. 1: Location of the study area (a), Zamba-Telecom Road (b)

The "Zamba-Telecom" road, shown in outline in the figure 1b, measures approximately 2km in length, starting from the Telecom Entrance in the south, where it intersects the Matadi main road, to its terminus located in the north. However, the figure highlights the part which was in the middle of the rehabilitation phase, measuring 1200m in length.

3. RESULTS AND DISCUSSIONS

3.1. Hydro-Climatic Context

Precipitation is obviously the essential factor in hydrological regimes since it constitutes the raw material for river flows. The nature of information what we need about them depends on the problem to be treated: assessment, maximum flood on a small or on a large pool, etc. On the other hand, the methods of interpretation may differ depending on the nature of existing observations which, often, we must be content with [11]. Processing the recordings makes it possible to determine the average of the data collected as well as the statistical laws to which the distributions of the values obtained from a station obey. Characteristic values are those reflecting the characteristics common to a series of measurements. This includes the mean and the standard deviation [12].

The rainfall data as well as the temperature data collected by the METTELSAT BINZA station are listed in the tables below:

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Table 1: Precipitation data in mm for 12 years

Year	J	F	M	A	M	J	J	A	S	O	N	D
2010	85.2	72.4	260.3	250.8	45.3	0.0	0.0	0.0	15.8	103.0	225.1	232.8
2011	286.4	98.0	31.1	380.9	187.1	0.0	0.0	0.0	73.9	318.1	535.1	227.4
2012	9.6	114.2	101.7	119.4	184.0	0.0	0.0	4.2	54.6	229.1	274.0	292.8
2013	204.1	212.0	216.7	385.5	249.2	0.0	0.0	0.0	25.8	180.7	262.4	339.0
2014	197.8	33.8	182.4	196.8	214.6	0.0	1.2	6.8	20.9	172.8	245.4	118.4
2015	48.8	87.0	189.9	192.7	97.7	0.0	0.0	0.0	13.2	74.4	389.3	351.1
2016	100.2	251.6	419.0	198.1	204.6	2.8	0.0	63.6	15.8	107.4	311.6	220.1
2017	153.2	237.5	55.7	167.0	226.8	21.2	0.0	0.0	56.4	103.4	148.5	382.8
2018	259.1	180.3	79.0	180.0	191.7	5.9	0.0	0.0	2.0	139.1	250.0	510.5
2019	181.1	218.8	214.2	102.8	109.4	0.0	0.0	0.0	47.6	450.5	267.4	348.2
2020	269.4	165.4	157.8	380.5	177.2	0.0	3.2	0.0	11.5	187.0	261.5	217.6
2021	50.8	144.8	280.8	172.2	158.5	47.7	0.0	0.0	128.2	57.6	288.6	188.6

Table 2: Temperature data in °C for 12 years

Year	J	F	M	S	M	J	J	A	S	O	N	D
2010	25.3	25.7	26.1	25.9	24.5	22.9	22.1	22.7	25.4	26.6	25.3	25.8
2011	24.8	25.6	26.2	26.1	25.5	23.4	22.4	23.3	24.2	25.4	24.9	24.8
2012	25.9	26.1	27.4	27.1	25.8	24.2	22.1	23.1	25.1	25.2	25.1	25.3
2013	26.1	26.4	26.7	26.6	25.8	23.4	22.4	23.0	25.0	25.5	24.7	25.0
2014	25.4	26.3	26	26.4	26	24.0	21.6	23.4	24.5	25.2	25.5	25.5
2015	25.5	25.9	25.8	26.1	25.8	22.6	22.8	23.0	25.0	25.2	25.5	25.5
2016	25.9	26.1	26.6	25.9	25.4	23.7	22.3	23.5	25.0	25.7	25.4	25.0
2017	25.3	25.1	26.0	26.4	25.5	23.4	22.2	23.0	24.8	24.8	25.0	24.8
2018	24.6	25.6	26.5	26.7	25.0	24.2	23.0	24.3	26.0	26.2	26.0	25.8
2019	25.9	26.3	27.4	26.7	25.7	23.9	22.0	23.0	24.6	25.2	25.0	25.0
2020	25.1	26.3	26.8	26.9	26.2	23.3	22.8	23.6	24.5	25.4	25.4	25.3
2021	24.8	25.3	25.4	26.5	26.2	24.7	22.6	24.4	25.3	25.5	25.8	24.6

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Hydrological parameters were calculated using the data from tables 1 and 2.

Table 3. Hydrological parameters of the Mfuti watershed

N°	Parameter	Formula	Value	Reference
1	Annual rainfall module	$X = \frac{1}{12} * \sum_{i=1}^{12} Xi$	1688.04167 mm	[13]
2	The variance	$S^2 = \frac{1}{(\sum fi - 1)} * [\sum Ci^2 fi - \frac{\sum (Cifi)^2}{\sum fi}]$	13575.8365 $(mm)^2$	[12]
3	Standard deviation	$\sigma = \sqrt{S^2}$	116.515392mm	[12]
4	Coefficient of variation	$CV = \sigma * 100 / \overline{P}$	79.4 %	[12]
5	Rainfall index	$Pme = \frac{Xi}{12}$	139.5875mm	[12]
6	Extent	E = Pm Max – Pm Min	70.608333mm	[12]
7	Climatic dispersal rate	$TDC = \frac{(E-30)}{Pme} * 100$	29.0916687 %	[12]
8	Drainage density	$Dd = \frac{L}{A} = \frac{\sum_{i=1}^{n} Li}{A}$	645.25 m/km²	[11]
9	Hydrographic density	$Dh = \frac{n}{A}$	0.68 watercourses per km²	
10	Concentration time	$Tc = \frac{4 * \sqrt{A} + 1,5 * L}{0,8 * \sqrt{Hm - Hmin}}$	2.404084435 hours	[14]
11	Flow velocity	$V = \frac{9,528}{TC}$	4.940758247 km/h	
12	Evapotranspiration	$ETP = 16(10\, t / I)^a f(\lambda)$	1229.22mm	[15,16]
13	Effective runoff	R =P x 0.05	84.4020833 mm	[17]
14	Moisture capacity	C= P (10%)	168.804167mm	[15]
15	Effective infiltration	$Ie = Pan - (R + ETPan + C_{MFUTI})$	205.615417mm	[12]

The map shown in figure 2 presents the hydrographic network of the Mfuti watershed. We notice that the main watercourse is of order 3.

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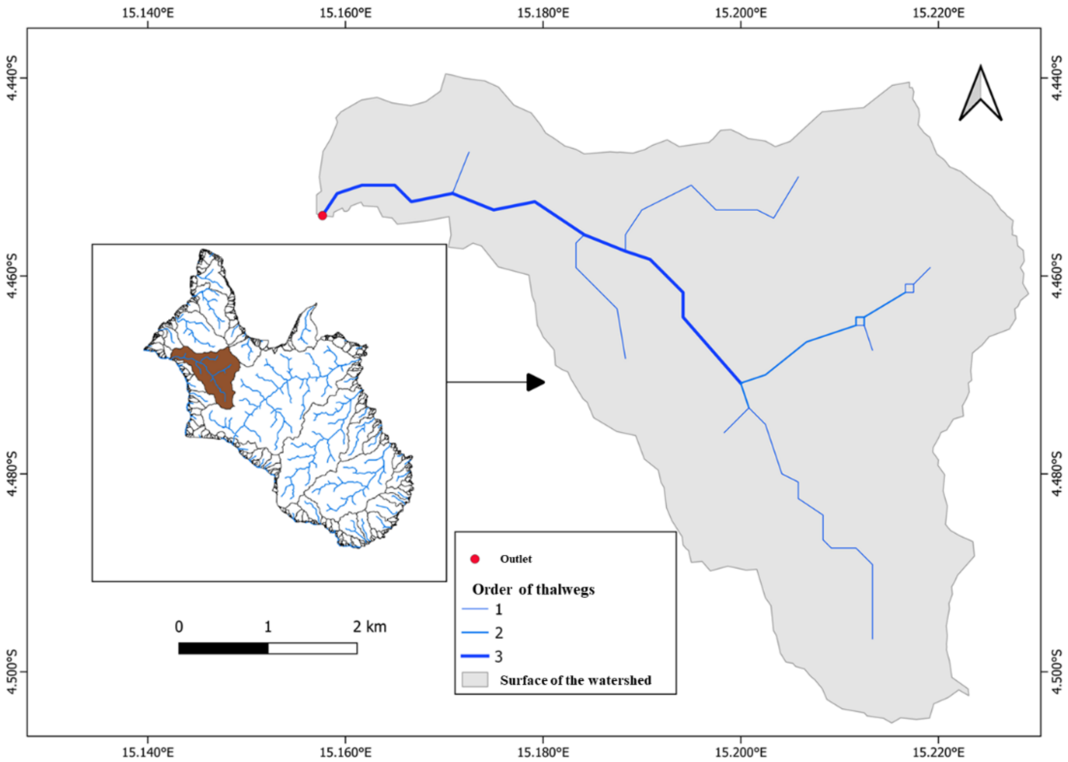

Fig. 2: Hydrographic network of the Mfuti watershed

3.2. MORPHOMETRY OF THE MFUTI WATERSHED

Regarding the topography of the Mfuti watershed, the altitudes measured using ArcGIS software are between 301 and 641m, which can be presented numerically in figure 3a and presented in three dimensions (3D) in figure 3b thanks to the processing carried out on the Global Mapper, ArcGIS, Excel and Surfer software.

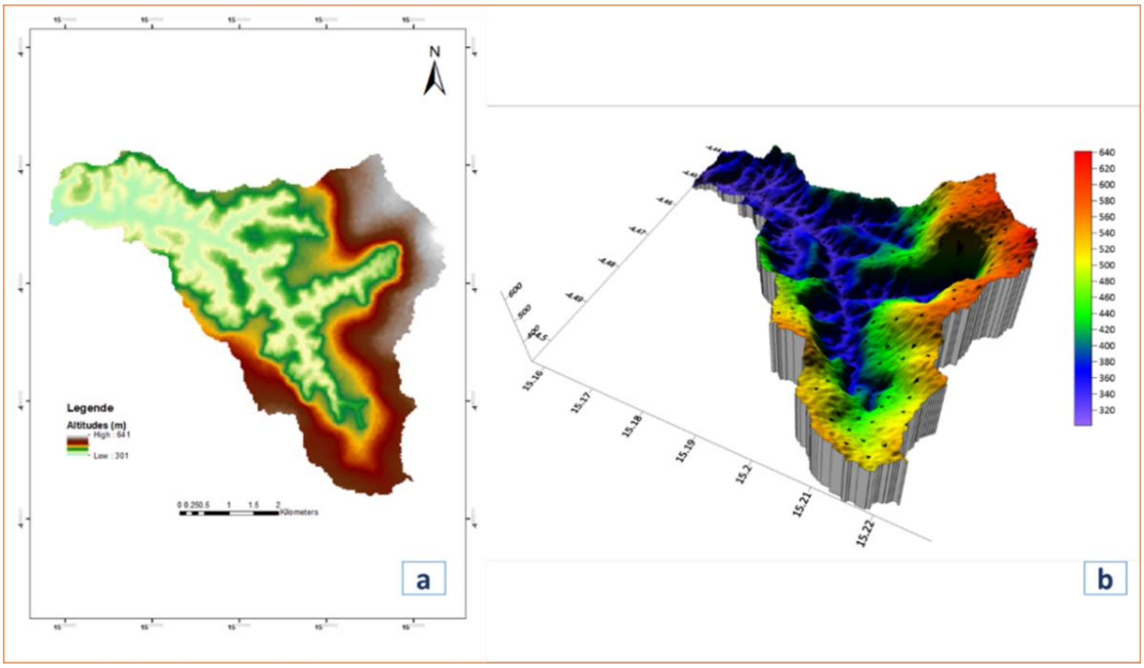

Fig. 3: Digital model of the basin topography (a) and three-dimensional modeling of the watershed (b)

The following table presents the morphometric parameters of the Mfuti watershed.

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Table 4: Morphometric parameters of the Mfuti watershed

N°	Setting	Formula	Value	Reference
1	Gravelius compactness index	$G = \frac{0,28*P}{\sqrt{A}}$	1.51	[18]
2	Equivalent rectangle	$L = \frac{G*\sqrt{A}}{1,12}(1+\sqrt{1-[\frac{1.12}{G}]^2}$ $l = \frac{G*\sqrt{A}}{1,12}(1-\sqrt{1-[\frac{1.12}{G}]^2}$	11.922 km 2.35 km	[12]
3	Average altitude	$Hmm = \frac{\sum Ci*fi}{\sum fi}$	428.9330516 m	[12]
4	Median altitude	$Hme = 381+40*\frac{(50-44,91)}{15,02}$	394.55526 m	[12]
5	Modal altitude	$Hmo = 341+40*\frac{(29,10-10,93)}{(29,10-10,93+29,10-15,05)}$	363.5595183 m	[12]
6	Slope index	$Ip = \frac{1}{\sqrt{L}}*\sum\sqrt{\frac{ai*(Hi+1-Hi)}{A}}$	0.5%	[12]
7	Overall slope index	$Ig = \frac{DU}{L}$	19.92241235 m/km.	[12]

The following figure presents the hypsometric curve of the watershed (a), the class including the modal altitude of the watershed (b) and the bell curve representing the modal class of the watershed (c).

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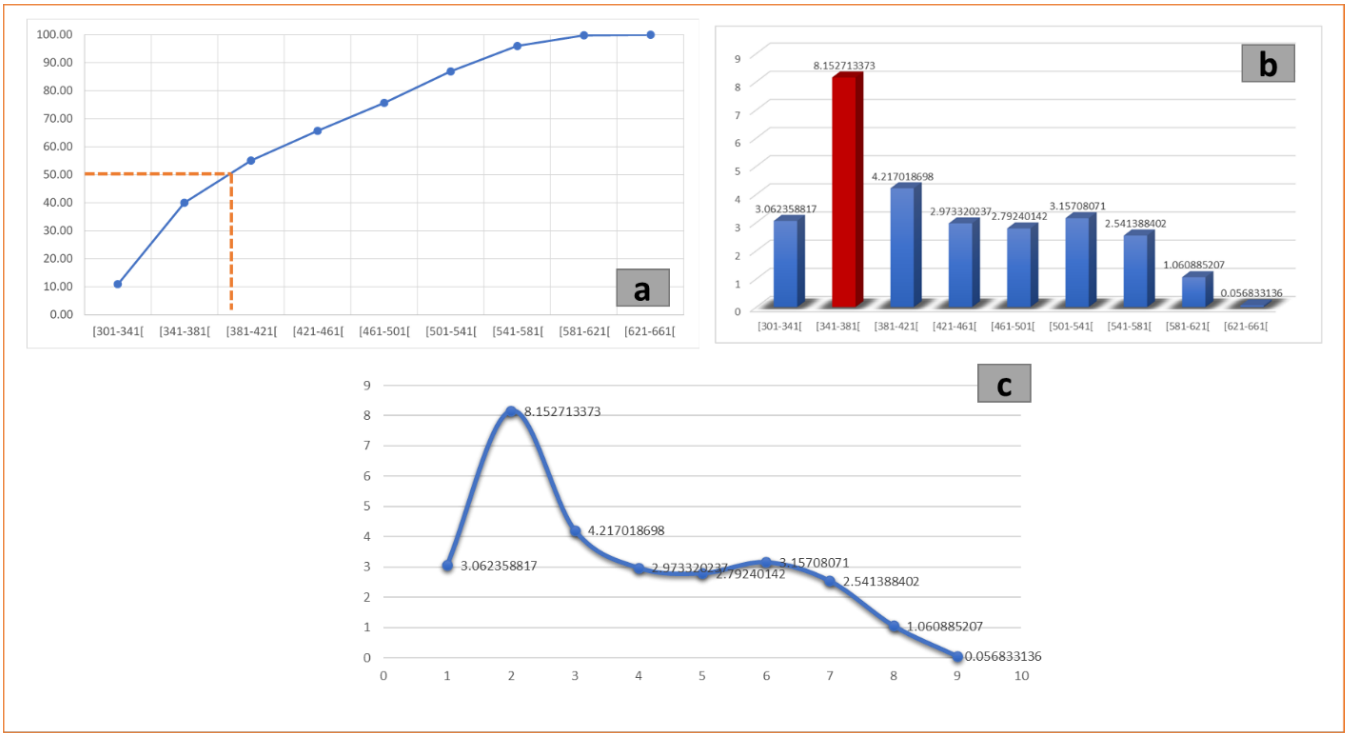

Fig. 4: Hypsometric curve of the watershed (a), Representation of the class including the modal altitude of the watershed (b) and Bell curve representing the modal class of the watershed (c).

According to the Overseas Scientific and Technical Research Office classification, the relief is quite moderate (figure 5).

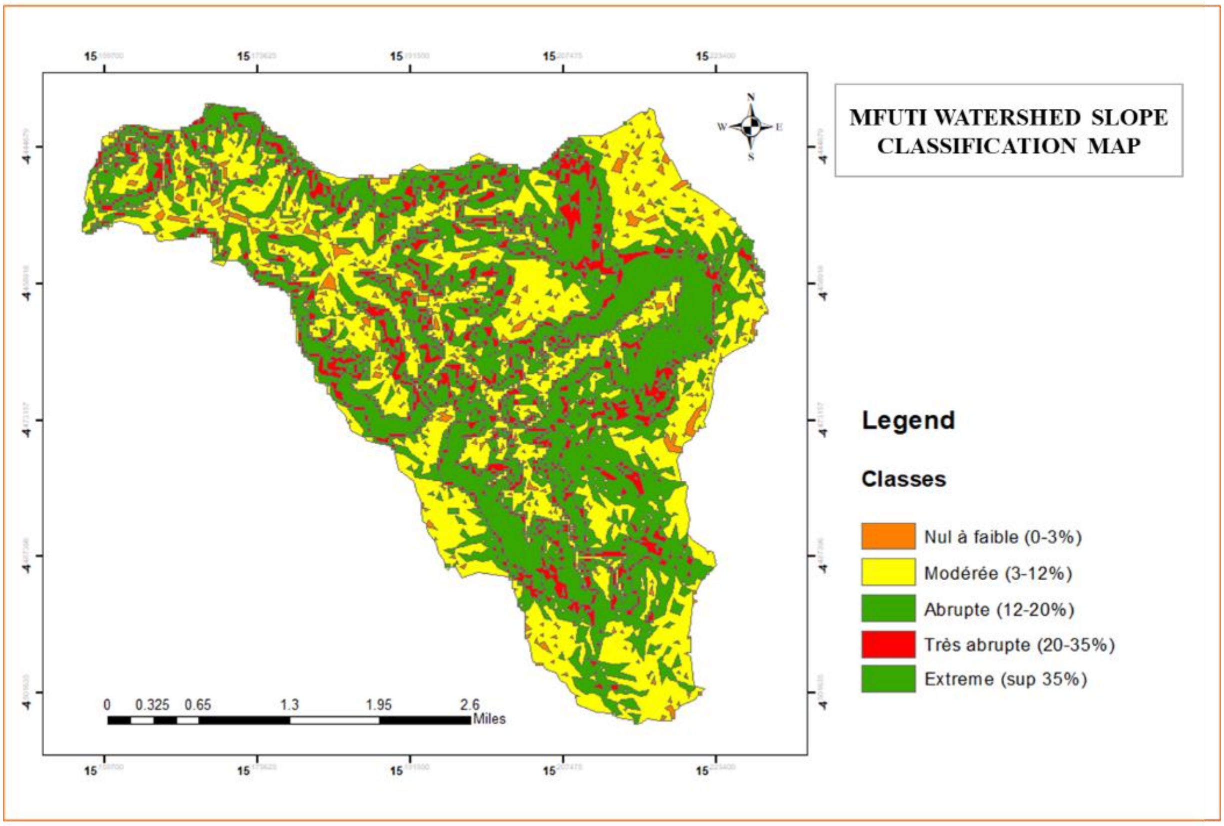

Fig. 5: Modeling of the different slopes in the watershed

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3.3. CHANNEL SIZING

Once the study and analysis of all the characteristics of the watershed has been carried out, for practical sizing and close to reality, in this large Mfuti watershed we have delimited a sub-watershed in order to size a canal to which the road will be attached, which at its lowest point will play the role of an outlet for water collected from the avenues to be led to the river.

In fact, the profile of the road is as follows:

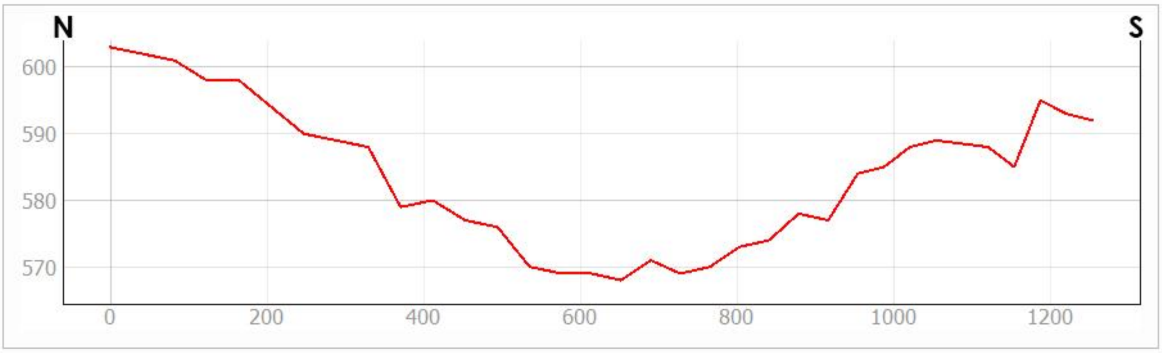

Fig. 6: Topographic profile of the Zamba-Telecom road

The waters will therefore flow from North to South and from South to North, on a slope estimated at 0.054 m/m. The sub-basin delimited with the QGIS software is shown in figure 7a and after modeling on Surfer this artificial watershed is shown in figure 7b. The arrows in figure 7b indicate the direction of rainwater flow which based on the topography, leaves the higher altitudes for the lower ones. In black is shown the canal which will receive all this rainwater.

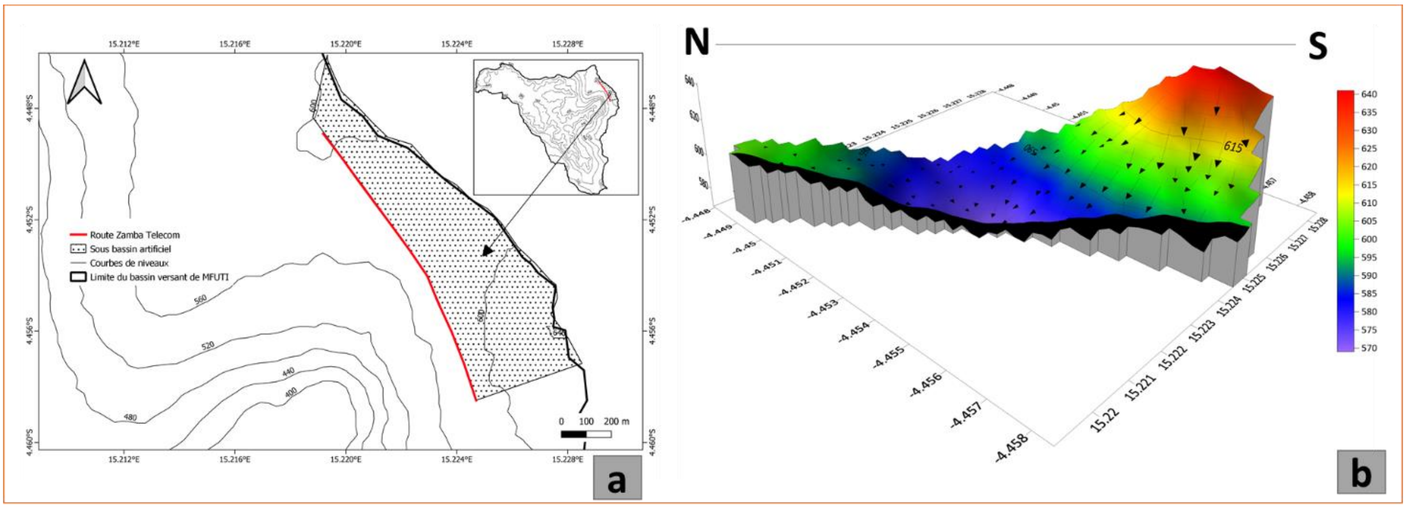

Figure 7: Section of the artificial basin (a) and basin cut in 3D (b)

In order to size this main channel, we used the Manning equation. But first of all, we will determine certain parameters using the following methods:

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Peak flow method according to SCS

Soil Conservation Services (SCS) peak flow method calculates peak flow based on drainage of the basin area, potential soil storage, and concentration time. This rainfall-runoff relationship separates total precipitation into direct runoff, retention, and initial abstraction to yield the following as the rainfall-runoff equation [19].

$$Q_d = \frac{(P - 0{,}2Sr)^2}{P + 0{,}8Sr}$$

With Qd: the precipitation height (mm); P: the amount of precipitation over 24 hours (mm); S_r: is the soil retention (mm), which could be obtained from the formula below:

$$Sr = 25{,}4(\frac{1000}{CN} - 10)$$

With CN: which serves to provide a simplified relationship between precipitation and runoff based on local land use, soil storage and infiltration conditions. The values of CN or even "Curve Number" appears in the table in the appendix, where we opted for the numerical value of 89, because we estimated that the ground is paved with open channels and moderate infiltration as well as moderate runoff [19]

Hence: S_r = 31.3932584 mm; with P = 99 mm. Therefore, Q_d = 69.2686273 mm and we can calculate the runoff coefficient (C) as follows: C= Qd / P hence: C= 0.6996831

Rational method

The rational method has been the most commonly used method for calculating peak flow for both urban and rural areas less than 80 ha since the 1900s. This method assumes that peak flow occurs when the entire watershed contributes to the flow and that the intensity of precipitation is the same throughout the drainage area and uniform over a duration equal to the concentration time [19].

$$Q_P = \frac{f_a.C.I.A}{360}$$

With Qp: peak flow of the watershed (m^3/s); f_a: is the antecedent precipitation factor, which is equal to 1.0 for a storm return period of 2 to 10 years, and 1.1; 1.2 and 1.25 for return periods of 25, 50 and 100 years, respectively; C: is the dimensionless runoff coefficient; I: is the intensity of the rain (mm/h); A: is the drainage area (ha) [19]

In our case, the precipitation factor that we choose is 1.0 because we are in the design of a main channel attached to a road. Therefore, our calculations will have a storm return period ranging from 2 to 10 years, taking into account the probable duration of this route. Considering our artificial sub-watershed which will collect water coming from the surrounding avenues, we therefore considered its surface area A= 45.4205 ha; C=0.6996831; I= 83.6 mm/h considering the maximum intensity of the intensity data collected at METTELSAT. By replacing each value in the formula, we will have:

$$Q_p = 7.3800121 \text{ m}^3/\text{s}$$

We therefore need to size a channel with the capacity to receive a total flow of 7.4 m^3/s. This is why we use the Manning equation:

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$$v = \frac{0.379}{n} R^{2/3} S_0^{1/2}$$

With v: speed (m/s); n: Manning coefficient; R: wetted perimeter (m); S_o = the slope of the land (m/m). For our case we want to dimension a channel with a rectangular wetted section, obviously with a free surface. However, we must also dimension the base and height of this channel to obtain its wetted perimeter and the wetted section, finally so that this channel receives the calculated flow.

Using an Excel sheet, we proposed the height and base values. Also, by introducing formulas such as: R =S/(B+2*H), with R: perimeter; S: wetted section; B: the base; H: height.

Knowing that the flow rate is equal to the speed multiplied by the wetted section. We therefore have the following situation:

Table 5: Channel sizing calculations

B	H	S	R	$R^{2/3}$	So	$So^{1/2}$	n	1/N	V
1.3	1.4	1.82	0.44390244	0.58191339	0.054	0.232379	0.025	40	2.05

Thus, with this simulation on Excel, we obtain a base and a height of the channel which influences the calculations on the Excel sheet, thus allowing us to have the flow capacity of the structure: Q=V*S, therefore Q=2.05*1.82; Q=3.731 m^3/s for half of the work. So, the total flow is Q*2= 7.462 m^3/s. These are the dimensions to be given to the canal.

3.4. GEOTECHNICAL TESTS

Particle size tests

Particle size tests consist of dividing a material into several granular classes of decreasing sizes using a series of sieves. The masses of the different rejects and sieves are related to the initial mass of material. The percentages obtained are used in numerical and graphic form.

Table 6: Results of particle size analyzes

Samples	Maximum diameter in mm	% Of fines
E1	0.9	11
E2	0.5	4
E3	1.0	8
Average	**0.8**	**7.6**

Which can be represented in the following way:

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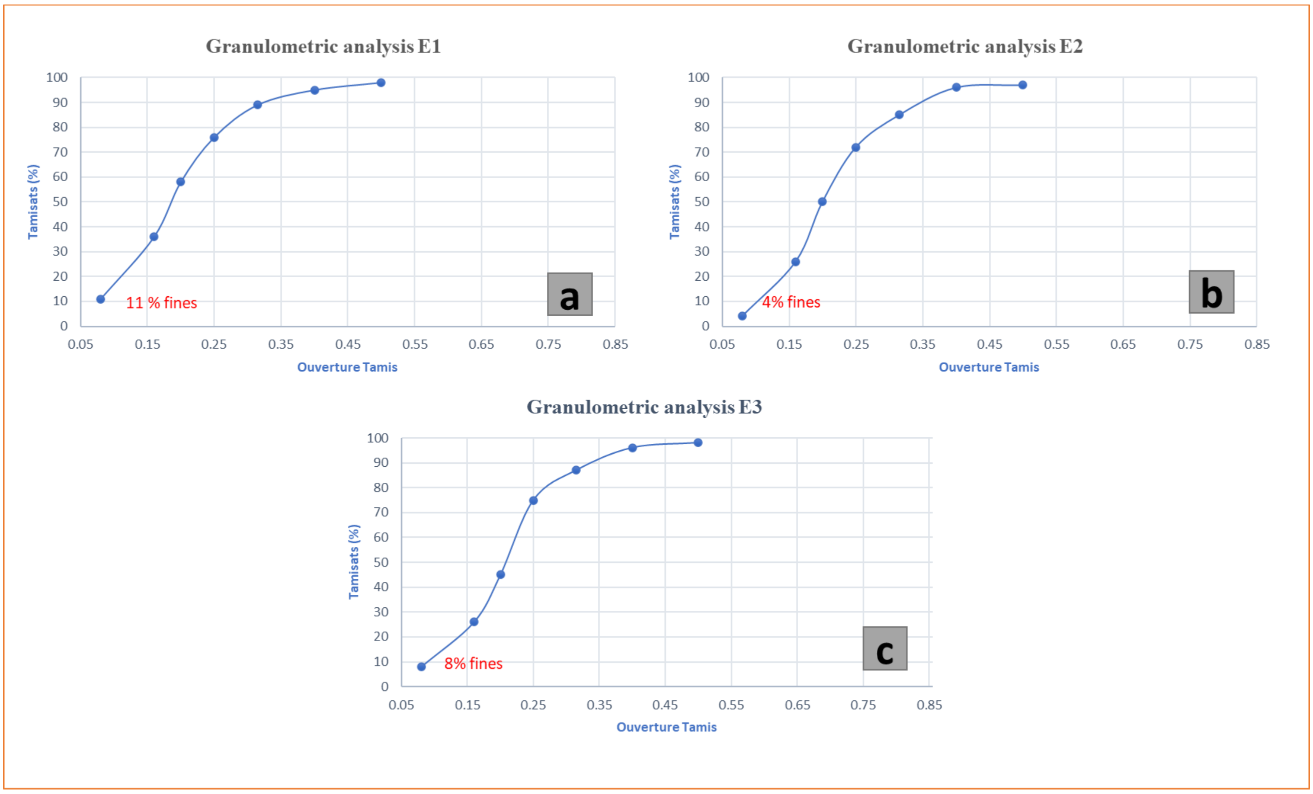

Fig. 8: Particle size curves of the samples

Natural water content (NF P94-050)

Natural water content is a test identification which allows us to know the quantity of natural water which is found in the soil sample [20]. It is expressed in % by the formula:

$$W (\%) = 100 (Ph - Ps) / Ps$$

With: Ph, the weight of the soil sample in its natural state; Ps: the weight of this soil sample after passing it in an oven at 105°C for 24 hours. It is the net dry weight which is equal to the difference in the total dry weight at weight of the tare used: Ph – Ps = Weight of water.

Table 7: Results of analyzes of the water content of the samples

N°	Sample	Water content
1	E1	4.2
2	E2	4.4
3	E3	3.5
	Average	4%

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Atterberg limits

The aim of this part is to determine the limits of liquidity and plasticity of a soil. It is carried out on the part of soil passing through a 400µm sieve. Atterberg limits are geotechnical parameters intended to identify a soil and also to characterize its condition.
Thus, the results obtained are presented as follows:

Table 8: Results of analyzes

Sample	Liquidity limit	Plasticity limit	Plasticity index
E1	15.57	6	9.57
E2	15.60	6	9.6
E3	13.2	6	7.2
Average	14.79	6	8.8

According to our particle size analyses based on the shape of the grain size curves, we can deduce the types of soil in question. Overall, we distinguish three types of particle sizes which are defined by the shape of a particle size curve. We have in particular: spread or continuous grain size, discontinuous or uniform grain size and grain size with several discontinuities or stairs. As a result, the shape our curve takes indicates a soil with uniform grain size. Based on the table of geotechnical characteristics of sandy soils, the refusal at 0.5 mm is less than 10%, in this case this soil is part of class S3, more precisely class 3a. For our three samples, the Atterberg limits give the average value of the Plasticity Index: 8.8; the liquidity limit: 14.79 and a plasticity limit of 6. We are therefore in the presence of a basin with solid, moderately plastic soil. Moreover, we can also characterize the consistency of one of the soil samples by the ratio below:

$$I_{C\ =} = \frac{WL-W}{Ip} = \frac{15.62-4.4}{9.62} = 1.17$$

With $I_{C:}$ liquidity index. If $I_c < 0$ the soil is plastic, If $I_c > 1$ the soil is solid, If $I_c = 0$ the soil is liquid.

3.5. ESTIMATION OF SOIL LOSSES IN THE WATERSHED

To do this part, we used ArcGIS software. First, we obtained the satellite image using the 10 m Sentinel-2 satellite. Which features time series of global land cover from 2017 to 2021. This layer displays a global land use/cover map. The global maps were produced by applying this model to the Sentinel-2 scene collection on Microsoft's planetary computer, processing more than 400,000 Earth observations per year [21]. The underlying deep learning model uses 6 bands of Sentinel-2 surface reflectance data: visible blue, green, red, near infrared, and two shortwave infrared bands. To create the final map, the model is run on multiple imaging dates throughout the year, and the outputs are composited into a final representative map for each year [21]. From our processing of the map relating to our study area we obtained the following results represented on the land use map of the watershed:

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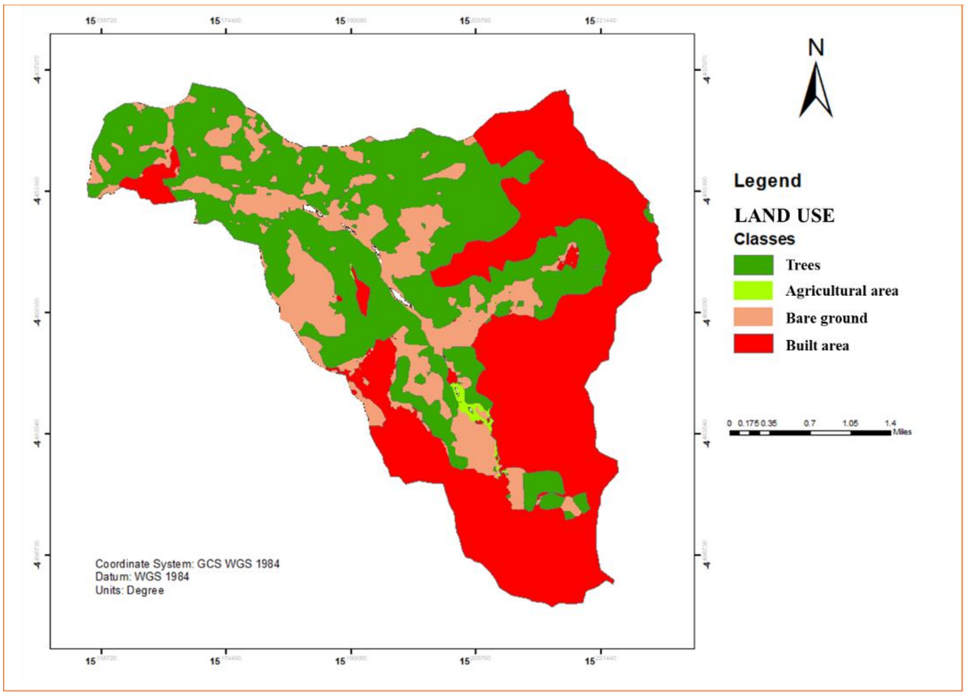

Figure 9: Land use map of the Mfuti watershed

According to our results (table 9), urbanization occupies 43% of the entire watershed with vegetation around 39%. This reflects a rate of runoff higher than that of infiltration.

Table 9: Percentage of land occupation

Classes	Areas (ha)	Occupancy percentage
Water	2.5	0.08924109
Trees	1099.3	39.2410937
Crops	13.3	0.47476262
Bare ground	471.8	16.8415792
Built area	1209.4	43.1712715
Course	5.1	0.18205183
Total	2801.4	100

Application of the "USLE" equation

The Universal Land Loss Equation (USLE) only provides for the importance of soil losses resulting from sheet or channel erosion on a simple slope without taking into account additional soil losses which may be attributable to other forms of erosion associated with gullying, wind or tillage [22]. Erosion values obtained by applying these factors can vary considerably due to different weather conditions. Therefore, the values obtained by USEL more accurately represent long-term averages [22].

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The equation is written as follows: **A = R x K x LS x C x P,** with A: expressing the possible long-term average annual soil losses in tons per acre per year; R: corresponds to the rain and runoff factor by geographic area; K: represents the soil erodibility factor; LS: is the length and inclination factor of the slope; C: corresponds to the cultivation (vegetation) and management factor; P: corresponds to the conservation practice factor. It reflects the effects of practices that reduce the quantity of runoff and the speed of runoff and thereby reduce the extent of erosion. In order to obtain the different values of the factors of the universal equation for land losses, we used the Geographic Information System.

Determination of the value of the aggressiveness of rainfall (R)

The R factor is the potential capacity of rain to produce storm erosion. It was calculated with the following equation, proposed based on annual precipitation or the Fournier index [23], using the monthly average precipitation compiled [24]: $R=0.0483*P^{1.610}$

In which R = aggressiveness or erosiveness of rainfall, P = Average annual rainfall in millimeters. So, **R = 138.852024 MJ.mm/ha.h.year**

Hudson [25] defines erosivity as the potential capacity of rain to produce erosion. This potential capacity of rain is often attributed to its physical characteristics. Among these we can cite: the quantity, intensity, size of the raindrops, the distribution of the size of these drops, and the speed of fall. [26].

Estimation of soil erodibility (K)

The soil erodibility factor expresses the vulnerability of a soil to being eroded by rain. The vulnerability of a soil depends on its structure, texture, organic matter content and permeability [26,27]

The erodibility of the tropical soils tested varies from 0.01 to 0.30 after a few years of cultivation: the margin for maneuver is therefore narrow. But under demographic pressure, crops are expanding onto increasingly fragile lands. We then observe a rapid mineralization of soil organic matter and an inexorable degradation of their physical properties, in particular their infiltration capacity and their resistance to the energy of rain and runoff [28]. We therefore estimated the erodibility of soils in the Mfuti watershed at **0.2 t. ha.h/ha.MJ.mm** based on work carried out in the N'djili watershed [24].

Calculation of the Topographic Factor (LS)

Topography is a crucial factor in the occurrence of rain erosion in that it influences the speed of rainwater flow on the slope [28]. The topographic factor derives from the terrain relief constructed from the Shuttle Radar Topography Mission (SRTM) image. From the relief, we extract the slopes whose combination of inclination and length generates the topographic factor. The LS factor describes the topography of the land, taking into account the slope (S factor) and the morphology of the land (L factor).

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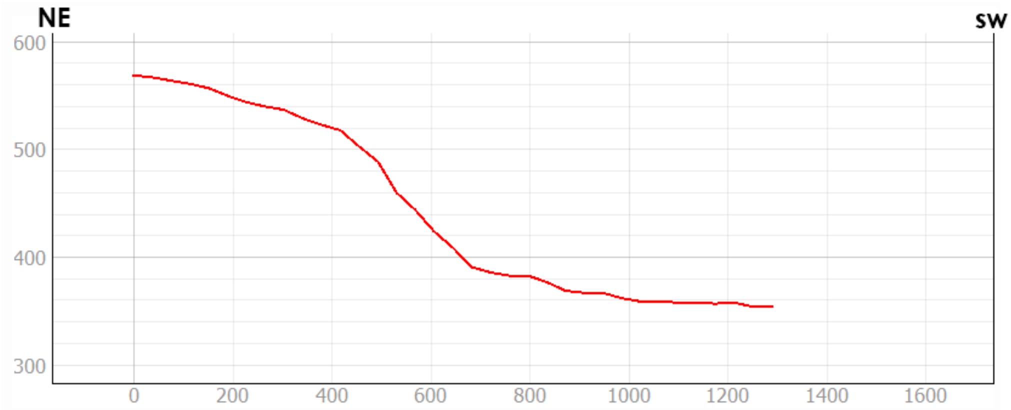

Figure 10: Topographic profile of the road to the river

The greatest slope of this topographic profile is estimated at 27.14% with a length of 700 m. By applying the formula: **LS = [0.065 + 0.0456 x (slope) + 0.006541 x (slope)^2] x (LP/ Const) ^{NN}** With, Slope: slope inclination (%); LP: slope length (m); const = 22.1; NN = 0.5 if the slope is >= 5%; NN = 0.4 if the slope is 3.5 to 5%; NN = 0.3 if the slope is 1 to 3.5%; NN = 0.2 if the slope is < 1%. After calculation we obtain **LS = 34.4463663**

The slope criterion is used to highlight the capacity of runoff to detach and transport soil particles. The higher the value of the slope, the faster the runoff and the more it develops significant erosive energy and therefore the more it erodes the soil [24].

Estimation of the Cultural Factor (C)

Factor C takes into account land use (plant cover, developments and agricultural practices). Indeed, erosion particularly affects certain types of crops while it is less severe or simply absent for certain activities and developments. [28]. The C factor is defined as a ratio of soil loss on cultivated land under specific conditions to the corresponding soil loss on fallow land [39]. It can be calculated using nomograms [28] or estimated by taking known values for a certain type of vegetation or crop (Table 10).

Table 10: Values of factor C depending on land use [28, 30]

Land use class	Value of C
Waters/swampy areas	0
Vegetation	0.001
Bare lands	1
Degraded vegetation	0.7
Urban areas	0.2

Calculation of factor (P)

The P factor takes into account soil conservation practices. Anti-erosion practices concern all the cultural techniques implemented to reduce runoff and erosion. Among these techniques, we find contour cultivation (contouring), the laying of grassy strips between two growing areas, natural or artificial mulching, or the laying of cover plants [28,29]. For our case, this factor was determined based on the factors shown in the table below:

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Table 11: Value of the P factor depending on the slope and developments [30]

Slopes in %	P factor for contour layout	P factor for strip crops	P factor for terraces
<7.0	0.55	0.27	0.1
7.0-11.3	0.6	0.3	0.12
11.3-17.6	0.8	0.4	0.16
17.6-26.8	0.9	0.45	0.18
>26.8	1	0.5	0.2

After calculating and finding all the factors or elements of the universal land loss equation, we can replace them in this equation in order to estimate the average quantity of soil lost. We know that **A = R x K x LS x C x P**

So, A = 138.852024 x 0.2 x 34.4463663 x 0.7 x 0.5; **A = 334.806338 tonnes/acre/year or 827.339941 tonnes/ha/year**

We obviously considered the largest slope, that is to say the one leaving the road up to the Mfuti River. As we know, for this route the topographical factor plays a major role in its disadvantage and runs the risk of suffering potential erosion during heavy rains. This is why we suggest that the topographical factor be reduced and soil conservation practices improved. Let us reduce the slope sufficiently at this level as well as at many points in the watershed where the slopes are steep or even very steep. If we managed to reforest this area and reduce the cultural factor to 0.058 (dense reforestation) and backfill this land to reduce this large slope created by the gullying to 10%, the soil losses of **827.339941 t/ha/year** will drop considerably to a value of **13.16128333 t/ha/year.** In this case, this land in the watershed to which the road is intrinsically attached upstream will be within the tolerance threshold for soil loss in the intertropical region, i.e., **20t/ha/year.**

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

This work aimed to size a canal for efficient water drainage, in order to put an end to the erosion problems of the Zamba-Telecom road. The water will then be transported through a main collector to the Mfuti river. We also carried out a large study on the watershed in which the road is located and also characterized the soil in this basin in order to understand its behavior. The municipality of Mont Ngafula, subject for years to numerous erosion phenomena, has the main causes: the construction of houses in a disorderly manner without good control from the authority responsible for town planning and housing; the overpopulation of the urban environment, such as for example where the "Zamba - Telecom" road is located, whose urbanization occupies 43% of its watershed, favors the establishment of plots and houses that are too concentrated in places that shouldn't even be busy like observed. This causes very high rainwater runoff, on steep slopes where the water flow speed is still too high. And this rainwater can sometimes overflow at the level of the canals because of their silting or blockage, following a population occupying the basin in an unregulated manner and which has no waste management plan, and this impacts on the life of water sanitation works in general. The road can be developed in the best possible way, however, without controlling elements such as: hydrology,

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geology or the geotechnical and geomorphological parameters of this watershed, or even its urbanization in question, we cannot claim to have a work that will last. Leaving the road upstream from the East (about 595 m above sea level) to the West, downstream (about 320 m above sea level), where the Mfuti river is located, all along this route is a large slope with exposed terrain, without significant vegetation. We fear that during the next showers there will be further gullying.

4.2 Recommendations

Everyone should take responsibility. The population must know that the water pipe system is an asset that they must take care of. That is to say, do not fill it with sand or rubbish for effective drainage of water. And the authority responsible for town planning and housing must make this population aware of doing so; that reforestation work be organized in the various areas devoid of vegetation in the watershed, mainly on the slope leaving the road to the river in order to limit soil loss; limit and control construction and land sales in the watershed and improve soil conservation practices in this basin; if possible, infiltration wells should be installed in different plots or households in order to reduce runoff.

SUPPLEMENTARY INFORMATION

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Availability of data and materials

All data generated or analyzed during this study are included in this published article

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