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Erosion and Sedimentation Impact on Storage Volume of Lom Pangar Hydroelectric Dam, Cameroon

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***Abstract*-For many purposes such as hydropower production, irrigation, flood control, many reservoirs are built throughout the planet. Because of the processes of erosion and sedimentation, these infrastructures generally face a big problem of accelerated reduction of their storage capacity. Consequently, a good knowledge of the change of storage for proper planning and management is very important. This work is carried out in order to determine the sediment transport into the Lom Pangar reservoir to check the decrease in the active storage volume. The RUSLA equation has been used for the determination of soil erosion in the catchment because of its ease of use and less data demande. The gross erosion was evaluated to be 19.7 million tons of soil per year with an average of 2.75 million tons per year that effectively reach the outlet. On that quantity that reach the outlet, the Brune′s sediment trap efficiency was applied and it was found that 0.04% of Lom Pangar reservoir decreases per year, an amount smaller than the 1% of annual worldwide reduction of water reservoir. That result obtained, shows that the soil erosion and then the sedimentation do not affect significantly the active storage of the Lom Pangar reservoir. But the region is experiencing an important land cover change with impact on erosion rate.**

***Keywords*-Erosion, sedimentation, Reservoir life span.**

I.INTRODUCTION

Erosion refers to the detachment of the soil particles mainly by the natural forces wind, water, ice or vegetation. When these detached particles mix with organic and inorganic materials during the process of erosion, sediments are formed. Basically, sediments refer to the complex mixture of organic and inorganic particles in the water. In case of reservoir sediments, water is the major source of erosion. Water flows over land causes increase in total suspended solids concentration in the river and hence adding sediments to the reservoir [1]. The process of sedimentation seriously affects reservoirs worldwide. As the river enters the impoundment, the flow velocities decrease and the sediment carrying capacity drops, causing sedimentation, which reduces the reservoir's storage capacity.

According to Petkovsek [2], sedimentation is the main cause for 1% of annual reduction of water reservoir worldwide. The majority of existing dams and other impounding structures continuously trap sediment and have no specific provisions for sustained long-term use. The life span of the storage capacity of the dam is frequently designed to be no less than 100 years [3]. However, sometime the dams reach their design capacity in a shorter time due to the sedimentation problem. Sediment yield is the net result of soil erosion and processes of sediment accumulation, so it depends on variables that control water and sediment discharge to reservoirs. Typically, sediment yield reflects the influences of climate (precipitation), catchment properties (soil type, topography), land use/cover, and drainage properties (stream network form and density) [4]. Erosion varies from low values in humid, low-relief catchments to very high values in arid, mountainous areas. Due to human modifications, erosion rates rise above natural levels, a phenomenon known as accelerated erosion. Accelerated erosion is a serious matter that reflects increased population and expansion of arable lands use [5].

The present study, used the model-based approach to assess soil erosion risk per year in the Lom Pangar River Basin. The availability of input data is a critical selection criterion when assessing soil erosion risk at the regional (or national) scale. Even though a wide variety of models are available for assessing soil erosion risk, most of them simply require so much input data that applying them at regional or national scale becomes problematic. The well-known Revised Universal Soil Loss Equation (RUSLE) developed by Wischmeier and Smith [6], was used because it is one of the least data demanding erosion models that has been developed and it has been applied widely at different scales.

From the potential soil loss, the study intended to evaluate the sediment reaching the outlet of the basin and study the dynamics of sediment in the hydropower reservoir then establish its lifespan. The change law of soil conservation in this area is revealed, which provides basis for soil and water conservation planning and regional sustainable development decision-making.

II. MATERIEL AND METHOD

1. Study Area

Lom Pangar watershed is located in Cameroon in major part precisely within the East and Adamaoua regions with a small part in Central Africa Republic, a country that borders Cameroon in his eastern part. That geographical location gives to Lom Pangar the characteristic of trans-boundary river basin of surface area 19700 km^2. The Lom River runs throughout Central Africa Republic for a distance of about 5 km around before reaching the Cameroonian territory. That river basin presented in Figure 1 is located between latitudes 4o10″00N and 7o11″00N and longitudes 13°30″00E and 15o02″00E. Since 2016, the hydropower reservoir has been constructed at the outlet of Lom Pangar river basin in the forestry part of East Cameroon. The Lom Pangar hydropower dam is located at about 350 km in the North East of Yaoundé, the capital city of the country and precisely at around 120 km from the capital city of the East region, Bertoua.

The site of the Dam in Lom River is 5 km downstream from the confluence of Lom and Pangar rivers, and around 13 km in the East of the confluence of the rivers Lom and Djerem. The geographical location of the Dam is: latitude N 05 o 25″ , longitude E 13 o 30″ and has for mains purposes, the regulation of the Sanaga river to increase the power generation of two hydropower plants located downstream during the dry season and generation of 30 MW power onsite, for the eastern grid of Cameroon. It has 50 meters height and 610 km^2 seize for a storage capacity of six billion m^3.

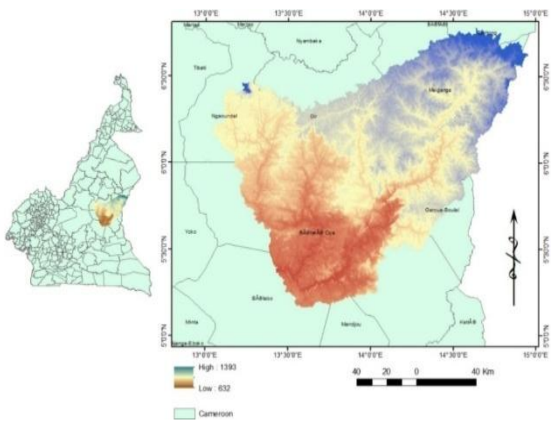

Figure. 1. Lom Pangar Watershed defined in ArcGIS 10.2.2.

2. Data source and processing

2.1. Rainfall Data Acquisition

The rainfall data was collected from the Electricity Development Corporation (EDC), the public institution in charge of the Dam construction in our study area. For that, availabledaily data have been collected for a period of 4 years, from 2014-2017 for the determination of average annual rainfall presented in Table 1, useful for determining the rainfall erosivity factor,

Table 1. Rainfall data.

	Stations Coordinates		Rainfall mm/yr.
	X	Y	
1	473384.91	571942.41	1571.3
2	268960.04	564938.56	1573
3	285156.45	599957.81	1564
4	413415.45	668683.09	1497
5	513219.31	747476.40	1464
6	284718.71	755793.47	1456.4

2.2. Digital Elevation Model (DEM)

The DEM map of Lom Pangar was obtained from the national institute for cartography of Cameroon in the format of SRTM (Shuttle Radar Topography Mission). It was used for the watershed delineation including stream definition, outlets and inlets as well the calculation of the sub basins parameters and the Slope Length and Slope Steepness factors (LS-factors). The DEM resolution is a very important characteristic, because affect the watershed delineation; stream network. The DEM used in this study has a resolution of 30m 30m and was projected to WGS 84 UTM 33N.

2.3. Soil Data

The soil data was downloaded from the harmonized soil data base website, result of a collaboration between the FAO with IIASA, ISRIC-World Soil Information, Institute of Soil Science, Chinese Academy of Sciences (ISSCAS), and the Joint Research Centre of the European Commission (JRC). The soil map was processed in ArcGIS 10.2.2 in order to clip from the global raster soil map, ours study area and identify the different soil type present in the catchment. Based on the soil database, we determined the proportion of different components of the soil (% silt, % organic matter, % clay) present in ours catchment.

2.4. Landsat Data Acquisition for Land Use Cover Change

In order to assess land use cover change, the Landsat image 2000 and 2017 of our watershed of interest were collected. Those satellite data are produced by the United States Geological Survey (USGS) and freely available from the USGS Global Visualization Viewer (USGS GLOVIS) platform (http://glovis.usgs.gov/).

2.5. Stream Flow Data

For the purpose of this study, discharge data from 1971 till 2003 were obtained from the Electricity Development Corporation and from previous studies conducted for the Lom Pangar reservoir project by the World Bank. The stream flow data used in this work was monthly stream flow for more than thirty years of collection. That data was helpful for the computation of the average annual inflow estimated to 7683x106 m3/yr in order to come up with the capacity inflow ratio of the reservoir.

3. Model description

The RUSLE is a simple empirical model, based on regression analyses of soil loss rates on erosion plots in the USA. The model presented in Eq. 1 is designed to estimate long-term annual erosion rates. Although the equation has many shortcomings and limitations, it is widely used because of its relative simplicity and robustness [7]. It also represents a standardised approach.
Soil erosion is estimated using the RUSLE Eq. 1 as follows:

$$A=R\times K\times LS\times C\times P \text{-------------(1)}$$

Where:
A= Mean (annual) soil loss;
R= Rainfall Erosivity factor (MJ/ha.mm/h);
K= Erodibility factor (t.ha.h/ha/MJ/mm);
LS= Combined Slope Length and Steepness factor;
C= Land Use/Land Cover factor;
P = conservation factor

The conservation factor P for this study was decided to be 1 to avoid any underestimation of sediment yield. That factor is defined as the ratio of soil loss from the area with conservation measures to the area without any management practices or conservation measures to control soil erosion. The value of P mainly depends on the erosion control measure adopted and varies from 0 to 1.
The procedures used to estimate the RUSLE factors are explained in detail in the following sub-sections.

3.1. Rainfall Erosivity factor, R

The RUSLE rainfall erosivity factor (R) for any given period is obtained by summing for each rainstorm, the product of total storm energy (E) and the maximum 30-minute intensity (I30). According to Renard and Freimund [8], R is the sum of individual storm EI-values for a year average over long time periods (more than 20 years).
Long-term average R-values are correlated with more readily available rainfall by Roose [9] for the west and central African countries as presented by Eq.2. The R equation was established function of the average annual rainfall in millimetres (P).

The relation:

$$R=(0.5\pm0.05)\ P \qquad \text{----------} (2)$$

3.2. Soil Erodibility factor, K

This factor represents the susceptibility of soil to erosion by direct rainfall and runoff water [10]. The value of K was computed using the empirical equation given in Eq. 3 which was developed by Habtamu [11]. The equation needs only the soil texture or average percentage of each soil particles (Sand, Silt, and Clay) in the catchment. The formula is as given below.

$$k=a\left(\frac{\%\ \text{Silt}}{\%\ \text{Clay}+\%\ \text{Sand}}\right)^{b} \qquad \text{----------} (3)$$

Where, K = Soil Erodibility factor (t.ha.h/ha/MJ/mm)
% Sand = percentage of sand in the soil; % Silt = percentage of silt in the soil; % Clay = percentage of clay in the soil; a = 0.32 and b = 0.27 are constant factors
In order to perform this calculation, HWSD+FAO soil map available at http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/ was used for the investigation. Therefore, for the different soils identified in the catchment, the proportion of different component was obtained from the soil database.

3.3. Combined Slope length and steepness factors, (L S)

The combined slope length and steepness factors (L.S) account for the effect of topography on soil erosion. LS is a dimensionless factor that represents inclination and slope length, It was estimated from a Digital Elevation Model (DEM) using following formula of Desmet and Govers [12]., cited by Panos et al. [13]under raster calculator of the ArcMap.

$$L=\left(\frac{\lambda}{22.1}\right)^{m} \qquad \text{---------}(4)$$

$$M=\frac{F}{(1+F)} \qquad \text{--------} (5)$$

$$F=\frac{\sin\beta/0.0896}{3(\sin\beta)^{0.8}+0.56} \qquad \text{--------} (6)$$

$$L(i,j)=\frac{[A_{(i,j)}+D^{2}]^{m+1}\text{-}[A_{(i,j)}]^{m+1}}{(X^{m}.D^{m+2.}(22.13)^{m})} \qquad \text{-------}(7)$$

Where,
L is the slope length; λ is the horizontal plot length, and m is a variable exponent calculated from the ratio of rill-to-inter-rill erosion, as described in Renard et al. [14]

$$S=10.8\sin\theta+0.03,\ \text{slope gradient}\leq 9\%$$

$$S=16.8\sin\theta\text{-}0.50,\ \text{slope gradient}>9\% \text{---------}(8)$$

Where,
S is the slope steepness, and θ is the slope angle.
Depending on the measured slope gradient, a different equation for must be used. Choosing S allows the RUSLE to be more finely tuned for different terrains. This is important because the topographic factor (and the RUSLE entirely) is very sensitive to the slope steepness (S).

3.4. Land use/land Cover factor, C

The Land use/land Cover factor C is defined as the ratio of soil loss from cropped land under specific conditions to the corresponding loss from clean-tilled, continuous fallow [6]. The value of C mainly depends on the vegetation's cover percentage and growth stage. Vegetation cover, after topography is the second most important factor that controls soil erosion [15]. In the context of this study, remote sensing was used to acquire satellite images and classify them as a function of different type of covers using ENVI software in order to have good knowledge of the covers. Concerning the C factor, we used the remote sensing approach based the normalized difference vegetation index (NDVI), approved by many researches to be suitable for the modelling of soil erosion erosion [16] [17] [18]. The NDVI is a well-known factor used that indicate the greenness of the cover and computed as the spectral reflectance difference between the red and near infrared bands of the satellite image [19]. (Eq. 9)

$$NDVI=\frac{NIR-RED}{NIR+RED} \quad --------- (9)$$

where NIR is the surface spectral reflectance in the near-infrared band and corresponding to the Band 5 of the landsat 8 (OLI) image.

RED is the surface spectral reflectance in the red band and corresponding to the Band 4 of the landsat 8 (OLI) image. The relation used for C factor determination was proposed by Durigon et al. [20] and adapted by Colman [21], designed for tropical area with more intense rainfall, characteristics that guided our choice because designate our study Area.

$$C = 0.1\left(\frac{-NDVI+1}{2}\right) \quad ------ (10)$$

4. Sediment Delivery Ratio, (SDR)

The sediment delivery ratio is defined as the fraction of gross erosion that is transported from a given catchment in a given time interval [22]. It is a dimensionless scalar and can be expressed as follows:

$$SDR = Y/E ------------- (11)$$

Where

Y is average annual sediment yield per unit area

E is average annual erosion over that same area.

In general, the sediment detached from the soil aggregates of land of the watershed undergoes either deposition or is transported by the flow to reach a certain cross section or stream. SDR accounts for the amount of sediment that is actually transported from the eroding sources to the catchment outlet compared to the total amount of soil that is detached over the same area above that point. It often has a value between 0 and 1 due to sediment deposition caused by change of flow regime and reservoir storage.

Sediment delivery ratio is one of the keys factor with difficult computation in order to determine the sediment yield of the watershed. Currently, many researchers in the purpose of its determination have developed several methods. However, in the case of this study the relation developed by Vanoni [23]; Renfro [24]; USDA-SCS [25], were used. They were developed using the data from 300 watersheds throughout the world to develop a model by the power function. These models are considered more generalized one to estimate SDR.

$$SDR\ (\%) = 0.42\ (2.56A)^{-0.125} \quad --------------- (12)$$

Where A = drainage area in square kilometres.

$$\log(SDR) = 1.7935 - 0.14191 \log(A) ---------- (13)$$

Where A = drainage area in km^2

$$SDR = 0.51 \times 2.59\ A^{-0.11} \quad --------------- (14)$$

Where A = drainage area in km^2

5. Trap efficiency of reservoir and its estimation

In the purpose of storing water for multiples uses, many reservoirs have been built throughout the world during the past 100 years. In most cases, sediment has been deposited in the reservoirs and decreased the volume of life storage; that phenomenon decreases not only the economic value of the reservoirs but also shortening their operational life. In some cases, the amount of sediment deposited in reservoirs have been similar to those that the engineers incorporated into their designs, and the reservoirs are functioning adequately. Other reservoirs have had higher rates of sediment deposition than estimated and are either providing smaller volumes of life storage during their design life or have filled, or will fill, with sediments before the design periods are reached [26]. Both occurrences result in serious economic losses with adverse sociological effects.

According to Sultana, and Naik [27], trap efficiency (Te) is the proportion of the stream sediment that is trapped in the reservoir. For the purpose of this work, Brune's (1944) method has been used. It is the most common method used for determining the trap efficiency of reservoirs. Brune developed an empirical relationship between trap efficiency and the ratio of reservoir capacity to the annual inflow (C/I), which is shown in Eq.15.

$$Te=\frac{\left(\frac{C}{I}\right)}{0.00013+0.01\left(\frac{C}{I}\right)+0.0000166\sqrt{\left(\frac{C}{I}\right)}} \quad ---------- (15)$$

III. RESULTS AND DISCUSSION

1. Calculation of RUSLE Factors

1.1. Rainfall Erosivity Factor

Based on the Eq. 2 developed by Roose [9] for Central and West Africa, the average erosivity (R) value for Lom Pangar catchment given in Figure 2 was calculated to vary from 800 to 852.5 MJ mm ha−1 h−1 yr−1. These values of erodibility were computed using the average annual rainfall recorded at the gauge stations located at the hydropower reservoir and those located in the surrounding area. The erosivity was interpolated over the catchment, then converted to raster in ArcGis10.2.

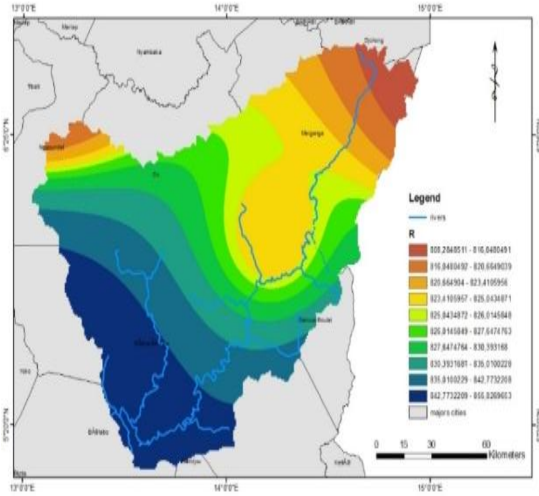

Figure. 2. Erosivity map.

1.2. Soil Erodibility factor (K-factor)

Different soil types with their textures were obtained from FAO world soil map processed using ArcGis 10.22 and the world FAO soil map database. Therefore based on USDA soil texture class identified in the catchment, the Erodibility factor has been calculated according to Habtamu [11]. The values of k factors of the different soil types identified are presented in Figure 3 and Table 2. Announced operations led to identification of following soil types: OrthicFerral sols covering 14.19% of the total surface area of the catchment and base on it texture, has a k value of 0.196 t.ha.h/ha/MJ/mm, OrthicAcrisol with 22.7% coverage of total surface area and k value of 0.24 t.ha.h/ha/MJ/mm, Ferralsols with 9.37% and k value of 0.196 t.ha.h/ha/MJ/mm, Dystric Nitosols with 29.5% and k value of 0.23 ha.h/ha/MJ/mm, Dystric Nitosols 24.19% with k value of 0.264 t.ha.h/ha/MJ/mm.

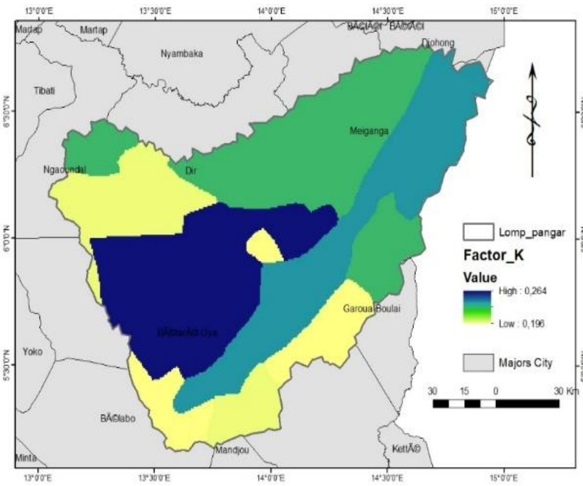

Figure. 3. Soil average K_factor of Lom Pangar Catchment.

Table 2. K Factor For Different Soil Texture.

Soil type	Sand (%)	Silt (%)	Clay (%)	Area (km^2)	%	K factor
OrthicFerral Sols	60	14	26	2857	14.19	0.196
OrthicAcrisol	49	27	24	4570	22.7	0.24
Ferralsols	60	14	26	1587	9.37	0.196
Dystric Nitosols	22	23	55	5949	29.5	0.23
Nitosols	44	33	23	4870	24.19	0.264
Total	-	-	-	19 700	100	0.245

1.3. Slope- and slope length factors

The LS factor accounts for the effect of topography on erosion in (R) USLE. The slope length L represents the effect of Slope length on erosion and the slope steepness (S) reflects the influence of slope gradient on erosion. Following the methodology given above, the results are shown in Figure 4 Representing the map of LS factor. Values vary from the minimum of 0.029
to the maximum of 5354.6 with an average value for the entire catchment 1.05 as presented in Table 3.

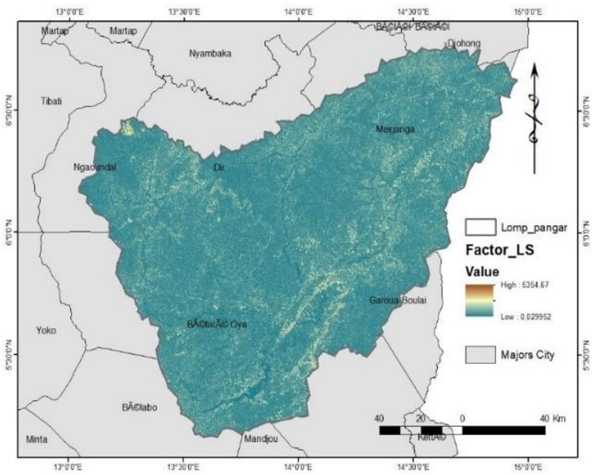

Figure 4. Lom Pangar Catchment LS map.

1.4. Plant cover factor C

Plant cover is effective in preventing erosion to the extent that it absorbs the kinetic energy of raindrops, covers a large proportion of the soil during periods of the year when rainfall is most aggressive, slows down runoff, and keeps the soil surface porous. After supervised classification of the Landsat 8 image, we came up with four main classes of cover as presented in Figure 8b, which are forest that represent 26 % of the total catchment, waterbodies covering 2.2 % of the catchment area, savannah covering 70.5% and built up area covering 1.4% of the catchment. The C factor map following in figure 5 resulted from the application of Durigon et al.

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[20] method and adapted by Colman [21], method well adapted to the climate of the studied area and that gave values that vary from 0.022 to 0.06.

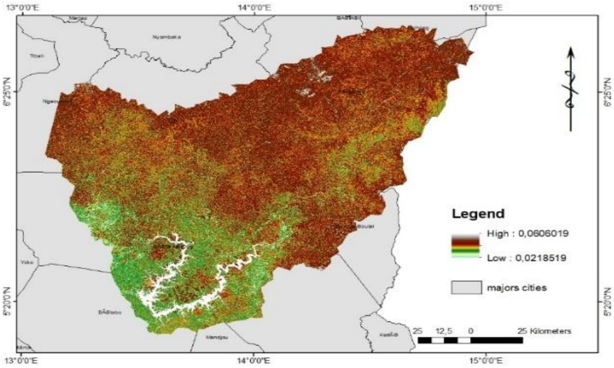


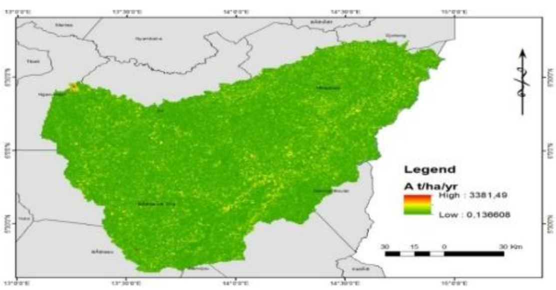
Figure 5. Different C_factors in Lom Pangar Catchment.

2. Soil loss from the catchment

To evaluate the soil loss from the watershed using RUSLE model, different factors of the model generated in raster format, have been multiplied in the raster calculator of the arcGis 10.2.2 software using the following script: A= "Factor_LS"*"Factor_R"*"Factor_K"*"Factor_C".

The result of that above operation is the map of soil erosion risk in Figure 6 A and B that follows in ton/ha/year. It has been established too that in Lom Pangar catchment 73% of the area has soil erosion rate varying between 0 and 7t/ha/yr, 23.5% having the rate between 7-20t/ha/yr and 2.5% of the area with more than 21t/ha/yr. Table 3 give the maximum, minimum and average of different RUSLE factors. Dividing the river basin in different slope values, 52.7% of the total surface area has the gentle slope with the value varying between 0 to 5° generating a corresponding average soil loss of 8.7t/ha/year. The moderate slope of 5 to 14° covers 45.2% of the river basin with a corresponding average soil loss of 10.4t/ha/year. The steep slope with value varying from15 to 63° covers 2.1% of the surface area with the average soil loss of 13t/ha/year as is summarized in table 4.

Concerning the land covers of the river basin, the average soil loss per different cover type is summarised in table 5 and the average value of erosion rate for the forest was estimated to 9.19 t/ha/year, scrubland 9 t/ha/year, water bodies 16.4 t/ha/year and built up and bare soil 8.79 t/ha/year.



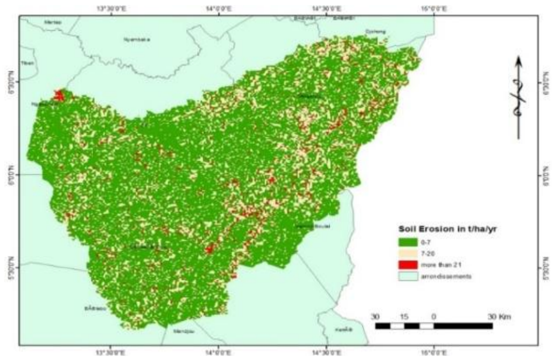


Figure 6A,B. Erosion Map of Lom Pangar.

Table 3. Average values of different soil erosion factors in Lom Pangar Catchment.

Factors	Maximum value	Minimum value	Average
R	855.826	808.28	823.06
LS	5354.6	0.029	1.05
C	0.06	0.0218	0.45
K	0.264	0.196	0.245
P	-	-	1

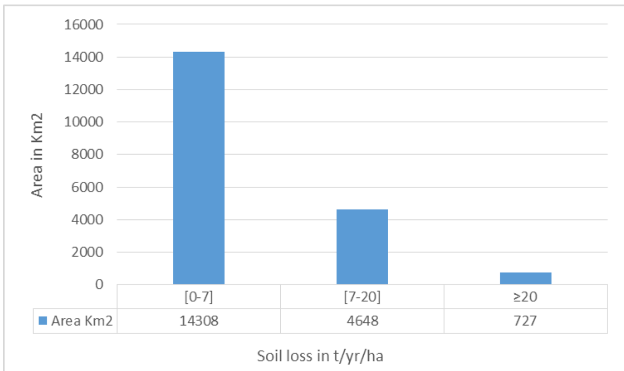


Figure 7. surface Area covered by different soil loss ranges.

Table 4. average soil loss function of the slope in degree.

Slope In Degree	% Surface Area	Average Soil Loss In T/Year/Ha
0-5°	52.7%	8.7
5-14°	45.2%	10.4
14-63°	2.1%	13

Table 5. average soil loss function of the cover type of the river basin.

Land Cover Type	Percentage Area Covered	Average Soil Loss In T/Year/Ha
Urban And Bare Soil	1.41%	8.79
Water	2.2%	16.4
Scrubland	70.5%	9
Forest	26%	9.19

Based on the above results, the average soil loss in ton/ha/year was determined based on the average values of different characteristics of the catchment to be 10 t/ ha/year

3. Sediment Delivery Ratio (SDR)

The sediment eroded from a watershed undergoes either deposition, either transportation to reach the cross section of the stream. The ratio between the observed sediment yield at a cross section of a stream and the total quantity of soil eroded in the catchment above that section is the sediment delivery ratio. Using the equations developed by Vanoni [23]; Renfro [24] USDA-SCS [25], the average sediment delivery ratio for this study catchment is 14% and Based on this result, the annual sediment yield is:

$$T=0.14\times19700\times10\times100= 2\ 758\ 000 \text{ t/yr} \quad (16)$$

4. Change of storage volume of the reservoir

The storage volume of the reservoir at any specific time is a function of the sediment load in the stream and the Capacity of the reservoir to retain that sediment known as its trap efficiency. Table 6 below gives the change of storage of Lom Pangar reservoir based on the quantity of sediment trapped. The trap efficiently value at any specific time is calculated using the Brune's formula (Eq.15) based on the value of the capacity-inflow ratio which is equal to the storage capacity of the reservoir divided by the annual average inflow in m^3/year. The average annual sediment inflow in m^3 is equal to the mass of the average annual sediment reaching the reservoir divided by specific weight of sediments (1150 kg/m3).Sediment Trapped is equal to average annum sediment inflow in m^3 multiplied by the corresponding trap efficiently

Table 6. Calculation of Change of Storage.

Period (yr)	A (m^3)	B (m^3/yr)	C	D (%)	E (m^3)	F (m^3)	G (m^3)	H (%)
1-20	6000	7683	0.78	98.4	2.5	50	49.3	100.00
20-40	5951		0.77	98		50	49	99
40-60	5902		0.77	98		50	49	98.4
60-80	5853		0.76	98		50	49	97.5
80-100	5804		0.76	98		50	49	96.7

Storage Capacity $A\times10^6$
Average Annual Inflow (I) $=B\times10^6$
Reservoir Capacity/Annual Inflow Ratio C=A/B
Trap Efficiency of the reservoir: D
Average Annual Sediment Inflow $E\times10^6$
Sediment Inflow for different Periods $F\times10^6$
Sediment Trapped in the reservoir $G\times10^6$
Percentage change of reservoir capacity: H

5. Impact of land use land cover change on soil erosion in Lom Pangar Catchment

In the objective of investigating how the change in land cover operates in our catchment, two different land use maps of years 2000 and 2017 were classified in four dominant classes in the region with are scrubland, forest, water and built up or urban. The dynamic of land cover for these periods presented in figure 8 a, b and table 7 shows the reduction of the forest coverage from 39.9% of the total catchment area in 2000 to 26% in 2017, but opposite scenario for scrubland that increase from 59% of the total surface area in 2000 to 70.5% by mainly forest conversion in 2017, built up that increases from 1.04% to 1.41% of the surface because of dam project and water bodies that changes from 0.1% in 2000 to 2.2% of the total surface area in 2017 due to the reservoir construction.

This dynamic of land cover led to the change in soil erosion risk that seriously increase from 5.9 t/ha/year in 2000 to 10t/ha/year because mainly of the conversion of forest, able to reduce the raindrop energy causing detachment of soil particle, reduce runoff means of sediment conveyance to the river, stabilises the soil and per consequent the erosivity [28]

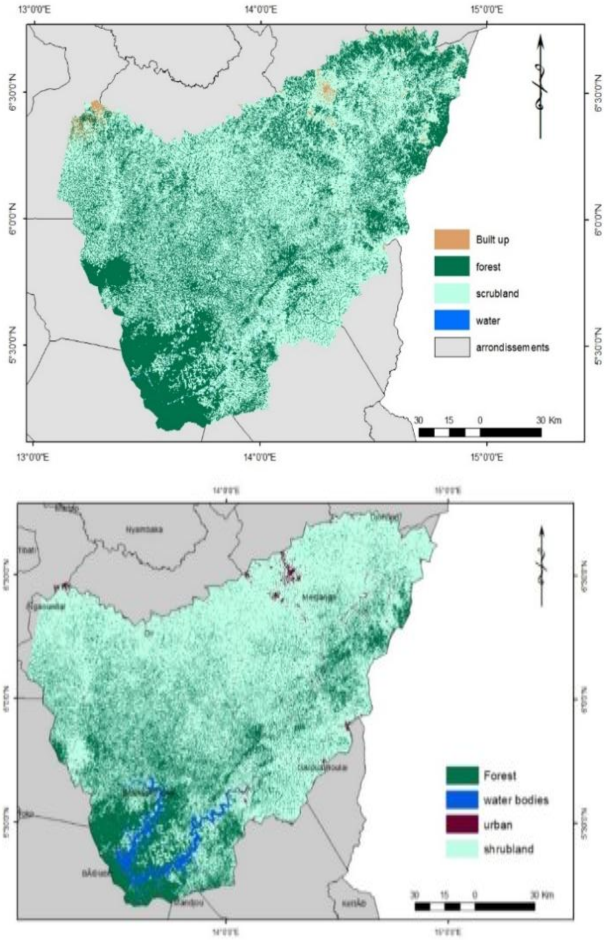


Fig. 8a. Land Cover Map 2000 of Lom Pangar River basin and 8b. Land Cover Map 2017 of Lom Pangar River basin.

Table 7. Impact of land cover change of soil erosion in the Lom Pangar catchment.

	2000			2017		
Cover type	Area Km²	% Area	Average soil loss in t/ha/yr	Area Km²	% Area	Average soil loss in t/ha/yr
Forest	7956	39.9	5.9	5158.13	26	10
Built up	208	1.04		281.6	1.41	
water	19	0.1		434.4	2.2	
Scrubland	11721	60		14065.3	70.5	

IV. CONCLUSIONS

Sedimentation is worldwide known as phenomena that affect seriously reservoirs. This affects reservoir by reducing the capacity storage of the infrastructure, which in our case is used to regulate the flow and stabilize the production of power in the greater Sanaga catchment.
In order to determine the impact of sediment in the Lom Pangar reservoir storage capacity, in the context of sediment data scarcity, the RUSLE was used and has evaluated erosion to be 19.7 million ton per year in Lom Pangar. That total soil does not entirely reach the outlet and the quantification of the amount reaching the outlet was done using the sediment delivery ratio formula established for similar environment to our research catchment. The result gave a ratio of 14% of the total sediment that reaches the outlet. That amount represents 2.758 million ton/year that reaches the reservoir.

Having the total sediment reaching the outlet, the reservoir capacity of 6 billion m^3 and the average annual inflow of 7683 million m3 per year, the useful life of reservoir was developed based on the Brune′s trap efficiency formula. The change of storage is evaluated to be 0.04% per year in Lom Pangar watershed, smaller than the 1% of annual worldwide reduction of water reservoir. The main reason to low soil erosion from the Lom Pangar area is the gentle slope of less than 13° that covers almost the entire catchment and the presence forest covering more than the quarter of the river basin. Based on the construction design parameter, the useful life of reservoir is generally 100 years; per consequent, it can be retained from our result that sedimentation is not a major problem for Lom Pangar reservoir. However the catchment undergoes an important land conversion mostly from forest to scrubland, result of timber exploitation and other human activities. Those actions increasethe erosion rate because expose the soil to raindrop energy and runoff.

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