International Journal of Civil Engineering, Construction and Estate Management
Vol.5, No.3, pp.1-10, August 2017
Published by European Centre for Research Training and Development UK (www.eajournals.org)

MODELING THE EVOLUTION IN THE CONCENTRATION OF SOLIDS BASED ON TIME OF THE MEWOU RIVER IN THE MIFI BASIN

Kamdjo Grégoire (Ph.D)[1], Gouafo Casimir (Ph.D)[1], Keyangue Tchouata Jules Hermann (Ph.D)[2], Ngapgue François[3] and Yerima Bernard Palmer Kfuban[4]

[1]Fotso Victor University Institute of Technology, Department of Civil Engineering, Laboratory of Industrial and Systems Engineering Environment (LISIE), University of Dschang Cameroon
[2]Department of Mine-Mineral Processing-Environment, University of Ngaoundere, Cameroon
[3](Associate Professor), Fotso Victor University Institut of Technology, University of Dschang, Cameroon; Laboratory of Industrial and Systems Engineering Environment (LISIE)
[4](Professor), Department of soil Science, Faculty of Agronomy and Agricultural Sciences, University of Dschang, Cameroon. Laboratory for the Soil and Environment, Faculty Agronomy and Agricultural Sciences (FASA)

ABSTRACT: *The objective of this study is to evaluate and model the evolution of the concentration of solids, as a function of the time of the Mewou river, in the Mifi watershed. We have determined from the samples taken from this watercourse and from the specialized laboratories the concentrations of soil exported. The MATLAB software allowed us to simulate the evolution of the concentration of solids, according to the time of this stream. This evolution is characterized by the polynomial model equation of degree nine with a correlation coefficient of 0.5702 and a coefficient of determination of 0.325:* $C_s = a^* t^9 + b^* t^8 + c^* t^7 + d^* t^6 + e^* t^5 + f^* t^4 + g^* t^3 + h^* t^2 + i^* t + j$

KEYWORDS: Solids Concentration, Time, Model, Function, Simulate.

INTRODUCTION

Rainwater,charged with carbon dioxideand other elements through the atmosphereand the surface of the soil,dissolves part of their mineralsand triggers a series of chemicalsreactions,causing the chemical weathering of rocks (Fournier, 1969). As such, the dry rocky elements are fragmented, reduced to the size of sand, silt or clay. Erosion is a process that tends to reduce the surface of continents the thickness of soil and rock, by physically pulling the solid particles that are exported suspended by surface runoff into rivers to reach the oceans and intra continental basins (Probst, 1992). Several authors see water erosion in the tropics from two angles: geological or normal erosion and accelerated erosion ((El-Swaify et *al*., 1982). As a general point of view, human activities are the main causes of erosion, just as much as deforestation, agriculture, livestock and urbanization. This is the origin of the presence of solid particles in streams creating solid flow.

This study is the quantitative assessment and modeling of the concentration of solids, based on the time of rivers.

ISSN 2055-6578(Print), ISSN 2055-6586(online)

LITERATURE/THEORETICAL UNDERPINNING

Mathematical models generally consist of a set of variables chosen to represent the object studied and a set of mathematical relationships between these variables chosen to represent its function (Zug and Vazquez, 2010). The conceptual validity of an instrument is its capacity to produce a measure, which must agree with the theoretical links between the measured concepts (Martel et *al*., 2009). In other words, it is to collaborate the conceptual or theoretical significance of the measure. The conceptual validity of the models is done by calculating the correlation between the data obtained from the measurements and the model. Each author characterizes the region or watershed studied, using the most representative and reliable model (Bouanani, 2005), that is, having a good correlation coefficient between the data collected and the model, taking into account errors in measurements, and any inaccuracies caused during the experiment or other conditions related to the phenomena studied, such as coherence between soil transport and precipitation, soil transport and erosion.

Quantitative assessment of the disaggregation of soils in watersheds can be carried out using two approaches. The first approach is to quantify erosion through models, involving morphological, climatic and hydrological parameters. The second approach is to estimate the quantities of suspended matter discharged by the watercourses at the outlet of the basin studied. Most erosion quantification measures are done on standard size plots (Wischmeier et *al*., 1971, Roose, 1967, Roose et *al.*, 1998). Meanwhile, the study of suspended transfers at the watershed scale proves to be an effective tool for understanding and quantifying soil erosion processes.

Several models have been presented by different researchers, based on representative physical parameters (Albergel et *al*., 2001, 2003). Below are some of his models:

- The annual flow of suspended solids exported from a watershed of Wood (1977) and Williams (1989), given by the formula As = $\sum_j^N (t_{j+1} - t_j) Q_j C_j$.The terms Cj, Qj, N and (tj+1 – tj) respectively correspond to the concentration measured at instant tj, to the liquid flow rate at instant tj, to the number of samples taken over the year in question, and to the time separating two consecutive levies.

- The calculation of the suspended solid flow is based on the measurement of the liquid flow rate of the flow. The average solid flow of suspended sediment passing through an average flow section is calculated by the product of the average concentration of suspended sediment Cs by the average liquid flow rate Q_1 for a given period of time. This method was used in this work.

  The concentration of suspended sediment Cs and the liquid flow rate (Q_1) generally evolve according to a power model (Etchanchu and Probst 1986, Walling and Webb 1981, Walling 1984, Wood 1977, Tavares 2010) Expressed with coefficients a and b by Cs = a * Q_l^{b-1}. Another empirical relationship, called the solid transport curve (Cambell and Bauder, 1940, Crawford, 1991) links the solid flow to the liquid flow along Qs = a * Q_l^b.

  The parameters a and b are generally estimated, by linear regression of the variables, transformed into Log:

  LogQs = Loga + b * LogQ_l. “1”

- Modeling the evolution in theconcentration of solids based onliquid flow rates of the mewou riverin the mifi basin:

  $Cs = a*Q_l^2 + b*Ql + c$ (Gouafo C. et *al*., 2017) “2”

- Modeling the evolution of sediment discharge based on liquid flow rates of the mewou rier in the mifi basin:

$$Qs = a^* Ql^9 + b^* Ql^8 + c^* Ql^7 + d^* Ql^6 + e^* Ql^5 + f^*Ql^4 + g^* Ql^3 + h^*Ql^2 + i^* Ql + j$$ (Gouafo C. et *al*., 2017) "3"

The catchment area of the South Mifi, coverings an area of 1640 km^2, is drained by four large rivers; We can distinguish the Mape to the north, a tributary of the Mbam; the Nkam to the south-west which, under the name of Wouri, flows into the sea at Douala and drains the south-western edge of the Bamileke plateau and the locality of Dschang; the Ndé in the south-east, a tributary of the Noun, which drains much of the mountainous region of western Cameroon, after having taken its source in Mount Oku (3070 m).

Geological studies show that the locality essentially comprises the formations of the basement, and the volcanic formations; covering most of the highlands of western Cameroon (Olivry, 1976). The formations of the base are mainly composed of calco-alkaline embedded gneisses. The basin of the South Mifi (study site) is composed of 77% of "basalt plateau", 20% of basement formations and 3% of alluvial and basanitoid trachytes. The soils of the western region come from the alteration of these rocks and are mainly red ferralitic soils, on basement materials or basalts of the plateau, or humifers on trachytes and mountain basalts. Several types of hydromorphic soils are observed, as well as poorly evolved soils, pyroclastic or ash-derived basalts.

METHODOLOGY

Field site and Sampling

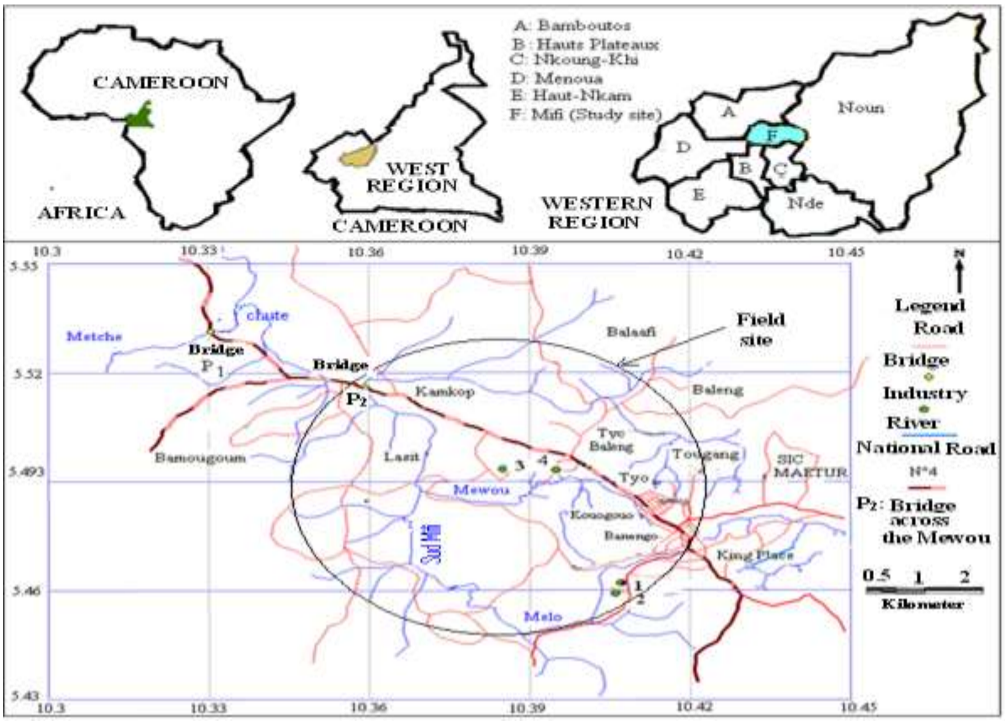

Figure 1: Part of the hydrographic of southern Mifi showing the location of the bridge P2 Mewou

Source: Made using, a GPS, from a background map of the region (2012)

ISSN 2055-6578(Print), ISSN 2055-6586(online)

The station selected to determine the quantities of soil exported by the Mewou river (found in the South Mifi) is located at coordinates 5 ° 30'8 "N; 10 ° 22'7" E, Alt. 1279 m, on national road number 04 (Figure 1), designated P_2 in Figure 1.

According to Rodier et *al*., (2009) and MINEDD (2006), in order to have a representative sample of sediment concentration, the material must be buried in water so that the sample is not surfaced precisely in a place where water is not calm.

The samples were taken, once a week, over a 19 months of study period. A total of 76 samples were considered to determine the quantities of soil exported, in addition to 76 measurements of the flow of the Mewou river. The determination of the quantity of exported soil, was done in the Laboratory of Industrial and Environmental Engineering Systems (LISIE) of the University of Dschang.

Climate of the region

The climate in the studied area was relatively stable over the years. From the ombrothermal diagram according to Gaussen and Bagnouls (1952) (Figure 2), the studied area have two seasons: the rainy season from 15 March to 15 November and the dry season from 16 November to 14 March . The meteorological conditions of the region are represented by meteorological data from the weather station at Bafoussam-Bamougoum Airport (Appendix 1 and Appendix 2). This station is located close to the studied area, and in the recruitment area (catchment area) of the waters of the Mewou river, which is one of the watercourses of the Mifi Sud catchment area. It is located between 5 ° 32'13 "N and 10 ° 21 '16" E at altitude 1325 m.

The annual rainfall over the past 12 years (2002 to 2013, see Appendix 1) varied from a minimum of 1410.1 mm in 2011 to a maximum of 2026.2 mm in 2013. The maximum rainfall was 477.9 mm in July 2013 and the minimum rainfall was 0.0 mm in January 2007, 2010, February 2004, February 2007, 2008 and December 2003, 2005, 2007, 2009, 2010 and 2011.

From this meteorological data, the mean temperature in the dry season is 23.2 ° C. It was greater than the average temperature in the rainy season 21.86.

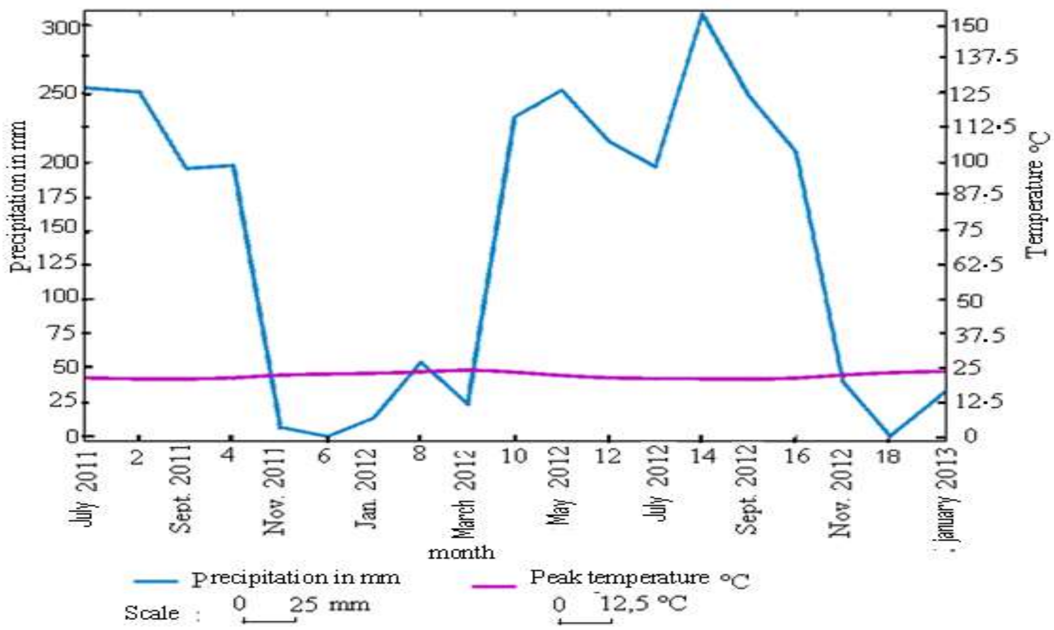

Figure 2: Ombrothermic diagram according Gaussen and Bagnouls (1952), of Bafoussam and surroundings

ISSN 2055-6578(Print), ISSN 2055-6586(online)

Methods of experimentation

 Assessment of water flow and exported soil

The flow rate Q_l in m^3/s was determined using a gauging float (Rodier et *al*. 2009, Bernard 1994) following the formula:

$Q_l = 0.8*L*H*V$ "4"

Where L = useful width (flowable) in m, H = average water depth in m and V = maximum velocity (flow rate) of the water surface in m/s.

The amount of exported soil concentration (Cs), of the Mewou watercourse expressed in kg / l was determined by oven drying of the water samples collected from the Mewou River at 105 °C. The amount of soil exported (Qs) by water in g/s or in kg/s was determined from the water flow rate (Q_l) following the expression: $Qs = Q_l * Cs$

Where Cs is the weight of soil per liter of water exported (in g/l; g/m^3 or in Kg/m^3). For a period of time T, we had a soil loss (Q_T) from the expression:

$Q_T = Qs*T.$ "5"

RESULTS/FINDINGS

Year	Month	Duration of the month in days	Liquid flow rate in (l/s)	exported soil (g/l)	exported soil (kg/s)
2011	July	31	8 900	0.29	2.581
	August	31	32 711	0.26	2.079
	Sept.	30	8 350	0.1	0.752
	October	31	11 474	0.16	1.858
	Nov.	30	10 311	0.22	2.331
	Dec.	31	6 363	0.27	1.657
2012	Jan.	31	3 727	0.11	0.374
	Fév.	29	2 373	0.15	0.377
	March	31	2 151	0.1	0.208
	Apr.	30	5 372	0.98	7.746
	May	31	5 513	0.23	1.317
	Jun	30	9 037	0.26	2.796
	July	31	11 630	0.26	3.018
	August	31	12 786	0.3	2.928
	Sept.	30	13 831	0.23	3.158
	Oct.	31	16 326	0.332	5.407
	Nov.	30	12 598	0.14	1.764
	Dec.	31	7 543	0.09	0.679
2013	Jan.	31	5 953	0 .3	1.786

In the present study, the Pearson coefficient of correlation R and the determination coefficient R^2 were determined using Microsoft Office Excel (Microsoft, 2010) and the MATLAB software (Jerome, 2009). This software allowed us to develop a new-order polynomial model that better accounts for the relationship between the evolutions of solid flows as a function of time according to the equation of the form:

$C_s = a* t^9 + b* t^8 + c* t^7 + d* t^6 + e* t^5 + f* t^4 + g* t^3 + h* t^2 + i* t + j$ “6”

Where Cs represent the concentration of solids, t is the time, and the coefficients a, b, c, d, e, f, g, h, i and j vary, depending on the Cs values obtained during the study.

The data in Table 1 made it possible to construct the curves of variation of the solids concentrations of the Mewou stream as a function of time according to the polynomial model.

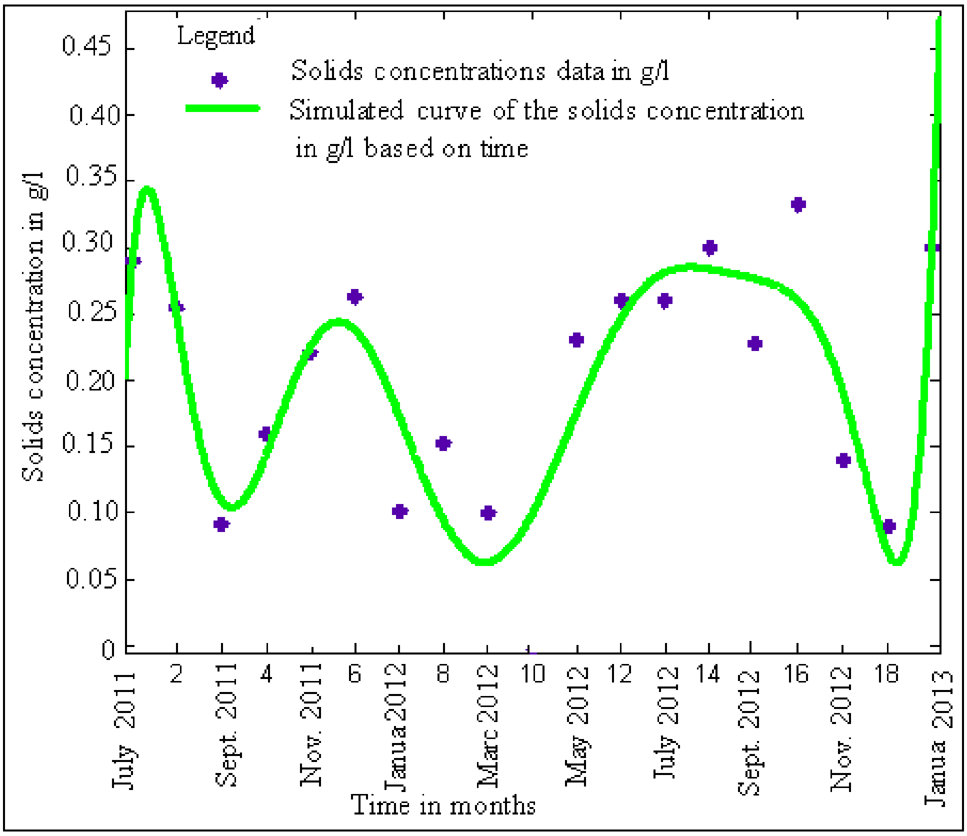

Figure 3: Variation of the solids concentration in g/l of the Mewou stream based on time in months

The model of the evolution of the Mewou stream concentration as a function of time is represented by the curve of Figure. 3, with a correlation coefficient of 0.5702 and a determination coefficient of 0.325. This model is polynomial of degree nine:

$C_s = 0.00000003381*t^9 – 0.000003084*t^8 + 0.0001191*t^7 – 0.002531*t^6 + 0.03222*t^5 –$

$0.2503*t^4 + 1.159*t^3 – 2.988*t^2 + 3.707*t – 1.366$ “7”

Where: Cs: Concentration in solids in g / l and t: Time in months.

The correlation coefficient of 0.5702 indicates a moderate correlation (Legates and McCabe, 1999, Donner and Eliasziw, 1987). This model is validated in this range of the correlation coefficient.

ISSN 2055-6578(Print), ISSN 2055-6586(online)

This model indicates that the concentrations of suspended solids increase or decrease in perfect synchronization with the liquid flow rate. Indeed, during the dry season at the moment when the liquid flows decrease, this concentration engages a downward slope (decrease from November 2011) and the minimum concentration is obtained in March 2012, that is to say at the end of The dry season when the flow of water is low. The curve becomes ascending from the month of April 2012 period of the beginning of the rains. Thus the cycle is renewed. Wood (1977) found the same phenomenon: the growth of sediment input during flood periods and the decrease during low water periods. Thus, in flood climates, the concentrations may be higher because there is a lot of material available, whereas in the fall, the materials are less frequent and the concentrations are lower for the same flow rate.

Transported sediments originate from bed and bank by erosion or slippage, and tributary tributaries (Williams, 1989). The material of the bed transported in suspension at the measuring station may be influenced by the volumes, height, power of previous floods, the power of the current to pass any obstacle and by the vegetation cover which can retain or release the sediments. Sediment from the slopes can come from the land by runoff. In some places, man plays an important role in sediment production through cultivation practices, as stirring the soil encourages sediment transport and even reduces water infiltration due to reduced vegetation cover (Tavares, 2010). The basin which has as an outlet the Mewou stream is located in an agricultural area. This river has tributary tributaries that cross the town of Bafoussam where some spaces lack vegetal cover.

IMPLICATION OF THE MODEL TO RESEARCH AND PRACTICE

¬ This study may allow process station managers to know the time of year or the transport of sediments is very important;
¬ It allows to predict the periods of high siltation of the dams of water retention;
¬ The study determines the amount of sediment transported as a function of time

CONCLUSION

The evolution of the concentration of solids in suspensions in water, as a function of the time of the stream Mewou, to model, the polynomial model of degree nine. Based on the data from this study, the equation is as follows:

$$C_s = 0\,.00000003381*t^9 - 0.000003084*t^8 + 0.0001191*t^7 - 0.002531*t^6 + 0.03222*t^5 - 0.2503*t^4 + 1.159*t^3 - 2.988*t^2 + 3.707*t - 1.366 \text{“7”}$$

Where : :

Cs: The solid concentration in g/l and t: The time in months

This equation is of the form:

$$C_s = a* t^9 + b* t^8 + c* t^7 + d* t^6 + e* t^5 + f* t^4 + g* t^3 + h* t^2 + i* t + j \text{“6”}$$

Where: Cs represents the solid concentration, t is the time in months and the coefficients a, b, c, d, e, f, g, h, i and j vary with the Cs values obtained during the study. The above equation

ISSN 2055-6578(Print), ISSN 2055-6586(online)

can be used to predict the solid concentration as a function of time of this stream in future years.

FUTURE RESEARCH

- Modeling the concentration of solids according to rainfall;
- Modeling the amount of solids depending on rainfall
- Modeling of water flow depending on rainfall

Appendix 1: Rainfall (mm / month) in Bafoussam-Bamougoum from January

	2002 to December 2013												
Month	Jan.	Feb.	March	April l	May	June	July	August	Sept.	Oct.	Nov.	Dec.	
years													Tota
2002	4.0	16.	123.1	147	128.	280.	315.	253.	254.	247.		18.	1588
2003	1.1		39.2	128	123.	232.	222.	276.	234.	267.			1580
2004	1.2		40.3	266		256.	287.	244.	195.	323.	141.	17.	1867
2005	52.9	83.	76.7		238.	177.	175.	309.	299.	230.			1760
2006	8.1	75.	149.5		298.	209.	246.	310.	254.	153.			1836
2007	0.0		29.6	262	176.	221.	273.	236.	194.	280.	143.		1817
2008	5.6		106.5	207	171.	201.	179.	239.	290.	152.			1561
2009	2.7	14.	42.2		201.	170.	268.	383.	223.	260.			1665
2010	0.0	48.	87.2		215.	249.	161.		302.	228.			1555
2011	9.8	32.	80.9	105	197.		253.	251.	195.	197.			1410
2012	13.7	54.	23.6	233	252.	215.	196.	308.	247.	207.			1791
2013	27.9	15.	119.7	181	187.	176.	477.	210.	279.	236.		15.	2026

Source: Weather Station Bafoussam-Bamougoum Airport (5°32’13”N, 10° 21’ 16” E, Alt.1325

Appendix 2: average monthly temperature of daily temperature of the station Meteorological from the airport Bafoussam-Bamougoum period 2002-2013 in ° C

Mont **Years**	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
2002	23.	24.	24.8	24.2	23.9	22.7	22.	21.3	21.4	21.	23.0	22.9
2003	23.	24.	24.9	23.1	22.7	21.0	20.	21.0	20.7	21.	22.3	22.7
2004	23.	24.	24.7	22.7	23.3	21.5	20.	22.7	21.1	21.	22.2	22.5
2005	22.	24.	23.9	24.0	21.6	21.4	20.	20.6	21.0	21.	21.0	21.3
2006	22.	23.	23.1	22.7	22.0	19.4	21.	20.9	20.9	21.	22.2	22.1
2007	22.	24.	24.7	25.6	22.3	21.5	20.	20.6	20.9	21.	21.7	22.2
2008	22.	23.	23.5	20.1	22.0	21.3	20.	20.7	20.2	21.	22.9	22.5
2009	23.	24.	24.8	22.9	22.3	21.6	21.	20.8	21.0	21.	22.3	23.0

ISSN 2055-6578(Print), ISSN 2055-6586(online)

2010	23.	23.	24.4	23.9	23.2	21.8	21.	21.1	20.2	21.	22.5	23.0
2011	22.	23.	24.1	23.6	22.8	21.8	21.	21.0	21.1	21.	22.7	22.7
2012	23.	23.	24.6	23.4	22.2	21.4	21.	21.2	20.9	21.	22.6	23.3
2013	23.	24.	23.5	23.3	23.2	22.5	21.	21.4	21.4	21.	22.1	21.8

Source: Weather Station Bafoussam-Bamougoum Airport (5°32'13"N, 10° 21' 16" E,

REFERENCES

Albergel, J., Nasri, N., Boufaroua, M. & Pépin, Y.(2001). Assessment of erosion on the small watersheds of the hill lakes of the Tunisian ridge. Technical Documents in Hydrology 51, pp. 63-70

Albergel, J., Pepin, Y., Boufaroua, M. & Nasri, S. (2003). Erosion and solid transport in small Mediterranean watersheds.Hydrology of the Mediterraneanand Semiarid Regions (Proceedings of an international symposium held at Montpellier, April 2003). IAHS Publ. no. 278, 2003, pp. 373-379.

Cambell, F.B. & Bauder, H. (1940). A rating-curve methode for determining silt-discharge of stream, EOS Trans. Am. Geophys. Union, 21, 603-607.

Crawford, C.G. (1991). Estimatin of suspended –sediment rating curves and mean suspended-sediment load, journal of hydrology, 129, 331-348.

Donner, A & Eliasziw, M.(1987). Sample size requirements for reliabilitystudies. Stat Med. 1987; 6: 441-448.

El-Swaify, S. A., Dangler, E. W. & Armstrong, C. L. (1982). Soil Erosion by Water in the Tropics. 630 US ISSN 0271-9916. Research Extension Series 024, p. 184.

Etchanchu, D. & Probst, J.L.(1986).Erosion and transport of suspended matter in a catchment area in an agricultural region. A method of measuring surface runoff, its load and the two components of solid transport in a watercourse. C. R. Acad. Sci. Paris, 302, Series II, No. 17 1063-1067.

Fournier, F.(1969).Water erosion and climate.Technical Information Bulletin of Meteorology and Agriculture No. 237. Pp.111-115.

Gaussen, H. & Bagnouls, F.(1952).The xerothermic index. Bulletin of the Association of French Geographers, No. 222-223, 1952, pp. 10-16.

GOUAFO, C., KAMDJO, G., KEYANGUE,T. J. H., YERIMA, B. P. K. & NGAPGUE, F.(2017). Modeling The Evolution In The Concentration of Solids Based on Liquid Flow Rates of The MEWOU River In The MIFI Basin. International Journal of Civil Engineering and Technology, 8(4), 2017, pp. 719–729.,April 2017

GOUAFO, C., KAMDJO, G., KEYANGUE, T. J. H. & YERIMA, B. P. K. (2017). Modeling the evolution of sediment discharge based on liquid flow rates of the mewou river in the mifi basin. International Journal of Civil Engineering, Construction and Estate Management Vol.5, No.2, pp.1-12, May 2017

Jerome, B.(2009).MATLAB R2009b « MatrixLaboratory ».SocietyMathworks.

Legates, D. R. & McCabe, G.J.(1999). Evaluating the use of "goodness-of-fit" measures inhydrologic and hydroclimatic model validation. Water ResourcesResearch 35: doi: 10. 1029/1998WR900018. Issn: 0043-1397.Florida Avenue N.W. Washington, D.C.

Martel, J., Dugas, C., Lafond, D.& Descarreaux, M.(2OO9).Validation of the French version of the Bournemouth Questionnaire. J Can Chiropr Assoc. 2009 Jun; 53 (2): 111-120. French.

MicrosoftO.(2010).MicrosoftOffice2010Homeand Business.PCLicenseEnglish.

MINEDD(2006).Sample collection in river: Sampling techniques for physico-chemical analysis. Technical Guide November 2006. Water Agency Loire-Brittany-Avenue of Buffon. 132p.

Olivry, J. C.(1976).Hydrological regimes in Bamileke, Cameroon Cah. ORSTOM, ser. . Hydrol. ml. XIII, No. 1. P. 37-71 ..

Probst, J.L.(1992).Geochemistry and hydrology of continental erosion . Mechanisms, current global assessment and fluctuations during the last 500 years Geological Sciences. Memoire Nº 94. ISSN 0302 - 2684, pp. 60.

Rodier J,Legube B, MerletN.&Coll.(2009). Analysisofthe water .9^{e}édition Dunod, Paris, France. P .1579.

Roose, E. (1967).Ten years of measurement of runoff and erosion in Sefa, Senegal.. Agron. Trop. , 22,2 : 123-152.

Roose, E., De Noni, G. & Lamachère, J-M.(1998).Erosion at ORSTOM: 40 years of multidisciplinary research. Res. Ero. Orstom, Montpellier, France. 66 p.

Tavares, J.D.P.(2010). Soil erosion in Cape Verde: process and quantification at the level of three watersheds of the island of Santiago. Earth Sciences. University of Burgundy, 2010. French.

Walling, D. E.(1984). The sediment yields of African rivers. IAHS Publ., Harare Symp. 144, 265-283Seltzer, P., 1946 - le climat de l'Algérie. Univ. Alger. Inst. Météo et Phys du Globe, Carbonnel. 219 p., 2 cartes.

Walling, D. E. & Webb, B. W.(1981). The reliability of suspended load data. In: Erosion and Sediment transport measurement. IAHS Publ., 133, 177-194.

Williams, G. P. (1989). Sediment concentration versus water discharge during single hydrologic events in rivers. J. Hydrol. 111, 89–106.

Wischmeier, W. H., Johnson, C.B. & Cross, B.V.(1971). A soil erodibility monograph for farm lands and construction sites. journal of soil and water. Vol. 265.

Wood, P.A.(1977). Controls of variation in suspended sediment concentration in river Rother, West Sussex, England. Sedimentology 24: 437-445.

Zug, M., Vazquez, J.(2010). Modeling of sanitation networks. Concepts, Approaches and Steps. Courses 3rd year of ENGEES. ANJOU SEARCH ENGEES.

ISSN 2055-6578(Print), ISSN 2055-6586(online)