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MODELING THE EVOLUTION OF SOLID FLOWS RATE BASED ON RAINFALL OF THE MEWOU RIVER IN THE MIFI BASIN

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ABSTRACT: *The objective of this study is to evaluate and model the solid rates based on rainfall over the Mewou River, in the Mifi watershed. We have determined in the specialized laboratories the quantities of solid exported from the samples taken from this watercourse. The MATLAB software allowed us to simulate the evolution of solids discharge based on rainfall over this stream. This evolution is characterized by the polynomial equation of the eight degree with a correlation coefficient of 0.9999 and a coefficient of determination of 0.9998:* $Q_s = a*p^8 + b*p^7 + c*p^6 + d*p^5 + e*p^4 + f*p^3 + g*p^2 + h*p + i$*. This model is more interesting than the polynomial model of degree two* ($Q_s = a*p^2 + b*p + c$) *and the power model* ($Q_s = a*p^b$) *developed by other authors.*

KEYWORDS: Solids Flows; Rainfall; Model; Simulate; Mewou; Mifi Basin.

INTRODUCTION

Rainwater, charged with carbon dioxide and other elements passes through the atmosphere and the surface of the soil. It dissolves part of their minerals through this process and triggers a series of chemical phenomena, causing chemical weathering of rocks (Fournier, 1969). Thus, 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 principle, human activity is the main cause of erosion, as a result of deforestation, agriculture, livestock and urbanization. This is the origin of the presence of solid particles in streams creating the solid flow. This study aims at evaluating quantitatively and model solid flows rate based on Rainfall.

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 results, 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 $\mathrm{As} = \sum_j^N (t_{j+1} - t_j) Q_j C_j$. 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: $\mathrm{Log}Qs = \mathrm{Log}a + b * \mathrm{Log}Q_l$.

- Modeling the evolution in the concentration of solids based on liquid flow rates of the mewou river in the mifi basin $Cs = a*Q_l^2 + b*Ql + c$ (Gouafo, C. et *al*., 2017).

- Modeling the evolution of sediment discharge based on liquid flow rates of the mewou river 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).

- Modeling the evolution in the concentration of solids based on rainfall in Maghreb basins

$Cs = a^*\log(p) + c$ (Probst and Amiotte, 1992)

According to Olivry (1976), 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 Nde 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).

METHODOLOGY

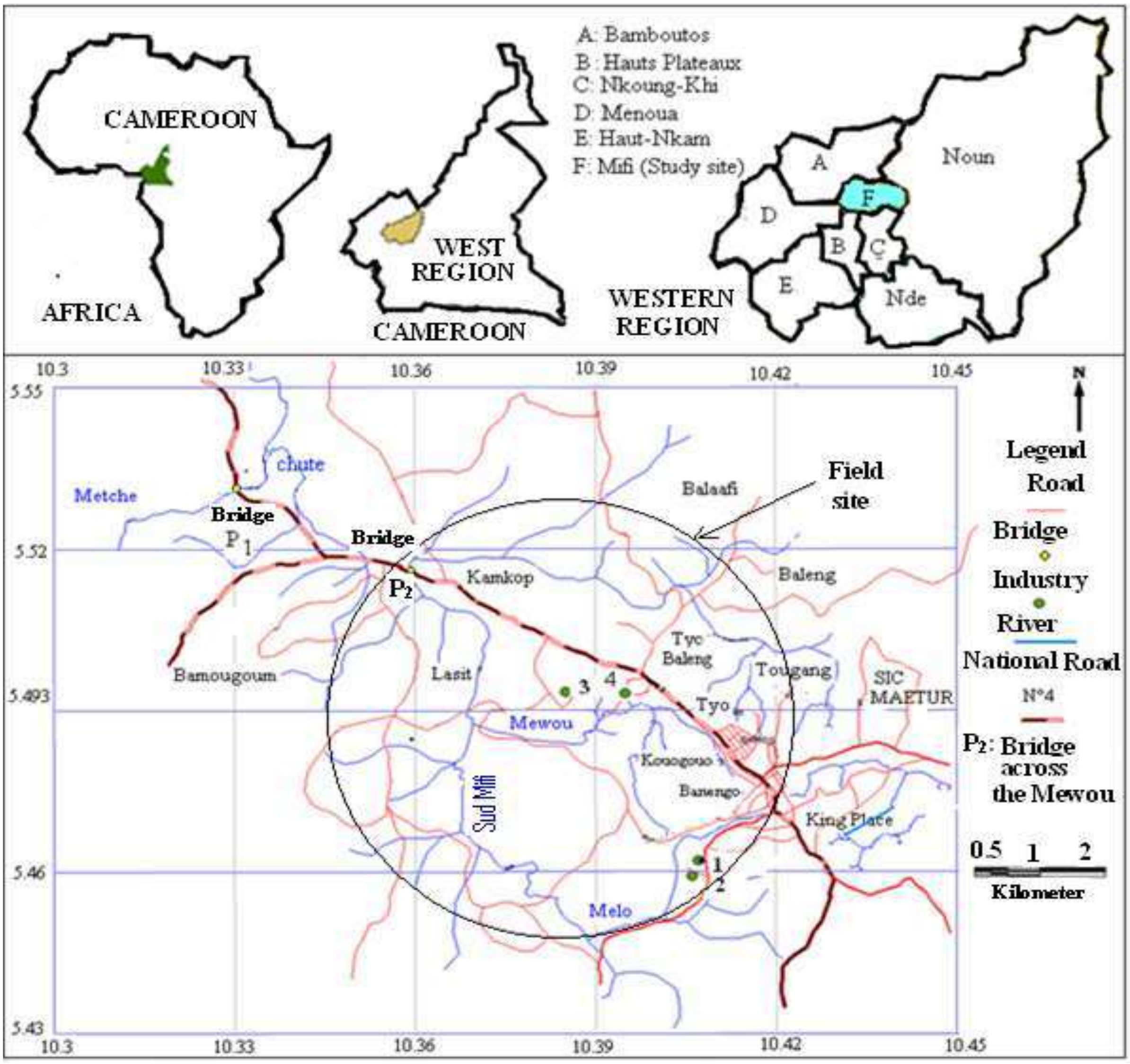
Field site and Sampling

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 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.

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

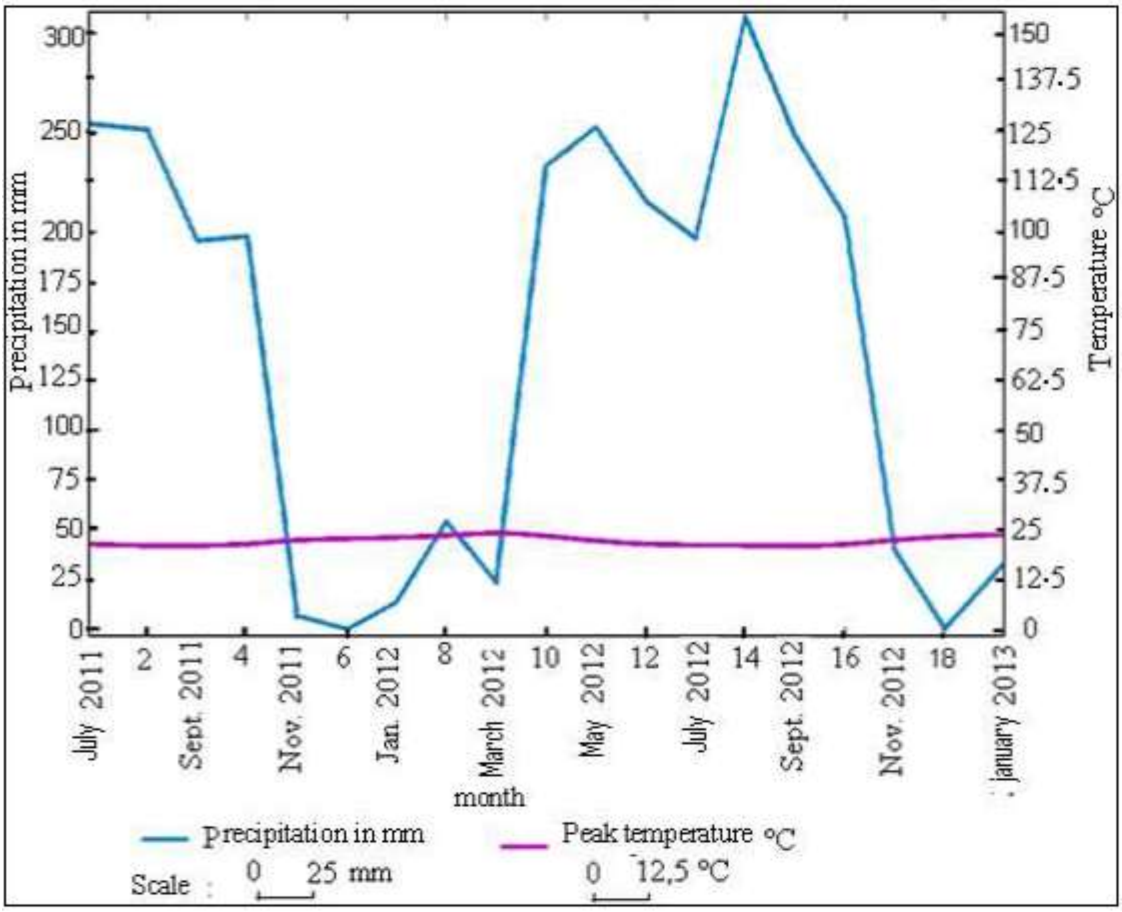


Source: Made using, a GPS, from a background map of the region (2012)

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).

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



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 South catchment area. It is located between 5 ° 32'13 "N and 10 ° 21 '16" E at altitude 1325 m. The annual rainfall over the passed 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.

Methods of experimentation

Assessment of water flow and exported soil

The flow rate Ql in m^3/s was determined using a gauging float (Rodier et *al*., 2009 Bernard, 1994) following the formula: $Ql = 0.8*L*H*V$ 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 kg/s was determined from the water flow rate (Ql) following the expression: Qs = Ql * Cs.

RESULTS/FINDINGS

Table 1: Liquid flow rate (l/s), concentration of solids discharge (g/l) and Rainfall in (mm/month, mm/day) and time (month) of the Mewou river from July 2011 to January 2013.

Time in Month	Duration of the month in days	Liquid flow rate in (l/s)	Concentration of solids discharge in	solid flows (kg/s)	Rainfall in (mm/month)	Rainfall in (mm/day)
July	31	8 900	0.29	2.581	253.8	8.19
August	31	32 711	0.26	2.079	251.2	8.11
Sept.	30	8 350	0.1	0.752	195.4	6.52
October	31	11 474	0.16	1.858	197.6	6.38
Nov.	30	10 311	0.22	2.331	6.7	0.23
Dec.	31	6 363	0.27	1.657	0.0	0.0
Jan.	31	3 727	0.11	0.374	13.7	0.44
Fév.	29	2 373	0.15	0.377	54.1	1.76
March	31	2 151	0.1	0.208	23.6	0.77
Apr.	30	5 372	0.98	7.746	233.0	7.77
May	31	5 513	0.23	1.317	252.4	8.14
Jun	30	9 037	0.26	2.796	215.3	7.17
July	31	11 630	0.26	3.018	196.4	6.34
August	31	12 786	0.3	2.928	308.0	9.94
Sept.	30	13 831	0.23	3.158	247.8	8.26
Oct.	31	16 326	0.332	5.407	207.1	6.68
Nov.	30	12 598	0.14	1.764	39.6	1.32
Dec.	31	7 543	0.09	0.679	0.3	0.01
Jan.	31	5 953	0 .3	1.786	27.9	0.9

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 neworder polynomial model that better accounts for the relationship between the evolutions of solid flows as a function of long-term liquid flows according to the equation of the form:

$$Q_s = a*p^8 + b*p^7 + c*p^6 + d*p^5 + e*p^4 + f*p^3 + g*p^2 + h*p + i$$

Where Qs represent the solids flows rate in kg/s, p the rainfall in mm/day, and the coefficients a, b, c, d, e, f, g, h and i vary, depending on the Qs values obtained during the study.

DISCUSSION

The data collected have been transformed into averages, and in some cases, presented in tabular form and curves. Table 1 summarizes liquid flows, concentration of solids discharge, solid flows and rainfall during the study period from July 2011 to January 2013.

The data in Table 1 made it possible to construct the curves of variation of the solids flows based on rainfall of the Mewou River in the Mifi Basin, respectively, according to the polynomial and power models (Figure 3a, Figure 3b, Figure 3c).

Figure 3a: Change in solid discharge Qs in kg/s of the Mewou watercourse based on Rainfall in mm/day, (polynomial model $Q_s = a*p^8 -+ b*p^7 + c*p^6 + d*p^5 + e*p^4 + f*p^3 + g*p^2 + h*p + i$*)*

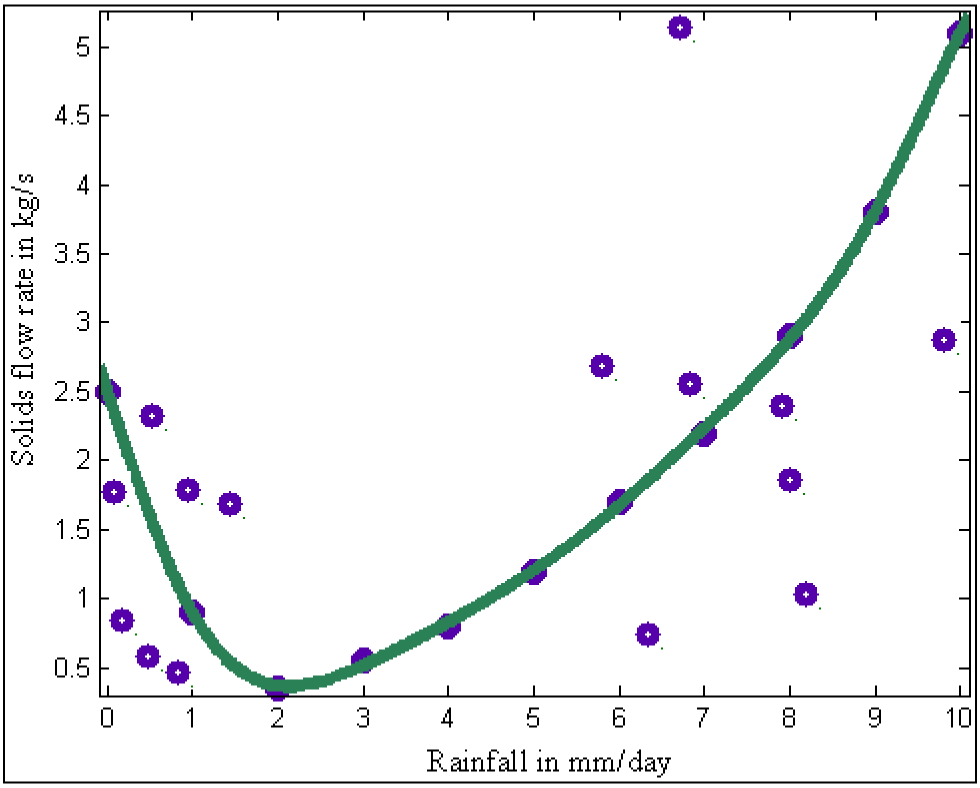


Figure 3b: Change in solid discharge Qs in kg/s of the Mewou watercourse based on Rainfall in mm/day (polynomial model $Q_s = a*p^2 + b*p + c$

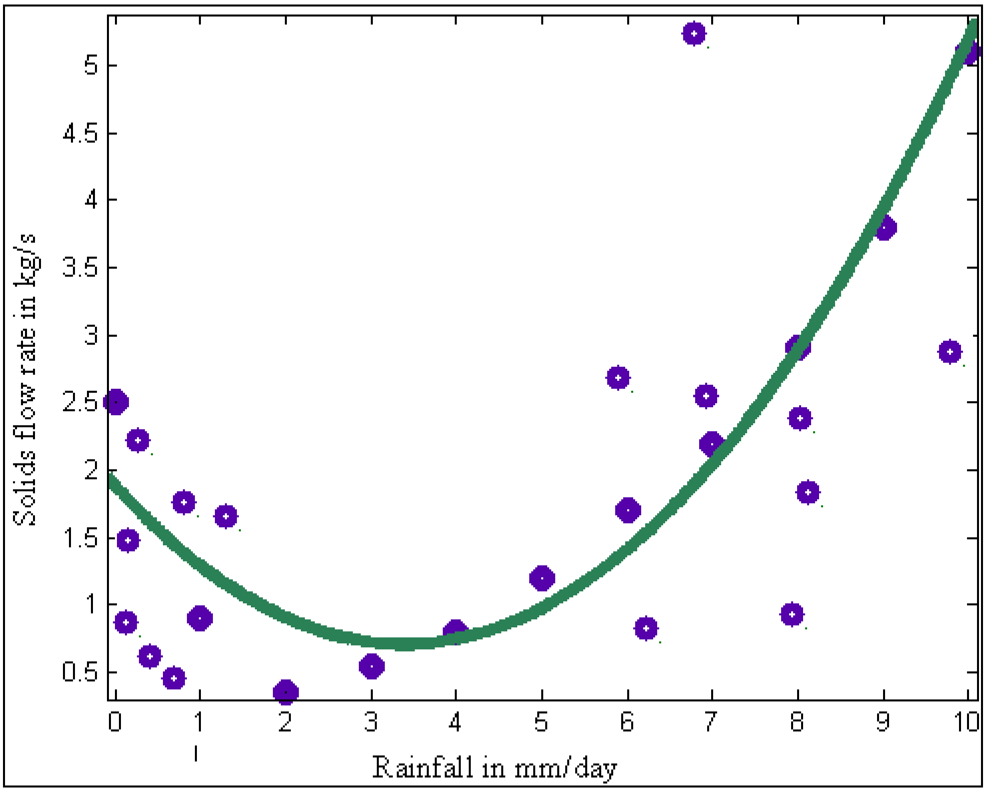
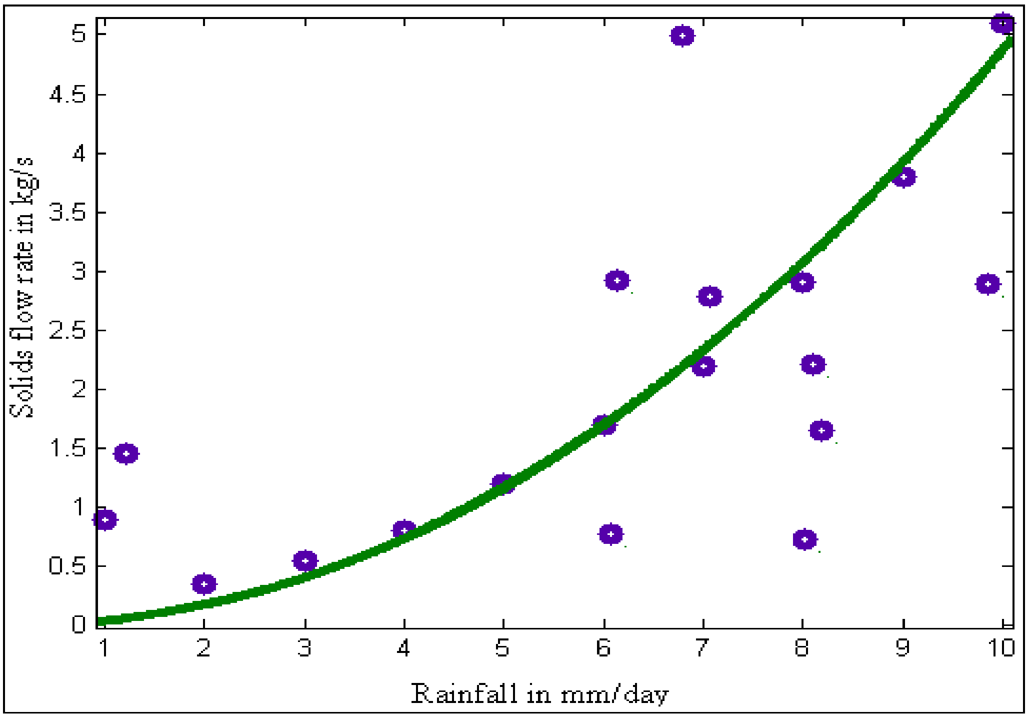


Figure 3c: Changes in solid discharge Qs in kg/s of the Mewou watercourse based on Rainfall in mm/day (power model Qs = a p^b)*



Coefficients a, b, c, d, e, f, g, h and i varied according to the values of Qs obtained during the study, making it possible to write the equations of the respective polynomial and power models as:

$Qs = 0.0004526*p^8 + 0.0004526*p^7 - 0.007565*p^6 + 0.06574*p^5 - 0.3093*p^4 + 0.6992*p^3 - 0.1708*p^2 - 1.884*p + 2.501$; $Qs = 0.1025*p^2 - 0.6937*p + 1.881$ and $Qs = 0.04181*p^{2.067}$

Table 2 summarizes the correlation coefficients R and determination coefficient R2, with respect to the points, passing at best in the cloud of points harvested.

Table 2: The correlation coefficients R and determination coefficient R2, with respect to the points, passing at best in the cloud of points harvested.

Models		Correlation coefficient (R)	Determination coefficient (R^2)	authors
Polynomial model degree eight	$Qs = 0.0004526*p^8 + 0.0004526*p^7 - 0.007565*p^6 + 0.06574*p^5 - 0.3093*p^4 + 0.6992*p^3 - 0.1708*p^2 - 1.884*p + 2.501$	0,9998	0,9996	Authors of this article (Kamdjo G. et *al.* (2017)
Polynomial model degree two	$Qs = 0.1025*p^2 - 0.6937*p + 1.881$	0,9521	0,9065	Bouanani (2005)
Power model	$Qs = 0.04181*p^{2.067}$	0.9585	0,9167	Legates and McCabe (1999) ; Donner and Eliasziw (1987)

The three models have significant coefficients of correlations (Legates and McCabe, 1999, Donner and Eliasziw, 1987), with values greater than 0.91. The three models have deviations, 4.77% between Figure 3a and Figure 3b and 4.13% between Figure 3a and Figure 3c.

The best model is that of Figure 3a which has the best correlation coefficient.

The analysis of the graphs (Figure 3a) indicates that solid flows rate are are high at the beginning of the rainy season (low rainfall, precipitation < 2 mm/day). This can be explained by the amount of solids accumulated during the dry season. Then, these quantities of solids increase in perfect synchronization with precipitation (rainfall > 2 mm/day). Wood (1977), observed the same phenomenon: the growth of sediment supply during periods of high precipitation. Thus, at the beginning of precipitation, concentrations may be higher because there is a lot of sediment available. During the periods of heavy precipitation, the force of the current accentuates the growth of solids flows rate. Transported sediments originate from bed and bank by erosion or slippage, and tributary tributaries (Williams, 1989).

In some places, the man plays an important role in the production of sediment by farming practices, for stirring the soil, it promotes the transport of sediments due to the reduction of 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 will permit managers of treatment stations to predict sediment quantities, to extract water as a function of precipitation;
- The study permits to determine the amount of sediment, transported according to precipitation.

CONCLUSION

The polynomial model $Q_s = a^* p^2 + b^* p + c$ developed by (Bouanani, 2005) and the power model $Qs = a^* p^b$ developed by (Legates and McCabe, 1999); Donner and Eliasziw, 1987) do not give a good explanation of this phenomenon. The polynomial model of eight degree $Q_s = a^*p^8 – + b^*p^7 + c^*p^6 + d^*p^5 + e^*p^4 + f^* p^3 + g^* p^2 + h^* p + i$, obtained in this study, using MATLAB software, is recommended for future predictions.

The evolution of the solids flows rate as a function of the precipitation of the Mewou stream, has as model the polynomial model of eight degree. Based on the data from this study, the equation is as follows:

$$Qs = 0.0004526^*p^8 + 0.0004526^*p^7 - 0.007565^*p^6 + 0.06574^*p^5 - 0.3093^*p^4 + 0.6992^*p^3 - 0.1708^*p^2 - 1.884^*p + 2.501$$

Where: Qs is the solids flows rate in kg/s and p the rainfall in mm/day
This equation is of the form: $Q_s = a^*p^8 – + b^*p^7 + c^*p^6 + d^*p^5 + e^*p^4 + f^* p^3 + g^* p^2 + h^* p + i$.
Where: Qs represents solids flows rate, p the precipitation in mm/day and coefficients a, b, c, d, e, f, g, h and i varies according to the Qs values obtained during this studies.

CONSTRAINTS \LIMITATIONS OF THE STUDY

- The impact of the soil transportation on the surrounding soil;
- The impact of the release of the pollutants of the industries on the water quality of the Mewou river.

RECOMMENDATIONS

- The impact of the Solid Flows on the Mewou River and environment;
- The soil degradation could be reduced through reforestation of the degraded uplands, this will reduce runoff and increase the recharge of aquifers.

REFERENCES

Albergel, J., Nasri, N., Boufaroua, M. et Pépin, Y., 2001. Erosion Assessment on small watersheds, small lakes of the Tunisian dorsal. small watersheds, small lakes of the Tunisian dorsal. Technical Documents In Hydrology 51, pp 63-70

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

Bernard, 1994. Course of general chemistry, 2nd edition, Dunod; Paris. 405p.

Bouanani, A., 2005. Hydrology, Transportation Solid and Modelling Study of some sub basins of Tafna (NW- Algeria). Doctoral thesis. University Abou Belkaïd Tlemcen.

Cambell, F.B. et 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 and Eliasziw, M., 1987. Sample size requirements for reliability studies. Stat Med. 1987; 6: 441-448.

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

Etchanchu, D. and Probst, J.L., 1986. Erosion and transportation of suspended solids in a watershed in agricultural area method of measuring the surface runoff, charge and two components of the sediment transport in rivers. C. R. Acad. Sci. Paris, 302, série II, n° 17 1063-1067.

GOUAFO, C., KAMDJO, G., KEYANGUE,T. J. H., YERIMA, B. P. K. and 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. and 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

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

Gaussen, H. and Bagnouls, F., 1952. The xerothermic index. Bulletin of the Association of French Geographers, n° 222-223, 1952, pp. 10-16.

Jerome, B., 2009. MATLAB R2009b « Matrix Laboratory ». Society Mathworks.

Legates, D. R. and McCabe, G.J., 1999. Evaluating the use of "goodness-of-fit" measures in hydrologic and hydroclimatic model validation. Water Resources Research 35: doi: 10. 1029/1998WR900018. Issn: 0043-1397.Florida Avenue N.W. D.C.

Martel, J., Dugas, C., Lafond, D., Descarreaux, M., 2OO9. Validation of the French version of the questionnaire. Bournemouth.J Can Chiropr Assoc. 2009 Jun53 (2): 111–120. French.

Microsoft O., 2010. Microsoft Office 2010 Home and Business. PC License English.

MINEDD, 2006. The Sample collection in rivers: Sampling techniques for liquid analysis. Technical Guide November 2006. Water Agency Loire- Britain Avenue Buffon.132p.

Olivry, J. C, 1976. Hydrological regimes in Bamileke region, 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 balance and fluctuations in the last 500 million years. Geological Sciences. Memory. Nº 94. ISSN 0302 – 2684, pp.60.

Probst, J. L. and Amiotte S. P., 1992. Fluvial suspended sediment transport and mechanical erosion in the Maghreb. Hydrol. Sci. J. 37(6), 621-637

Rodier J, Legube B, Merlet N, Coll. 2009. Analysis of the water . 9^{e} édition Dunod, Paris, France. P .1579.

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

Roose, E., De Noni, G. and Lamachere, J-M., 1998. Erosion to ORSTOM: 40 years of multidisciplinary research. Res. Ero. Orstom, Montpellier, France. 66 p.

Tavares, J.D.P., 2010. Soil erosion, Cape Verde: `process and quantification across three Watershed of the island of Santiago. Earth Sciences. Bourgogne University, 2010.French.

Walling, D. E., 1984. The sediment yields of African rivers. IAHS Publ., Harare Symp. 144, 265-283Seltzer, P., 1946 – Algeria climate. Univ. Alger. Inst. Mateo and Phys. of globe, Carbonnel. 219 p., 2 Map.

Walling, D. E. et 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. et 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. Modelling of sanitation. Concepts, approaches and steps. During the 3rd year. ANJOU ENGEES SEARCH.

APPENDIX

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	23.6	24	24.8	24.2	23.9	22.7	22.	21.3	21.4	21.	23.0	22.9
2003	23.4	24	24.9	23.1	22.7	21.0	20.	21.0	20.7	21.	22.3	22.7
2004	23.2	24	24.7	22.7	23.3	21.5	20.	22.7	21.1	21.	22.2	22.5
2005	22.9	24	23.9	24.0	21.6	21.4	20.	20.6	21.0	21.	21.0	21.3
2006	22.3	23	23.1	22.7	22.0	19.4	21.	20.9	20.9	21.	22.2	22.1
2007	22.9	24	24.7	25.6	22.3	21.5	20.	20.6	20.9	21.	21.7	22.2
2008	22.4	23	23.5	20.1	22.0	21.3	20.	20.7	20.2	21.	22.9	22.5
2009	23.5	24	24.8	22.9	22.3	21.6	21.	20.8	21.0	21.	22.3	23.0
2010	23.2	23	24.4	23.9	23.2	21.8	21.	21.1	20.2	21.	22.5	23.0
2011	22.8	23	24.1	23.6	22.8	21.8	21.	21.0	21.1	21.	22.7	22.7
2012	23.1	23	24.6	23.4	22.2	21.4	21.	21.2	20.9	21.	22.6	23.3
2013	23.7	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,