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MODELLING AND SIMULATION OF SOIL AND SEDIMENT EXPORTED THROUGH STREAM FLOW, CHANGES IN THE RIVER FLOW AND IN EXPORTED PHYSICOCHEMICAL PARAMETERS: LONG TERM ENVIRONMENTAL IMPLICATIONS AND MITIGATIONS STRATEGIES: CASE OF THE RIVER MEWOU (SOUTH MIFI) IN THE WESTERN TROPICAL HIGHLANDS OF CAMEROON

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ABSTRACT: *This study aims at determining the impact on water, agriculture and the environment of the soil constituents exported by the Mewou river on the southern Mifi through modeling of the changes in the river flow and in the exported physico-chemical constituents and to identify mitigate strategies. The average exported soils varied in t/km^2 from 195.34 in 2011 to 256.02 in 2012. The flow variation of water and chemical constituents were each characterized by a general equation with a model:*

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

Environmental pollution was identified by water turbidity, 146.9 NTU, and in mg/l Organic matter 2.33, Cd^{2+} 11, Pb^{2+} 48.20, NH_4^+ 2.8, PT 0.84, Al^{3+} 0.593, NO_2^- 4.645. It is recommended that to mitigate soil loss, pollution and increase recharge of water table, the use of Vetiver (Chrysopogon zizanioides) hedges and by installation of wastewater treatment plants by each industry and the Municipal council for the household wastes.

KEYWORDS: Physico-chemical, soil loss, Chrysopogon zizanioides, model, Pollution.

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INTRODUCTION

Cameroon, like most developing countries is facing the problem of soil loss through stream flow. According to Yerima and Van (2005), restoration of the eroded soils is difficult because the process of soil formation is very slow, that we can even say that the soil is not a renewable resource. Similarly Barrow (1991), defines erosion as the removal of soil materials by water or by wind at rates higher than those of soil formation. The eroded soils end up being transported, as sediment, into water bodies and cause, direct pollution (turbidity) or indirectly (by absorption of pollutants) and the problems of sedimentation, which have an impact on the use of the resource by humans and the ecological functions (Ponsaud, 2007). Dajoz (1996) , Hamburg and Cogbill (1988), report that acids cause leaching of various heavy metals that are toxic to vegetation, causing death of trees and the exposure of soils to different degradations.

LITERATURE

Erosion increases where the vegetation cover is absent, where rainwater that is not slowed down for infiltration runoffs carrying away the surface soil (Garouani et *al*., 2004). Pollutants are transported and propagated at clean sites specifically, pollution of groundwater's. According to Schneider (2001), the deposition of sediments causes siltation of rivers and water plants. This natural phenomenon is accentuated on industrial and urban wastes as well as agricultural practices that lead to discharges pollutants in to waters (McDowell et *al*., 2001; Mickelson et *al*., 2001; Walton et *al*., 2000). Sediment is essentially characterized by its mineral composition and organic matter content. The contamination of sediments results from industrial and urban wastes and agricultural practices (Schneider, 2001). These contaminants are grouped into three groups:

- The nutritive elements (phosphorus and ammonia) from urban waste waters, industrial and agricultural effluents that are causing eutrophication (Huet et *al*., 2005). The eutrophication of water plans causes a decrease in oxygen levels. The photosynthesis mechanism increases the pH level of water, which makes ammonia highly toxic at very low concentration for fishe and enhances cyanobacteria growth, plankton which is sometimes toxic, leadings to the limitation even restriction of washing and other uses of water (To such public health risks as dermatosis, conjunctivitis, gastroenteritis and even hepatic and neurological attacks);

- Heavy metals that often occur in traces amounts (Sial et *al*., 2006; Ullah et *al*., 2009), and indispensible for metabolism except lead, mercury cadmium which are toxic. Once the tolerance threshold is exceeded metals become toxic, and some of these metals are carcinogenic (Dajoz,1996; Schneider, 2001);

- The last group of contaminants consists of organic micro-pollutants (pesticides, chlorinated solvents…). According to Herr (2012), concentrations of chlorides > 250 mg/l give water a bad taste (salty flavor). Furthermore, salt causes a systematic increase in arterial pressure and an increase in the hypertensive frequencies in the population, mortality due to high cerebra-vascular accidents, notably in overweight persons and the accentuation of osteoporosis. In agriculture, improvement of the health

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of plants by the use of insecticides, fungicides, chemical fertilizers, contribute to the destruction of saprophytic soil microbes, that are responsible of organic matter decomposition into humus, that increasing natural soil fertility and reduced dependence on chemicals fertilizers.These chemicals, toxic to most organisms are now found in rivers and groundwater resulting from soil erosion and the infiltration of its products in the soil. Chemical fertilizers through soil application contribute to eutrophication of waterways through erosion the amounts of phosphorus (P), potassium (K) and nitrogen (N) used in watercourses. Table 1 indicates the amounts of insecticides, fungicides and chemical fertilizers used in the region.Siltation is a natural phenomenon that leads for the natural disappear of streams by filling up. The problems created by sedimentation today, comes from the increase in the rate of silting up as well as the increased toxicity of sediments. Following FAO (2010), statistics in several big rivers, the flow represents only 5% the volume of the original rivers, some rivers like the Huan He one reported not reach the sea throughout the year. Large lakes, for example Lake Chad may soon disappear (Kolawole, 2012). Sediments produced by soil erosion silt up reservoirs, compromising the production of hydropower and water supply. To handle shortage in electrical power supply, ENEO, the Cameroonian company that manages the production and distribution of electrical energy, uses a strategy called load shedding which consists of temporarily suspending energy supply in some zones of low priority, thus causes damage to a part of the population. The Cameroon authorities spend large amounts of money each year for the dredging of the Douala port so that it remains operational; the nest of the river Wouri on which this port is built continues to shrink. According to FAO (2010), we are witnessing a high degradation of soil quality and ecosystems over vast areas across the whole continent, as well as the impoverishment of the biodiversity and an changes in the values of our cultural heritage and natural beauty.

TABLE 1 : SOME PESTICIDES AND FERTILIZERS USED FOR DIFFERENT CROPS IN THE REGION AND THE APPLICATION RATE PER HECTARE

	Tomato	Peppers	Potato	watermelon	onion	corn	yam	cabbage	carrot	plantain banana	pineapple
Fertilizer (chemical fertilizers) t/ha	0.05	0.4	0.4	0.2	0.3	0.3	0.25	0.5	0.5	1	1.75
Pesticides (insecticides) l/ha	16	8	20	40	20	40	4	80	60	6	38

Source: (Njonga, 2013)

Many solutions have been proposed by sevarel authors to resolve the problems leading to erosion and pollution of waters and soils. Schneider (2001), proposes the cleaning of sediments of streams. This cleaning constitutes an operation for the restoration of the natural environment. The treatment of cleaned sediments allows limited environmental impact. Cleaning can cause major disruption of watercourses by destruction of the water beds, the

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substratum and the existing vegetation, by the modification of flows and removal of the sediment surface. This surface, sediment-water interface, is the seat of chemical and biological reactions participating in the self-purification of the environment and the protection of groundwater. This is why cleaning must be done only in cases of excessive clogged waterways. Huet et *al.* (2005), recommend that to limit the application of phosphorus in streams, the factor which causes eutrophication in soft waters in the natural environment; in coastal regions, nitrogen is the limiting factor due to it overabundant in these coastal regions and causes the green tide. Thus there is a need to restrict detergents or washing powders containing phosphates. Yerima and Van Ranst (2005), have observed that by to keeping sediments out of water in we increase the longevity of reservoirs and reduce pollution. Protective practices can be vegetative, mechanical or a combination of the two.

The survey have been carried out due to the exportation of soil by the Mewou River, environmental implications and pollution genered. This study focuses on the evaluation of the quantities of soil exported by the rivers and analysis of some physico-chemical parameters of water samples taken from this river in other to evaluate their eco-toxic effects. It also aims the modelling and simulation of soil and sediment exported through stream flow, changes in the river flow and in exported physico-chemical parameters. Identifying measures that can be used to limit soil exportation, mitigate pollution and promote recharge of flow groundwater.

MATERIALS AND METHODS

The Study Area: Geographical Location and Population

Bafoussam, the capital of the West region of Cameroon is located 300 km from Yaounde, in the Mifi catchment in the Western Highlands between longitude 9° 30' and 10° 35' east and latitude 5° and 6° north, at an average altitude of 1450 meters. The latest statistics released by the Directorate of Statistics and National Accounts (D.S.N.A.) and the General Population Census Service (G.P.C.S.) (2000), shows that this region has a population of 1,339,791 inhabitants, with an annual growth rate of 2.37 %. The population as at the year 2013 was estimated at 1,816,695 inhabitants. Bafoussam is region of high agricultural activity.

Hydrography of the Site

The area of the Watershed is 1640 km^2. This region is drained by four major rivers: the Mape, northern tributary of the Mbam; the Nkam to the south-west, which flows into the sea in Douala under the name of the Wouri, and drains the southwest edge of Bamileke and the region of Dschang; the Nde southeastern tributary of the Noun and the Noun, which drain much of the mountainous region of Western Cameroon after taking its rise at Mt Oku (3070 m). The Mewou River is transformed into an open sewer as it runs through the city and surrounding villages over a distance of about 35 km before forming the River Noun. Along its path, resident farmers use it for irrigation of cereals and forage crops.

Geology of the Site

The region is essentially composed of a basement and volcanic complex made up of mostly of gneisses embrechites of alkaline rocks (Pauwels et *al.*, 1992). The average white series, corresponds to an acidic phase composed, of trachytes of pliocene age in the upper Bamboutos Mountains, which the black bottom series is composed of basalts of Eocene age "basalt plateau"

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which covers most of the basin of the South Mifi. The black upper series corresponds to a complex quaternary basic phase composed of volcanic (ash) and volatiles in Bamoun area and on the northern edge of the Bamileke plateau (Baleng). The South Mifi area is made of 77% by a "basalt plateau" and 20% by basement complex composed of acidic rocks (trachytes) basanitoïdes. The soils of this region are derived from the degradation of these rocks and are mainly ferralsols in the basalt plateaus, or humic ferralsols on trachyte and basalt in mountainous area. Hydromorphic soils and soil of pyroclastic origin occur in this region and are more fertile than the latter soils.

The station retained for this study is located on the bridge over the Mewou river at the point of intersection (5° 30’ 8” N , 10° 22’ 7” E , Alt. 1279 m) along the national road number 04 (Figure 1).

Sampling and Analysis

All samples were collected in plastic containers of 500 ml capacity. The sampling equipment was immerged into the water where flow was turbulent. This emerged the collection of a representative water sample. The samples were sent to the laboratory six hours before the determination of the following physico-chemical parameters: TP, Mg^{2+}, Cd^{2+}, Zn^{2+}, Pb^{2+}, Al^{3+}, HCO_3^-, turbidity, NH_4^+, NO_2^- , Cl^- and SO_4^{2-}. Mg^{2+} was determined according to Pauwels et *al.* (1992), based on its extraction from water with a solution of ammonium acetate (CH_3COONH_4); in the NH_4^+ ion, added in excess displaces quantitatively the cations adsorbed on the exchange complex (humus, clay and sesquioxydes). The determination of exchangeable Mg^{2+} in the extract was done by complexometry. Total phosphorus (TP) was determined by the spectrometry, according to Pauwels et *al.* (1992). The determination of Cd^{2+}, Zn^{2+}, Pb^{2+} and Al^{3+} was by atomic absorption spectrophotometry (Benedetto, 1997). According to Pauwels et *al.* (1992), Al^{3+} was determined by atomic absorption spectrophotometry, KCl and the total acidity dosage (H^+ and Al^{3+}) obtened by titrating with NaOH , determination of aluminum was done by colorimetry. Turbidity was determined using spectrometry method at a wavelength of 720 nm (Pauwels et *al.*, 1992). NH_4^+ (ammonia) were determined according to Pauwels et *al.* (1992), using a specific electrode detector of ammonium gas (NH_3) the host being sufficiently basic to transform the ammonium ions (NH_4^+) to ammonium gas (NH_3).

The concentration of the chloride (Cl^-) was determined according to Rodier et *al.* (2009) by the method of the Carpenter- Volhard, chlorides of a known volume of water are precipitated in the presence of nitric acid by an excess nitrate of titrated silver, and the excess of silver salt is determined by a titrated solution of ammonium thio-cyanate in the presence of iron alum.

According to Rodier et *al.* (2009), colloidal sulphur (SO_4^{2-}) is extracted from water by trichloroethylene, in fact after the evaporation of the solvent, the sulphur is re-got by pure acetone. The acetic solution gives, in the presence of a reactive alkaline, a cytosol of sulphur from sky blue to deep green, suitable for a spectrometric dosage. Nitrite (NO_2^-) were determined by the method of continuous flow, indeed nitrites are determined by spectrometry after diazotization with sulfanilamide ($C_6H_8N_2O_2S$) and coupling with the N-1 naphthylethylenediamine (Pauwels et *al.*, 1992; Rodier et *al.*, 2009).

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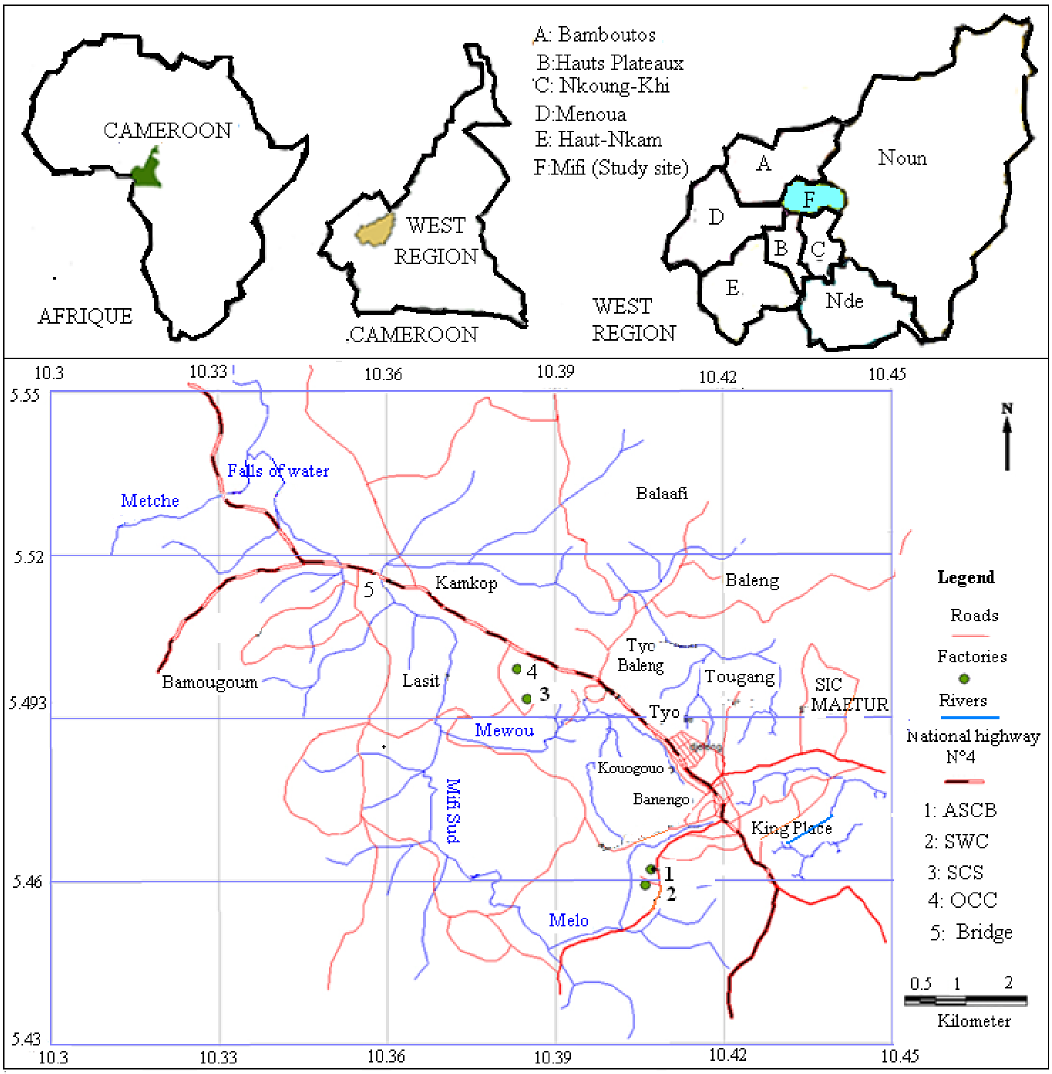
Bicarbonate (HCO_3^-) was determined by the titrimetric method in fact, the determination of bicarbonate was based on the determination of the alkalinity. One neutralized a certain volume of water (100 ml) by the hydrochloric acid (HCl) in the presence of the indicator dye phenolphthalein ($C_{20}H_{14}O_4$). Strontium chloride has been added to reduce interference associated with high levels of carbonate and from alkalinity we deduce the concentration HCO_3^- (NF EN ISO 9963-2, 1996). Total phosphorus (TP) was measured with the spectrophotometric method by ammonium molybdate (NF EN ISO 6878, 2005) .

Fig.1: Partial hydrographic network of southern Mifi showing the Mewou stream on the Mifi



South watershed on the Mifi South; site locations of ASCB (Anonymous Society of Cameroon Brewery); SWC (Soap factory of Western Cameroon); SCS (Soap factory of Cameroon Society) ; CCO (Cosmetic Complex of west)

Measurement of the Stream Flow Rate

According to Rodier et *al.* (2009); Bernard (1994) and Allan (1996), the flow rate Qv in m^3/s was determined by a gauging float and given by the following formula:

$$Q_V = 0.8*L_u*P_m*V \quad \text{(Eq. 1)}$$

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

Measurement of the Amount of Exported Soil

The amount of exported soil was determined by oven drying at 105 °C water samples collected from the Mewou river. The amount of dry soil (Mts) exported by water in g/s or in kg/s was determined from water flow rate (Qv) following the expression:

$$M_{ts} = Q_V*m_t \quad \text{(Eq. 2)}$$

Where m_t is the weight of soil per liter of water exported (in g / m^3 or in kg/m^3)

For a period of time T, we have a soil loss (M_{tsT}) from the expression:

$$M_{tsT} = M_{ts}*T \quad \text{(Eq. 3)}$$

The study of pollution and soil depreciation by exportation of pollutants substance was based on the analysis of physico-chemical parameters, carried out in specialized laboratory in the country using standard procedures.

Statistical Analysis of Data

The Pearson correlation coefficient R was determined using Microsoft Office Excel (Microsoft, 2010). The results obtained were transformed into averages, and in some cases in the form of tables or curves. The "MATLAB R2009a" software (Jerome, 2009), was used for data simulation over several years.

RESULTS

The evaluation of the amount of soil exported by the river Mewou and its impact on environment was made by measuring the amount of soil exported and the physico-chemical composition of the soil. Table 2 below shows the flow rate of the river Mewou in m^3/s and soil exported in t/ month during the period from July 2011 to January 2013.

Variation of Flow Rate, Rainfall , Soil Exported, and Physico-Chemical Parameters

Variation of Flow Rate

The flow rate of the water varies from 2.151 m^3/s to 32.711 m^3/s. The minimum flow rate occurred in March 2012 and the maximum flow rate was observed in August 2011. The curve (Ct_2) of figure 2 shows the trend of variation of the water flow during the study period. The regression line (Dr_2) indicates a general decreasing trend of water flow rate with a Pearson correlation coefficient of $R = 0.941$. This curve (Ct_2) is a simulated polynomial with the model in Eq. 4 where Y is the water flow rate at time t:

$$Y = 0.002373*t^9 - 0.2204*t^8 + 8.7*t^7 - 190.3*t^6 + 2\,517*t^5 - 20\,650*t^4 + 103\,600*t^3 - 299\,800*t^2 + 437\,300*t - 213\,300 \quad \text{(Eq. 4)}$$

The Pearson correlation coefficient between rainfall and flow rate is R = 0.453.

Variation of Rainfall

The rainfall varies from 0.0 to 308 mm / month (Table 1). The maximum rain fall is obtained in August 2012 and the minimum value in December 2011. Figure 2 shows the curve (Ct_1) the trend of the rainfall variation. The regression line (Dr_1) shows a general decreasing trend of rainfall during the study period, with a Pearson correlation coefficient of R = 0.908. This curve is simulated polynomial with the model in Eq. 5 where Y is the rainfall and t the time:

$$Y = -0.00001545*t^9 + 0.001405*t^8 - 0.05412*t^7 + 1.149*t^6 - 14.64*t^5 + 114.1*t^4 - 527.6*t^3 + 1\,346*t^2 - 1\,688*t + 1\,027 \quad \text{(Eq. 5)}$$

Figure 2: Variation of the rainfall in mm/month and variation of flow rate of the Mewou stream (Sourthern Mifi) in 0.1 m3/s from July 2011 to January 2013. Triangles and lozenges show experimental data, line shows simulation.

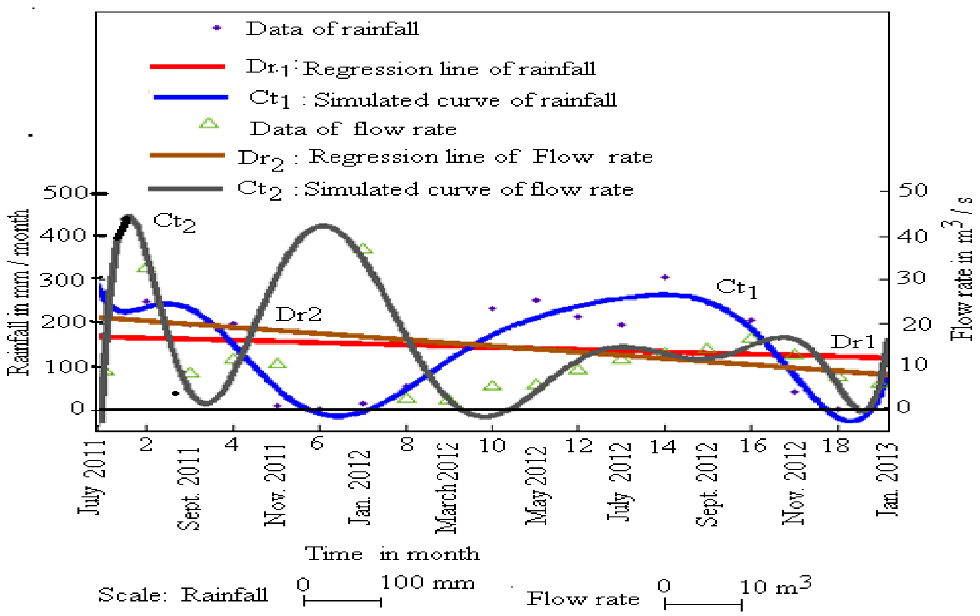


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TABLE 2: FLOW RATE (M^3/S), RAINFALL (MM/MONTH) AND THE AMOUNT OF SOIL EXPORTED T/MONTH) OF THE RIVER MEWOU DURING THE PERIOD FROM JULY 2011 TO JANUARY (2013).

Years	Month	Duration in days of the month	Average water flow rate in m^3/s (Qvm)	Rainfall in mm per month	soil exported in g / l (mt)	Soil exported g/s	Soil exported per month in t (MtsT)
	July	31	8.90	253.8	0.29	2 581	6 913
	August	31	32.711	251.2	0.26	2 079	5 568.4
	September	30	8.35	195.4	0.092	752	1 949.2
	October	31	11.474	197.6	0.16	1 858	4 976.5
2011	November	30	10.311	6.7	0.22	2 331	6 042
	December	31	6.363	0.0	0.264	1 657	4 438.11
	January	31	3.7 3	13.7	0.102	374.3	1 002.45
	February	29	2.373	54.1	0.153	376.8	944.11
	March	31	2.151	23.6	0.1	208	556.36
	April	30	5.372	233.0	0.98	7 746	20 078.67
	May	31	5.513	252.4	0.23	1317	3 527.86
	June	30	9.04	215.3	0.26	2 796	7 247.23
	July	31	11.63	196.4	0.26	3 018	8 084
	August	31	12.79	308.0	0.3	2 928	7 842.63
	September	30	13.83	247.8	0.23	3 158	8 184.27
	October	31	16.33	207.1	0.332	5 407.6	14 483.72
	November	30	12.6	39.6	0.14	1 764	4 571.56
2012	December	31	7.543	0.3	0.09	678.9	1 818.3
2013	January	31	5.953	27.9	0.3	1 786	4 783.62

Variation of Soil Exported

The amount of soil exported varies from 556.357 to 20,078.669 t / month (Table 2). The least amount of soil exported was in March 2012 and the peak in April 2012. Figure 3 shows the curve (Ct_2) of the trend of soil exportation. The regression line (Dr_2) shows a general increasing trend in the amount of soil exportation. Pearson correlation coefficient R = O.622. This curve (Ct_2) is a simulated polynomial whith the model in equation Eq. 6 where Y is the amount of soil exported and t the time:

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$$Y = 1.022*t^9 - 85.19*t^8 + 2\,959*t^7 - 55\,440*t^6 + 607\,000*t^5 - 3\,931\,000*t^4 + 14\,560\,000*t^3 - 28\,190\,000*t^2 + 22\,850\,000*t + 1\,354\,000 \quad \text{(Eq. 6)}$$

The Pearson correlation coefficient between rainfall and soil exported is R = 0.515.

Figure 3: Variation of rainfall (mm/month) and soil exported (t/month) by the Mewou stream (Sourthern Mifi) from July 2011 to January 2013; plus and stars show experimental data.

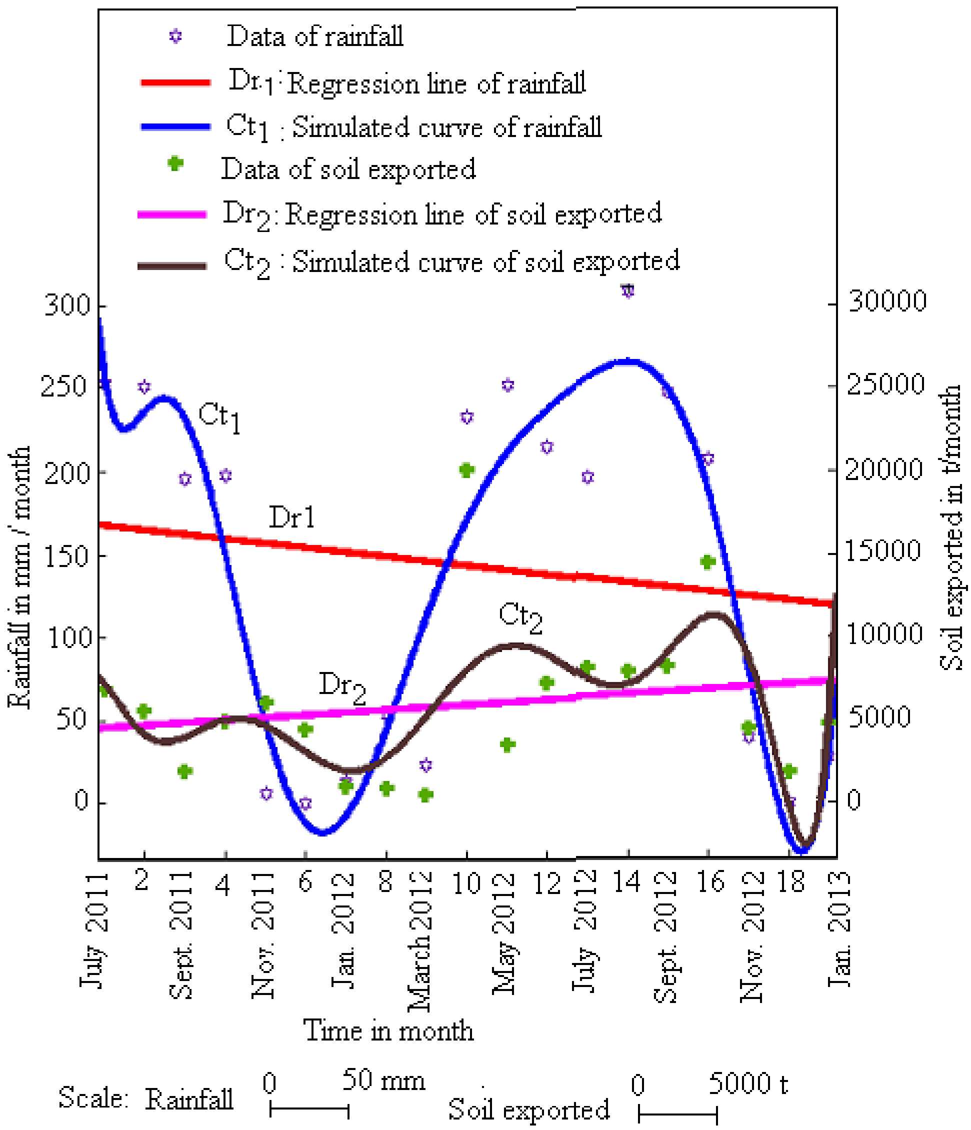

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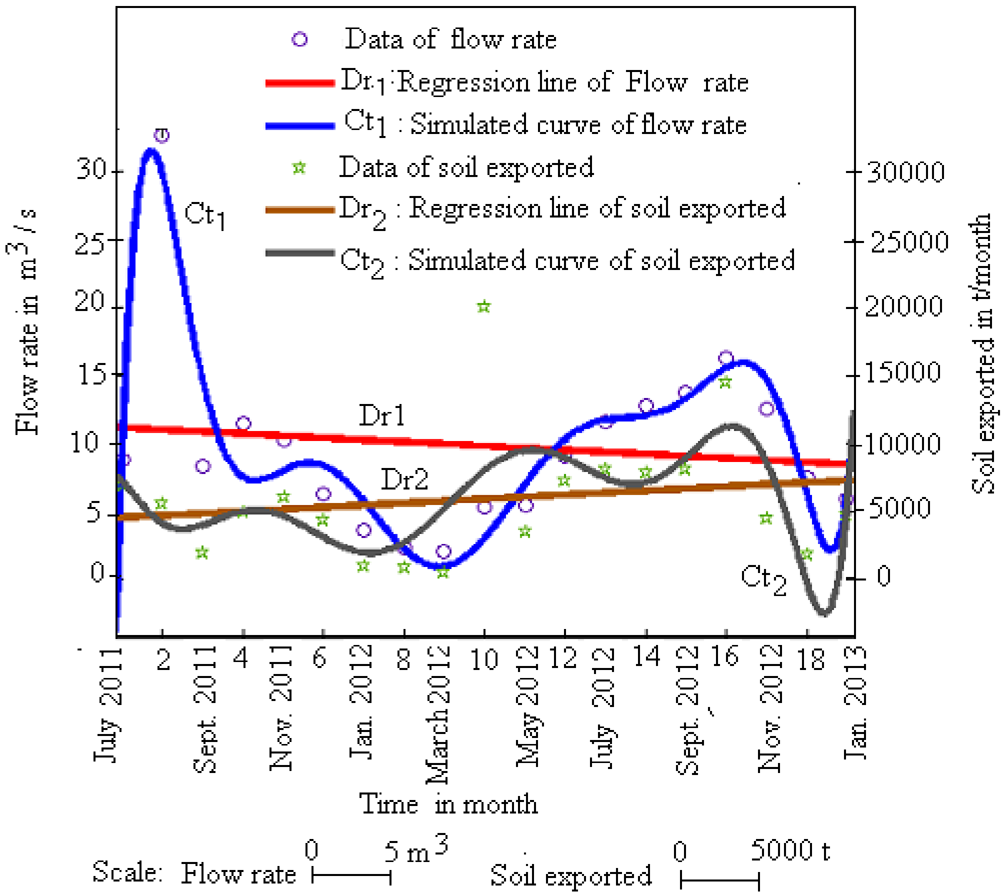
Figure 3 present the curve (Ct_1) and (Ct_2) that indicates the trend variation of flow rate and soil exported by the river Mewou. The Pearson correlation coefficient between flow rate and soil exported is R = 0.237.

Figure 4: Variation of flow rate (m^3/s) and soil exported (t/month) (Sourthern Mifi) by the river Mewou from July 2011 to January 2013; circles and stars show experimental data, lines shows simulation



Variation of Physico-Chemical Parameters

Table 3 shows the mean values of physico-chemical parameters of soil transported by the river Mewou at the bridge of the National Highway No. 4 and the threshold values. Mg^{2+}, Zn^{2+}, HCO_3^-, Cl^-, and SO_4^{2-} have values below the threshold concentrations (Table 3). The Turbidity (Turb.) has a value of 146.9 NTU which is greater than the threshold limit value of 5 NTU (Table 3). Cadmium (Cd^{2+}) has an average concentration of 11 mg/l, it is above the threshold limit value which is 0.01 mg/l (Table 3). Lead (Pb^{2+}) has an average concentration of 48.20 mg/l, it is greater than the threshold limit concentration of 0.01 mg/l (Table 3). Aluminum (Al^{3+}) has an average concentration of average 0.593 mg/l, it is greater than the maximum concentration value of 0.1 mg/l (Table 3). Ammonium (NH_4^+) has an average concentration of 2.8 mg/l; it is greater than the maximum value of 1.5 mg/l (Table 3). The total phosphorus (TP) has an average concentration of 0.84 mg/l which is greater than the threshold

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limit value of 0.2 mg/l. The nitrite (NO_2^-) has an average concentration of 4.645 mg/l, which is greater than the threshold limit concentration of 3 mg/l (Table 2).

Figure 5: Variation of flow rate (m^3/s) and magnesium (Mg) exported (t/month) (Sourthern Mifi) by the river Mewou from July 2011 to January 2013; circles and triangles show experimental data; lines shows simulation.

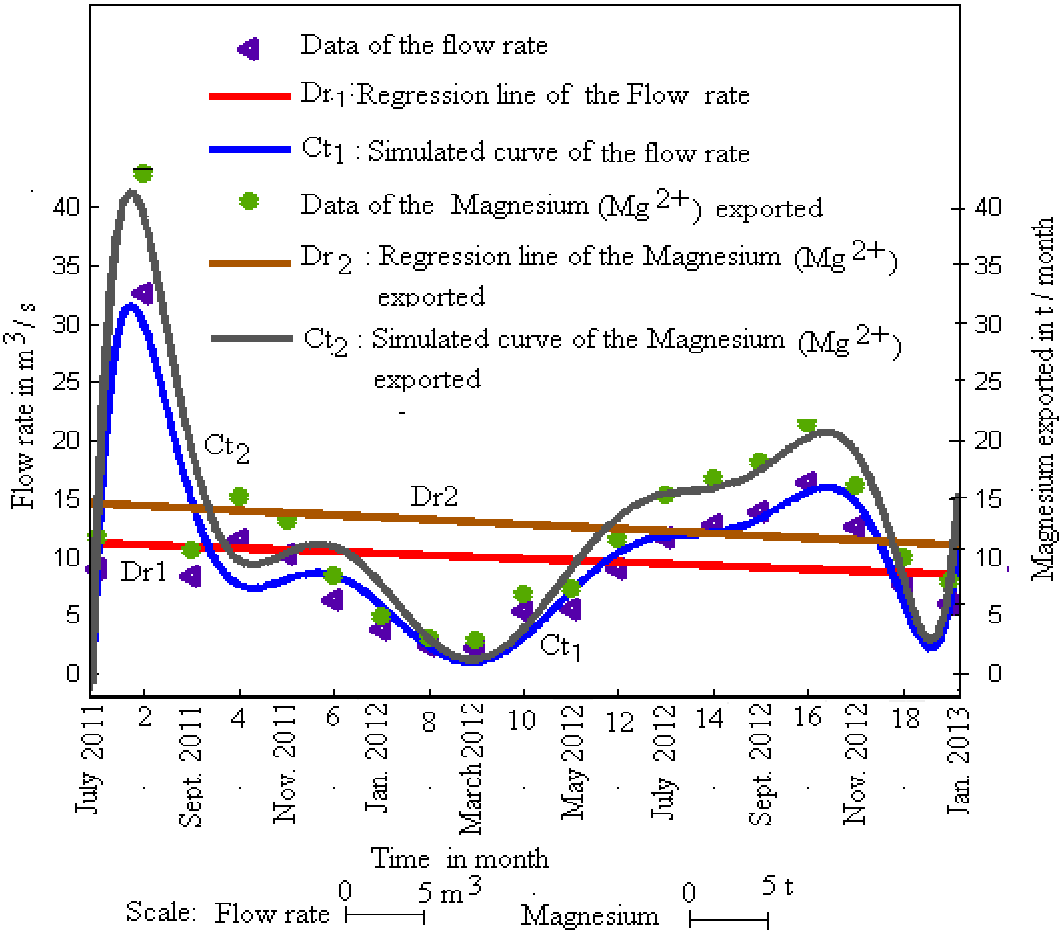

Table 4a and Table 4b present the amounts of each physico-chemical parameter exported per month by the river Mewou:

Magnesium (Mg^{2+})

The amount of total magnesium exported by the river Mewou varies from 2.822 to 42.938 t/month (Table 4a and Table 4b). The lowest value was obtained in March 2012 and the highest value in August 2011. Figure 5 shows the curve (Ct_2) of the trend of variation of the amount of magnesium exported. The regression (Dr_2) indicates a general decreasing trend of the magnesium exported (figure 5), with a Pearson correlation coefficient R = 0.939. This curve is simulated by polynomial whith the model in equation Eq. 7 where Y is the amount of magnesium exported and t the time:

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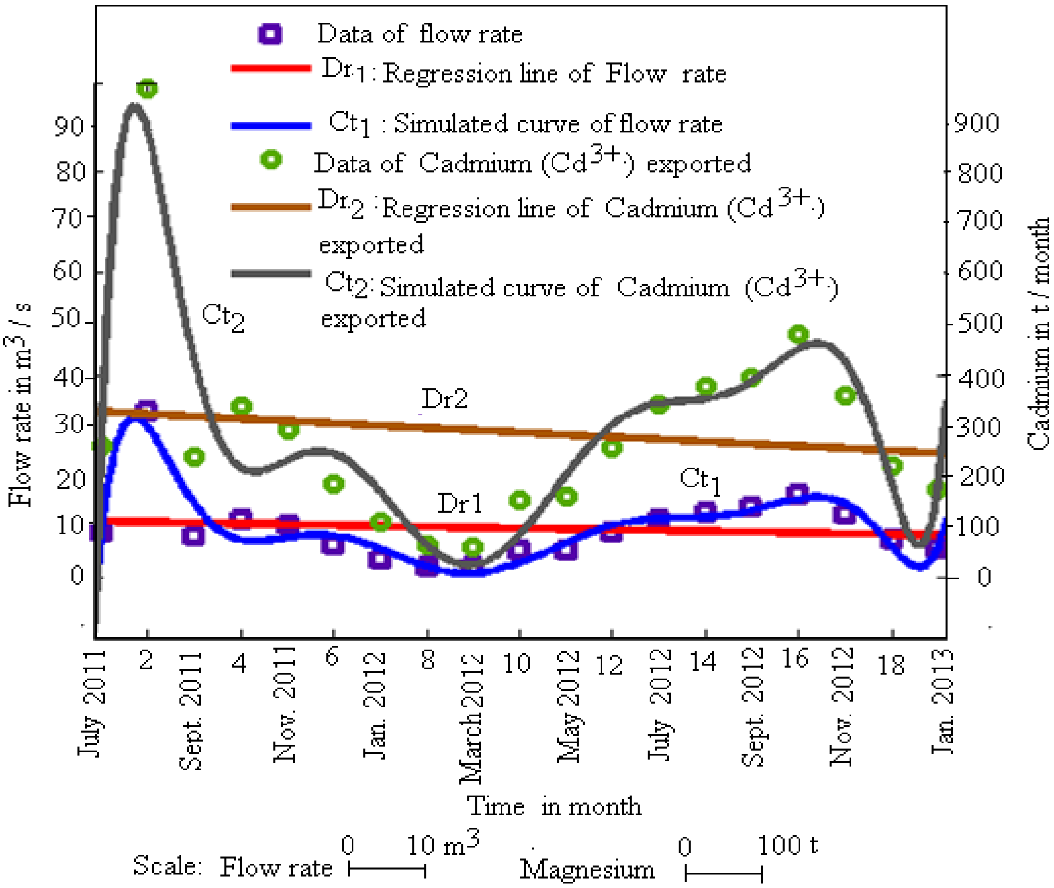
$$Y = 0.00307*t^9 - 0.2854*t^8 + 11.28*t^7 - 247*t^6 + 3\,273*t^5 - 26\,900*t^4 + 135\,100*t^3 - 391\,700*t^2 + 571\,800*t - 279\,000 \quad \text{(Eq. 7)}$$

Figure 6: Variation of flow rate (m^3/s) and cadmium (Cd^{2+}) t/month (Southern Mifi) exported by the river Mewou from July 2011 to January 2013. Circles and Squares show experimental data; lines shows the simulation



Cadmium (Cd^{2+})

The amount of cadmium exported by river Mewou varies from 63.360 to 963.922 t / month (Table 4a and Table 4b). The lowest value was obtained in March 2012 and the highest value in August 2011. Figure 6 presents the curve (Ct_2) of the trend of variation of the amount of cadmium exported. The regression line (Dr_2) indicates a general decreasing trend of cadmium, with a Pearson correlation coefficient of R = 0.939. This curve is simulated polynomial whith the model in equation Eq. 8 where Y is the amount of cadmium exported and t the time:

$$Y = 0.06956*t^9 - 6.466*t^8 + 255.5*t^7 - 5\,593*t^6 + 74\,060*t^5 - 608\,300*t^4 + 305\,400*t^3 -$$

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$$8\ 844\ 000*t^2 + 12\ 900\ 000*t - 6\ 293\ 000 \quad \text{(Eq. 8)}$$

Zinc (Zn^{2+})

The amount of zinc exported by river Mewou varies from 5.215 to 79.330 t / month (Table 4a and Table 4b). The lowest value was obtained in March 2012 and the highest value in August 2011. The simulated curve (Ct_2) of the trend of variation of the amount of zinc exported was similar to that of magnesium (Mg^{2+}) and cadmium (Cd^{2+}) (Figures 5 and Figure 6). Similarly the regression line (Dr_2) indicates a general downward trend of the amount of zinc exported as that of magnesium (Mg^{2+}) and cadmium (Cd^{2+}) (Figures 5 or Figure 6), with a Pearson correlation coefficient R = 0.939. This curve is simulated by the polynomial whit the model in equation Eq. 9 where Y is the amount of zinc exported and t the time:

$$Y = 0.005725*t^9 - 0.5321*t^8 + 21.03*t^7 - 460{,}3*t^6 + 6\ 095*t^5 - 50\ 060*t^4 + 251\ 300*t^3 - 727\ 900*t^2 + 1\ 062\ 000*t - 517\ 900 \quad \text{(Eq. 9)}$$

Lead (Pb^{2+})

The amount of lead exported by river Mewou varies from 277.627 to 4,223.729 t/month (Table 4a and Table 4b). The lowest value was registered in March 2012 and the highest value in August 2011. The simulated curve (Ct_2) of the trend of variation of the amount of lead exported was similar to that of magnesium (Mg^{2+}) and cadmium (Cd^{2+}) (Figures 5 or Figure 6). Similarly the regression line (Dr_2) indicates a general downward trend of the amount of lead exported as that of magnesium (Mg^{2+}) and cadmium (Cd^{2+}) (Figures 5 or Figure 6), with a Pearson correlation coefficient R = 0.939. This curve is simulated by the polynomial which the model in equation Eq. 10 where Y is the amount of lead exported and t the time:

$$Y = 0.3048*t^9 - 28.33*t^8 + 1\ 120*t^7 - 24\ 510*t^6 + 324\ 500*t^5 - 2\ 666\ 000*t^4 + 13\ 380\ 000*t^3 - 38\ 750\ 000*t^2 + 56530000*t - 27\ 580\ 000 \quad \text{(Eq. 10)}$$

Aluminum (Al^{3+}), Bicarbonate (HCO_3^-), Ammonium (NH_4^+), Nitrite (NO_2^-), Chloride (Cl^-), Sulfate (SO_4^{2-}) and Total phosphorus (TP)

The amount of aluminum (Al^{3+}), bicarbonate (HCO_3^-), ammonium (NH_4^+), nitrite (NO_2^-), chloride (Cl^-), sulfate (SO_4^{2-}) and total phosphorus (TP), exported by the river Mewou varies has shown in Table 4a and Table 4b. The lowest value was registered in March 2012 and the highest value in August 2011. The simulated curve (Ct_2) of the trend of variation of the amount of aluminum (Al^{3+}), bicarbonate (HCO_3^-), ammonium (NH_4^+), nitrite (NO_2^-), chloride (Cl^-), sulfate (SO_4^{2-}) and total phosphorus (TP) exported was similar to that of magnesium (Mg^{2+}) and cadmium (Cd^{2+}) (Figures 5 or Figure 6). Similarly the regression line (Dr_2) indicates a general downward trend of the amount of aluminum (Al^{3+}), bicarbonate (HCO_3^-), ammonium (NH_4^+), nitrite (NO_2^-), chloride (Cl^-), sulfate (SO_4^{2-}) and total phosphorus (TP) exported as that of magnesium (Mg^{2+}) and cadmium (Cd^{2+}) (Figures 5 or Figure 6), with a Pearson correlation coefficient R = 0.939. This curve is simulated by the polynomial whith the model in equation Eq. 11:

$$Y = a*t^9 + b*t^8 + c*t^7 + d*t^6 + e*t^5 + f*t^4 + g*t^3 + h*t^2 + i*t \quad \text{(Eq .11)}$$

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Where Y represents the amount of aluminum (Al^{3+}), bicarbonate (HCO_3^-), ammonium (NH_4^+), nitrite (NO_2^-), chloride (Cl^-), sulfate (SO_4^{2-}) or total phosphorus (TP) exported , t the time and the coefficients a, b, c, d, e, f, g, h, i and j varies according to the values of Y.

TABLE 3: PHYSICO-CHEMICAL PARAMETERS OF THE RIVER MEWOU AT THE THE NATIONAL HIGHWAY N° 4

parameters	standards values		Date of samples				
	limits	authors	2/3/2012	6/9/2012	2/08/2013	Average	Standard
Mg^{2+}(mg/l)	30	(Rodier, 1996)	0.4	0.58		0.49	0.127
Turbi. (NTU)	5	(Rodier et *al.*, 2009)	146.9	146.9		146.9	0
Cd^{2+} (mg/l)	0, 01	(Benedetto, 1997 ; Rodier et *al.*, 2009)			11	11	0
Zn^{2+} (mg/L)	3	(Ghaouti et *al.* 2005)	0.27	0.75		0.51	0.339
	5	(Dajoz, 1996)					
Pb^{2+} (mg/l)	0.01	(OMS, 2004)			48.20	48.20	0
Al^{3+} (mg/l)	5	(Hicham et *al.*,2008)	0.587	0.598		0.593	0.008
	0.1	(Rodier, 1996)					
HCO_3^-(mg/l)	518	(Belghyti et *al.*, 2009)	3.04	3.75		3.395	0.502
NH_4^+(mg/l)	1.5	(OMS, 2004)	5.6	0.00		2.8	3.96
TP (mg/l)	0.2	(Dajoz, 1996)			0.84	0.84	0
NO_2^- (mg/l)	3	(OMS, 2004)	6.44	3.25		4.645	2.256
Cl^- (mg/l)	25	(Rodier et *al.*, 2009)			1.065	1.065	0
	250	(OMS, 2004)					
SO_4^{2-} (mg/l)	20	(Rodier et *al.*, 2009)	0.21	0.11		0.16	0.071

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TABLE 4A: AMOUNTS OF PHYSICO-CHEMICAL PARAMETERS EXPORTED PER
MEWOU IN T/MONTH DURING THE PERIOD FROM JULY 2011 TO

Années		2011					
Month		July 2011	August	September 2011	October 2011	November 2011	December 2011
Dmj	j	31	31	30	31	30	31
Qm	m^3 /s	8.90	32.72	8.35	11.48	10.31	6.36
Mg^{2+}	t/month	11.68	42.94	10.61	15.06	13.1	8.35
Cd^{2+}	t/month	262.22	963.92	238.1	338.06	294	187.47
Zn^{2+}	t/month	21.6	79.33	19.6	27.82	24.2	15.43
Pb^{2+}	t/month	1149	4223.73	1043.2	1481.31	1288.23	821.46
Al^{3+}	t/month	14.14	52	12.84	18.23	15.85	10.11
HCO_3^-	t/month	80.93	297.5	73.48	104.34	90.74	57.86
NH_4^+	t/month	66.75	245.36	60.6	86.1	74.84	47.72
NO_2^-	t/month	110.73	407.04	100.54	142.75	124.15	79.16
Cl^-	t/month	25.4	93.33	23.05	32.73	28.46	18.15
SO_4^{2-}	t/month	3.82	14.02	3.46	4.92	4.28	2.73
TP	t/month	20.03	73.61	18.18	25.82	22.45	14.32

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TABLE 4B: AMOUNTS OF PHYSICO-CHEMICAL PARAMETERS EXPORTED PER
IN T / MONTH DURING THE PERIOD FROM JANUARY 2012 TO JANUARY

Années		2012												2013
Month		January	February	March	April	May	June	July	August	September	October	November	December	January
Dmj	j	31	29	31	30	31	30	31	31	30	31	30	31	31
Qm	m^3/s	3.73	2.38	2.15	5.37	5.52	9.04	11.63	12.79	13.83	16.33	12.6	7.54	5.95
Mg^{2+}	t/month	4.9	2.92	2.82	6.83	7.24	11.48	15.27	16.78	18.15	21.43	16.0	9.90	7.82
Cd^{2+}	t/month	109.82	65.4	63.36	153.164	162.427	257.67	342.66	376.72	394.36	481.01	359.2	222.24	175.4
Zn^{2+}	t/month	9.04	5.38	5.22	12.61	13.37	21.21	28.2	31.01	32.46	39.59	29.56	18.29	14.44
Pb^{2+}	t/month	481.2	286.56	277.627	671.135	711.72	1129.07	1501.47	1650.77	1727.968	2107.668	1573.915	973.8	768.58
Al^{3+}	t/month	5.92	3.53	3.2	8.26	8.76	13.9	18.47	20.31	21.26	25.93	19.4	11.98	9.46
HCO_3^-	t/month	33.9	20.2	19.6	47.27	50.2	79.53	105.76	116.27	121.72	148.46	110.86	68.59	54.14
NH_4^+	t/month	27.96	16.65	16.13	39	41.35	65.59	87.22	95.9	100.38	122.44	91.43	56.57	44.65
NO_2^-	t/month	46.4	27.62	26.76	64.68	68.6	108.81	144.7	159.11	166.53	203.12	151.68	93.85	74.1
Cl^-	t/month	10.63	6.33	6.14	14.830	15.73	24.95	33.18	36.48	38.18	46.57	34.78	21.52	16.98
SO_4^{2-}	t/month	1.6	0.95	0.93	2.23	2.37	3.75	4.99	5.48	5.74	7	5.23	3.23	2.55
TP	t/month	8.4	5	4.84	11.7	12.4	19.68	26.17	28.77	30.12	36.73	27.43	16.97	13.4

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DISCUSSIONS

Changes in Water Flow

General decrease in water flow rate (Figure 2) was observed over time. The regression line (Dr_2) (Figure 2), indicates a decrease in the amount of flow. Figure 7 shows a prediction of flow rate using Matlab numerical calculation (Jerome, 2009). However, the negative flow rates (Figure 7) indicate the depletion of the water within the aquifer. From this prediction line, a water shortage could increase after 75 months. That is in September 2017 if no remediation are taken to correct this trend. This indicates that from September 2017, one may not have water in this river during some period (February and March) in the dry season. In this region the drying up of stream during the year is regular. However, in the rainy season, one could have a regular flow as the network of neurons phenomenon indicates (Figure 8), consistency in the flow variation of rainfall over a period of 12 years (2002-2013), with an increasing trend during the twelfth year 2013. But the flow is no longer sufficient for loading dams used for the production of electrical energy. The Pearson correlation coefficient of water flow data is 0.941 which is different from the Pearson correlation coefficient of rainfall data 0.908. Pearson correlation coefficient between rainfall and water flow rate during the study period is 0.454; the coefficient of 0.454 indicates that there is no correlation between the flow rates and rainfall. We cannot predict flow rate from rainfall because the correlation coefficients is different from one ($0.454 \neq 1$). This can be explained by the fact that the refill of groundwater is not regular as there is loss of rainfall through runoff and evapotranspiration. In the region the drying up of rivers during the dry season is regular phenomenon. The decrease of water flow rate is due to the destruction of vegetation by human activities such as: bush fires, the use of chemical fertilizers, poor farming methods and deforestation. Vegetation slows down runoff provides movements that increase porosity, promotes microbial activities that increase porosity, thereby promoting water infiltration into the soil for the refill of the groundwater and consequently the rivers.

Figure 7 : Prediction of the variation of flow rate (l/s) of the river Mewou (Sourthern Mifi) from July 2011 to June 2021 using the software MATLAB

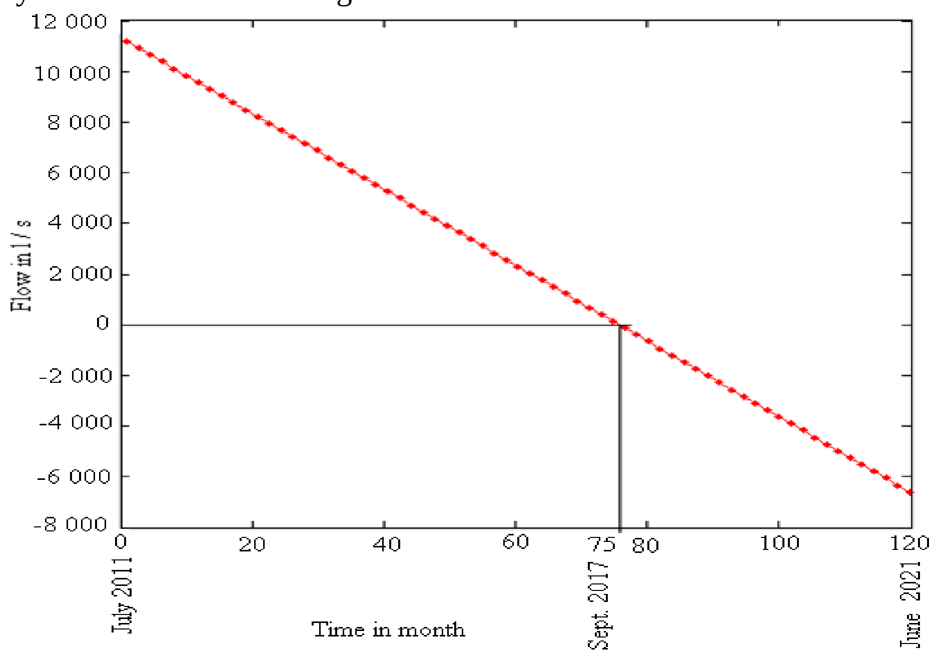
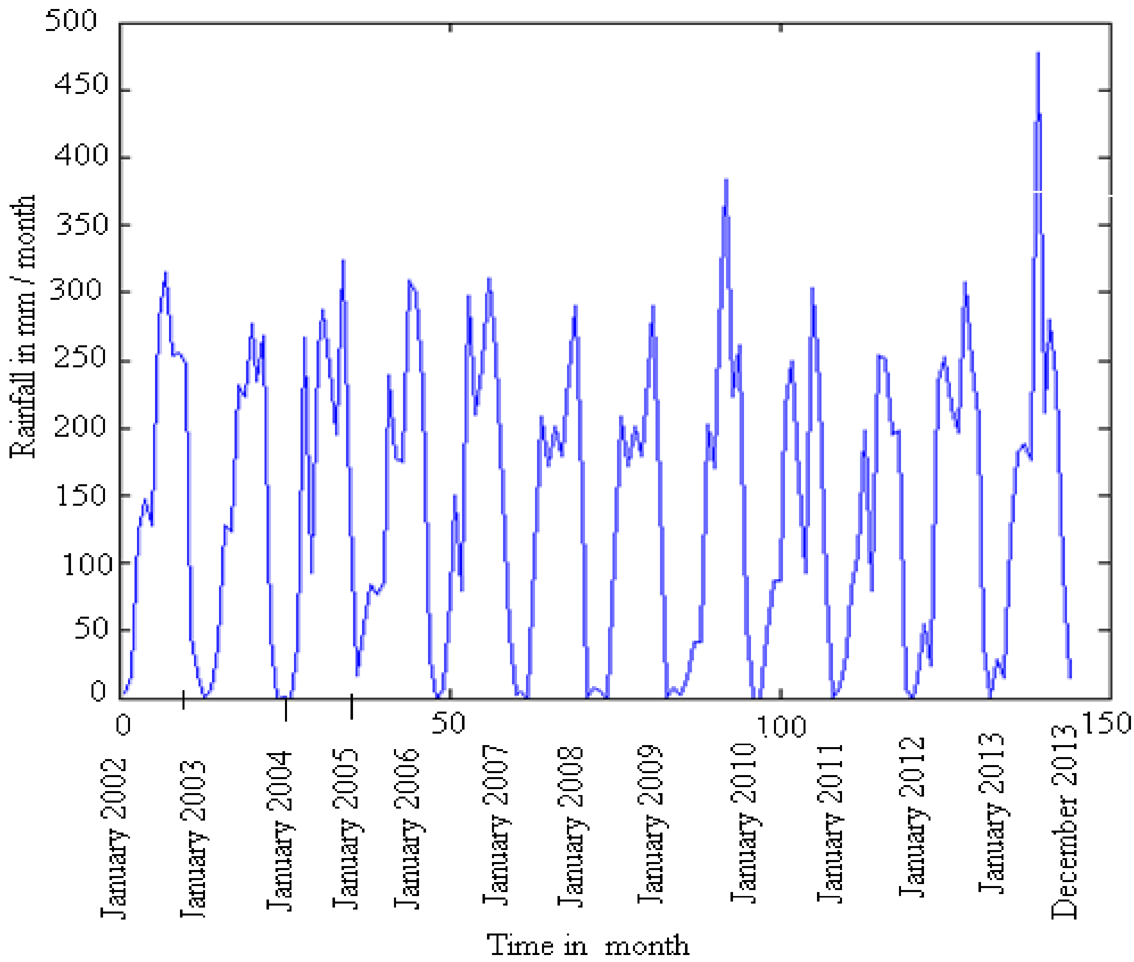


Figure 8: Variation of rainfall Bafoussam-Bamougoum from January 2002 to December 2013.



Exportation of Soil by the River Mewou and Silting

The watershed that feeds river Mewou has an area of 306 km^2 (Olivry, 1976-2000). The amount of soil exported by this river was 0.19534 t / km^2 in 2011 and 0.256015 t / km^2 in 2012. Figure 3 indicates that the amount of soil exported is increasing. The Pearson correlation coefficient between flow rate and soil exported is R = 0.237, indicating that there is no correlation between the flow rate and the amount of soil exported. We cannot predict the amount of soil exported from the flow rate, because the correlation coefficients are different from 1 ($R = 0.237 \neq 1$). Soil loss is due to excessive runoff and surface erosion, resulting from low water infiltration and enhanced by deforestation and farming methods unsuited to the relief of the region. Erosion removes a greater part of the clay and soil humus and leaves behind rough sands, gravels and stones. The greater part of soil fertility is associate with the clay and humus components. These elements are equally important in the bacterial activity of the soil structure, soil permeability and its water retention capacity. The soils exported cause siltation of river beds, dams that retain water for production of electrical energy in the dry season and agricultural irrigation. Douala port must be dredged regularly in order to remove these soils despite this port continues to shrink. We must fight against this export upstream.

The soils exported cause siltation of rivers beds and dams that retaine water for the purposes of production of electrical energy in the dry season.

Exported Soil and Environmental Pollution

The physico-chemical analysis of the soils revealed considerable amounts of: turbidity (Turb.) , Cd^{2+}, Zn^{2+}, Pb^{2+}, NO_2^-,HCO_3^-, Cl^-, NH_4^+, SO_4^{2-}, Al^{3+}, TP and Mg^{2+} (Table 3) which indicates that the environment is polluted when they reach a certain concentration in water.

Turbidity (Turb.)

Turbidity refers to the suspended solids of inorganic or organic origin degree of water clarity. It takes account of the amount in water (Bechac et *al*., 1983). The water in the Mewou has a 146.9 NTU > 5 NTU that is tolerable level (Table 2). This water is polluted because NTU > 50 NTU (Rodier et *al.*, 2009). The value of this turbidity indicates that the water may reduce the penetration of useful sunlight to aquatic life for photosynthesis.

Cadmium ion (Cd^{2+})

Cadmium causes respiratory and renal disorders, if its concentration is > 0.01 mg/l (Table 3). The cadmium concentration in the watercourse of Mewou is 11 mg/l (Table 3). This water is a threat to agriculture and yet it seeps along its course in cultivated soils. People subjected to this pollution through the integration of the pollutants in through bio magnification of matter, in biological communities, thereby exerting a negative effect on countless plant and animal species.

Zinc ion (Zn^{2+})

Toxicity to fish is exercised from a few milligrams per liter (Dajoz, 1995). For agricultural use, the withering of plants can occur from 5 mg/l (Table 3). For water intended for human consumption, the recommended threshold value is 3 mg/l (Table 3). In this study the Zn^{2+} concentration is 0.51 mg/l on average and presents no danger for agricultural activity and human consumption but may be toxic to fish.

Lead ion (Pb^{2+})

According to (Benedetto, 1997; Rodier et *al.*, 2009 ; Allègre, 1990), lead causes nervous system disorders, and also affects the liver and kidneys. According to Rodier et *al.* (2009), it decreases the life of the red blood cells by the alteration of its membrane. The threshold value in surface water and consumption is 0.01 mg/l (Table 3). The concentration of lead in the water Mewou is 48.20 mg/l, much higher than the tolerated concentration. This can be explained by the fact that the sampling point is located in the vicinity of a major road. Equally lead is a natural constituent, widely distributed in the earth's crust at levels of about 13 mg/kg soil (Benedetto, 1997). Given the high rainfall or temperature and chemical weathering, through hydrolysis, lead may be released or leached into the streams. The large amount of sediment transported which are constituents of the earth's crust. This concentration represents a danger to human health and aquatic life.

Nitrite (NO_2^-)

Nitrite is toxic (carcinogenic). OMS (2004), recommends for water intended for human consumption a limit of 3 mg/l. For this study the concentration is 4.645 mg/l (Table 3), which is greater than the tolerated threshold value. This water cannot be recommended for agricultural activities because they may be integrated into the cycle of matter through biocenoses and end up persisting in humans.

Bicarbonate ($HCO3^-$)

The bicarbonate ions interfere with the electron exchange in the exchange complex, prevents good iron binding by plants, insolubilized phosphates, and is poor absorption of manganese (Mn), Ca / K antagonism ...(Soltner, 2013). Their presence in the soil is harmful to plant life. The allowable limit in water is 518 mg/l (table 3). This study has a value of 3.40 mg/l (Table 3), which is below the threshold value (518 mg/l). However presence in water its suggests its presence in the soil, which is damaging to the exchange complex. The bicarbonate derive from the weathering of carbonate minerals, dissolved CO_2 in the soil and groundwater, which is produced by the bacterial decomposition of organic matter, and the photosynthetic fixation of atmospheric CO_2 (Berner and Berner, 1987).

Chloride (Cl^-)

They are not harmful, but are an important indicator of pollution. Current unpolluted waters have less below 25 mg/l (Table 3). For tap water chlorides has a maximum allowable level of 250 mg/l (Table 3). The Mewou has a concentration of 1.065 mg/l (Table 3). This concentration does not indicate the pollution of this rivers, however this stream is polluted by heavy metals (Cd^{2+}, Zn^{2+}, P_b^{2+} , Al^{3+}, et Mg^{2+}).

Ammonia ($NH4^+$)

Ammonia or ammonium nitrogen is the main chemical indicator of direct pollution. It reflects a process of incomplete decomposition of organic matter (Rodier et *al.*, 2009). For water consumption the threshold value is 1.5 mg/l (Table 3). This study reveals a value of 2.8 mg/l (Table 3), for the waters of river Mewou. This concentration indicates a nitrogen pollution of the river.

Sulfate ion (SO_4^{2-})

The sulfate ion in presence of anaerobic bacteria of the genus desulfuvibrio accepts an electron and is reduced to sulfur gas H_2S (Tchobanoglous , 1987) and contributes to the formation of acid rain; the latter is also responsible for the occurrence of odors in eutrophic environments (subject to eutrophication water). This study shows an average concentration of 0.16 mg/l (Table 3) which is below the ecotoxicity threshold value of sulfate concentration of 20 mg/l (Table 3).

Aluminum (Al^{3+})

Aluminum comes from phosphate fertilizers. Good quality water should not have aluminum concentration in excess of 5 mg/l (Table 3). An amount greater than 0.10 mg/l may cause secondary chemical precipitation in storage tanks (Table 3). It can cause reduced ossification and Elsheimer's disease. This study shows an average concentration of 0.593 mg/l (Table 3), is lower than the threshold value for water consumption but can cause secondary chemical precipitation in storage tanks.

Total phosphorus (TP)

When total phosphorus exceeds a concentration of 0.2 mg/l (Table 3), it causes algae blooms in the water, depleting the water of dissolved oxygen, which causes the disappearance of aquatic fauna. The Mewou stream has a concentration of 0.84 mg/l (Table 3), which is greater than the allowable limit. This may be from current sources: industrial discharges in the Bafoussam vicinity (Gouafo and Yerima, 2013) domestic wastes and leaching from phosphate fertilizers or pesticides applied on crop lands.

Magnesium ion (Mg^{2+})

Magnesium is an element which is responsible for water hardness. At high levels, it gives the water an unpleasant bitterness. It has a laxative effect. Threshold value is 30 mg/l (Table 3). Magnesium is a constituent of chlorophyll and activator of certain enzymes of plants (Soltner, 2013). Leaching can create its deficiency in soils. The concentration of 0.49 mg/l for the river Mewou is below the threshold value, but this low value is presents problems to agricultural soils.

Why Chemical Parameters Varied During the Year?

Table 3 indicates the chemical parameters of the water. The month of March 2012 represents the end of the dry season and the month of September 2012 represent the rainy season.

Magnesium ion (Mg^{2+})

The concentration is 0.4 mg/l in the dry season and 0.58 mg/l in the rainy season (Table 3). This can be explained by the fact that in the rainy season weathering increasing its concentrations.

Turbidity (Turb.)

Its value is constant 146.9 NTU during dry season and rainy season (Table 3), indicating a permanent pollution of watercourses Mewou. This stability of turbidity can be explained by the fact that the river runs through the town receives in passing the industrial and domestic wastewater.

Zinc ion (Zn^{2+})

It has a concentration of 0.27 mg/l in the dry season and 0.75 mg/l in the rainy season (Table 3). This concentration is higher in the rainy season. This can be explained by the fact that the solubility of zinc sulfate is higher in water (Benedetto, 1997). As the zinc is contained in the rocks, after solubilization of the zinc by rain is eroded in to the streams by runoff.

Aluminum ion (Al^{3+})

Concentration of 0.587 mg/l in the dry season and 0.598 mg/l in the rainy season (Table 3). The difference between its concentrations is insignificant.

Bicarbonate (HCO_3^-)

This concentration is 3.04 mg/l in the dry season and 3.75 mg/l in the rainy season (Table 3). Its largest value in the rainy season is due to greater leaching exported during this season.

Ammonium (NH_4^+)

It has a concentration of 5.6 mg/l in the dry season and 0.00 mg/l in the rainy season (Table 3). The value of 0.00 in the rainy season indicates that during the rainy season crops consume all ammonium nitrogen obtained by mineralization of organic matter.

Nitrite (NO_2^-)

The nitrite concentration of 6.44 mg/l in the dry season and 3.25 mg/l in the rainy season (Table 3), indicates that in the dry season the deficiency in oxygen is greater. The deficiency of oxygen causes denitrification, nitrate (NO_3^-) are then converted to nitrite (NO_2^-) (Gingras, 1997). This transformation is more pronounced in the dry season resulting in severe nitrite pollution.

Sulfate (SO_4^{2-})

The sulfate concentration was 0.21 mg/l in the dry season and 0.11 mg/l in the rainy season (Table 3). Low concentration in the rainy season is due to its high consumption by plants. During the rainy season a sulfate part of participates in the formation of acid rain in the presence of anaerobic bacteria of the genus desulfuvibrio accepts an electron and reduces H_2S hydrogen sulfide gas (Tchobanoglous, 1987), that's why his concentration is lower.

IMPLICATION TO RESEARCH AND PRACTICE

The water flow of the Mewou presents a general downward trend over time, indicating a low groundwater recharge. There is no correlation between flow rate and the rainfall because the correlation coefficient is too low (R = 0.454). This can be explain that the recharge of groundwater is not regular due to losses of rainfall by runoff, evapotranspiration and plant uptake. The amount of soil exported presents a general upward trend. This indicates an increasing wear of the soil with the loss of the more granular rich surface of the resistance to erosion of the more compact of dense subsoils. This unfortunately signals to near depletion of the rich surface soils which one required for increased crop production.

Environmental pollution has been detected by the turbidity of the water, which was 146.9 NTU it is 29.38 times greater the tolerated level value of 5 NTU. Indeed the MO, Cd^{2+}, Pb^{2+}, $NH4^{+}$, TP, Al^{3+}, Fe^{3+} and $NO2^{-}$ are higher than the permissible threshold levels (Table 3). This represents a threat to aquatic life and agriculture. The presence of metallic micro pollutants such as Zn^{2+}, even at low concentration remains a problem for aquatic life due to the phenomenon of bioaccumulation.

CONCLUSION

Treatment of discharges of each industry and municipal treatment of domestic discharges contribute to the reduction of pollution loads of OM, Cd^{2+}, Pb^{2+}, NH_4^+, TP, Al^{3+}, Fe^{3+}, Zn^{2+} and NO_2^-. It is r e c o m m e n d that the use of Vetiver (Chrysopogon zizanioides) hedges to mitigate runoff soil losses (Gouafo and Yerima, 2014), reduce pollution by the degradation of pollutants by mineralization, volatilization and formation of non-extractable residues (Norbert, 2012). And the absorption and accumulation of metals (heavy metals and other pollutants) reducing the transfer of micro-pollutants to surface waters and groundwater (Norbert, 2012; Truong et *al*., 2009), with their abundant rooting and deep "up to 4 meters" thick (Tony, 2008). This plant will reduce upstream pollution of surface waters and groundwater. Therefore the spacing will depend on the slope of the land concerned. If the slope of the land is α and the effective height of Vetiver H "height which can hold water" Spacing between two rows of Vetivers will be:

$$Es = \frac{H}{\tan \alpha} \qquad \text{(Eq .12)}$$

We found that the variation of the water flow (Qv) of Mewou watercourse and the variation of the chemical parameters exported such as Mg^{2+}, Cd^{2+}, Zn^{2+}, Pb^{2+}, Fe^{3+}, Al^{3+}, HCO_3^-, NH_4^+, TP, NO_2^- were each characterized by a model of the form :

$$Y = a*t^9 + b*t^8 + c*t^7 + d*t^6 + e*t^5 + f*t^4 + g*t^3 + h*t^2 + i*t + j \qquad \text{(Eq.11)}$$

Where Y represents of the amount of the element in question, t time and the coefficients a, b, c, d, e, f, g, h, i and j varies according to the values of Y. The above equations can be used to predict soil loss, and the concentrations of the elements lost by this river in future years.

FUTURE RESEARCH

A study on the pollution of the food produced in the vicinity of the watercourse should be made, in order to determine how far the banks agriculture would be possible without pollution.

A study to propose methods for agriculture without chemical (organic farming), would fight against the pollution of the water by pesticides used in agriculture.

The soil and losses could be reduced through reforestation of the degraded uplands. This will reduce runoff and increase the recharge of aquifers.

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