

Soil and nutrient loss from soil degradation in the Western Tropical Highlands of Cameroon: evidence from stream flow data of river Mewou (South Mifi) and implications for long term agricultural productivity

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# Abstract

This study aims at determining the impact of soil and nutrient loss from the soil exported by the Mewou river on the southern Mifi (Western Cameroon), their implication for long term agricultural productivity and to identify measures to limit these losses and maintain soil fertility. The average exported soil varies in  $t/km^2$  from 195.34 in 2011 to 256.015 in 2012. Results for exported physico-chemical parameters indicate that the following parameters : OM, OC, TP, PO<sub>4</sub><sup>3-</sup>, TN, NH<sub>4</sub><sup>+</sup>, Ca<sup>2+</sup>, Mg<sup>2+</sup>, K<sup>+</sup>, Fe<sup>3+</sup>, Al<sup>3+</sup> and SO<sub>4</sub><sup>2-</sup> obtained from wastewaters of the Mewou had a general decreasing tendency from 2011 to 2012 indicating soil depreciation. The variation of water flow and chemical parameters were each characterized by a general equation with a curve of the order:

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

We recommend the use of the Vetiver (*Chrysopogon zizanioides*) hedges to reduce soil erosion, leaching of cations from the soil exchange complex and to enhance the recharge of the water table; planting density will be a function of the slope of the land concerned. In addition, farmers would grow the hedges along the contours. This will delay runoff and enhance recharging of groundwaters through increased infiltration and reduce soil loss and thus increase agricultural productivity and flow rate.

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#### Introduction

Cameroon, like most developing countries is facing the problem of nutrient losses associated with leaching and soil erosion. According to Yerima and Van Ranst (2005), the restoration of eroded soils is difficult because the process of soil formation is so slow, that we can even say that the soil is not a renewable resource. In the same way Barrow (1991), defines erosion as the removal of soil materials by water or by wind at rates higher than those of soil formation. This erosion considerably affects soil productivity. The eroded soils end up being transported, as sediment, into water bodies and cause problems of sedimentation (Ponsaud, 2007), which have an impact on the use of this resource by humans and other ecological functions. According to Dajoz (1996), and Hamburg and Cogbill, (1988), acids cause leaching of soil nutrients such as Ca2+, K + and  $Mg^{2+}$ and liberates Al3+ and various heavy metals that are toxic to vegetation, resulting in the death of trees and the exposure of soils to different rates of degradation. Erosion increases where vegetation cover is absent, where rainwater that was not stopped for infiltrated, runoffs carrying away the surface soil (Garouani et al., 2004). The world average of sediment yield through discharge per unit area of drainage basin is estimated at 150 tones / yr, with great variation from place to place (Milliman, 1990). According to FAO (2010), improving food security in the world depends on land and water resources and the way they are used. Deforestation and poor agricultural practices greatly increase erosion (Allan, 1996). Following the FAO (1981), between 1980 and 2000, the surface of available arable soils per inhabitant in developing countries passed from 0.37 to 0.25 ha with a 19 % loss of soil productivity. Yerima and Van Ranst (2005), also observed that the sorting action of water or erosion removes a greater part of the clay and humus and leaves behind sand, gravel and stones which are less productive. The greater part of soil fertility is associated with clay and humus content. These elements are equally important in the bacterial activity on the soil structure, and the permeability and water retention capacities. Thus, an

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eroded soil is degraded chemically, physically and biologically. With increasing demographic pressure, climate change and the high competiting demand for land resources (soil and water) is leading to aggravated food insecurity. Berner and Berner (1987), observe that soils exported by rivers contain: suspended inorganic matter (Al, Fe, Si, Ca, K, Mg, Na and P), dissolved major ions (Ca<sup>2+</sup>, Na<sup>+</sup>, Mg<sup>2+</sup>, K<sup>+</sup>, HCO<sub>3</sub><sup>-</sup>, SO<sup>2+</sup>, Cl<sup>+</sup>); dissolved nutrients (N and P), suspended and dissolved organic matter, gases (N<sub>2</sub>, CO<sub>2</sub>, O<sub>2</sub>), and trace metals. According to Berner and Berner (1987), and Stumm. and Morgan (1981), Na, K, Ca, Mg, and Cl are derived primarily from particles in the air, whereas SO42-, NH4+ and  $NO_{3}$  are derived mainly from atmospheric gases. Calcium is the most abundant cation in the world's rivers; it originates almost entirely from the weathering of sedimentary carbonate rocks although pollution and atmospheric inputs constitute other sources (Allan, 1996). Magnesium likewise originates almost entirely from the weathering of rocks, particularly Mg silicate minerals and dolomite. Atmospheric inputs are minimal and pollution contributes only slightly (Allan, 1996). Sodium is generally found in association with chloride, indicating their common origin (Allan, 1996). Weathering of NaCl containing rocks accounts for most of the Na<sup>+</sup> and Cl<sup>-</sup>. However, inputs from sea salts can contribute significantly, especially near the coasts. Pollution, due to domestic sewage, fertilizers and road salt, is an important factor (Allan, 1996). Berner and Berner (1987) estimate that, world-wide, about 28% of the sodium in rivers is anthropogenic. Potassium in river water, originates from the weathering of silicate materials especially potassium feldspar and mica. Silica also derives from the weathering of silicate rocks. Bicarbonate (HCO<sub>3</sub>-) derives almost entirely from the weathering of carbonate minerals. However, the immediate source of most of the bicarbonate is CO<sub>2</sub> dissolved in soil and ground water, which is produced by bacterial decomposition of organic matter, and from the photosynthetic fixation of atmospheric CO<sub>2</sub>. Sulphate has many sources, especially from the weathering of sedimentary rocks and pollution (from fertilizers,

wastes, mining activities); biogenically derived sulphate in rain, and volcanic activity are additional inputs. In areas of acid rain, sulphate concentrations are high relative to overall ionic concentrations (Likens *et al.*, 1977). Sulphate and bicarbonate concentrations tend to be inversely correlated in stream water, especially in low alkalinity areas.

Siltation is a natural phenomenon that causes the water to disappear naturally by filling up streams of water reservors where there is lack of water for drinking and irrigated farming. The problems created by this sedimentation, comes from the increase in the rate of siltation by sediments. According to FAO (2010), in several big rivers, the flow rates represent only 5% of the volume of the original rivers, with some rivers like the Huan He, not r e a c h i n g the sea throughout the year. Large lakes, such as Lake Chad, are consistently reducing (Kolawole *et al.*, 2012). Equally, sediments produced by soil erosion silt up reservoirs, compromising the production of hydropower and water supply for irrigated agriculture. FAO (2010), observes that we are currently witnessing a high depreciation of soil and ecosystems qualities over vast surfaces across the whole continent, as well as the depreciation of the biodiversity and an alteration in the cultural heritage's and esthetic beauty.

To solve the problem of erosion several authors have proposed different solutions, cleaning (Schneider, 2001), being one of the options. However, cleaning can cause major disruption of watercourses by destruction of the waterbed, the substratum and the existing vegetation, through the modification of flow and removal of the sediment surface. This surface sediment-water interface is the seat of chemical and biological reactions participating in the auto-purification of the environment and the protection of groundwater. This explain why cleaning must be done only in cases of excessively clogged waterways. Huet et al. (2005), observe that we need to limit the introduction of phosphorus in streams, in order to limit eutrophication of soft waters in natural environments, as well as detergents or washing powders containing phosphates from entering water bodies. keeping sediments out of water bodies increase the longevity of reservoirs (Yerima and Van Ranst, 2005). Protective practices can be vegetative, mechanical or a combination of the two.

In the Bafoussam area like in most of the tropical environments, south of the sahara few studies have been carried out on the exportation of soil by river systems and their impacts on the degradation of soil fertility. In the area under study if nothing is done, this city risks facing water scarcity or shortage, resulting the decrease in agricultural productivity, which will lead to a hunger crises. Our study focuses on the evaluation of the quantity of soil exported by river Mewou, through the analysis of some physicochemical parameters of water samples taken from the river Mewou, with the aim of evaluating their effects on soil fertility. It also aims at identifying measures that would reduce soil exportation, enhance recharge of groundwater and maintain soil fertility.

## Materials and methods

## The study area

Bafoussam, the capital of the West region of Cameroon and a region of high agricultural activity is located at an altitude of 1450 m in the Mifi catchment in the Western Highlands of Cameroon between longitude 9° 30' and 10° 35' east and latitude 5° and 6° north. 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 had a population of 1,339,791 inhabitants in the year 2000, with an annual growth rate of 2.37 %; the population was estimated at 1,816,695 inhabitants in the year 2013.

## Hydrography of the Site

The Watershed has an area of 1640 km<sup>2</sup>. This region is drained by four major rivers: the Mape, northern tributary of the Mbam; the Nkam to the southwest, 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 drains most 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 and seeps into the ground over a distance of about 35 km before joining the River Noun. Along its path, resident farmers use it for irrigation of cereals and forage crops.



**Fig. 1.** Partial hydrographic network of southern Mifi showing the Mewou stream on the Mifi South watershed.

#### Geology of the site

According to Olivry (1976-2000), the region is essentially composed of a basement and volcanic complex made up of mostly gneisses and embrechites. The average white series, corresponds to an acidic phase composed of trachytes Pliocene age in the upper Bamboutos Mountains, while the black bottom series is composed of basalts of Eocene age 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 the Bamoun area and on the northern edge of the Bamileke plateau. The South Mifi area is made of 77% by a "basalt plateau" and 20% by base most complex composed of acidic rocks (trachytes). The soils of this region are mainly feralsols derived from the weathering of these rocks in the basalt plateaus,

or humic ferralsols on trachyte and basalt in mountains. 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 ( $5^{\circ}$  30' 8" N , 10° 22' 7" E , Alt. 1279 m) along the national road number 04 (fig. 1).

#### Sampling and analysis

All samples were collected in plastic containers of 500 ml according to Rodier et al. (2009), with the sampling equipment submerged into the water in the area of turbulent flow to enable collection of representative samples for the chemical and physical composition of the water. The samples were sent to the laboratory six hours before the determination of the following Physico-chemical parameters: OM, OC, TP, PO<sub>4</sub><sup>3-</sup>, Ntot, NH<sub>4</sub><sup>+</sup>, Ca<sup>2+</sup>, Mg<sup>2+</sup>, K<sup>+</sup>, Na<sup>+</sup>, Fe<sup>3+</sup> , Al<sup>3+</sup>, and SO<sub>4</sub><sup>2-</sup>. OC was determined according to Pauwels et al. (1992), based on its oxidation by potassium dichromate (K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>) in a strong acid medium (H<sub>2</sub>SO<sub>4</sub>), OM contains averagely 58% OC or %OC\*1.724= %OM. Total phosphorus (TP) and Orthophosphate (PO<sub>4</sub><sup>3-</sup>) were determined spectrophotometrically according to NF EN ISO 6878 (2005), using ammonium molybdate. Total Nitrogen (TN) present in water was oxidized to nitrates in an autoclave, with an alkaline persulfate solution. The nitrates were subsequently reduced to nitrites and assayed by the method of continuous flow effect, nitrites were determined by spectrometry after diazotization with sulfanilamide and with the coupling N-1 naphthylethylenediamine (Rodier et al., 2009). Ammonia ions (NH<sub>4</sub><sup>+</sup>) were determined according to Pauwels et al. (1992), using a specific electrode detector of ammonia gas (NH3) the solution being sufficiently basic to transform the ammonium ions (NH4<sup>+</sup>) to ammonia gas (NH3). Ca2+, Mg2+, K+ and Na+ were extracted from water with an ammonium acetate (CH<sub>3</sub>COONH<sub>4</sub>) solution. The NH<sub>4</sub><sup>+</sup> ions, added in excess displace quantitatively the cations adsorbed by the exchange complex

(humus, clay and oxides). The exchangeable cations in the extract was determined by flame spectrometry for (K<sup>+</sup>, Na<sup>+</sup>), and by complexiometry for (Ca<sup>2+</sup>, Mg<sup>2+</sup>) (Pauwels *et al.*,1992). Fe<sup>3+</sup> and Al<sup>3+</sup> were determinated through atomic absorption spectrophotometry (Benedetto, 1997). Colloidal sulphur (SO<sub>4</sub><sup>2-</sup>) was extracted from water with trichloroethylene, after evaporation of the solvent; and sulphur precipitated in pure acetone and determined spectrometrically following closing the procedure of Rodier *et al.* (2009).

The flow rate Qv in m<sup>3</sup>/s was determined using a gauging float (Rodier *et al.* 2009; Bernard 1994) following the formula:

 $Q_V = 0.8 * L_u * P_m * V$  ( Eq.1 )

Where Lu = 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.

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

$$M_t = Q_v^* m_t$$
 (Eq.2)

Where mt is the weight of soil per liter of water exported (in g/m<sup>3</sup> or in Kg/m<sup>3</sup>) For a period of time T, we have a soil loss ( $M_{tsT}$ ) from the expression:  $M_{tsT}=M_{ts}*T$  (Eq. 3) **91**, 119-126.

The study of soil depreciation through amount of nutrients elements and amount of soil exported was based on the analysis of physico-chemical parameters, carried out in specialized laboratories 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 and discussions**

Variation of soil exported, flow rate, rainfall and physico-chemical parameters

The evaluation of the amount of soil exported by the river Mewou and its impact on soil fertility was made by measuring the amount of soil exported and the physico- chemical composition of the soil. Table 1 below shows the flow rate of the river Mewou in l / s, rainfall in mm / month and soil exported in kg / month during the period from July 2011 to January 2013.

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<sub>1</sub>) of the trend of the rainfall variation. The regression line (Dr<sub>1</sub>) shows a general decreasing trend of rainfall during the study period, with a Pearson correlation coefficient of R = 0.908. This curve is simulated by the polynomial equation function where Y is the rainfall and X the time (Eq. 4):

 $Y = -0.00001545 * X^{9} + 0.001405 *$  $X^{8} - 0.05412 * X^{7} + 1.149 * X^{6} 14.64 * X^{5} + 114.1 * \qquad X^{4} - 527.6 *$  $X^{3} + 1346 * X^{2} - 1688 * X + 1027 \text{ (Eq. 4)}$ 

The flow rate of the water varies from 2,151 to 32, 711 l / s (Table 1). The minimum flow rate occurred in March 2012 and the maximum flow rate was observed in August 2011. The curve (Ct<sub>2</sub>) of figure 2 shows the trend of variation of 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<sub>2</sub>) is simulated by the polynomial equation

function where Y is the water flow rate at time X (Eq.5):

 $Y = 0.002373 * X^{9} - 0.2204 * X^{8} +$   $8.7 * X^{7} - 190.3 * X^{6} + 2517 * X^{5} -20650 * X^{4} + 103600 * X^{3} 299800 * X^{2} + 437300 * X - 213300$ (Eq.5)

The Pearson correlation coefficient between rainfall and flow rate is R = 0.453. The amount of soil exported varies from 556.357 to 20,078.669 t / month (Table 1). The lowest amount of soil exported was in March 2012 and the peak in April 2012. Figure 3 shows the curve (Ct<sub>2</sub>) of the trend of soil exportation. The regression line (Dr<sub>2</sub>) shows a general increasing trend in the amount soil exported, with a Pearson correlation coefficient R = 0.622. This curve  $(Ct_2)$  is a simulated by the polynomial equation where Y is the amount of soil exported and Х the time (Eq. 6):

**Table 1.** Flow rate (l / s), rain fall (mm / month) and the amountof soil exported (kg / month)of the river Mewou during the period from July 2011 to January 2013.

Y	Month	Duration in days of	Average water	Rainfall	Soil	Soil	Soil exported/ month
e	(M)	the month (Dmj)	flow rate	(mm/ month)	exported	exported	kg
ar			(l/s) (Qvm)		(g/l) (mt)	(g/s) (Mts)	(MtsT)
	July	31	8 900	253.8	0.29	2 581	6 912 950
	Aug.	31	32 711	251.2	0.255	2 079	5 568 394
	Sept.	30	8 350	195.4	0.092	752	1 949 184
2	Oct.	31	11 474	197.6	0.16	1 858	4 976 467
0	Nov.	30	10 311	6.7	0.22	2 331	6 041 952
11	Dec.	31	6 363	0.0	0.2634	1 657	4 438 109
	Jan.	31	3 727	13.7	0.102	374.3	1 002 445
	Feb.	29	2 373	54.1	0.153	376.8	944 110
	Mar.	31	2 151	23.6	0.1	208	556 357
	Apr.	30	5 372	233.0	0.98	7 746	20 078 669
	May	31	5 513	252.4	0.23	1317	3 527 855
	June	30	9 037	215.3	0.26	2 796	7 247 232
	July	31	11 630	196.4	0.26	3 018	8 083 947
	Aug.	31	12 786	308.0	0.3	2 928	7 842 623
2	Sept.	30	13 831	247.8	0.228	3 158	8 184 266
0	Oct.	31	16 326	207.1	0.3317	5 407.6	14 483 716
1	Nov.	30	12 598	39.6	0.14	1 764	4 571 562
2	Dec.	31	7 543	0.3	0.09	678.9	1 818 285
2	Jan.	31	5 953	27.9	0.3	1 786	4 783 622
0							

 $Y = 1.022 * X^{9} - 85.19 * X^{8} + 2959 * X^{7} 55440 * X^{6} + 607000 * X^{5} - 3931000 *$   $X^{4} + 14560000 * X^{3} - 28190000 *$  $X^{2} + 22850000 * X + 1354000$ (Eq. 6)

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

Figure 4 presents the curve  $(Ct_1)$  and  $(Ct_2)$ that indicate the trend of variation of flow rate and soil exported by the river Mewou. The Pearson correlation coefficient (R) between flow rate and soil exported is 0.237.

Table 2 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. TN,  $Ca^{2+}$ ,  $Mg^{2+}$ ,  $K^+$ ,  $Na^+$ , OC,  $SO_4^{2-}$ ,  $Fe^{3+}$  and  $PO_4^{3-}$  have values below the threshold concentrations (Table 2). Organic matter (OM) has a concentration of 2.3274 mg/l which is greater than the threshold concentration of 2 mg/l (Table 2). Aluminum (Al<sup>3+</sup>) has an average concentration of 0.593 mg/l; it is greater than the threshold value of 0.1 mg/l (Table 2). Ammonium

 $(NH_4^+)$  has an average concentration of 2.8 mg/l, it is greater than the threshold value of 1.5 mg/l (Table 2). Total phosphorus (TP) has an average concentration of 0.84 mg/l which is greater than the threshold value of 0.2 mg/l (Table 2).

Parameters	Standard values		Sampling				
i urumeters	Threshold	Author	2/2/	6/0/	2/08/	Average	Standard
NT (mg/l)	10	ISO and MINEP	-/ 3/ )	0/9/	2,243	2.243	0
		(2005)				10	
$Ca^{_{2+}}$ (mg/l)	200	Rodier (1996)	1.04	1.08		1.06	0.028
Mg <sup>2+(</sup> mg/l)	30	Rodier (1996)	0.4	0.58		0.49	0.127
K+ (mg/l)	15	Rodier et al.	0.051	0.291		0.171	0.170
Na+ (mg/l)	200	(2009) OMS (2004)	0.065	0.065		0.065	0
OM (mg/l)	2	Rodier (1996)			2.33	2.33	0
OC (mg/l)	2	Rodier et al.			1.35	1.35	0
		(2009)					
Fe <sup>3+</sup> (mg/l)	0.3	Ghaouti et	0.258	0.25		0.254	0.006
	0.05	<i>al.</i> (2005) Rodier (1996)					
Al <sub>3+</sub> (mg/l)	5	Hicham et al.	0.587	0.598		0.593	0.008
		(2008)					
	0.1	Rodier (1996)					
NH <sub>4</sub> <sup>+</sup> (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
PO <sub>4</sub> <sup>3-</sup> (mg/l)	0.5	Rodier et al.	0.42	0.125		0.271	0.209
		(2009)					
SO42- (mg/l)	20	Rodier <i>et al.</i> (2009)	0.21	0.11		0.16	0.071

**Table 2.** Physico-chemical parameters of the river Mewou at the bridge of the National Road No. 4 and the standard and threshold values

#### Total Nitrogen (TN)

The amount of total nitrogen exported by the river Mewou varies from 12.921 to 196.553 t / month (Table 3.1 to table 3.2). The lowest value was obtained in March 2012 and the highest value in August 2011. Figure 5 shows the curve (Ct<sub>2</sub>) of the trend of variation of the amount of total nitrogen exported. The regression line (Dr<sub>2</sub>) indicates a general decreasing trend of total nitrogen, with a Pearson correlation coefficient of R = 0.940. This curve is simulated by the polynomial equation (Eq. 7) where Y is the amount of total nitrogen exported and X the time:

 $Y = 0.01176 * X^{9} - 1.103 * X^{8} + 44.09 *$  $X^{7} - 978.7 * X^{6} + 13190 * X^{5} - 110600 *$ 

 $X^4$  + 568800 \*  $X^3$  - 1691000 \*  $X^2$  + 2523000 \* X - 1247000 (Eq. 7)

Figure 5 shows the curve  $(Ct_1)$  and  $(Ct_2)$  of the trend of variation of flow rate and total Nitrogen exported by the river Mewou. Pearson correlation coefficient (R) between flow rate and total nitrogen exported is 0.868.

#### Calcium (Ca<sup>2+</sup>)

The amount of calcium exported by the river Mewou ranges from 6.105 t / month to a high of 92.887 t/ month (Table 3.1 to table 3.2). The lowest value was observed in March 2012 and the highest value in August 2011. Figure 6 shows the simulation curve  $(Ct_2)$  of the trend of variation of the amount of calcium exported. The regression line  $(Dr_2)$  figure 6 indicates a general downward trend, with a Pearson correlation coefficient (R) of 0.939. This curve is simulated by the polynomial equation (Eq. 8) where Y is the amount of calcium exported and X the time:

 $Y = 0.006703 * X^{9} - 0.6231 * X^{8} +$ 24.62 \* X<sup>7</sup> - 538.9 \* X<sup>6</sup> + 7137 \* X<sup>5</sup> -58620 \* X<sup>4</sup> + 294300 \* X<sup>3</sup> -  $852300 * X^2 + 1243000 * X - 606500$ (Eq. 8).

Figure 6 shows the simulated curves  $(Ct_1)$  and  $(Ct_2)$  of the trend of variation of flow rate and amount of Calcium exported by the river Mewou with a Pearson correlation coefficient (R) between flow rate and Calcium exported of 0.9997.

Table 3.1. Amounts of physico-chemical parameters exported per month by river Mewou	t / month during
the period from July 2011 to December 2011.	

Years		2011					
Month		July	Aug.	Sept.	Oct. 2011	Nov.	Dec.
Dmj		31	31	30	31	30	31
Qm	$m^3/s$	8.900	32.717	8.350	11.474	10.311	6.363
Ntol	t/month t/month	53.468	196.553	48.548	68.936	9.947	38.229
Ca <sup>2+</sup>		25.268	92.887	22.940	32.576	28.330	18.065
$\mathrm{Mg}^{_{2^{+}}}$	t/month	11.680	42.938	10.605	15.059	13.096	8.351
K+	t/month	4.076	14.985	3.701	5.255	4.570	2.914
Na+	t/month	1.550	5.696	1.407	1.998	1.737	1.108
OM	t/month	55.480	203.948	50.372	71.527	62.204	39.665
OC	t/month	32.181	118.300	29.218	41.489	36.081	23.008
Fe <sup>3+</sup>	t/month	6.055	22.258	5.497	7.806	6.789	4.329
$Al^{3+}$	t/month	14.136	51.964	12.834	18.224	15.849	10.106
$\mathrm{NH}_{4^{+}}$	t/month	66.746	245.362	60.601	86.051	74.835	47.719
TP	t/month	20.024	73.608	18.180	25.815	22.451	14.316
PO <sub>4</sub> 3-	t/month	6.496	23.879	5.898	8.375	7.283	4.644
SO42-	t/month	3.814	14.021	3.463	4.917	4.276	2.727

Dmj = Duration in days of the month; Qm = Average water flow in m<sup>3</sup> / s.

# Magnesium (Mg<sup>2+</sup>)

The amount of magnesium exported by the river Mewou varies from 2.822 to 42.938 t / month (Table 3.1 to table 3.2). 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 magnesium exported was similar to that of total nitrogen and calcium presented in figures 5 or 6. Similarly the regression line  $(Dr_2)$  indicates a general downward trend of the amount of magnesium exported as that of total nitrogen and calcium reported in figures 5 or 6, with a Pearson correlation coefficient (R) of 0.939. This curve is simulated by the polynomial equation (Eq. 9) where Y is the amount of magnesium exported and X the time:

$$Y = 0.00307 * X^{9} - 0.2854 * X^{8} + 11.28 *$$
  

$$X^{7} - 247 * X^{6} + 3273 * X^{5} - 26900 * X^{4} +$$
  

$$135100 * X^{3} - 391700 * X^{2} + 571800 *$$
  

$$X - 279000$$
(Eq. 9)

The Pearson correlation coefficient (R) between flow rate and Magnesium exported by the Mewou stream is 0.9997.

#### Potassium (K+)

The amount of potassium exported by the river Mewou ranges from 0.985 to 14.985 t / month (Table 3.1 to table 3.2). 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 potassium exported has the same shape as that of total nitrogen and calcium presented in figures 5 or 6. The regression line  $(Dr_2)$  indicated a general downward trend of the amount of potassium exported as that of total nitrogen and calcium presented in figures 5 or 6, with a Pearson correlation coefficient of R = 0.939. This curve is simulated by the polynomial equation (Eq.10) where Y is the amount of potassium exported and X the time:

$$Y = 0.001071 * X^{9} - 0.09961 * X^{8} + 3.937 *$$
  

$$X^{7} - 86.22 * X^{6} + 1142 * X^{5} - 9388 * X^{4} +$$
  

$$47160 * X^{3} - 136700 * X^{2} + 199600 * X -$$
  

$$97370$$
(Eq. 10)

The Pearson correlation coefficient (R) between flow rate and the amount of Potassium exported by the Mewou stream is 0.9998.

**Table 3.2.** Amounts of physico-chemical parameters exported per month by river Mewou t / month during the period from January 2012 to Junuary 2013.

Years		2012												2013
Month		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.2	Oct.	Nov.	Dec.	Jan.
Dmi	1	2012	2012	2012	2012	2012	2012	2012	2012	20	2012	2012	2012	2013
O	0 /	J <b>-</b>	-9	J-		J.			J-	10.01		10 ( 0	J-	
Qm	m <sup>3</sup> /S	37.273	2.373	2.151	5.372	5.513	9.037	11.63	12.79	13.81	16.33	12.60	7.543	5.953
Voore	t /month	22.392	13.333	12.92	31.234	33.124	52.545	69.88	76.82	80.41	98.08	73.24	45.32	35.77
Ca <sup>2+</sup>	t /month	10.582	6.301	6.105	14.759	15.652	24.830	33.02	36.30	38.00	46.35	34.61	21.42	16.90
$Mg^{_{2+}}$	t /month	4.892	2.913	2.822	6.823	7.235	11.478	15.26	16.78	18.15	21.43	16.00	9.900	7.814
$K^+$	t/month	1.707	1.017	0.985	2.381	2.525	4.006	5.327	5.856	6.335	7.477	5.584	3.455	2.727
Na+	t/month	0.649	0.387	0.375	0.905	0.960	1.523	2.025	2.226	2.408	2.842	2.123	1.313	1.036
ОМ	t/month	23.235	13.836	13.4	32.407	34.366	54.519	72.5	79.71	83.44	101.8	76.00	47.02	37.11
OC	t/month	13.477	8.026	7.776	18.798	19.934	31.624	42.1	46.2	48.4	59.03	44.1	27.27	21.53
Fe <sup>3+</sup>	t/month	2.536	1.510	1.463	3.751	3.850	5.950	7.657	8.699	9.106	11.11	8.294	5.132	4.050
$Al^{3+}$	t/month	5.920	3.525	3.195	8.257	8.756	13.891	18.47	20.31	21.26	25.93	19.36	11.98	9.456
$\mathrm{NH}_{4}^{+}$	t/month	27.953	16.645	16.13	38.987	41.345	65.589	87.22	95.89	100.4	122.4	91.43	56.57	44.65
ТР	t/month	8.387	4.994	4.839	11.697	12.404	19.677	26.17	28.77	30.1	36.73	27.43	16.97	13.40
PO <sub>4</sub> 3-	t/month	2.721	1.620	1.570	3.794	4.024	6.383	8.489	9.332	9.769	11.92	8.898	5.505	4.345
$\mathrm{SO}_4^{2^-}$	t/month	1.597	0.951	0.922	2.228	2.363	3.748	4.984	5.480	5.736	6.996	5.225	3.233	2.551

Dmj = Duration in days of the month;  $Qm = Average water flow in m^3 / s$ .

# Sodium (Na+)

The amount of sodium exported by the river Mewou varies from 0.375 to 5.696 t / month (Table 3.1 to table 3.2). The lowest value was observed in March 2012 and the highest value in August 2011. The simulated curve ( $Ct_2$ ) of the trend of variation of the amount of sodium exported has a similar shape as that of total nitrogen and calcium presented in figures

5 or 6. The regression line  $(Dr_2)$  indicates a general downward trend of amount of sodium exported similar to that of total nitrogen and calcium reported in figures 5 or 6, with a Pearson correlation coefficient (R) of 0.939. This curve is simulated by the polynomial equation (Eq.11) where Y is the amount of sodium exported and X the time:

$$Y = 0.0004072 * X^{9} - 0.03786 * X^{8} +$$
  

$$1.496 * X^{7} - 32.77 * X^{6} + 434.2 * X^{5} -$$
  

$$3568 * X^{4} + 17920 * X^{3} - 51950 *$$
  

$$X^{2} + 75850 * X - 37010$$
(Eq. 11)

The Pearson correlation coefficient (R) between flow rate and the amount of Sodium exported by the Mewou stream is 0.9998.

#### Organic Matter (OM)

The amount of organic matter exported by the river Mewou ranges from 13.406 to 203.948 t / month (Table 3.1 to table 3.2). The lowest value was observed in March 2012 and the highest value in August 2011. The simulated curve ( $Ct_2$ ) of the trend of variation of the amount of organic matter exported has a similar shape as that of total nitrogen and calcium reported in figures 5 or 6. The regression line ( $Dr_2$ ) indicates a general downward trend of amount of organic matter exported similar to that of total nitrogen and calcium reported in figures 5 or 6, with a Pearson correlation coefficient, R = 0.939. This curve is simulated by the polynomial equation (Eq.12) where Y is the amount of organic matter exported and X the time:

$$Y = 0.01472 * X^{9} - 1.368 * X^{8} + 54.06 *$$
  

$$X^{7} - 1183 * X^{6} + 15670 * X^{5} - 128700 *$$
  

$$X^{4} + 646100 * X^{3} - 1871000 * X^{2} +$$
  

$$2730000 * X - 1332000$$
(Eq. 12)

The Pearson correlation coefficient (R) between flow rate and the amount of Organic matter exported by the Mewou stream is 0.888.

Table 4. Rainfall (mm/month) in Bafoussam-Bamougoum from January 2002 to December 2013.

Month	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
years												
2002	4.0	16.4	123.1	147.5	128.5	280.6	315.1	253.7	254.6	247.9	47.0	18.1
2003	1.1	7.0	39.2	128.6	123.2	232.3	222.6	276.9	234.6	267.9	47.5	0.0
2004	1.2	0.0	40.3	266.5	92.7	256.6	287.8	244.5	195.9	323.7	141.0	17.0
2005	52.9	83.6	76.7	86.4	238.6	177.2	175.2	309.8	299.5	230.0	30.1	0.0
2006	8.1	75.2	149.5	79.3	298.1	209.9	246.3	310.6	254.3	153.3	49.7	2.6
2007	0.0	0.0	29.6	262.2	176.0	221.1	273.7	236.6	194.3	280.7	143.3	0.0
2008	5.6	0.0	106.5	207.7	171.7	201.0	179.1	239.4	290.4	152.2	0.3	8.0
2009	2.7	14.8	42.2	41.3	201.9	170.3	268.7	383.7	223.2	260.4	56.2	0.0
2010	0.0	48.2	87.2	86.9	215.8	249.6	161.3	93.3	302.9	228.2	82.0	0.0
2011	9.8	32.6	80.9	105.4	197.7	79.0	253.8	251.2	195.4	197.6	6.7	0.0
2012	13.7	54.1	23.6	233.0	252.4	215.3	196.4	308.0	247.8	207.1	39.6	0.3
2013	27.9	15.3	119.7	181.8	187.9	176.3	477.9	210.6	279.6	236.6	96.8	15.8

Bafoussam-Bamougoum Airport Meteorological station (5°32'13"N,10° 21'16" E, Alt.1325 m).

#### Iron (Fe<sup>3+</sup>)

The amount of iron exported by the river Mewou varies from 1.463 to 22.268 t / month (Table 3.1 to table 3.2). The lowest value was observed in March

2012 and the highest value in August 2011. The simulated curve ( $Ct_2$ ) of the trend of variation of the amount of iron exported has a similar shape to that of total nitrogen and calcium reported in figures 5 or 6.

The regression line  $(Dr_2)$  indicates a general downward trend of amount of iron exported similar to that of total nitrogen and calcium reported in figures 5 or 6, with a Pearson correlation coefficient (R) of 0.939. This curve is simulated by the polynomial equation (Eq. 13) where Y is the amount of exported iron and X the time:

 $Y = 0.001613 * X^{9} - 0.1498 * X^{8} + 5.911 * X^{7} 129.3 * X^{6} + 1710 * X^{5} - 14030 * X^{4} + 70390 *$  $X^{3} - 203800 * X^{2} + 297200 * X - 145000$ (Eq. 13).



**Fig. 2.** Rainfall (mm / month) and flow rate (1001/s) variation of the Mewou stream (Sourthern Mifi) from July 2011 to January 2013.

The Pearson correlation coefficient (R) between flow rate and the amount of iron exported by the Mewou stream is 0.9996. *Aluminum (Al<sup>3+</sup>)* 

The amount of aluminum exported by the river Mewou varies from 3.195 to 51.964 t / month (Table 3.1 to table 3.2). The lowest value was observed in March 2012 and the highest value in August 2011. The simulated curve (Ct<sub>2</sub>) of the trend of variation of the amount of aluminum exported has a similar shape to that of total nitrogen and calcium reported in figures 5 or 6. The regression line (Dr<sub>2</sub>) indicates a general downward trend of amount of aluminum exported similar to that of total nitrogen and calcium reported in figures 5 or 6, with a Pearson correlation coefficient (R) of 0.939. This curve is simulated by the polynomial equation (Eq. 14) where Y is the amount of exported aluminum and X the time:

 $Y = 0.008537 * X^9 - 0.7936 * X^8 + 31.36 * X^7 - 686.4 * X^6 + 9089 * X^5 - 74660 * X^4 +$ 

$$374800 * X^3 - 1085000 * X^2 + 1583000 * X - 772400$$
 (Eq. 14)

The Pearson correlation coefficient (R) between flow rate and the amount of aluminum exported by the Mewou stream is 0.9997.



**Fig. 3.** Variation of rainfall (mm/ month) and soil exported (100 tonnes / month) by the Mewou stream (Sourthern Mifi) from July 2011 to January 2013.

#### Ammonium (NH<sub>4</sub>+)

The Amount of ammonium exported by the river Mewou varies from 16.128 to 245.362 t/month (Table 3.1 to table 3.2). The lowest value was observed in March 2012 and the highest value in August 2011. The simulated curve (Ct<sub>2</sub>) of the trend of variation of the amount of ammonium exported has a similar shape as that of total nitrogen and calcium presented in figures 5 or 6. The regression line (Dr<sub>2</sub>) indicates a general downward trend of amount of ammonium exported similar to that of total nitrogen and calcium presented in figures 5 or 6, with a Pearson correlation coefficient (R) of 0.939. This curve is simulated by the polynomial equation (Eq. 15) where Y is the amount of ammonium exported and X the time:

 $Y = 0.01771 * X^{9} - 1.646 * X^{8} + 65.04 * X^{7} - 1424 * X^{6} + 18850 * X^{5} - 154800 * X^{4} + 777300 * X^{3} - 2251000 * X^{2} + 3284000 * X - 1602000$ (Eq. 15)

The Pearson correlation coefficient (R) between data of flow rate and the amount of ammonium exported by the Mewou stream is 0.9997.

Total phosphorus (TP)

The amount of total phosphorus exported from the river Mewou varies from 4.839 to 73.608 t / month (Table 3.1 to table 3.2). The lowest value was observed in March 2012 and the highest value in August 2011. The simulated curve ( $Ct_2$ ) of the trend of variation of the amount of phosphorus exported has a similar shape to that of total nitrogen and calcium presented in figures 5 or 6. The regression line ( $Dr_2$ ) indicates a general downward trend of amount of phosphorus exported similar to that of total nitrogen and calcium presented in figures 5 or 6, with a Pearson correlation coefficient (R) of 0.939. This curve is simulated by the polynomial equation (Eq. 16) where Y is the amount of total phosphorus exported and X the time:

 $Y = 0.005312 * X^{9} - 0.4938 * X^{8} + 19.51 * X^{7} 427.1 * X^{6} + 5656 * X^{5} - 46450 * X^{4} + 233200 *$  $X^{3} - 675400 * X^{2} + 985200 * X - 480600$ (Eq. 16)



**Fig. 4.** Variation of flow rate (1001 / s) and soil exporated (100 t / month) (Sourthern Mifi) by the river Mewou from July 2011 to January 2013.

The Pearson correlation coefficient (R) between flow rate and the amount of phosphorus exported by the Mewou stream is 0.9997.

#### Available phosphorus (PO<sub>4</sub><sup>3-</sup>)

The amount of available phosphorus exported by the river Mewou varies from 1.570 to 23.879 t / month (Table 3.1 to table 3.2). The lowest value was observed in March 2012 and the highest value in August 2011. The simulated curve (Ct<sub>2</sub>) of the trend of variation of the amount of assimilable phosphorus exported has a similar shape to that of total nitrogen and calcium presented in figures 5 or 6. The regression line (Dr<sub>2</sub>) indicates a general downward trend of amount of assimilable phosphorus exported similar to that of total nitrogen and calcium presented in figures 5 or 6, with a Pearson correlation coefficient (R) of 0.939. This curve is simulated by the polynomial equation (Eq. 17) where Y is the amount of available phosphorus exported and X the time:

$$\begin{split} Y &= 0.001723 * X^9 - 0.1602 * X^8 + 6.329 * X^7 - \\ &138.5 * X^6 + 1835 * X^5 - 15070 * X^4 + 75640 * \\ &X^3 - 219100 * X^2 + 319600 * X - 155900 \end{split} \label{eq:solution}$$



**Fig. 5.** Variation of the flow rate (100 1/ s) and of total NitRogen (TN) exported (t / month) by river Mewou from July 2011 to January 2013.

The Pearson correlation coefficient (R) between flow rate and the amount of available phosphorus exported by the Mewou stream is 0.9997.



**Fig. 6.** Variation of the flow rate (1001/ s) and amount of calcium  $(Ca^{2+})$  exported (t / month) by the river Mewou from July 2011 to January.

#### Sulfate (SO42-)

The amount of sulfate ions exported by the river Mewou varies from 0.922 to 14.021 t / month (Table 3.1 to table 3.2). The lowest value was observed in March and the highest value in August 2011. The simulated curve ( $Ct_2$ ) of the trend of variation of the amount of sulfate exported has a similar shape to that of total nitrogen and calcium presented in figures 5 or 6. The regression line  $(Dr_2)$  indicates a general downward trend of amount of sulfate exported similar to that of total nitrogen and calcium presented in figures 5 or 6, with a Pearson correlation coefficient (R) of 0.938. This curve is simulated by the polynomial equation (Eq. 18) where Y is the amount of exported sulfate and X the time:

 $Y = 0.001012 * X^{9} - 0.09405 * X^{8} + 3.716 * X^{7} - 81.35 * X^{6} + 1077 * X^{5} - 8848 * X^{4} + 44420 * X^{3} - 128600 * X^{2} + 187700 * X - 91540$ (Eq. 18)

The Pearson correlation coefficient (R) between flow rate and the amount of sulfate ions exported by the Mewou stream is 0.9997.

#### Discussions

#### Changes in water flow

A general decrease in water flow rate (Figure 2) was observed over time. The Regression line (Dr<sub>2</sub>) figure 2, indicates a decrease in the amount of flow. Figure 7 shows a prediction of flow rate using Matlab numerical calculation (Jerome, 2009). 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; following September 2017 if no remedial actions are taken to correct this trend. This indicates that from September 2017, one may not have water in this river during some periods (February and March) in the dry season. In this region the drying up of rivers during the year is regular. However, in the rainy season, one could have a regular flow as the network of neurons phenomenon figure 8, indicates consistency in the flow variation of rainfall over a period of 12 years (2002-2013), with an increasing trend during the twelfth year, 2013. 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 are different from each other.

groundwater is not regular as there is loss of rainfall through runoff and evapo-transpiration. 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. Indeed, vegetation slows down runoff thereby promoting water infiltration for the refill of the groundwater and consequently the rivers.

This can be explained by the fact that the refill of



**Fig.** 7. Prediction of the variation of flow rate (1 / s) of the river Mewou from July 2011 to June 2021 using the software MATLAB.

Exportation of soil by the river Mewou and silting

The watershed that feeds river Mewou has an area of 306 km<sup>2</sup> (Olivry, 1976-2000). The amount of soil exported by this river was 0.19534 t/km2 in 2011 and 0.256015 t/km<sup>2</sup> in 2012. Figure 3 indicates that the amount of soil exported is increasing. The Pearson correlation coefficient (R) between flow rate and soil exported is 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 coefficient is very low. 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 associated with the clay and humus fractions. These elements are equally important in the bacterial activity of the soil structure, soil permeability and its water retention capacity. The exported soils cause siltation of river beds and dams that retain water for

production of electrical energy in the dry season and agricultural irrigation. It is necessary for efforts to be made to reduce the amount of soil loss from the upland areas.

#### Exported soil and its effect on soil fertility

The physico-chemical analysis of the soils exported revealed loss of high concentrations of  $Al^{3+}$  which causes soil acidity and TN, OM, OC,  $Ca^{2+}$ ,  $Mg^{2+}$ ,  $K^+$ ,  $NH_{4^+}$ , TP, PO<sub>3</sub><sup>-</sup>, Fe<sup>3+</sup>, and SO<sub>4</sub><sup>2+</sup> which are plant soil nutrients.



**Fig. 8.** Variation of rainfall in Bafoussam-Bamougoum from January 2002 to December 2013.

#### Total Nitrogen (TN)

Nitrogen is the basic element of living matter. In case of deficiency the leaves become small and yellowishgreen in color, resulting in a disease called chlorosis (Soltner, 2013). Plants take up only the mineralized form of N that is to say ion, though the soil has a large reserve of nitrogen, the mineralized form is small. Water contains more mineralized nitrogen than soils. The nitrogen found in water results from soil fertility depletion. The waters of the river Mewou exported on the average 3.044  $t/km^2$  in 2011 and 1.991 t/km<sup>2</sup> in 2012 (Table 3.1 to table 3.2). From the regression line Dr<sub>2</sub> in figure 5, there is a decrease of the amount of Nitrogen exported by the Mewou stream. Hence, we can conclude that soil total nitrogen available to plants is being depleted. Figure 9 shows a prediction of the depletion of available nitrogen using the Matlab numerical calculation. The Pearson correlation coefficient (R) between the flow rate and total nitrogen exported is 0.868. The coefficient of 0.868 indicates that we can predict the amount of total nitrogen exported from the flow rate because the flow rate can explain about 86.8% of the variance but can not explain 13.2%.



**Fig. 9.** Prediction of the variation in the exportation of Total Nitrogen (TN) by the Mewou river from July 2011 to October 2032 (kg / month) using the software MATLAB.

#### Organic Matter (OM)

The presence of organic matter (OM) in the water (Table 3.1 to table 3.2) indicates the progressive loss of soil humus. Humus is most dominant in the upper part of the Earth's crust which contains soil nutrients. The exported soil contained 3.148 t/km<sup>2</sup> OM in 2011 and 2.066 t/km<sup>2</sup> in 2012. The regression line in figure 5 or 6 show a general decreasing trend in the amount of organic matter exported. This indicates a gradual depletion of the soil fertility. The Pearson correlation coefficient (R) between the flow rate and the organic matter exported by the Mewou stream is 0.8883. We can predict the amount organic matter exported from the flow rate because flow rate can explain about 88.83% of the variance but can not explain 11.17%.

# Calcium, Magnesium, Potassium and Sodium (Ca<sup>2+</sup>, Mg<sup>2+</sup>, K<sup>+</sup>, Na<sup>+</sup>)

The cations (Ca<sup>2+</sup>, Mg<sup>2+</sup>, K<sup>+</sup>) maintain on the soil exchange complex, a balance with the anions (PO<sub>4</sub><sup>3-</sup>, SO<sub>4</sub><sup>2-</sup>, NO<sub>3</sub><sup>-</sup>, Cl<sup>-</sup> ...), if one nutrient is deficient in the soil, it becomes a limiting factor. For example on the exchange complex, the cation Ca<sup>2+</sup> by taking the place of two H<sup>+</sup> ions helps to reduce soil acidity. Leaching of cations contributes to lower the cation exchange capacity (CEC) of the soil. The amount of Ca<sup>2+</sup> exported was 1.438 t/km<sup>2</sup> in 2011 and 0.941 t/km<sup>2</sup> in 2012. The amount of Mg<sup>2+</sup> exported was 0.665 t/km<sup>2</sup> in 2011 and 0.437 t/km<sup>2</sup> in 2012. The K<sup>+</sup> exported by this river was 0.232 t/km<sup>2</sup> in 2011 and  $0.1525 \text{ t/km}^2$  in 2012. The regression line (Dr<sub>2</sub>) is similar to that in figures 5 or 6 indicates a general decreasing trend in the amount of cations exported; this show a depreciation in the amount of soil cations. This depreciation of the soil nutrients pushes farmers to abandon the area and search for more fertile soils in remote areas. The predicted curve for the cations is similar to that of total nitrogen (TN) presented in figure 9.

#### Ammonium (NH<sub>4</sub>+)

The plant uses the mineralized form of nitrogen to feed its tissues.  $NH_{4^+}$  nitrogen is mineralized or fixed on the soil exchange complex. The ammonium loss through export by streams contributes to deprive the soil of this important element in the nutrition of the plant tissues. In 2011 the river Mewou exported 3.799 t/km<sup>2</sup> of  $NH_{4^+}$  and 2.486 t/km<sup>2</sup> in 2012. The regression line ( $Dr_2$ ) is similar to that of total nitrogen presented in figure 5 or 6 indicates a general decreasing trend of exported  $NH_{4^+}$  by water, indicating a impoverishment of soil nutrients. The predicted curve for  $NH_{4^+}$  is similar to that of total nitrogen reported in figure 9.

# Aluminum, Total Phophurus and Phosphate ( $Al^{3+}$ , TP, $PO_{4^{3-}}$ )

Total phosphorus (TP) is half of the soil reserves (Soltner, 2013). The amount of phosphate ions (PO<sub>4</sub><sup>3-</sup>) in the soil solution is low. Its mobilization is difficult both in acidic, neutral or basic media. PO<sub>4<sup>3-</sup></sub> leaching poses a real threat to the stability of the soil. In acid soils, it binds with Aluminium (Al<sup>3+</sup>) and iron to form poorly soluble compounds; in soils rich in active limestone, it forms tricalcium phosphate that insoluble (Soltner, 2013). In 2011 the TP exported by the river Mewou was 1.140 t/km<sup>2</sup> and 0.746 t/km<sup>2</sup> in 2012. The PO<sub>4</sub><sup>3-</sup>exported by this river in 2011 was 0.370  $t/km^2$  and 0.242 t/km<sup>2</sup> in 2012. The regression line (Dr<sub>2</sub>) is similar to that of total nitrogen presented in figures 5 or 6 and indicates a decreasing trend in the amount PT and PO43- exported. This indicates the of progressive impoverishment of the soil in PO43- and TP. The prediction curves for  $Al^{3+}$ , TP,  $PO_4^{3-}$  are similar to that of total nitrogen presented in figure 9.

#### Fer (Fe<sup>3+</sup>)

In acidic soils,  $Fe^{3+}$  fixes  $PO_{4^{3-}}$  to form poorly soluble compounds (Soltner, 1992), and contributes to reduce soil acidity. Leaching contributes to the enhancement of soil acidity. The amount of  $Fe^{3+}$ exported was 0.3447 t/km<sup>2</sup> in 2011 and 0.2126 t/km<sup>2</sup> in 2012. The regression line (Dr<sub>2</sub>) is similar to that of total nitrogen presented in figure 5 or 6 and indicates a general decreasing trend in the amount of  $Fe^{3+}$  exported, or depletion of soil iron. The predicted curve for  $Fe^{3+}$  is similar to that of total nitrogen figure 9.

#### Sulfate (SO<sub>4<sup>2-</sup></sub>)

After mineralization, sulfur is released as sulfate  $(SO_4^{2-})$  and is absorbed by plants in significant quantities (Soltner, 2013). Leaching deprives plants in this region of their nutrients. In 2011 the amount of  $SO_4^{2-}$  exported was 0.217 t/km<sup>2</sup> and 0.142 t/km<sup>2</sup> in 2012. The regression line (Dr<sub>2</sub>) is similar to that of total nitrogen (figures 5 or 6) and indicates a general decreasing trend, or depletion of soil sulfate. The predicted curve for  $SO_4^{2-}$  is similar to that of total nitrogen in figure 9.

#### Conclusion

The water flow of the Mewou presents a general decreasing trend over time, indicating a lowering of the recharge of groundwater. The rainfall presents a general decreasing trend over time during the study period indicating decreases in precipitation. However, the problem is the low groundwater recharge because variation in rainfall is not significant (figure 8). In 2013 rainfall increased (figure 8). The amount of soil exported presents a general increasing trend. This indicates an increasing wear of the more erodible topsoil due to erosion. Analysis of physico-chemical soil parameters revealed the presence in the soil exported of the cations Ca2+, Mg2+, K+, Na+ , NH4<sup>+</sup> and anions PO4<sup>3-</sup>, SO4<sup>2-</sup> which constitute a part of the soil exchange complex. With the progressive depreciation of the soil, to combat soil erosion through runoff and leaching of chemical

elements which constitute part of the soil exchange complex and enhance the recharge of the water table, the flow rate and water quality of the Mewou, we recommend:

The use of Vetiver (*Chrysopogon zizanioides*) hedges; therefore the spacings will depend on the slope of the land in questions. If the slope of the land is  $\alpha$  and the effective height of Vetiver H (H = the height which can hold water), the spacing between two rows of Vetivers (Es) will be:

$$Es = \frac{H}{\tan \alpha}$$
(Eq. 19)

Vetiver with their abundant thick and deep roots (up to 4 meters) (Tony, 2008), will slow down the leaching of the soil exchangeable cations. Their thick, compact and very long leaves will reduce runoff and soil erosion and facilitate water infiltration, thus stabilizing the flow of the Mewou and maintenance of the soil fertility.

Farmers should grow the Vetiver along the contours. This will reduce runoff and enhance the recharge of the groundwater through increased infiltration and reduce soil loss and hence increase the agricultural productivity.

This study indicates that in the variation of the water flow (Qv) of the watercourse of Mewou river, exported chemical parameters such as Ca<sup>2+</sup>, Mg<sup>2+</sup>, K<sup>+</sup>, Na<sup>+</sup>, OM, Fe<sup>3+</sup>, Al<sup>3+</sup>, NH<sub>4</sub><sup>+</sup>, TP, Ntol , SO<sub>4</sub><sup>2-</sup> and PO<sub>4</sub><sup>3-</sup> were each characterized by an equation of the form :

$$\begin{split} Y &= a * X^9 + b * X^8 + c * X^7 + d * X^6 + e \\ &+ X^5 + f * X^4 + g * X^3 + h \\ &* X^2 + i * X + j \end{split}$$

Where Y represents the amount of the element in question, X time with the coefficients a, b, c, d, e, f, g, h, i and j vary according to the values of Y.

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