

Full Length Research Paper

Physicochemical properties of soils and some water sources on the Eastern Flank of Mount Cameroon

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Human activities such as agriculture, construction of houses and automobile workshops and natural processes alter the properties of soils and water which affect the health of plants, animals and humans. This work was therefore, aimed at investigating some physicochemical properties of soils and some water sources on the Eastern Flank of Mount Cameroon with altitude and selected natural and/or anthropogenic activities. Soils and water were sampled in February 2010 and analysed for their physicochemical properties using standard methods. The results of the soil analysis showed that all the soils in the region were acidic. Most of the physicochemical properties of the water analysed were within acceptable limits of WHO. The water sources between Tiko and Wonya-Mavio, Buea had higher nitrate. There were significant positive relationships ($p < 0.05$ and $p < 0.01$) between nitrogen and altitude and carbon and altitude, respectively. Magnesium and ECEC showed a significant negative correlation ($p < 0.05$) with altitude while calcium showed a highly significant negative correlation with altitude. Natural sources of pollution identified are weathering, erosion and sea water intrusions. The anthropogenic ones include wastes from homes, laundry, fertilizers and factories. Stringent soil and water management scheme or legislature is recommended.

Key words: Soils, physicochemical properties, Mount Cameroon, pollution, water, human activities, fertilizers.

INTRODUCTION

Soil is the dynamic link between the biosphere and lithosphere and constitutes a practically not renewable (very low rate of formation) natural resource, with a key role for the environment and for agriculture (Moraetis et al., 2016). Some factors such as altitude, parent rocks, vegetation and anthropogenic activities influence the

physicochemical properties of soil and water like pH, organic matter, CEC, soil texture and water chemistry. The soil is composed of air, water, inorganic and organic matter in varying proportions. Its physicochemical properties such as texture, organic carbon, cation exchange capacity (CEC) and pH are determined by the

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percent composition of the above parameters (Wild, 1996). Soil pH affects nutrients availability and the optimal condition for this is at pH 5 to 7 (Arp and Krausse, 2006).

Soil texture affects drainage, water and nutrients storage and the optimal conditions for this are sandy loam, loam and silt loam soils (Arp and Krausse, 2006). A research conducted in Australia on comparing the chemical properties of a long term cultivated site to those of an uncropped and highly grazed reference site in a red brown earth soil showed that the total carbon decreased from 3.74% on the grazed site to 1.66% on the cultivated site. This was attributed to the fact that cultivated soil was more prone to surface sealing and erosion processes than the grazed soil (Whitbread et al., 1998).

In another study, it was observed that the rate of change in bulk density decreased with depth. For entire soil profile (0-horizon to 40 cm) the rate of carbon accrual was 1.5% per year. Nitrogen (N) stocks were affected by disturbance in the 0-horizon. Nitrogen accumulated at 0.6% for the entire soil profile (Maloney, 2008).

The soil plays a great role in the environment which can be seen in chemical and physicochemical adsorption, agricultural and pollutant retention. The chemical and physical properties of soils are controlled largely by clay and humus. They are the centres of activity around which chemical reactions and nutrient exchanges occur. Furthermore, by attracting ions to their surfaces, they temporarily protect essential nutrients from leaching and then release them slowly for plant use (Brady, 1984).

Soil productivity is dependent on the ability of the soil to provide water, nutrients and oxygen to plant root system as well as limiting exposure of the root system to toxic gases or solutions (Schumacher, 2006). Tillage erosion causes reduction in effective rooting depth, plant nutrients; available plant water soil organic matter and land area (Schumacher, 2006). Bush fire destroys vegetation and leaves the soil bare, loose and susceptible to erosion. Every year acid rain causes hundreds of millions of dollars' worth damage to storey buildings and statutes throughout the world (Chang, 2005).

Some activities often lead to the destruction or contamination of the environment. The natural activities include contaminated rain water (e.g. acid rain which results from emission of acidic gases into the air), winds, volcanic eruptions and forest fires. The anthropogenic activities come from industries (paper, automobile, and oil industries), homes (household wastes, paints and pesticides) and agriculture (e.g. fertilizers). Farming and grazing involve the use of fertilizers which is source of pollution (Asongwe et al., 2016).

Uncontaminated rain water is naturally acidic and generally has a pH of about 5.6. Generally acid rain is derived from SO_x and NO_x. Acid rain is, however, more acidic than normal rain water and typically has a pH value of about 4 (Brown et al., 2003). Acid rain is also toxic to vegetation and aquatic life. Many well-documented cases

show dramatically how acid rain has destroyed agricultural forest land and killed aquatic organisms (Chang, 2005). In the North-Eastern United states and adjacent part of Canada, acid rain has killed fish, decimated forests, injured crops and released harmful substances into the soil (Silberberg, 2000).

Humans, animals and precipitation (runoff) are the principal agents (mechanisms) of contaminant transport (Folefac et al., 2009). There are a wide number of water bodies along the mount Cameroon region. Some of these are streams, wells and rivers. Groundwater is the only reliable water resource for drinking, domestic, and agricultural purposes for the people living in the Mount Cameroon area (Ako et al., 2012). Runoffs into these water bodies often carry or contain chemical substances which could be dangerous at high concentrations. The inhabitants use these water bodies for various purposes such as bathing, cooking washing of clothes or cars etc. The probability that they are often contaminated from wastes dumped into them and from the human activities that take place around them could therefore be high.

Water is used in homes for various activities, in industries and to give support to aquatic life and the mangroves. Despite the fact that there are many natural or fresh water sources in the country, water management and challenges are enormous. Numerous studies within Cameroon portray that most water resources used for domestic consumption are polluted (Asongwe, 2010; Forton et al., 2012).

We need good, clean potable water for good health. There has been increasing indiscriminate disposal of domestic, industrial and agricultural wastes on soil and water that exposes them to pollution. Water pollution is therefore an area of great concern. This work is therefore, aimed at investigating the physicochemical properties of soils and some water sources within the Eastern flank of Mount Cameroon relating them to natural and/or anthropogenic activities within this sub-region. It is also also aimed at comparing properties of uncultivated (for at least two years) soil to those of cultivated soil and variation with altitude and make recommendations.

MATERIALS AND METHODS

Description of site

The area under study is the West slope of Mount Cameroon, in Fako Division of the South West Region of Cameroon. It spans from Limbe down beach and Mile 4 through Mutengene, Tiko including Mile 14 Dibanda, Mile 16 Bolifamba, Mile 18 Molyko, Bomduma, Bokwango to Vasingi in Buea Sub-Division. It lies between longitudes 8° 5' E and 9° 32'E and latitudes 3° 50'N and 4° 22' N (Figures 1 and 2).

The region is composed mainly of volcanic rocks which range from massive basaltic lava flows around the upper slopes of Mt. Cameroon to pyroclastic materials further down slope (Endeley et al., 2001; Manga et al., 2013). The soils have been weathered and partly covered by more recent deposits; hence the soils are mostly

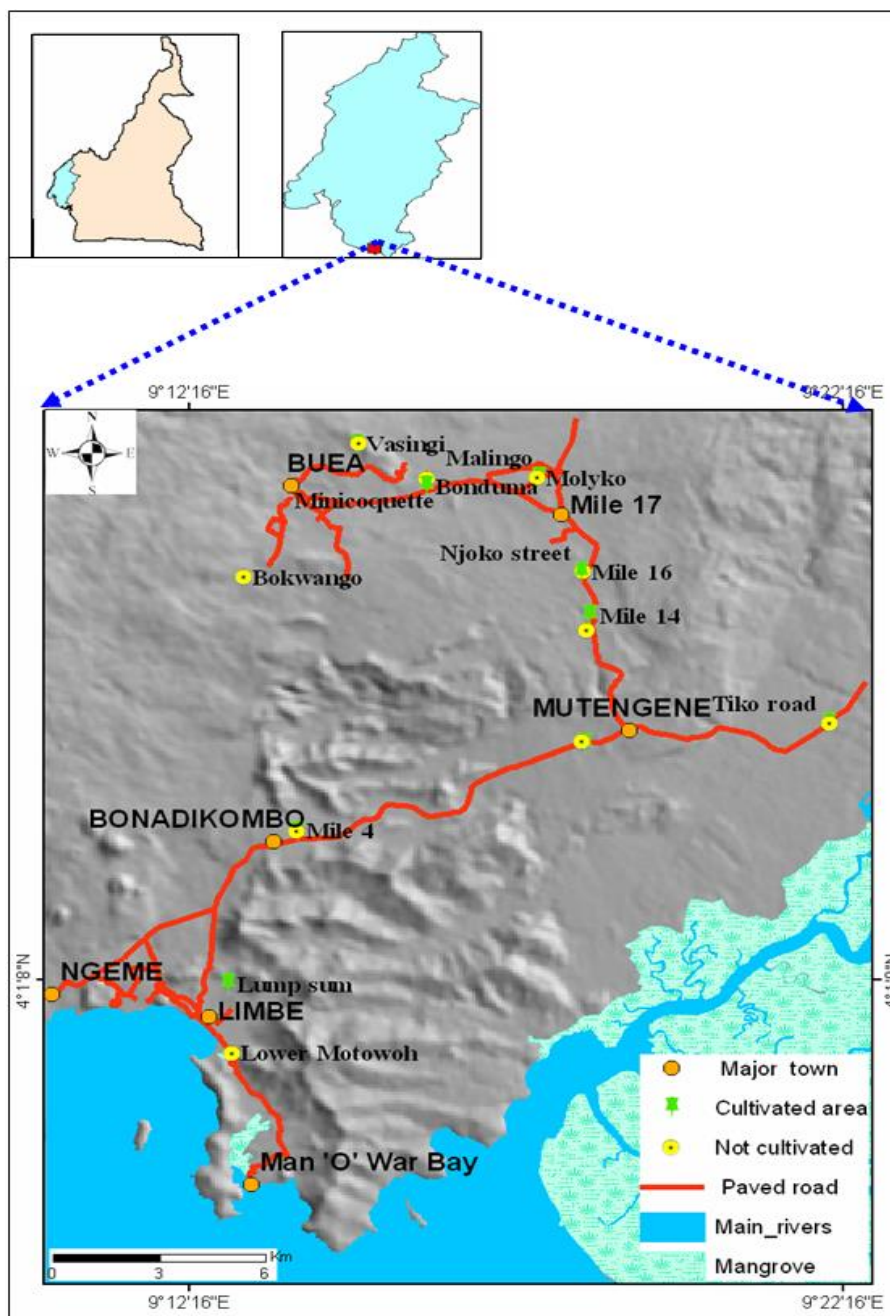


Figure 1. Map of the study area showing sample points (Drawn from GPS data by Che Vivian, PhD. Department of Geology, University of Buea).

black and are well drained due to the generally hilly nature of the terrain. Climatic conditions such as temperature (20 to 28°C), and annual rainfall (3000 to 5000 mm) (Manga et al., 2013) are favourable for agriculture. The geochemistry of volcanic rocks from the entire CVL shows that the rocks all have MgO > 4% and are relatively rich in trace elements (Fitton and Dunlop, 1985). The area has many hills, gully, streams as well as underground water. It is prone to many natural hazards, such as floods and eruptions. The population is cosmopolitan with most of the people living on small

scale or peasant farming. Most of the land is occupied by the Cameroon Development Corporation (CDC) for Banana, Palm and Rubber plantations. Limbe has a lot of industrial activities such as petroleum, fishing, agriculture, photography etc. A lot of construction work is going on especially in Buea to cater for the increasing population especially the University of Buea students and staff (Figures 1 and 2).

The likely sources of pollution would be the volcanic rocks and sea intrusions (Natural) and activities such indiscriminate dumping

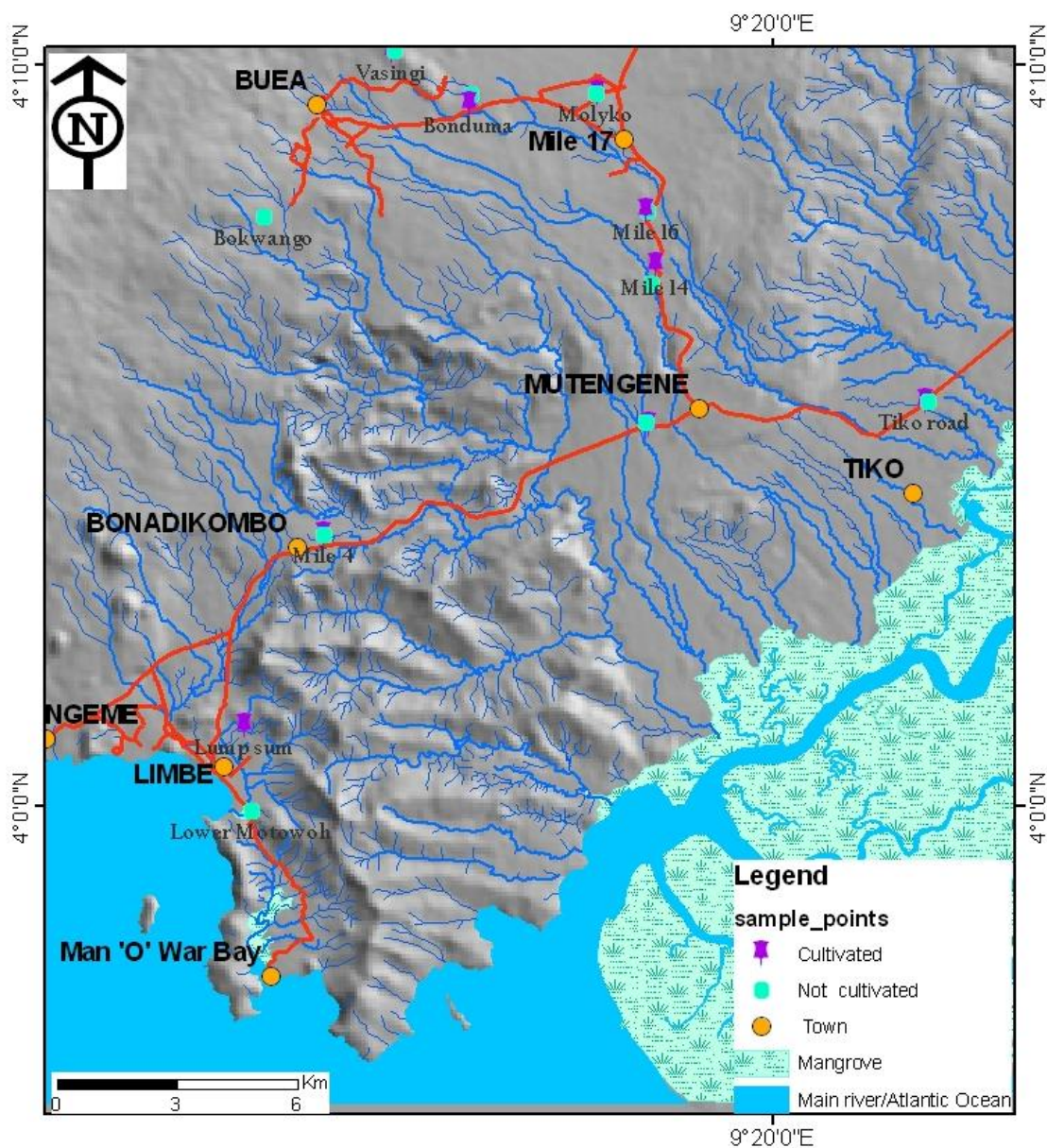


Figure 2. Hydrological map of the study area (Drawn from GPS data by Che Vivian, PhD. Department of Geology, University of Buea).

of waste, laundry, use of chemicals in farms and industries, location of latrines etc (anthropogenic).

Sampling of soils

Top soil samples were collected using a hand trowel from cultivated and abandoned (Non-cultivated) areas at the range of 15 to 20 cm depth. The points were chosen at different altitudes such that a cultivated point had a corresponding non-cultivated point a few metres away from each other. At each collection point, four soil samples were collected at about 1 m apart and bulked. The sampling points were geo-referenced using a 12-channel Garmin

etrex Global Positioning System (GPS) (Table 1).

Water sampling

Some common water sources of each locality were chosen. Water was collected into 1.5L containers. Table 2 gives the sampling stations for water samples, source of water and their locations. Main water types in the study area are Ca-Mg-HCO₃ and Na-HCO₃. Three processes control the spring water quality. CO₂-driven silicate weathering and reverse cation exchange are the most important processes affecting the hydrochemistry of the spring waters. While tropical oceanic monsoon chloride-rich/sulfate-rich

Table 1. The sampling stations for soil samples, their location, altitude, GPS location and Human activities around them.

Sampling station	Location	Altitude (m)	GPS location	Human activity
1 (NC)*	Lower Motowo Down Beach	4.27	N 03° 59.904'; E 009° 12.950'	Fishing and sales of sea products
2 (C)	Tita Street Beach	31.39	N 04° 01.0141'; E 009° 12.872'	Farming, domestic waste dump, use of fertilisers
3 (C)	Mile 4	231.65	N 04° 03.650'; E 009° 13.931'	Farming, Domestic waste dump, use of fertilisers
4 (NC)	Mile 4	224.94	N 04° 03.698'; E 009° 13.934'	Palm plantation
5 (C)	Limbe Road Mutengene	194.46	N 04° 05.132'; E 009° 18.335'	Farming, construction of buildings
6 (NC)	Limbe Road Mutengene	177.39	N 04° 05.159'; E 009° 18.297'	Palm plantation
7 (C)	Douala Road, Tiko	46.33	N 04° 05.458'; E 009° 22.067'	Farming
8 (NC)	Douala Road Tiko	28.65	N 04° 05.457'; E 009° 22.090'	Rubber plantation
9 (NC)	Mile 14	381.61	N 04° 07.044'; E 009° 18.370'	Abandoned for long
10 (C)	Mile 14	412.09	N 04° 07.279'; E 009° 18.412'	Farming, domestic waste dump, use of fertilizers.
11 (NC)	Mile 16	484.63	N 04° 08.026'; E 009° 18.311'	Construction of houses, domestic waste dump
12 (C)	Mile 16	462.08	N 04° 08.013'; E 009° 18.279'	Farming, construction of houses, fertilizers
13 (C)	Malingo Street Molyko	465.43	N 04° 09.609'; E 009° 17.638'	Farming, intense construction of houses
14 (NC)	Malingo Street Molyko	563.88	N 04° 09.590'; E 009° 17.617'	Construction of houses
15 (NC)	Mini Coquette Bondoma	699.21	N 04° 09.469'; E 009° 15.930'	Abandoned
16 (C)	Mini Coquette Bouduma	688.54	N 04° 09.465'; E 009° 15.903'	Farming, construction of houses
17 (NC)	Bokwango Towards Sasse	945.18	N 04° 07.943'; E 009° 13.150'	Domestic waste dump, abandoned
18 (C)	Bokwango Towards Sasse	945.79	N 04° 07.936'; E 009° 13.132'	Farming, domestic waste dump
19 (C)	Vasingi	1017.12	N 04° 10.182'; E 009° 14.848'	Farming, domestic waste dump
20 (NC)	Vasingi	997.31	N 04° 10.192'; E 009° 14.883'	Domestic waste dump

*C, Cultivated; NC, Not cultivated for at least two years.

rainwater seems to affect spring water chemistry at low-altitude areas (Ako et al., 2012). Figures 3 and 4 also show some of the water sampling points.

Soil analytical methods

Various methods were used to analyse the soils for their physicochemical properties.

Particle size analysis

Particle size analysis was done by sedimentation and decantation method (Akinola, 1986). To 50 g of dry sample

in a 250 ml beaker was added distilled water above the soil to soak. 20 ml of 0.5 N sodium hexametaphosphate (NaPO_4)₆ was added to the mixture and allowed to stand for 15 minutes. A magnetic stirrer and bar was used to stir the mixture for five minutes. The content of the beaker was transferred into a 1-L measuring cylinder and water added to the 1 L mark. Using one palm of the hand to cover the mouth of the cylinder and the other palm to hold its bottom, the contents of the cylinder were shaken several times and then allowed to stand for two hours.

After two hours, the suspension was decanted using a tube. The sand and silt sediments were transferred into a beaker, rinsing the measuring cylinder with distilled water, using a wash bottle. It was allowed to stand for 30 min to an hour and a second decantation was done. The sand

and silt was dried on a giant hot plate for about 12 h, stirring until the sticky nature was absent. The beaker, sand and silt were weighed. Water was added into the beaker containing sand and silt and allowed to soak, stirring and washing with hand several times, decanting until the water above the sand was very clear. The sand was dried in the oven and then weighed after cooling.

Chemical analysis

Soil pH was measured in 1:2 soils: water suspension as well as in soil: KCl suspension using a PHS-2CW Microprocessor pH/mV glass - electrode meter.

Organic carbon was determined in the Walkley-Black

Table 2. Sampling stations, location and altitude for water sources.

S/N	Source	Location	Altitude (m)	Remarks
1	Well	Beach Limbe	4.27	Not covered, used for domestic activities
2	Stream	Beach Limbe	4.27	Running stream, dirty.
3	Stream	Mile 4 Limbe	231.65	Running stream used for domestic activities
4	Spring	Mutengene	194.46	Used for domestic activities
5	Well	Douala Road Tiko	46.33	Covered, used for domestic purposes
6	Stream	Ndongo Tiko	46.33	Dominance of vegetation
7	Stream	Benyo (Mile 14)	412.09	Agricultural activities, used for laundry and equally for domestic activities.
8	Stream	Washing point Mile 16	484.63	Washing of vehicles
9	Spring	Mile 18	462.08	Used for domestic activities
10	Well	Wonya Mavio	563.88	Covered, used for domestic activities and gardens around it.
11	Spring	Bonduma	699.21	Dominance of vegetation, used for domestic activities
12	Stream	Ndongo Molyko	688.54	Disposal of waste , used for laundry, some domestic and irrigation
13	Stream	Ndongo Likomba	70.64	Used for laundry, Waste disposal
14	Stream	Ndongo Mile 16	462.08	Waste disposal
15	Spring	Vasingi	997.31	Used for domestic activities
16	Spring	Mile 4 Limbe	231.65	Used for domestic activities

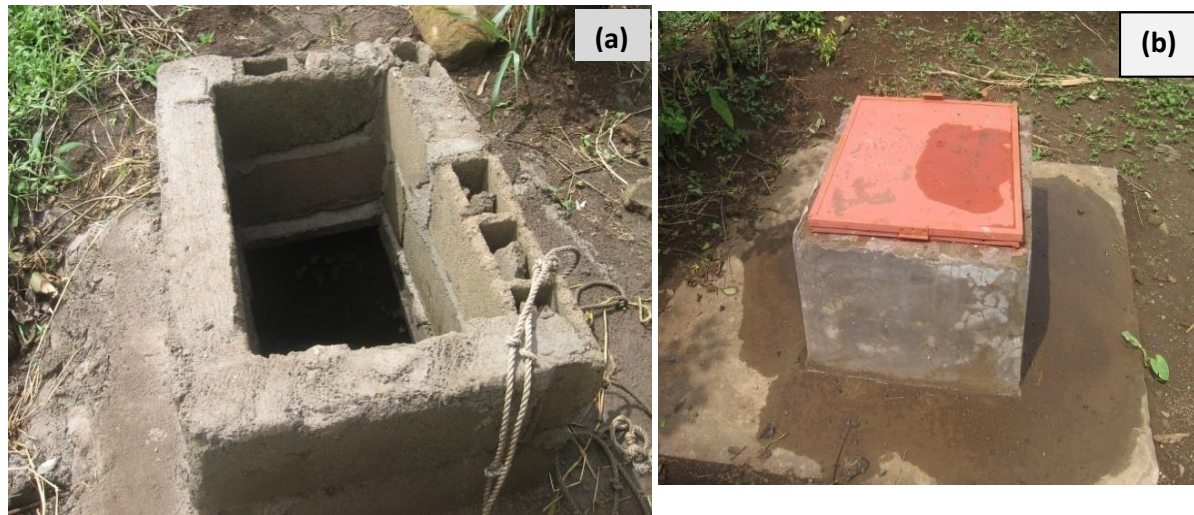
**Figure 3.** Open (a) and closed wells (b) at Wonya-Mavio, mile 18 Buea.



Figure 4. Springs at Mercedes street, (a) Bonduma and (b) Mile 18, Wonya- Mavio, Buea.

dichromate titration method following digestion with potassium dichromate and concentrated sulphuric acid (Walkley, 1987). The concentration of the green chromium obtained after oxidation is determined by colorimetry. A factor $F = \text{mg C/OD}$ was calculated for each standard, an average calculated and % carbon calculated from $\% \text{C} = \text{OD sample} \times 1.33/5$.

Total nitrogen was determined by modified macro-Kjeldahl method (Jackson, 1958). Soil was digested at 370°C on a Digestion System 40 1016 Digester with concentrated sulphuric acid in the presence of sodium sulphate-Selenium catalyst. The digest was diluted and the nitrogen as $(\text{NH}_4)_2\text{SO}_4$ was determined by colorimetry.

Available phosphorus was extracted with Bray-P-1 solution and the colour was developed using Murphy and Riley reagent, and ascorbic acid. A solution of 0.1 N HCl and 0.03 N NH_4F was used to extract available phosphorus from the soil. Phosphorus was determined by colorimetry using ammonium molybdate and ascorbic acid. Available phosphorus was read at a wavelength of 882 nm (Bray et al., 1945). Exchangeable potassium was extracted with 1 N NH_4OAC (pH 7) and was determined using a Gallenkamp Digital Flame Analyser.

Water analytical methods

Various methods were used to analyse the physicochemical properties of the different water sources.

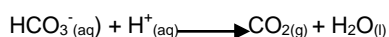
Bicarbonate (HCO_3^-)

The concentration of bicarbonate (HCO_3^-) was determined by titration. For each sample, 50 mL was transferred into a 250 ml conical flask pipette. Four drops of methyl red indicator was put in sample and titrated with 0.01 N HCl from burette and the volume of the acid titrated and the end-point recorded where a steady colour changed to orange was observed.

The concentration of HCO_3^- :

$$\text{mg/L} = \frac{(Y-X) \text{ mL} \times 0.01 \times 103}{V (50 \text{ mL})}$$

Y = initial volume of acid; X = final volume at end-point; V = volume transferred



Chloride (Cl^-)

Chloride (Cl^-) ion concentration determination was carried by titration. One hundred millilitres of sample was transferred into a 250 ml conical flask using a pipette. Four drops of K_2CrO_4 indicator added to the sample with small quantity of CaCO_3 . AgNO_3 solution titrated drop wise from the burette until solution turns a permanent orange tinge colour. The volume of the AgNO_3 was added until an end-point (end-point = point where a permanent orange tinge colour) was observed. A blank titration was also performed with distilled water and the volume subtracted from the samples. The chloride concentration was gotten as follows:

$(\text{Sample titration} - \text{blank titration}) \times 10 = \text{mg/L of } \text{Cl}^- \text{ in the sample.}$

Magnesium (Mg^{2+})

Magnesium (Mg^{2+}) ion concentration was analysed using the colorimetric method. One millilitre of water samples and standards, 1.25 ppm $\text{Mg}^{2+} (\text{aq})$ (prepared from magnesium ribbon, dilute HCl and 25 ml of 1 N ammonium acetate) were pipetted into clean test tubes. Four millilitres of calcium chloride solution and 10 ml of titan yellow mixture added immediately. 2 ml of alkali mixture was then added and was vigorously shaken on the electric homogenizer for 60 min for colour development and read on a spectrophotometer.

Nitrate (NO_3^-)-nitrogen (N)

For NO_3^- -N determination, the colorimetric method was used. Five millilitres of standard and water samples were pipetted into clean test tubes. One millilitre salicylic acid (5 g dissolved in 1 L concentrated H_2SO_4) solution was added to each test tube, immediately mixed well and left for 30 min. Ten millilitres of 4 M sodium hydroxide was then added to each tube and left for one hour for full colour development. The colour was stable for 12 h and

absorbance read at 410 nm wavelength on an SP-300 spectrophotometer. A factor F , for the standards was calculated and the average F_{av} used to calculate the NO_3^- -N as:

$$\% \text{NO}_3^- \text{-N} = 0.0004 \times F_{av} \times (\text{Abs-blank})$$

Sulphate (SO_4^{2-})

Sulphate (SO_4^{2-}) ion was analysed by turbidimetry with 10 mL of standard solutions of sulphates (0.543 g of K_2SO_4 + 68 mL of 25% HCl all in 1000 mL distilled water) and water samples pipetted into test tube. Two millilitres of 25 mL standard solution was added to samples and standards. One millilitre of the turbidimetric reagent (gelatine/ BaCl_2) was added and finally made to 15 mL with distilled water. The contents were then shaken and allowed to stand for about 20 min and absorbance measured at 450 nm wavelength on an SP-300 Spectrophotometer.

Phosphate (PO_4^{3-})

Phosphate (PO_4^{3-}) ion was determined by colorimetry (using ammonium molybdate-ascobic acid blue coloration method). Five millilitres of water sample and standard solution (prepared by dissolving 0.526 g of KH_2PO_4 in 50 mL extracting solution (0.1 N HCl + 0.03 N NH_4F all to 1000 mL with distilled water) were pipetted into clean test tubes. Five milliliters of mixed reagents (250 mL of 2.5 M Conc. sulphuric acid, 75 mL of 4% ammonium molybdate) was added to each test tube. 15 mL distilled water was added and stirred vigorously and kept for 15 min for colour development and absorbance read at 650 nm wavelength on the spectrophotometer. The Perkin-Elmer Spectrophotometer 295E was used for all the readings.

Sodium (Na^+) and potassium (K^+)

The concentrations of sodium (Na^+), potassium (K^+) were determined using the Gallenkamp Digital Flame Analyser. The principle of flame photometry is such that over certain concentration ranges, light emitted as electrons fall to their ground state after atomic excitation by flame, which is directly proportional to the concentration of the samples or standard (1.491 g KCl/L or 0.1169 g NaCl/L) being aspirated. The instrument translates the emitted photon to digits, which were read on the digital display on the meter.

Experimental data was analyzed with the statistical package SPSS14.0 and EXCEL 2007 for Windows. Correlation analyses were also done to establish the likely sources of pollutants.

RESULTS AND DISCUSSION

Physicochemical properties of soils

The results of the physicochemical properties of the soils from the study area are presented in Table 3. The results indicate that 60% of the soils in the region are loam while 40% are clay-loam. In 70% of the soils, the clay content ranged from 16 to 25%. This indicates that the clays are almost uniformly distributed in the soils of this area and might have been derived from basaltic rocks that dominate this region (Endeley et al., 2001).

The soil pH in water ranged from 5.60 to 6.71 which is adequate. The optimal range for availability of nutrients is 5 to 7 (Arp and Krasse, 2006). This implies fertilizer application is needed for maintenance. Soil pH plays an important role in the availability of nutrients. The different forms of some nutrient elements are greatly determined by the pH of the soil (Brady, 1984). Ngane et al. (2012) also observed low pH values in some soils from South-Eastern Cameroon.

Magnesium and calcium concentrations decreased with altitude (Figure 5). The highest values (35.84 mmol/100 g and 12.28 mmol/100 g for Ca and Mg, respectively) were recorded in Limbe Downbeach (4.27 metres above sea level) and the lowest values (7.09 mmol/100 g and 2.22 mmol/100g for Ca and Mg, respectively) were observed in Vasingi (997.3 m above sea level). Calcium had a significant negative correlation ($r = -0.57$, $p < 0.01$) while magnesium had a significant negative correlation ($r = -0.50$, $p < 0.05$) with altitude (Figure 6). These significant negative relationships between these properties of soils and altitude could be attributed to weathering of rocks at higher altitudes and transportation to lower altitudes.

The results of properties of soils from cultivated and uncultivated areas are presented in Tables 4 and 5, respectively. The mean value of organic carbon in the non-cultivated area was 2.89% while that of the cultivated areas was 2.62% showing a decrease in organic carbon on cultivation. In a similar research conducted in Australia; on comparing the chemical properties of a long term cultivated site to those of an uncropped and highly grazed reference site in a red brown earth soil, total carbon decreased from 3.74% on the grazed site to 1.66% on the cultivated site. The mean total nitrogen content in the non-cultivated areas was 0.32% while in the cultivated areas; it was 0.24% showing a decrease in total nitrogen content on cultivation. Again on cultivation; the mean ECEC decreased from 20.17 to 17.85 mmol/100g representing 11.50% decrease in ECEC on cultivation. This implies the numbers of exchangeable sites are reduced on cultivation and contamination of water sources with cations shall increase. The mean available phosphorus decreased from 26.7 to 17 mg/kg. This represents a 36.33% decrease in available phosphorus on cultivation. Generally, there was a significant decrease in nutrients on cultivation or the properties of the cultivated areas were different from those of non-cultivated areas. Farmers may be tempted to increase fertility of the soils by fertilization. The inhabitants are advised not to cultivate around residential areas or around the water sources. In a similar study, Kizilkaya et al. (2010) found that land use change and subsequent tillage practices resulted in significant decreases in organic matter, total porosity, total nitrogen and soil aggregates stability.

From the correlation analysis of the soil properties (Table 6 and Figures 6 and 7), there were negative

Table 3. Physicochemical properties of soils from the study area

S/N	Moist content	pH		Org. C	Tot. N	C/N	Avail. P	Exchangeable bases				Exch. acidity	ECEC	BS	Sand	Silt	Clay	Textural class*
	(%)	H ₂ O	KCl	(%)	(mg/kg)	mmol/100g				(%)	(%)				(%)			
						Ca	Mg	K	Na									
1	14.87	6.15	5.09	1.92	0.21	9	65	35.84	12.28	0.64	0.07	0.29	49.12	99.41	36.4	40.6	23.0	L
2	16.82	5.93	4.77	1.54	0.11	14	1	19.41	6.40	0.33	0.04	0.34	26.52	98.72	33.0	29.8	37.2	C L
3	16.41	6.03	4.90	2.27	0.12	19	2	15.61	4.87	0.65	0.08	0.31	21.52	98.56	34.6	31.0	34.4	CL
4	17.32	5.83	4.80	2.78	0.18	15	11	10.04	3.02	0.39	0.06	0.43	13.94	96.92	46.0	31.1	22.9	L
5	9.64	6.23	5.21	1.98	0.26	8	45	17.00	5.89	0.82	0.11	0.25	24.07	98.96	47.7	35.7	16.6	L
6	13.59	6.22	5.04	2.45	0.26	9	51	17.52	5.84	1.59	0.15	0.26	25.36	98.98	46.2	35.4	18.4	L
7	12.26	6.26	4.99	1.87	0.12	16	23	14.09	4.69	0.37	0.08	0.20	19.43	98.97	35.5	40.6	23.9	L
8	14.50	5.84	4.42	1.67	0.11	15	4	13.68	4.31	0.90	0.07	0.42	19.38	97.83	29.7	42.2	28.1	CL
9	17.83	6.02	4.93	3.12	0.28	11	3	12.02	4.34	0.33	0.05	0.29	17.03	98.30	37.0	32.6	30.4	CL
10	17.60	6.24	5.18	3.12	0.28	11	5	11.51	3.74	0.82	0.06	0.11	16.24	99.32	32.2	30.6	37.2	CL
11	19.9	6.05	4.71	2.00	0.16	13	1	9.43	3.77	0.95	0.07	0.49	14.71	96.67	13.4	32.1	54.5	C
12	14.44	5.85	4.46	1.99	0.09	22	38	7.51	2.85	0.22	0.07	0.31	10.96	97.17	21.7	48.7	29.6	CL
13	21.99	5.60	4.46	2.45	0.48	5	29	8.35	3.32	0.68	0.13	0.87	13.35	93.48	32.4	43.7	23.9	L
14	19.01	6.01	4.47	2.07	0.54	4	34	11.28	3.42	1.27	0.12	0.51	16.60	96.93	38.1	41.0	20.9	L
15	13.42	6.71	5.30	3.72	0.54	7	35	13.65	4.53	1.99	0.19	0.33	20.69	94.41	38.7	46.3	15.0	L
16	12.42	6.09	4.78	3.22	0.24	6	12	7.09	2.59	0.37	0.05	0.44	10.54	95.83	31.1	49.8	19.1	L
17	20.48	6.18	5.08	6.30	0.71	9	53	8.65	2.87	1.07	0.12	0.57	13.28	95.71	28.5	42.0	29.5	CL
18	21.19	5.80	4.40	4.74	0.58	8	11	15.38	6.69	0.28	0.04	0.52	22.91	97.73	28.6	46.3	25.1	L
19	20.60	6.18	5.00	3.03	0.12	25	4	8.66	2.22	1.69	0.18	0.25	13.00	98.10	31.7	41.6	26.6	L
20	18.17	5.77	4.60	2.88	0.25	12	10	7.16	2.72	0.99	0.09	0.58	11.54	94.97	32.4	46.8	20.8	L

*L = loam, CL= clay loam, C = clay.

correlations between ECEC and Clay ($r = -0.12$) and ECEC and organic carbon ($r = -0.26$) which were insignificant ($p > 0.05$). The negative correlation between ECEC and clay could be an indication that the clays are mostly 1:1 clays or oxide and hydroxide clays, which have very little exchange sites for cations. The negative correlation between ECEC and organic matter could be an indication that the soils are made up of substances which are neither fulvic acid nor humic acid. This implies most of the soils could be

young soils. Magnesium increased with calcium (Figure 7a). This implies both magnesium and calcium could have the same origin.

Organic carbon and clay constitute the absorption complex of soils. This implies that the exchangeable bases can be mobile through the clays and will not be trapped. Hence, they can find their way into drinking water sources in this region. This is dangerous. If the amounts of these bases have not yet reached threshold values this could be because the activities leading to their

presence in soils are not yet very much. The highest exchange acidity was at Malingo Street, 0.87 mmol/100g. The highest concentration of Na^+ was at Bonduma, 0.19 mmol/100g. This implies the soils at these areas are unstable and landslides can occur in these areas. High exchange acidity and high concentration of Na^+ ions will destroy soil colloids and expose the charges.

There was a significant positive correlation ($r = 0.928$, $P < 0.01$) between Ca and Mg. This could be attributed to the fact that they owe their origin

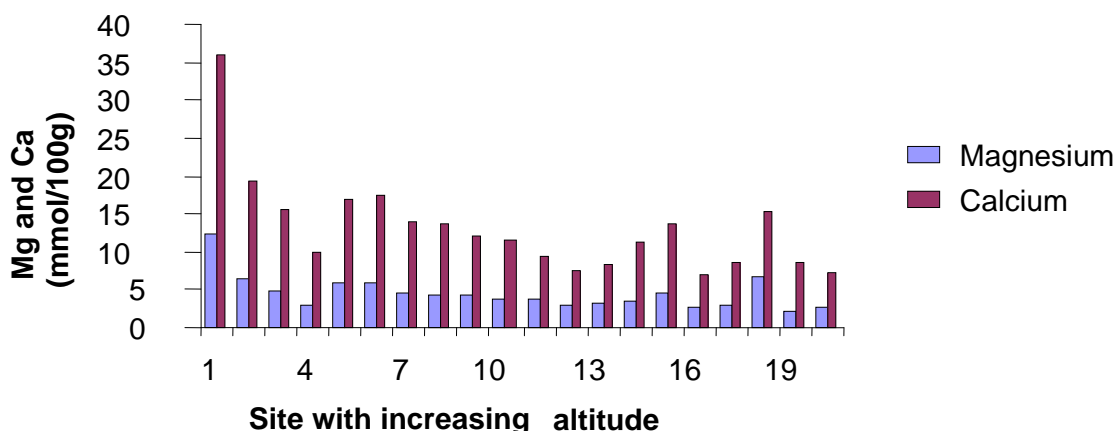


Figure 5. Magnesium and calcium concentrations in soils with altitude.

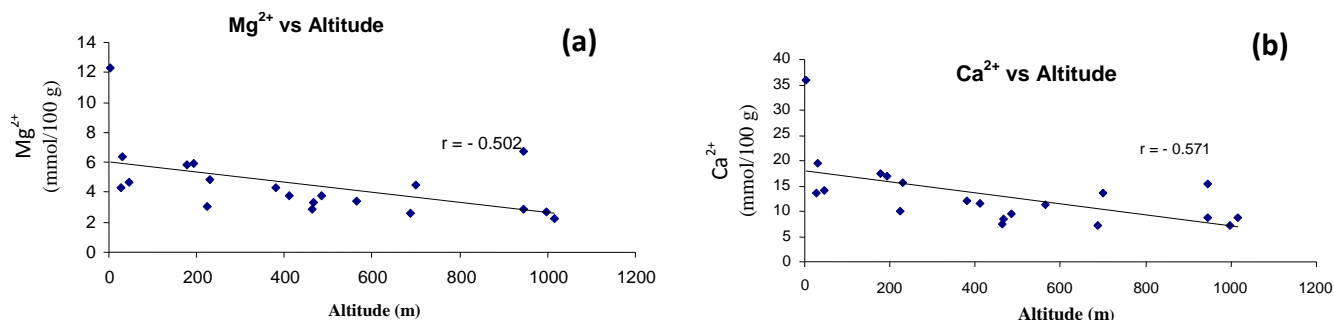


Figure 6. Relationships between calcium (a) and magnesium (b) and altitude.

from the same source probably the basaltic rocks of this area. This was same with potassium and sodium. Another significant positive correlation exists between ECEC and Mg ($r=0.983, P<0.01$) and between ECEC and Ca ($r=0.997, P<0.01$).

There was also a relation between calcium and available phosphorus though not significant. This implies they could probably have same origin.

With the exception of two samples, 17 and 18 (values 6.30 and 4.74%, respectively) in Bokwango that had adequate organic carbon, the rest had organic carbon less than 4%, which is low. This confirms the results of Nkweteyim (1999) where organic carbon ranged from 0.54 to 6.22%. Generally, with the exception of Bokwango and Vasingi the lower regions had high cultivation and housing activities going on, so much of the organic carbon in these places had been used up. Except in Mile 14 where carbon in both cultivated and non-cultivated areas was the same, 3.12% in all other towns the carbon in the non-cultivated area was higher than in the cultivated area. There was a significant positive correlation ($r = 0.71, p < 0.01$) between organic carbon

and altitude. This could be allied to the fact that as one moves higher the mountain vegetation abundance increases as much has been cut down at lower elevations for construction. Carbon is an essential component of plant bodies.

Most of the soils had total nitrogen less than 0.5%. This supports previous results of Nkweteyim (1999) in which total nitrogen ranged from 0.05 to 0.52% in the same region. The highest was at Bokwango, sample 17, uncultivated. This could be attributed to the non-cultivation of the area and less human activities. There was a significant positive relationship ($r = +0.54, p < 0.05$) between altitude and total nitrogen a probable reflection of an increase in vegetation intensity as the Mountain is ascended as in Carbon. This is confirmed by the positive correlation between total nitrogen and organic carbon with a positive correlation coefficient ($r = +0.74, p < 0.01$).

Based on the critical range of available P (10-15 mg P kg^{-1}) set by Tchuenteu (1994) for volcanic soils, available P was generally higher than this value in the soil obtained at Down Beach which could be attributed to the fact that no farming takes place in this area to deplete the

Table 4. Physicochemical properties of soils from cultivated portions of the study area.

S/N	Moist content (%)	pH		Org. C (%)	Tot. N	C/N	Avail. P (mg/kg)	Exchangeable bases				Exch. acidity	ECEC	BS	Sand	Silt	Clay	Textural class*
		H ₂ O	KCl					Ca	Mg	K	Na							
								mmol/100g										
2	16.82	5.93	4.77	1.54	0.11	14	1	19.41	6.40	0.33	0.04	0.34	26.52	98.72	33.0	29.8	37.2	C L
3	16.41	6.03	4.90	2.27	0.12	19	2	15.61	4.87	0.65	0.08	0.31	21.52	98.56	34.6	31.0	34.4	CL
5	9.64	6.23	5.21	1.98	0.26	8	45	17.00	5.89	0.82	0.11	0.25	24.07	98.96	47.7	35.7	16.6	L
7	12.26	6.26	4.99	1.87	0.12	16	23	14.09	4.69	0.37	0.08	0.20	19.43	98.97	35.5	40.6	23.9	L
10	17.60	6.24	5.18	3.12	0.28	11	5	11.51	3.74	0.82	0.06	0.11	16.24	99.32	32.2	30.6	37.2	CL
12	14.44	5.85	4.46	1.99	0.09	22	38	7.51	2.85	0.22	0.07	0.31	10.96	97.17	21.7	48.7	29.6	CL
13	21.99	5.60	4.46	2.45	0.48	5	29	8.35	3.32	0.68	0.13	0.87	13.35	93.48	32.4	43.7	23.9	L
16	12.42	6.09	4.78	3.22	0.24	6	12	7.09	2.59	0.37	0.05	0.44	10.54	95.83	31.1	49.8	19.1	L
18	21.19	5.80	4.40	4.74	0.58	8	11	15.38	6.69	0.28	0.04	0.52	22.91	97.73	28.6	46.3	25.1	L
19	20.60	6.18	5.00	3.03	0.12	25	4	8.66	2.22	1.69	0.18	0.25	13.00	98.10	31.7	41.6	26.6	L
Av	16.34	6.02	4.82	2.62	0.24	13.4	17	12.46	4.33	0.62	0.08	0.36	17.85	97.68	32.85	39.78	27.36	

*L=loam, CL=clay loam, C=clay.

Table 5. Physicochemical properties of soils non-cultivated portions of the study area.

S/N	Moist content (%)	pH		Org. C (%)	Tot. N	C/N	Avail. P (mg/kg)	Exchangeable bases				Exch. acidity	ECEC	BS	Sand	Silt	Clay	Textural class*
		H ₂ O	KCl					Ca	Mg	K	Na							
								mmol/100g										
1	14.87	6.15	5.09	1.92	0.21	9.00	65.00	35.84	12.28	0.64	0.07	0.29	49.12	99.41	36.40	40.60	23.00	L
4	17.32	5.83	4.80	2.78	0.18	15.00	11.00	10.04	3.02	0.39	0.06	0.43	13.94	96.92	46.00	31.10	22.90	L
6	13.59	6.22	5.04	2.45	0.26	9.00	51.00	17.52	5.84	1.59	0.15	0.26	25.36	98.98	46.20	35.40	18.40	L
8	14.50	5.84	4.42	1.67	0.11	15.00	4.00	13.68	4.31	0.90	0.07	0.42	19.38	97.83	29.70	42.20	28.10	CL
9	17.83	6.02	4.93	3.12	0.28	11.00	3.00	12.02	4.34	0.33	0.05	0.29	17.03	98.30	37.00	32.60	30.40	CL
11	19.90	6.05	4.71	2.00	0.16	13.00	1.00	9.43	3.77	0.95	0.07	0.49	14.71	96.67	13.40	32.10	54.50	C
14	19.01	6.01	4.47	2.07	0.54	4.00	34.00	11.28	3.42	1.27	0.12	0.51	16.60	96.93	38.10	41.00	20.90	L
15	13.42	6.71	5.30	3.72	0.54	7.00	35.00	13.65	4.53	1.99	0.19	0.33	20.69	94.41	38.70	46.30	15.00	L
17	20.48	6.18	5.08	6.30	0.71	9.00	53.00	8.65	2.87	1.07	0.12	0.57	13.28	95.71	28.50	42.00	29.50	CL
20	18.17	5.77	4.60	2.88	0.25	12.00	10.00	7.16	2.72	0.99	0.09	0.58	11.54	94.97	32.403	46.80	20.80	L
Av	16.91	6.08	4.84	2.89	0.32	10.40	26.70	13.93	4.71	1.01	0.10	0.42	20.17	97.01	4.60	39.00	26.40	

*L=Loam, CL=clay loam, C=clay.

Table 6. Correlation coefficients between physicochemical properties of soils examined.

Indices	Moist	pH (H ₂ O)	Org. C	Tot. N	Av. P	Ca	Mg	K	Na	Ex.ac	ECEC	BS	Clay	Silt	Sand
Moist-pH (H ₂ O)	-0.47*	-													
Org. C	0.40	0.17	-												
Tot. N	0.39	0.13	0.75**	-											
Av. P	-0.30	0.31	0.14	0.39	-										
Ca	-0.31	-0.23	-0.29	-0.13	0.43	-									
Mg	-0.26	0.15	-0.23	-0.06	0.42	0.93**	-								
K	0.038	0.57**	0.17	0.29	-0.25	-0.06	-0.15	-							
Na	0.02	0.49*	0.17	0.33	0.40	-0.13	-0.21	0.89**	-						
Ex. ac	0.57**	0.61**	0.25	0.50*	0.02	-0.35	-0.26	-0.05	0.06	-					
ECEC	-0.29	0.24	-0.26	-0.09	0.45*	0.99**	0.98**	-0.02	-0.09	-0.32	-				
BS	-0.34	0.19	-0.35	-0.50*	-0.03	0.57**	0.51*	-0.23	-0.34	-0.79**	0.53*	-			
Clay	0.42	-0.19	-0.12	0.30	0.50*	-0.11	-0.09	-0.24	-0.42	-0.04	-0.12	0.19	-		
Silt	-0.05	-0.07	0.29	0.33	0.30	-0.24	-0.17	0.10	0.24	0.38	-0.21	0.55*	0.52*	-	
Sand	-0.44	0.27	0.10	0.07	0.33	0.32	0.24	0.19	0.28	-0.27	0.31	0.24	0.71**	0.24	-
Alt	0.53*		0.71**	0.54*		-0.57*	-0.50*				0.53*				

*, **Significant at 5 and 1% levels, respectively.

phosphorus. In some areas the high values of available P could partly be due to the residual levels from previous P fertilization. According to Wild (1996), the absorbed nature of phosphates by soils makes the concentration in drainage water low even where phosphate fertilizers are applied.

The ECEC and altitude showed a negative correlation ($r = -0.53$, $P > 0.05$). This could be attributed to weathering. At higher altitudes there is weathering and the ions move downwards. Nitrogen and altitude showed a positive correlation ($r = 0.54$, $P < 0.05$). This was same for organic carbon and altitude ($r = 0.708$, $P < 0.01$). This was confirmed in the significant correlation between organic carbon and nitrogen ($r = 0.74$, $P < 0.01$). The soils generally had high CEC. CEC can directly influence the changes in soil pH, because

every time the clay particles capture cations, they release H^+ and Al^{3+} ions, which in high concentrations acidifies soil. Generally, tropical soils have low CEC, especially for high sandy and low pH soils. Tropical soils have a high humidity and acidity, contributing to an overall increase of CEC (Aprile et al., 2012).

The increase in carbon and nitrogen with height could be attributed to anthropogenic actions such as construction of houses and farming which are more common at the lower altitudes where there was more habitation. The higher carbon at higher altitude could also be attributed to above ground litter fall and root mortality which are the two primary processes that contribute to soil carbon inputs along an elevation gradient (Yang et al., 2009; Charan et al., 2012). In a similar study, Ji et al. (2015) found that soil organic carbon contents

and stocks were significantly higher at the high-altitude site than a low altitude site in the entire soil profile (0-60 cm). In another similar study, Charan et al. (2013) suggested altitudinal variations in soil physico-chemical properties at cold desert high altitude.

Physicochemical properties of water from study area

The results of water analysis are shown in Table 7 and the correlations are shown in Table 10. The pH of the water samples ranged from 6.16 to 8.54. The streams had generally higher pH than wells. This is could be due to the deposition of alkaline wastes into water sources or runoffs. The low pH in the wells could partly be attributed to the fact

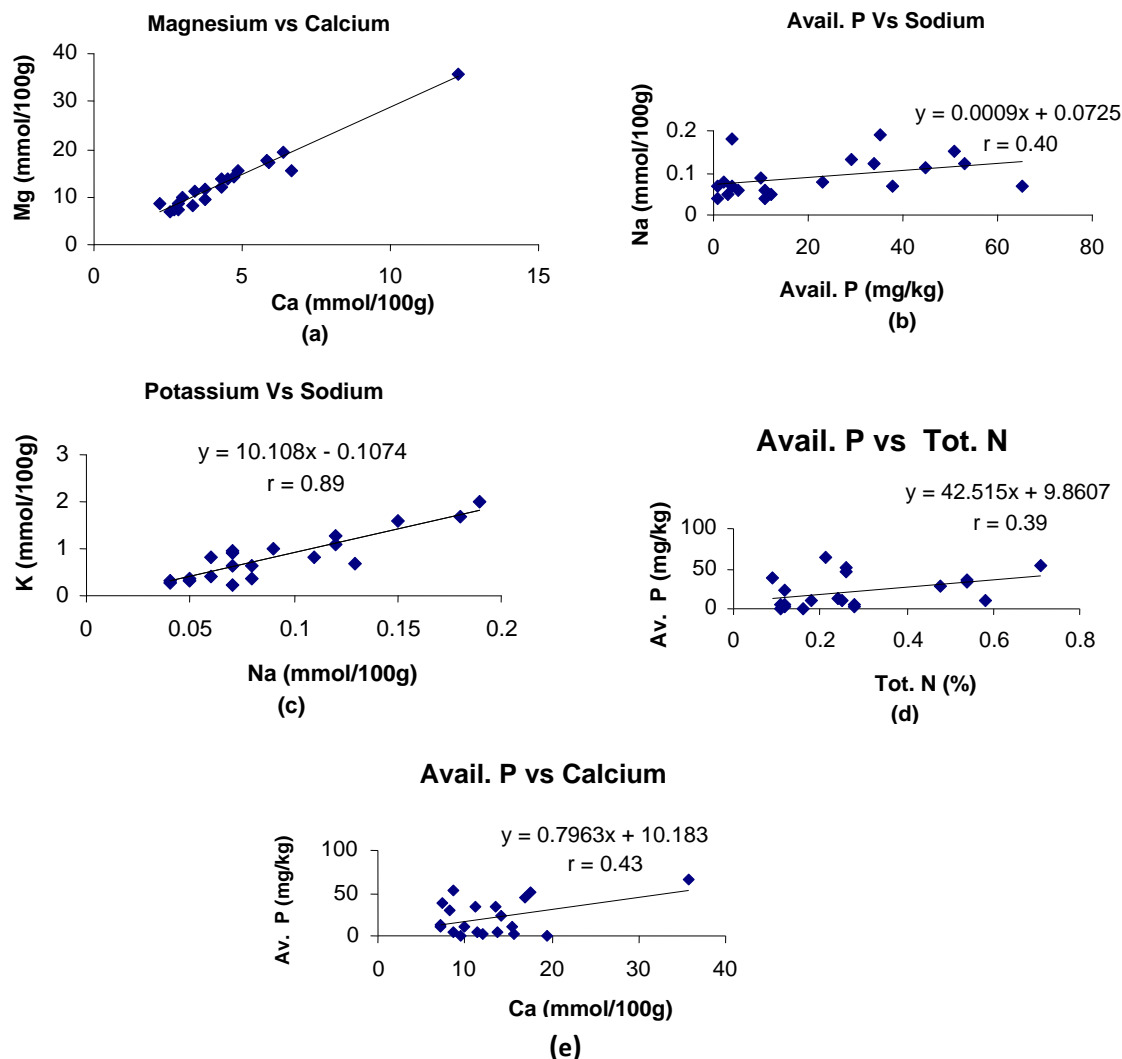


Figure 7. Relationships between some soil properties.

that tropical soils have colloids which are positively charged (Rowel, 1994). The average pH in the region was 7.7 which is within the range recommended by EU, Canada and USA, 6.5-8.5 (Chapman, 1997).

Nitrates were generally absent in most of the samples but the concentrations ranged between 0 to 4.93 mg/L. The average nitrate concentration in streams was 0.31 mg/L, 1.94 mg/L in wells and 0.68 mg/L in springs.

Samples 5 to 10 that is, between Tiko and Wonya-Mavio, Buea had nitrate. This implies water from these areas is unsafe for drinking. The highest concentration of 4.93 mg/L was obtained from a well at Wonya-Mavio. This may be attributed to farming, soil type and distance from two neighbouring toilets. Nitrate is detrimental to the health of humans especially children as it leads to methamoglobinaemia. Nitrates concentration increased

with an increase in altitude, an indication of addition of this property from the mountain probably released from this active volcano. The sulphate concentration was generally low in the region. However the highest, 5.28 mg/L was recorded at well at Douala road, Tiko. This could be attributed to effluents from the rubber factory.

Bicarbonate and magnesium showed a positive significant relation ($P < 0.01$; Figure 8d). This could be because both have the same origin which is natural. Temperature and sulphate showed similar correlation ($P < 0.01$, Figure 8e). This could be attributed to the non-dissolution of sulphates at higher temperatures. There was little or no carbon and nitrogen cycling and transfer from the high-altitude soils to the low-altitude waters since the low-altitudes waters had low values of nitrate and bicarbonate (Table 7). This implies the carbon in the

Table 7. Physicochemical properties of water sources from West Flank of Mount Cameroon.

S/N	Na ⁺	K ⁺	Mg ²⁺	HCO ₃ ⁻	NO ₃ ⁻	SO ₄ ²⁻	Cl ⁻	HPO ₄ ²⁻	Elect. Cond.	pH	TDS	Temp
	mg/L						(µs/cm)			(ppm)	(°C)	
1	0.23	0.78	13.44	168.36	0.00	2.55	4.00	0.00	336	7.24	168	28.3
2	0.23	2.26	11.64	145.18	0.00	3.68	25.00	0.03	302	7.59	150	30.7
3	0.15	3.74	12.84	189.10	0.00	3.73	23.00	0.36	320	7.38	160	31.7
4	0.07	1.09	12.36	153.72	0.00	2.61	1.00	0.10	362	7.44	133	27.5
5	0.15	0.04	7.68	69.54	0.90	5.28	4.50	0.04	210	7.12	102	28.9
6	0.15	1.09	10.20	97.60	0.80	4.03	2.00	0.20	225	8.34	112	29.6
7	0.60	1.87	13.8	118.34	1.01	3.38	0.00	0.12	232	8.30	116	28.9
8	0.07	0.78	8.64	79.30	0.65	1.84	0.00	0.06	347	8.54	188	25.9
9	0.07	0.39	3.96	39.04	0.65	1.31	2.00	0.00	297	8.04	140	24.9
10	0.07	1.09	5.04	24.40	4.93	3.44	2.00	0.01	129	7.71	64	25.1
11	0.15	0.39	2.88	34.16	0.00	1.42	0.00	0.02	236	7.75	118	24.3
12	0.15	1.48	10.44	9.39	0.00	2.25	0.00	0.00	257	8.31	130	25.8
13	0.15	1.09	11.28	124.44	0.00	2.73	0.00	0.04	315	7.22	151	28.5
14	0.07	0.39	5.28	58.56	0.00	1.93	0.00	0.15	285	7.76	187	27.5
15	0.07	0.00	9.12	54.90	1.17	2.08	2.00	0.02	228	6.80	150	23.3
16	0.37	2.65	12.72	170.80	0.00	1.78	14.00	0.04	315	7.55	235	25.5

form of carbonates or bicarbonates and nitrogen in the form of nitrates were trapped by the positive charges on the soil colloids.

The results of ground water and surface water presented in Tables 8 and 9 respectively. Apart from Nitrate whose mean concentration decreased from 1.0 mg/L in ground water to 0.31 mg/L in surface water; all the other properties had mean values significantly higher in surface water than in ground water (Tables 8 and 9). A lot of farming is being done around surface water and there indiscriminate dumping of various types of waste in streams. This difference in properties could be attributed to anthropogenic sources of pollution. They include among others; fertilizers, herbicides and insecticides, office wastes, wastes from construction sites, car washing points, garages,

petroleum filling stations and household wastes.

Sources of water and soil pollution in the study area

From the results of the water analysis, Na⁺, K⁺ and Mg²⁺ were comparatively higher at Beach Limbe than the other sources. This could be attributed to natural sea water intrusions and or weathering and movement of these substances from high altitude to low altitude. Correlation analysis indicated that magnesium had a significant negative correlation ($P > 0.05$) with altitude, an indication that this entity and its associates have as a major source natural weathering and transportation from uphill. River

Benyo had a high magnesium concentration more than other parameters. Sources of magnesium in this stream could be from the weathering of rocks present in this stream.

According to Endeley et al. (2001), the area is composed mainly of massive basaltic lava flows and the geochemistry of volcanic rocks from the entire Cameroon Volcanic Line (CVL) shows that the rocks have MgO > 4%. The weathering of the volcanic rocks might therefore be expected to lead to the presence of elevated level of this species in the stream. Another probable contributor of magnesium in this stream is anthropogenic due to the deposition of waste such as metallic objects, plastics etc. and laundry activities that go along the stream. Nitrates had the highest value (4.93 mg/L) at the Wonya Mavio well. This could be

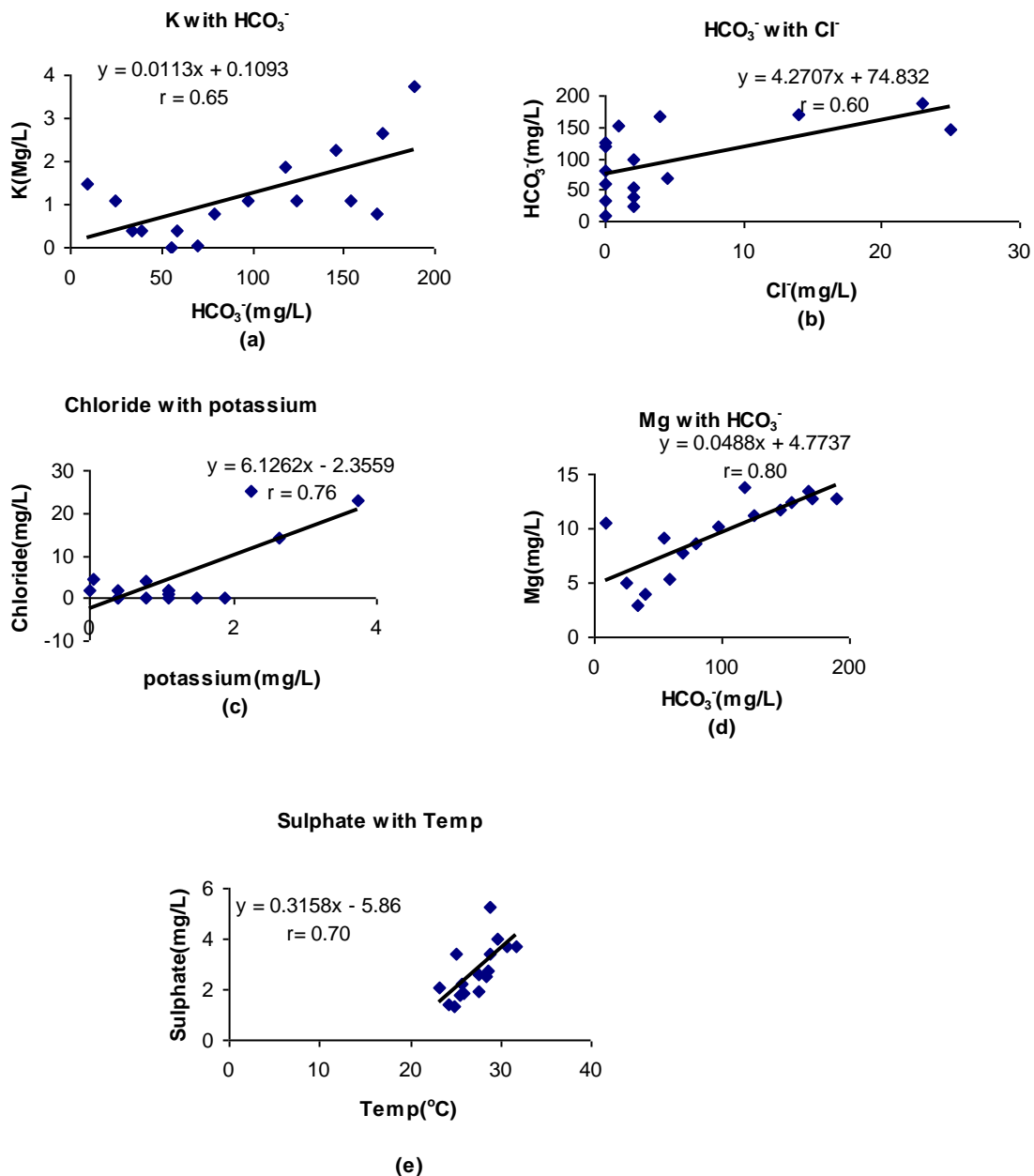


Figure 8. Relationships between some physicochemical properties of water.

allied to anthropogenic sources such as the use of nitrogenous fertilizers and/or intrusion of domestic sewage. Apart from residencies, there is a small garden at this point of sampling with probable usage of nitrogenous fertilizers. Wernick et al. (1998) found out a positive relationship between residential and agricultural activities on elevated nitrates in the Salmon River of British-Colombia. High nitrates are undesirable in water bodies as they can result in eutrophication and methemoglobinemia (Kross, 1993).

The highest sulphate value of 5.28 mg/L was obtained

from the well in Tiko. This could be attributed to anthropogenic sources probably due to the fact that this well is located near the rubber factory. Rubber effluents have high content of organic matter which is one of the major sources of sulphates. According to Rose et al. (1979), the concentration of sulphate in rainwater ranges between 1 to 3 mg/L. Therefore, the concentration of sulphate in this well which is higher than the range in rainwater confirms the fact that sulphates are probably being added into this system by anthropogenic activities. Chlorides concentrations were higher in Limbe waters

Table 8. Physicochemical properties of ground water sources from West Flank of Mount Cameroon.

S/N	Na ⁺	K ⁺	Mg ²⁺	HCO ₃ ⁻	NO ₃ ⁻	SO ₄ ²⁻	Cl ⁻	HPO ₄ ²⁻	Elect. Cond.	pH	TDS	Temp
	mg/L								(μ s/cm)		(ppm)	($^{\circ}$ C)
1	0.23	0.78	13.44	168.36	0.00	2.55	4.00	0.00	336.00	7.24	168	28.3
4	0.07	1.09	12.36	153.72	0.00	2.61	1.00	0.10	362.00	7.44	133	27.5
5	0.15	0.04	7.68	069.54	0.90	5.28	4.50	0.04	210.00	7.12	102	28.9
9	0.07	0.39	3.96	039.04	0.65	1.31	2.00	0.00	297.00	8.04	140	24.9
10	0.07	1.09	5.04	024.40	4.93	3.44	2.00	0.01	129.00	7.71	64	25.1
11	0.15	0.39	2.88	034.16	0.00	1.42	0.00	0.02	236.00	7.75	118	24.3
15	0.07	0.00	9.12	054.90	1.17	2.08	2.00	0.02	228.00	6.80	150	23.3
16	0.37	2.65	12.72	170.80	0.00	1.78	14.00	0.04	315.00	7.55	235	25.5
H	0.37	2.65	13.44	170.80	4.93	5.28	14.00	0.10	362.00	8.04	235	28.9
L	0.07	0.00	2.88	024.40	0.00	1.31	0.00	0.00	129.00	6.80	64	23.3
Av	0.15	0.80	.40	089.37	1.00	2.56	3.69	0.03	264.13	7.46	139	26.0

H=Highest value; L=Lowest value; Av=mean.

Table 9. Physicochemical properties of surface water sources from West Flank of Mount Cameroon.

S/N	Na ⁺	K ⁺	Mg ²⁺	HCO ₃ ⁻	NO ₃ ⁻	SO ₄ ²⁻	Cl ⁻	HPO ₄ ²⁻	Elect. Cond.	pH	TDS	Temp
	mg/L								(μ s/cm)		(ppm)	($^{\circ}$ C)
2	0.23	2.26	11.64	145.18	0.00	3.68	25.00	0.03	302	7.59	150	30.7
3	0.15	3.74	12.84	189.10	0.00	3.73	23.00	0.36	320	7.38	160	31.7
6	0.15	1.09	10.20	097.60	0.80	4.03	2.00	0.20	225	8.34	112	29.6
7	0.60	1.87	13.80	118.34	1.01	3.38	0.00	0.12	232	8.30	116	28.9
8	0.07	0.78	08.64	079.30	0.65	1.84	0.00	0.06	347	8.54	188	25.9
12	0.15	1.48	10.44	009.39	0.00	2.25	0.00	0.00	257	8.31	130	25.8
13	0.15	1.09	11.28	124.44	0.00	2.73	0.00	0.04	315	7.22	151	28.5
14	0.07	0.39	05.28	058.56	0.00	1.93	0.00	0.15	285	7.76	187	27.5
H	0.60	3.74	13.80	189.10	1.01	4.03	25.00	0.36	347	8.54	188	31.7
L	0.072	0.391	05.28	009.39	0.00	1.84	0.00	0.00	225	7.22	150	25.8
Av	.05	.59	10.52	102.74	0.31	3.00	6.25	0.12	285	7.93	149	28.6

H=Highest value; L=lowest value; Av=mean.

than in other samples. This might have resulted from natural processes of sea water intrusion and sea sprays as the area is proxy to the sea.

Concomitantly, higher chlorides of this area were masked by high potassium concentrations. According to Chapman (1997), potassium salts

are widely used in industries. This is an indication that industries found within this municipality constitute major sources of water pollution. Similar

Table 10. Correlation coefficients between physicochemical properties of water samples examined.

	Alt	Na	K	Mg	HCO ₃ ⁻	NO ₃ ⁻	SO ₄ ²⁻	Cl ⁻	HPO ₄ ⁻	EC	pH	TDS T
Alt	-											
Na	-0.22	-										
K	-0.32	0.45	-									
Mg	-0.49	0.56*	0.61*	-								
HCO ₃ ⁻	-0.69**	0.41	0.65**	0.80**	-							
NO ₃ ⁻	0.28	-0.14	-0.17	-0.35	-0.42	-						
SO ₄ ²⁻	-0.55*	0.17	0.21	0.30	0.24	0.25	-					
Cl	-0.40	0.18	0.76**	0.39	0.60*	-0.21	0.32	-				
HPO ₄ ²⁻	-0.24	0.06	0.56*	0.30	0.45	-0.18	0.35	0.37	-			
EC	-0.37	-0.03	0.27	0.45	0.62*	-0.75**	-0.36	0.25	0.16	-		
pH	0.11	0.18	0.09	-0.13	-0.31	0.05	-0.18	-0.26	0.08	-0.04	-	
TDS	-0.11	0.12	0.28	0.32	0.48	-0.62*	-0.49	0.30	0.09	0.73**	-0.07	-
Temp	-0.78**	0.29	0.55*	0.56*	0.64**	-0.29	0.70**	0.55*	0.64**	0.25	-0.03	-0.01 -

*, **Significant at 5 and 1% levels, respectively.

high values were obtained by Mafany (2000) in the Douala Municipality sampling fresh water bodies.

The pollutants likely originate from natural sources (volcanic rocks that weather) and sea intrusions but also from anthropogenic sources (waste, use of chemicals in CDC industry, laundry activities etc).

The new soil and water data shall help improve the livelihood of the people living along the area. They show that nitrogen and carbon increase with altitude and consequently cultivation shall yield more crops at higher altitudes. They also indicate that the highest nitrate was found in Wonya-Mavio, a village in Buea. The people living here would restrict the use of nitrogenous fertilizers and be careful of intrusion of domestic sewage.

Conclusion

All the soils in the region were acidic. Most of the

physicochemical properties of the water analysed were within acceptable limits of WHO. Nitrates were generally absent in most of the samples. The water sources between Tiko and Wonya-Mavio, Buea had higher nitrate. There were significant positive relationships ($p < 0.05$ and $p < 0.01$) between nitrogen and altitude and carbon and altitude, respectively. Magnesium and ECEC showed a significant negative correlation ($p < 0.05$) with altitude while calcium showed a highly significant negative correlation with altitude. Among the natural sources of pollution identified are weathering, erosion and sea water intrusions. The anthropogenic ones include wastes from homes, laundry, fertilizers, sewage and factories.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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