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An Assessment of the Springs and Spring Line on the Flanks of Mount Cameroon

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ABSTRACT Fresh water availability in good quantity and quality is indispensable to an efficient functioning of the biosphere and human communities. Underground and resurgent springs have been of great interest to institutional structures involved in spring water bottling, The Cameroon Utility Corporation (CAMWATER, local water management committees rural and urban inhabitants, as well as other stakeholders. This calls for an understanding of the distribution and the hydro-geological setting of these springs whose occurrence seems to coincide with Cameroon Volcanic Line. The pressure exerted on this shrinking resource necessitates a futurist management system on this pseudo-karstic geological terrain.

INTRODUCTION

Fresh water availability in recent times has become an object of world environmental concern especially in natural water harvesting communities. Regrettably, of the 1 403 337 000 km^3 of water in the earth, only 2.4% or 33 618 048 km^3 is made up of fresh water. Out of this amount, up to 87% is locked up in ice and snow while only 13% (4 378 536 240 km^3) is liquid water. From this, groundwater constitutes 95%, soil moisture 2% while lakes, rivers and streams constitute 3%. Multitudes of natural and human factors variously affect this liquid water. Aridity apart, different parts of the world are affected by the extreme extraction and spoliation of water from underground aquifers. The degree of such underground water exploitation in the 21st century has been a function of population upsurge, technology and human activities. More than one quarter of the world's fresh water is derived from mountains and half of humanity depend mountain water resources. At the 2014 World Water Day celebration that took place on the 22nd of March, the Food and Agricultural Organization observed that in a world of 7 billion people, 1.1 billion still live without clean drinking water and due to rapid population growth/urbanization, 30% of more water shall be needed by 2030 (www.unwater.org/worldwaterday). Water stress is fast becoming a common feature in different parts of the world. In South East Asia, the Quarterly Report on Bottled Water Quality from the Pakistani Council of Research noted in 2013 that in Pakistan, potable water quality is deteriorating continually due to biological contamination from human waste, chemical pollutants from industries and agricultural inputs. In India, mountain communities are facing water dilemma, and this has been the observation of Perrault (2014) as different stakeholders struggle for the control of the scarce resource (www.theflume.com/news/article) while the World Health Organisation notes in 2013 that by 2025, half of the world population will be living in water stressed areas. The global driving forces are climate change, increasing water scarcity, population growth, demographic changes and urbanization.

The several urban and rural communities on the slopes of Mount Cameroon exploit subterranean springs for multiple forms of domestic, industrial and other subsistence forms of livelihood. Commercial exploitation of these springs has been on an increase and so constitute a cause for concern (Table 1). Most of the springs on the slopes of Mount Cameroon originate from perched aquifers found on altitudes ranging from sea level to about 2000 m on the slopes of the mountain. Their water table is higher than that of the regional aquifer, thus giving a perched attribute. Perched aquifers occur where the downward percolation of infiltrating water is

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stopped by a relatively impermeable rock. Such a rock in the Mount Cameroon is constituted of thick layers of basalt and clays.

Table 1: The spatial location of water bottling companies on the slopes of Mount Cameroon

Water bottling companies	*Location*
Bakingili sachet water	Bakingili
SEME Mineral Water	Bakingili
Royal Pure Water	Limbe
VOLCAN	Ombe
HESCO	Mutengene
SUPERMONT	Mile 29

Springs on the eastern and southern slopes of Mount Cameroon provided for the water needs of close to 257,000 inhabitants in the region. The 2014 United Nations World Water Development Report has observed that many people in the world still lack access to basic judging from the fact that in 2013, a report by the WHO and UNICEF stated that 768 million people remain without access to an improved source of water. It is therefore important that where water resources are existing, they should be frugally exploited and managed. This fresh water resource is managed poorly as the springs, groundwater and aquifers are considered separately for exploitation by local and company stakeholders without due recognition of their interdependence. This activity is jeopardized by the exploitation intensity that does not guarantee sustainability. The situation is worsened further by periodic water stress in the dry season, due to shrinking supplies from springs and the rationing of pipe borne water by the former National Water Corporation (SNEC) and local community water management committees in the region. This puts a large and dense population in a delicate imbalance situation of fresh water availability and usage. Since springs appear to be the most abundant and natural water sources in the region, this study posits that their judicious exploitation can be a panacea to this dilemma.

The aim of this work is to carry a spatial distribution of the source points of springs on the slopes of Mount Cameroon and to establish the think they have with the mountain geomorphology. About 9.2% of the 118 villages in the Mount Cameroon region do not have any water supply, while pipe borne water is only available in 57% of the villages but with very low standards (Page 2000). Such mastery would permit the sustainable use of the fresh water from mountain springs by the mountain population. Ako et al. (2012) hold that **g**roundwater is the only reliable water resource for drinking, domestic, and agricultural purposes for the people living in the Mount Cameroon area even though nitrate contamination of groundwater in two areas of the Cameroon Volcanic Line (the Banana Plain and the Mount Cameroon area) have been observed (Ako et al. 2013). The authors posit that the average groundwater nitrate concentrations for the studied areas are: 17.28 mg/l for the Banana Plain and 2.90 mg/l for the Mount Cameroon area.

Mount Cameroon forms part of the Cameroon Volcanic Line (CVL). Deruelle et al. (1987), Ghogomu 2001) and Suh et al. (2003) observe that this line is a 1600 km- long chain of volcanic centers with a northeast-southwest orientation; depicting an alignment of oceanic horsts and continental volcanic massifs and grabens trending from Palagu Island in the Atlantic ocean to Lake Chad. The oceanic horsts include the islands of Palagu, Sao Tome, Principe and Bioko while the continental ones are Mounts Cameroon, Rumpi, Manengouba, Bamboutos, Mbam Massif, Oku and the Adamawa Plateau. The mountain is found in the South West Region of Cameroon (Fig. 1). This means that the springs develop along the mainline tectonic fractures of the CVL.

The study area extends from latitudes 30º 50' and 40 º 18' N and longitudes 80º 55' and 90º 25' E, between River Onge in the west to River Yoke in the north east and progresses southwestward to the Atlantic Ocean. It covers the Sub- Divisions of Buea, Limbe, Tiko, Muyuka and the District of Idenau.

MATERIAL AND METHODOLOGY

Field survey was carried out for reconnaisance of general water resources and springs in particular. Some 48 samples were randomly made from Idenau in the west coast to Owe in the north east was done in two phases: 24 samples were collected in the rainy season (October 14th and 15th 2005) and 24 in the dry period/season (March 14th and 15th 2006). Altitude and location of the sample sites were identified with the use of a GPS-Cobbra 500 and values were later transferred to the G.I.S using Garmin 12XL.

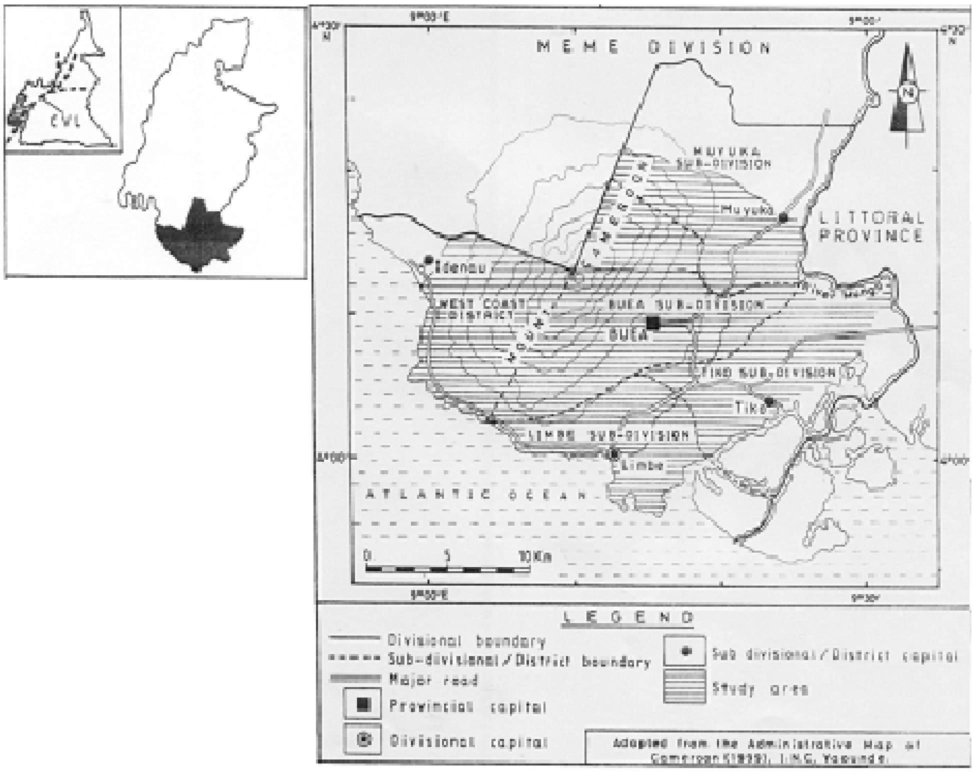

Fig. 1. The location of Mount Cameroon

RESULTS AND DISCUSSION

1. A Rich Ground Water Potential

The geology of the region is dominated by recent volcanic materials divided into units: Recent lava flows, Terraced pyroclastic materials and basalts, Lahars, Etindites, Interbedded basalts and sedimentary rocks and Tertiary-Quaternary sediments (Fig. 2). These quickly weather down to form clay which constitutes an impermeable infiltrating barrier to ground water that forms springs.

Massive basaltic lava flows exist at the upper slopes of the mountain. Lahar is mostly found in the north eastern flanks of the mountain. It dominates the entire Muea-Mamu region and parts of Saxenholf, Tole and the coast of Batoke. It extends to the Tertiary and Quaternary sandstones and shales of the Douala basin. This explains the widespread occurrence of springs along these geological margins.

The volcanic geology enhances a diversity of spring aquifers. Different types of perched aquifers are widespread in the area. Those that originate from lahars and those which originate from terraced pyroclastic materials and basalts. Many springs take their rise from these lahars because they contain a high amount of clay.

Impermeable layers of basalt sometimes underlie terraced pyroclastic materials. Water percolates through the scoracious materials to the perched water table. Dolgoff (1996) states that volcanic scoria superficially resemble a sponge with large air spaces. The air spaces created by the escape of gases facilitate a rapid percolation of water for recharge to occur. Recharge occurs from precipitation, downward flow from other springs and streams at higher altitude and from groundwater.

Most of the mineral elements in the springs are ensuing from the rocks. For instance some cones contain volcanic tuffs with a reddish brown colour due to the presence of ferromag-

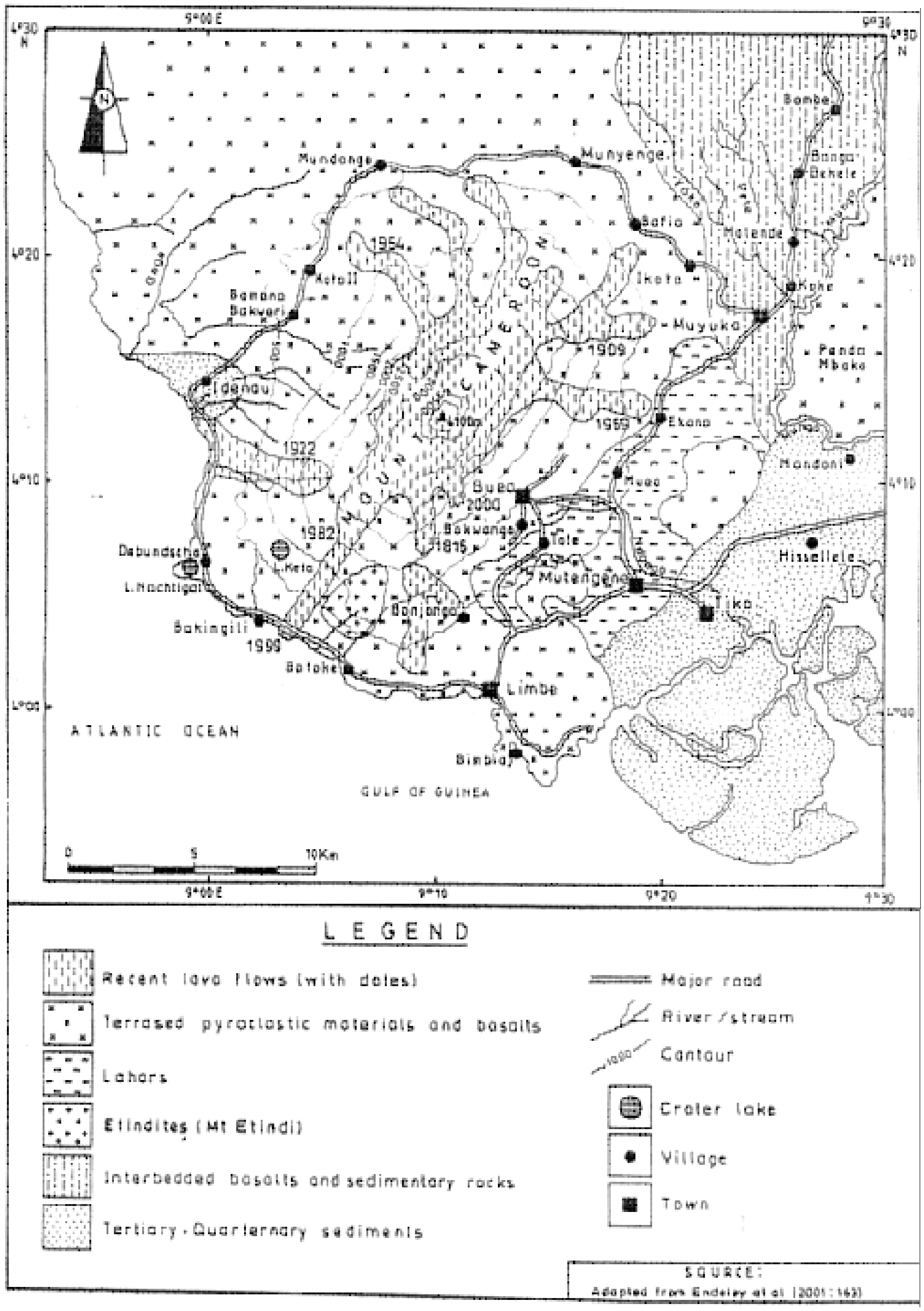

Fig. 2. The dominantly volcanic geology of Mount Cameron

nesian minerals. Large amounts are found in Etome village (260 m) and Batoke village in the Etinde region. Basaltic rocks are porphyritic, with a dark grey colour due to the presence of phenocryst of augite and olivine. These are the first minerals to crystallize as lava starts cooling on the surface with decreasing temperature (Wotany 1997).

While most of the lavas contain olivine and clinopyroxine (Suh et al. 2003). The rocks in Mount Etinde are made up of feldspathoids (nepheline, leucite and haugne) and pyroxene (Wotany 1997).

There is therefore a multitude of springs whose spatial distribution shows a spring line (Fig. 3). The characteristics that are numbered are provided (Table 3). Some springs possess karst characteristics. Changing water amount in mountainous environments will have numerous economic impacts on tourism, energy, agriculture, mining, natural hazards and the insurance sector as climate change is creating an impact on them (Beniston 2013). From their source, they flow over a short distance and disappear through a sinkhole and re-appear down slope as resurgent springs (Table 2). The two crater lakes identified are Lakes Nachtigal (33 m altitude) and Keta (1637 m altitude). The entire mountain slopes are made up of ravines or deep valleys which appear as dry valleys whose base are covered with scoracious material, colluvium, organic matter and solid wastes transported from the slopes by denudational forces. Increasing number of these valleys indicates decrease in groundwater.

Furthermore, some springs (intermittent springs) do not flow during the dry season when their valleys remain dry. Runoff occasionally flows through them following periods of intensive precipitation.

The soils on Mount Cameroon are divided into young volcanic soils, old volcanic soils and sedimentary soils. Young volcanic soils are reddish in colour, developed on recent lava flows; old volcanic soils are dark brown; developed on old lava flows while sedimentary soils are yellowish brown sandy clay soils mostly developed on lowland areas and sedimentary landscapes. Young volcanic soils are found in part of Saxenholf, Tole, Molyko, Muea, and Ekona. In Molyko, the soil is moderately deep and loamy. It is slightly acidic with a pH range of 5.5 to 6.5 (Hof et al. 1985).

Musaka soils are similar to Ekona soils with their stony sub-soil. They are moderately deep,

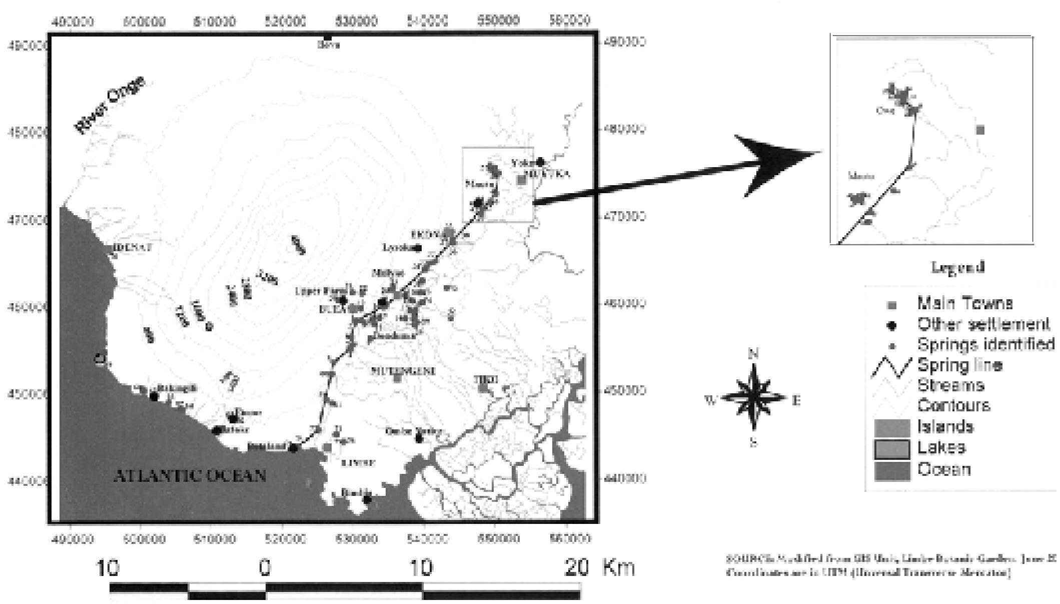

Fig. 3. Map of the springs and sprint line elements of Mount Cameroon

Table 3: Springs on the eastern and southern slopes of Mount Cameroon

No.	*Name of spring*	*Latitude (⁰)*	*Longitude(⁰)*	*Altitude (m)*
1	More spring. Small Soppo	4.14114	9.24152	778
2	Tole water	4.13921	9.24079	842
3	Tole New Camp spring	4.12333	9.25639	674
4	Sasse spring	4.11229	9.23585	651
5	Mile 9 Water-Sasse	4.09884	9.21875	617
6	Saxenholf Spring	4.14923	9.30068	544
7	Mevio	4.11694	9.23878	520
8	Balikabo spring	4.12450	9.23683	711
9	Mavanje-Small Soppo	4.14114	9.24777	771
10	Namunge small Soppo	4.13852	9.25966	714
11	Wange Spring- Soppo Likoko	4.14124	9.25996	711
12	Musole Spring	4.15363	9.24656	812
13	Ndongo water- Bulu	4.14368	9.30005	508
14	Ndongo water – Bulu	4.14387	9.30000	515
15	Mile 17 Hill	4.15174	9.29659	529
16	Woman Ndongo-Bonduma	4.15490	9.26961	670
17	Man Ndongo - Bonduma	4.15630	9.27150	663
18	Meanja Spring Gt. Soppo	4.27428	9.38979	711
19	Sand Pit spring	4.14417	9.26576	677
20	Upper Farms spring	4.16242	9.22339	1164
21	Liangamene-Bonalyonga –Wondongo	4.17021	9.23799	1051
22	Jonje spring- Meteh village	4.16888	9.24815	982
23	Bweteva spring	4.17515	9.28001	680
24	Koke spring	4.17295	9.27775	656
25	Molyko CDC Estate	4.16710	9.29184	582
26	Ekande Spring -Mile 16	4.13613	9.30177	501
27	Mile 16 water	4.13962	9.30386	503
28	Mile 18 spring	4.16165	9.29902	540
29	Down Njonji spring- Boniamavio	4.17006	9.30836	525
30	Up Njonji spring- Boniamavio	4.16973	9.30726	529
31	Three pomp Muea	4.18196	9.30895	519
32	Down water- Mamu village	4.20169	9.32213	458
33	Up tank water- Mamu village	4.19960	9.31684	442
34	Robinson spring- Moli village	4.19394	9.31249	485
35	Last Town spring- Ekona village	4.23173	9.33949	404
36	Pindi spring 1 Ekona Yard	4.22070	9.34060	368
37	Pindi spring 2 " "	4.22175	9.33962	384
38	Pindi spring 3 " "	4.22474	9.34029	366
39	Super Mont spring	4.25087	9.36932	157
40	Papa James spring Mautu	4.25897	9.36548	145
41	Secet water- Mautu	4.25884	9.36657	112
42	Up Tank spring –Mautu	4.25941	9.36397	153
43	Upper Papa James spring – Mautu	4.25850	9.36457	174
44	Kingdom spring- Mautu	4.26062	9.36748	124
45	Mile 29 spring	4.25466	9.37009	111
46	Masue spring- Meanja	4.26217	9.37874	91
47	Black bush water- Meanja	4.27099	9.38443	68
48	Api spring-Owe 1	4.29146	9.38689	68
49	Pa Adamu spring 1 - Owe1	4.29051	9.38496	90
50	Pa Adamu spring 2 - Owe1	4.29087	9.38527	83
51	Mondongo spring - Owe 1	4.29449	9.38239	68
52	Drinking spring - Owe 2	4.29469	9.38224	70
53	Mbo spring 1	4.29623	9.38252	73
54	Mbo spring 2 - Owe 2	4.29758	9.38308	71
55	Abakwa spring 1 - Owe 2	4.29686	9.38189	69
56	Abakwa spring II - Owe 2	4.29647	9.38003	70
57	Sapele spring – Owe 2	4.29839	9.37771	83
58	Catholic school spring - Owe 3	4.29935	9.37812	94
59	Limbe River- Bosumbu	4.06149	9.21139	781
60	Ewongo spring – Wotutu	4.08681	9.21675	426
61	Farm water- Samco quarter	4.05756	9.21717	301

Table 3: Contd...

No.	*Name of spring*	*Latitude (^{0})*	*Longitude(^{0})*	*Altitude (m)*
62	Matute spring – Etome	4.04187	9.11959	253
63	Ndive spring – Etome	4.04241	9.11476	270
64	Lyonga spring – mile 11	4.05107	9.06617	9
65	Cold water – Bakingili	4.05172	9.06297	4
66	Cold water Spring- Seme	4.05892	9.05146	5
67	Cold water spring - Wete-wete	4.07036	9.02530	9
68	Drinking water - Wete-wete	4.07159	9.02483	11
69	Debundscha Beach spring	4.10926	8.98544	6
70	Ndiba Road spring – Idenau	4.21373	8.99007	11
71	Jengele spring- upper Towe	4.02585	9.22127	124
72	Musaka Native spring	4.10451	9.18104	545
73	Mr. Peter spring – Bomaka	4.09117	9.18696	534
74	Boma spring – Bomaka	4.09604	9.18696	519
75	Botaland spring	4.01102	9.17201	33
76	Wovea spring	4.01049	9.16144	37
77	Pa Akoh water 1- Mabeta New Layout	4.00859	9.13961	67
78	Pa Akoh water 2	4.00862	9.13874	113

Source: Fieldwork (2006)

fairly stony in places; with dense heavy clay sub-soils formed in Quaternary basaltic pyroclastic materials (Hof el al. 1985) with a high amount of Mg^{2+}, Ca^{2+} and a lower amount of phosphorus. Muyuka area consists of deep well-drained moderately permeable sandy loam soils. At depths greater than 1m the substratum is of volcanic sedimentary origin. In Tole, top soils are acidic under tea cultivation. pH ranges from 4.1 – 4.6. Conversely, the Saxenhof soils are clayey soils found on old clayey mudflows or colluvial materials derived from redeposited pyroclastic products. pH value ranges from 5.3 to 5.8 in the first 35 cm as noted by the CDC. These soils are highly exploited for agriculture because of their richness in nutrients. It is the abundance and diversity of these resources that attract people into the region, which increases the human pressure on the springs.

2. Spring Line

It is observed that most of the springs in the study area take their rise from the southern and northeastern slopes of the mountain. This has resulted into a spring line running from the south to the north east. It is around this line that intensive human activities occur. The line cuts across regions of lahars deposits and pyroclastics. These Lahars have a high amount of clay, thereby constituting good aquifers.

High amounts of rainfall are experienced throughout the year despite the marked spatial variation from the west and southwest to the northeast. This rainfall sustains the springs for the most part of the year and particularly in the rainy season. On the west coast, Idenau receives an annual average of 8 392 mm while Debundscha receives 9 086 mm (Frasèr et al. 1997), giving it an equatorial type of climate. Conversely, rainfall amounts rapidly decrease north eastward (Fig. 4).

Conversely, Mpundu receives only an annual average of 2 080 mm of rainfall and thus a tropical type of climate prevails, marked by two seasons being the wet season and a dry season. Nonetheless, this still permits springs to develop along the spring line.

Climographs of selected stations depict a unimodal rainfall distribution indicating a marked decrease from December to March. Ngakfumbe (2001) remarked that this seasonal variation possibly resulted from the mesoscale factors of the Inter Tropical Discontinuity (I.T.D.), more especially the fluctuations in the depth of the humid, seasonal air mass of the south west monsoon that is not always sufficiently thick enough to spark off instability to produce rain between December and February. For this reason, some of the springs become intermittent and so pass for dry valleys at this time.

3. An Intense Human Activity That is Fresh Water Consuming

The human environment poses over riding effect on the fresh water resources in the region

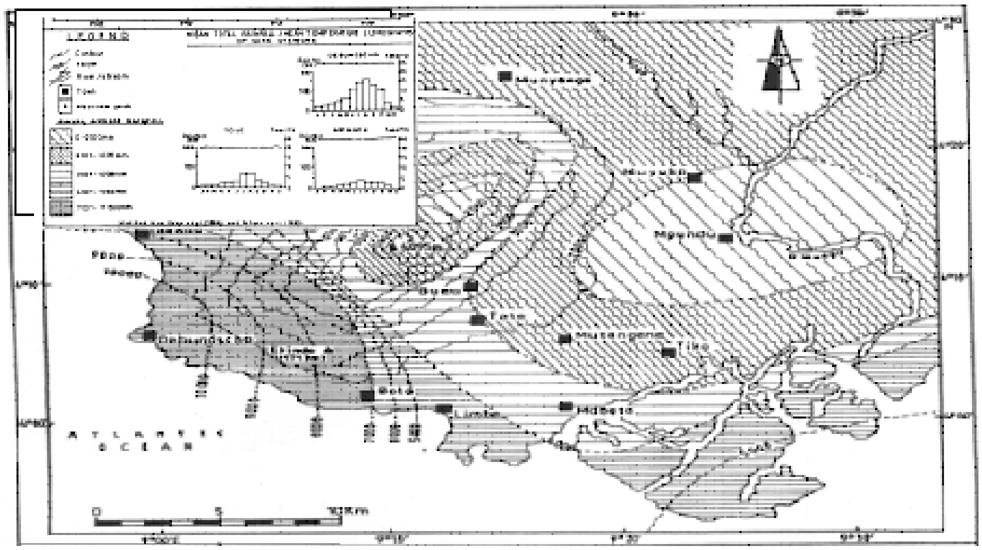

Fig. 4. Map of rainfall distribution on the Mount Cameroon region

through population increase and land use changes. Mountains of volcanic origin constitute attractive areas for settlement. On this consideration, we can agree with the view that the prediction of future water availability accurately and reliably is a key step for successful water resource management (Shrestha 2014). With a surface area of 2093 km^2, Fako Division is the most densely populated division in the South West Region. Population of the main towns in the Division is increasing rapidly (Table 4).

Density has increased from 118.5 inhabitants per km^2 in 1987 to 170.83 inhabitants per km^2 in 2000. In most of the constituting villages, there had also been an increased dependence on springs for domestic uses. In the South West Region of Cameroon, persistent low yields of *Colocasia esculenta* crop cultivated in the inland wetlands on the north eastern and southern slopes of Mount Cameroon have brought untold suffering to over 60% of the inhabitants by pushing them to greater levels of poverty (Orock 2014). Thus spring water exploitation could be seen as a new panacea to redress poverty in the region if sustainable measures are applied. But the sustainable management of water resources faces the difficult task of coordination, multiple, often competing uses of the resource in a way that balances environmental concerns and socio-economic demands and there exist few models that assess the tradeoffs between environmental and socio-economic impacts of water management in an integrated framework (Kragt 2013).

Table 4: Changes in population of principal towns from 1976-2002

Town	*1976*	*1987*	*Projection*	
			2000[1]	*2002*[2]
Buea	24 600	32 800	46 100	48 727
Limbe	27 000	44 600	80 700	85 299
Tiko	-	39 300	55 000	58 134
Muyuka	-	13 000	18 700	19 766

Sources: 1- Cameroon Statistical Year Book 2002. Department of Statistics and National Accounts (DSNA).
2: Fieldwork (March 2006).

CONCLUSION

This attempt to locate and map out springs on the Western and South eastern slopes of Mount Cameroon show that most of them are aligned from the southern flank to the north eastern flank; forming a spring line. This explains why spring water big extractive industries have emerged in this region like "VOLCANICS, SEME, HESCO, ETINDE, and SUPERMONT that bottle the spring water in plastic bottles ranging from 0.5 to 10 litres. There are also multitudes of small scale industrial water production from these springs in plastic papers under different labels. A gamut of springs takes their rise from this line. Yet it is in this region that intense human activities occur at different dimensions. This paper is thus a finger pointer to the government authorities of the urgent need to protect this spring line from the eminent abusive use and the resulting threats to the fresh water resources in particular and human ecology in general.

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