GEOTHERMAL DEVELOPMENT IN CAMEROON

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Received: January 20, 2020
Revised: February 23, 2020
Accepted: May 28, 2020

ABSTRACT

Africa is currently experiencing a period of economic growth. Its population is growing rapidly and its economies grow and diversify. To be sustainable, such growth requires a large investment in the energy sector. In the case of Cameroon hydroelectric energy is the main source of electrical power whereas the analysis of the geological point of view shows that Cameroon is unique in west-northern of Africa for its active volcanic line (with the last eruption of Mount Cameroon that last erupted in 1999 and 2000) that is a favorable zone for the production of power from geothermal resources. The Cameroon Volcanic Line (CVL) is 100 km wide linear magmatic megastructure oriented N30°E that extends more than 1500 km from Pagalu Island in the Gulf of Guinea to Lake Chad. Along this active volcanic line, more than one hundred and thirty thermal springs are found with the hottest spring at Woulndé (74°C).
The aim of this paper is to evaluate the importance of geothermal energy development in the Cameroon Volcanic Line through a geological investigation of areas (Mt. Cameroon and Adamawa) bearing springs with hottest temperatures. This work is a compilation of the bibliographic analysis find at the same topic of research with a source like an International reviewed article, local documents and a websites research. The absence of commitment and enthusiasm from the government is weakening the sector potentiality to be developed either by private sector investments and also foreign investors. Other applications of geothermal energy in Cameroon are also discussed.

Keywords: geology; thermal springs; geothermal energy; Cameroon volcanic line

INTRODUCTION

Global warming and continuous energy demand in the world market coupled with the rise in energy price have significantly drawn attention to the need of renewable energy (RE) resources. Africa as a continent is blessed with abundant energy sources, but imbalance between electricity production and generation still remains an issue in Sub-Saharan Africa (SSA) countries (UN-DESA, 2004). Based on the International Energy Agency (IEA) information, the Sub-Saharan Africa has mass population without access to adequate electricity (Alnaser and Alnaser, 2011). To be sustainable, such growth requires a large investment in the energy sector, particularly in Cameroon where distribution of electricity is mostly depended on hydroelectric power stations which is not evenly distributed; with only 20% of the population having access to the national grid. Those who utilize the electricity are those in the major cities while those at rural areas are not well connected. Cameroon is facing challenges regarding the electricity sector, whereby the demand for electricity exceeds the supply.

Cameroon is a country of Africa continent which lies within the Gulf of Guinea and bordered by six countries Nigeria, Chad, Central African Republic, Republic of Congo, Gabon and the Equatorial Guinea. With the land size of 475,000 Km^2 and 25,640,965 habitants (CDP, 2018), Cameroon is the most populated country in the Economic Community of Central African States (CEMAC).

As of 2015, Cameroon electricity generation capacity is at 817MW (Mas'ud et al., 2015) which hydroelectricity contributed to 88% and the remaining is from thermal power generation. The demand for electricity in Cameroon is estimated to reach 1455MW in 2014 and almost 5000 MW in 2020. The Cameroon government planned to install 2500MW of hydroelectric power between 2012 and 2020 and 298MW (Ayompe and Duffy, 2014) from thermal power plant by the year 2013, but this has not been fully implemented to date. Cameroon
From the geological point of view, Cameroon is particularly unique in west-northern Africa for its active volcanic line (Gaudru and Tchouankoue, 2002). the presence of a volcanic activity of Mount Cameroon with the last eruptions in 1999 and 2000) and the hundreds of hot springs with temperatures culminating in the Woulndé spring (74°C) as indicated by the Le Maréchal (1976) show that Cameroon is a favorable zone of

production of geothermal energy. Unfortunately, no feasibility studies have been carried out to identify their full potential.

The aim of this paper is to evaluate the importance of geothermal energy development in the Cameroon Volcanic Line through a geological investigation of areas (Mt. Cameroon and Adamawa) bearing springs with hottest temperatures. This paper will also evaluate the present and future renewable energy (RE) installations for Cameroon and give some recommendations based on the strength and weaknesses of the RE schemes. Finally, conclusion would be made on the ways to accelerate the geothermal energy policies.

GEOLOGICAL SETTING

The Cameroon Volcanic Line (CVL) is a 1600 km Y-shape chain of Tertiary to recent volcanoes (Fitton and Dunlop, 1985) that trends from the Annobon Island in the Gulf of Guinea into the African plate (Fig. 1). The CVL is oriented N30°E and segmented by several N70°E shear zones of Pan-African age (Deruelle et al., 2007), particularly evident on the continental sector. The oceanic sector consists of two seamounts in the Gulf of Guinea and four islands (Annobon, São Tomé, Principé and Bioko) (Lee et al., 1994). On the other hand, the continental sector consists of anorogenic plutonic complexes and volcanic constructs of varying sizes and shapes (Deruelle et al., 2007). The central volcanoes in the continental sector of the CVL include Mounts Etindé, Cameroon, Manengouba, Bambouto, and Oku, as well as two main plateaus; the Ngaoundéré and Biu (Fitton,1987; Halliday et al., 1988; Marzoli et al., 1999; Marzoli et al., 2000; Ngounouno et al., 2000; Nono et al., 2004; Rankenburg et al., 2005). North of the Oku massif (OVG) the volcanic line bifurcates into a Y-shape; Mt. Mandara-Biu Plateau branch in the north-west and Ngaoundéré Plateau branch in the north-east (Fitton et al., 1983). Of these volcanoes, Bioko, Mt. Etindé, and Mt. Cameroon volcanic centers are located close to the seismically-defined “ocean-continent boundary” (OCB) zone (Emery and Uchupi, 1984)

Mt. Etindé is a small densely forested and highly dissected volcano located on the SW flank of Mt. Cameroon. It rises to a height of 1713ma.s. l and is made up almost entirely of nephelinitic lavas rich in euhedral (3-7 mm) highly zoned clinopyroxenephenocrysts (Nkoumbou et al., 1995).

Mt. Cameroon is the highest (4095ma.s. l) volcano in West Africa occupying a surface area of about 1300 km^2. This volcano is the only presently active member of the CVL with seven eruptions recorded in the last 100 years, i.e., 1909, 1922, 1954, 1959, 1982, 1999, and2000 (Geze, 1943; Fitton et al., 1983; Suh et al., 2003). It is a composite volcano made of alkaline basanitic and basaltic flows interbedded with small amounts of pyroclastic materials and numerous cinder cones (Suh et al., 2003, 2008; Yokoyama et al., 2007).

Mounts Bambouto (2700 m a.s.l.) and Oku (3011 m a.s.l) are Oligocene to Quaternary strato volcanoes with lava successions comprising a strongly bimodal basalt-trachyte-rhyolite suite (Marzoli et al., 2000; Njilah et al., 2004, 2007; Kamgang et al., 2010,2013; Tchouankoue et al., 2012). Mt. Manengouba (2411 m a.s.l) is a well preserved central volcano whose summit hosts two concentric calderas (Elengoum and Eboga). Lavas range from basalts to trachytes, quartz trachytes, and rare rhyolites (Fitton, 1987; Kagou et al., 2010).

The Ngaounderé Plateau, in the north-eastern part of the CVL, consists of alkaline basalts and basanites capped by trachytesandphonolitic flows. The most recent volcanism in this area consists of cinder cones aligned in a WNW-ESE direction, sometimes producing small lava flows (Fitton, 1987; Nono et al., 2004). The Biu Plateau, which is located in the northern part of the Ngaounderé Plateau, consists of basaltic flows with a maximum thickness of 250 m. This plateau is composed of basanite to transitional basalts (Rankenburg et al., 2005).

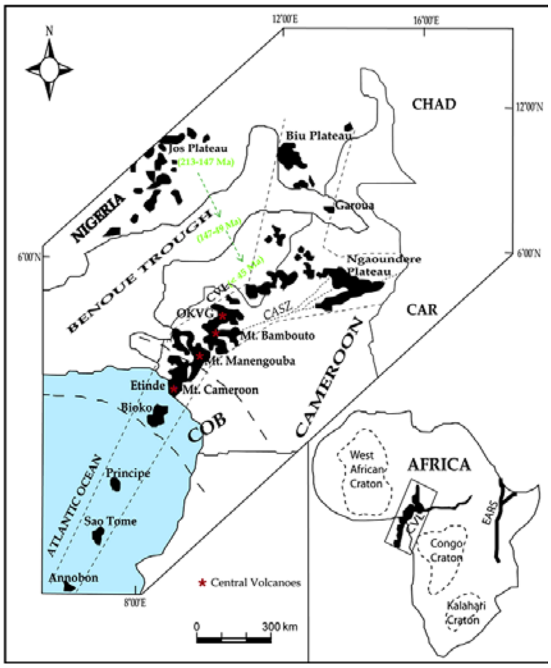

Figure 1. Location of the Cameroon Volcanic Line. COB =Continent Ocean Boundary, CAR =Central African Republic, CASZ= Central African Shear Zone, EARS=East African Rift System (Modified from Marzoli et al., 2000; Rankenburg et al., 2005; Ngako et al., 2006; Nkouathio et al., 2008).

In Cameroon, a spring is characterized as thermal when its temperature is above the mean temperature of 23°C (Le Maréchal, 1976). One hundred and thirty thermal springs were recorded by Le Maréchal (1976). They are concentrated in the corridor of the CVL (Fig.2). However, the current data available includes a detailed investigation of only 40% of the Cameroonian territory. Springs with highest temperatures were recorded at Woulndé (74°C) which is located in the Centre region of Cameroon, at the intersection between the CVL and the Adamawa shear zone, a transcontinental lineament that extends from Cameroon to the Red Sea. Just behind the Woulndé spring is the Lobe spring with a temperature of 49°C, located at the foot of Mount Cameroon that last erupted in 1999 and 2000.

The largest number of springs is located in the region of Adamawa (see table of annex). The location of these hot springs is distributed along the CVL as follows:

Areas of recent volcanism: Laopanga and Katil near Ngaoundere, Dimple near Foumban, Nilli near Mount Oku, Nsoung, Ngol, Ndibisi, Ahio, Ebuku, Bare and Melong in and around the massive Manengouba; Lobe near Mount Cameroon.

Large valleys: Woulndé, Mayo Lidi, Mberduga, Déodéo, Mamdugu, Donkere, Ntem, Bajao, Sep SepDjarandi, Koulania, Ayukaba, Ebinsi, Kan.

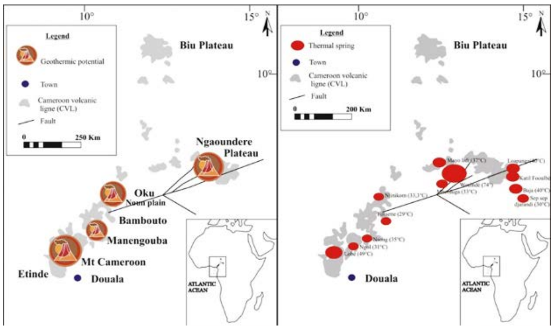

Figure 2. Localization of some major thermal springs of the Cameroon Volcanic Line (Tetchou and Tchouankoue, 2014).

METHODOLOGY

Like a methodology, this work is a compilation of the bibliographic analysis find at the same topic of research with a source like an International reviewed article, local documents and a websites research.

RESULTS AND DISCUSSION

Status of Geothermal Development in Cameroon

In Cameroon, the fundamental energy sources are coal, oil, hydropower, biofuel and waste (Kenfack and al., 2011). Among these energy sources, hydro power is the dominant electricity source with little attention paid to the other renewables like solar, wind, geothermal. Cameroon possess the highest hydroelectric power stations after The Democratic Republic of Congo (Tchouaha, 2012). The development of energy sector remains one of the major attractions for foreign investors and strengthening growth. The World Bank Investment Climate (WBGIC, 2014) has indicated that limited access to reliable electricity is among the major hindrance in conducting business in Cameroon and this is seriously damaging Cameroon growth domestic product growth (GDP) closer to 2% (Kenfack et al. 2011).

Status of Electricity Production in Cameroon

Energy remains an important aspect of any nation and Cameroon is not in rest from this. With the help of the United Nations development program and the World Bank, the government of Cameroon has adopted the National Energy Plan for Reducing Poverty (PANERP), the implementation of such projects aims to increase the access rate of energy in both the urban and rural areas (MEWRC, 2010). The major energy potentials in Cameroon are as follows:

Solar Energy

There is good solar potential in Cameroon but it is not well developed. The major cause of the poor state of solar energy development is the poor commitment and dedication of government in taking important steps to boost the sector. It is not widely used across Cameroon with only 50 PV installations currently exist. In most part of the country, the mean solar irradiance is approximately 5.8 kWh/m^2/day (LAUS, 2012). Solar power is mostly used for powering the cellular telecommunications network and street lights in many parts of the country (see fig. 3).

Wind Energy

In Cameroon wind energy speed ranges from 2 to 4m/s at 100 m height (LAUS, 2012). The only favorable site for wind energy in Cameroon are in the North and some coastal areas. There are some wind turbines installed in Douala especially in hotels and there are some potential zones for wind energy in Ngaoundéré and Moudou lake area, but this has never been investigated. Recently wind electric pumping system has been installed at NdohDjutissa (see Fig. 4). The Cameroon meteological services reported that wind speed is not sufficient for the development of wind turbines in some areas but this have not been fully investigated (Abdullahi et al., 2015).

Hydropower

Hydropower remains the main source of power generation in Cameroon. There as on for hydropower being the main source of energy for the countries is due to large river sand water falls. Some of the advantages of hydropower generation include easier environmental impact assessment, minimal construction works and possibility of fishing and irrigation. It is also easier to invest in hydropower technology than in other some other RE; because the other technologies have high initial capital cost of implementation and may supply only limited energy. Hydropower potential for Cameroon is currently estimated at 23 GW with production potential of 103 TWh per year (Reegle, 2014), but it remains unutilized. The major hydropower stations in Cameroon are namely Sogloulou(388 MW), Edea(263 MW) and Lagdo(72 MW) (FUAS, undated). There are also smaller hydropower potentials across Cameroon that had not been exploited. There is need for the government to take a leading role in making sure that those potential power stations are developed, in order to serve energy to both the rural and the urban dwellers of Cameroon.

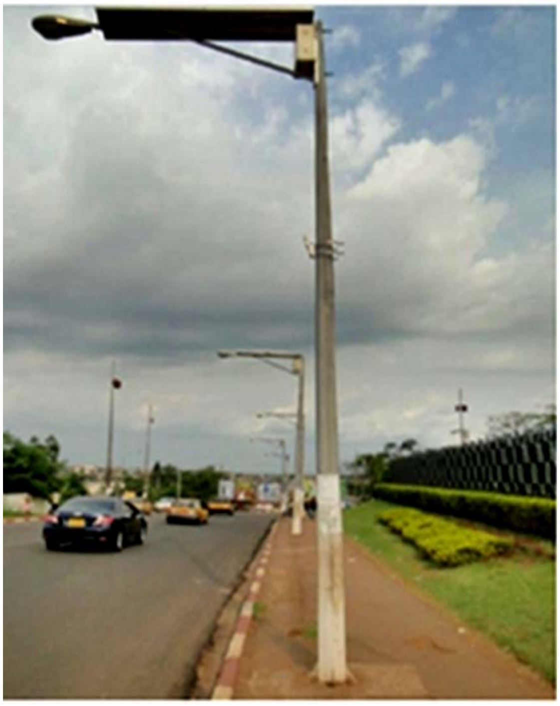

Figure 3. Solar PV utilization, solar powering streets in Yaoundé-Cameroon (Wirba et al., 2015).

Biomass Energy

Several types of biomass exist such as fiber biomass, organic fertilizer biomass, chemical biomass etc. The by-product of biomass if not properly handled, can have serious effect on social and environmental public health. Cameroon has third largest biomass potential in sub-Saharan Africa, with 25 million hectares of forest covering three-quarters of its territory (REEP, 2013). Biomass sources are categorized into agricultural, wood, animal sources, waste stream from timber and forest. Back in 2006, 66 sites with transformation capabilities of 2.7 million m^3 were recognized (GTZ, 2009). Presently, biomass is used virtually in all sectors of the economy in Cameroon i.e. industrial and residential. Biomass provides around75% and up to 90% of the energy requirement in residential and in the industry sectors respectively (GTZ, 2009). There is also huge utilization of palm oil for production of biodiesel mainly used for agricultural purposes. Furthermore, Abanda (2012) argues that firewood in remote area is being depleted without being replenished and that had led to many challenges of energy affordability and environmental impact. Therefore, other RE sources would have enormous environmental and energy potential.

Figure 4. Wind electric pumping system at NdohDjutissa in Cameroon (Nfah and Ngundam, 2012).

Geothermal Energy

Cameroon has potentials for geothermal energy which has not been tapped. There are hot water regions but no feasibility studies have been carried out to identify their full potential. According to the Cameroon report (LAUS, 2012), areas of interest identified include Ngaoundere region, Mt Cameroon region and Manengoumba area. This case will be well demonstrated by the geological study.

Direct Use of Geothermal Energy in Cameroon

One of the most versatile and common

utilizing form of energy is direct use of geothermal energy (Dickson and Fanelli, 2003). The early history for direct use of geothermal energy has been reviewed over 25 countries in the stories from a Heated Earth. The major direct application of geothermal energy includes: space heating and cooling, agriculture application, application to aquaculture, industrial processes, swimming, bathing and balneology, snow melting and heat pumps etc. In the case of Cameroon, the only direct use of geothermal energy at woulndé is for cooking. Here we have some women who came to boil eggs and bean when they are watching clothes.

INVESTMENT OPPORTUNITIES

Potential Investors

Cameroon has many opportunities for economic investment in the agricultural, mining, forestry, and oil and gas sectors. It boasts the largest and most diverse economy of the six countries in the Central African Monetary and Economic Union (CEMAC) sub-region, which is home to over 50 million people. The zone has a central bank and a common currency the CFA franc. Despite slow but steady economic growth hovering around 4 to 5% over the last half decade, the Government of the Republic of Cameroon (GRC) has started to publicly recognize that it must improve its investment climate. The GRC hopes that growth rates will surge with increased incentives to private sector businesses, but it has yet to demonstrate that it is committed to real investment climate reform. The Government's Vision 2035, a road map to become an emerging economy by 2035, stresses the importance of large-scale infrastructure development and foreign direct investment. Cameroon seeks investment in virtually every sector. Infrastructure development will continue to attract the biggest share of investment. In addition to roads, Cameroon has numerous projects for increasing power generation through power plants and hydroelectric dams; expanding rail, water, and electricity distribution; and other critical sectors such as health, housing, and agriculture. The largest projects underway include the Kribi Industrial Port Complex and the Lom Pangar Hydroelectric Project.

Investment Incentives

The April 2013 Investment Incentive Law lays down private investment incentives in the Republic of Cameroon. Some potential incentives to encourage investment and use of local content include exemptions from certain taxes, duties, and other non-tax related benefits such as assistance in obtaining the issuance of visas, work permits, environmental compliance certificates, land titles, and long-term leases if certain conditions are met. These incentives are applicable to Cameroonian or foreign nationals or corporations, but not to investments in sectors governed by special instruments, in particular the upstream oil, mining, and gas sectors. Someseries of investmentincentitives are :

- Value added Tax (VAT) covered by the public entity ((19, 25 %)
- Free registration of all contracts and agreements
- Coverage of all tax and custom duties by the public entity
- Exemption of inspection before embarkation of imported and material
- Five points discounts on the corporate tax for the five years of operation
- 25% bonus on the depreciation rate compare to the normal rate, starting the operation

CONCLUSIONS

This paper presented the latest evaluation of the RE progress in Cameroon and it's establish that it huge RE potential that have not been developed. The electricity demand is higher than the supply and this is attributed to the rise in population. At the moment, Cameroon is only concentrating on hydropower development, despite the abundant of other RE sources to tap into. There are also solar panel installations for powering street lights in some part of the country.

Geological studies showed that in Cameroon, the presence of an active volcanic line emphasized by thermal springs and the frequent eruptions of Mount Cameroon favors the development of a geothermal industry that can provide clean and renewable energy. Cooking is the only direct use of the geothermal energy found at Woulndé (74°C).

From the analysis in this paper, there are several challenges facing Cameroon RE development. It is clear that RE can play a role in reducing the energy demand, especially in the rural areas, where only 10-14% of the populations have accessed to electricity. This paper is promoting the utilization of RE sources to minimize the gap between energy demand and supply. To do that government of Cameroon have to train local manpower in renewable and create entrepreneurship funding for locals who are interested in venturing into this sector. Nevertheless, Cameroon remains attractive to investors because of its strategic location and with its strategic placement; investments in Cameroon have a potential market of some 250 million consumers.

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Annex: Distribution of thermal springs in Cameroon (Le Marechal, 1976)

Region	District	Name	Coordinnates Long/Lat.	Temperatures (°c)
Adamawa	Ngaoundéré	Bajanga	14°00'35'' 7°17'10''	23.8
	Meiganga	Baja	18°06'10'' 7°08'55''	40.0
	Meiganga	Barkeje	14°45'40'' 7°00'50''	23.0
	Tignère	Bemlari	12°13'30'' 7°44'25''	25.0
	Tignère	Burlel 1	12°18'55'' 7°37'15''	27.0
	Tibati	Damfili	13°00'00'' 6°96'00''	25.6
	Tignère	Deodeo	12°02'10'' 7°28'25''	28.5
	Tignère	Donkere	12°13'35'' 7°46'25''	26.4
	Meiganga	DzirKoya	14°40'25'' 6°56'00''	28.0
	Tignère	Falkoumre	12°35'30'' 7°19'35''	23.0
	Meiganga	Gbengubu	14°26'30'' 6°46'30''	23.0
	Ngaoundéré	Gogarma	14°15'30'' 7°18'25''	25.6
	Tignère	Guisire	12°24'25'' 7°25'10''	25.4
	Ngaoundéré	KatilFoulbe	13°56'00'' 7°06'00''	40.0
	Meiganga	Koulama	14°25'11'' 6°45'50''	26.0
	Ngaoundéré	Laobalewa 1	13°42'25'' 7°11'00''	23.4
	Ngaoundéré	Laofuru	13°35'25'' 7°12'10''	24.4
	Ngaoundéré	Laopanga	13°41'00'' 7°11'10''	40.0
	Tignère	Lasum	12°17'35'' 7°44'10''	28.8
	Meiganga	Mala0	14°02'20'' 6°46'40''	25.4
	Ngaoundéré	Matari	13°28'10'' 7°16'30''	23.0
	Tignère	Mayo Baleo	12°16'00'' 7°41'25''	25.2
	Tignère	Mayo Lidi	12°06'55'' 7°23'05''	37.0
	Tignhe	Nalti	12°28'00'' 7°49'30''	24.5
	Banyo	Nialan	11°35'25'' 6°31'00''	23.4
	Tignhe	Patarlay	12°19'40'' 7°37'35''	25.0
	Meiganga	Sep SepDjarandi	14°58'40'' 7°05'00''	30.0

	Meiganga	Sep SepMaloko	13°27’50’’ 6°21’20’’	23.0
	Banyo	VoureMba	11’54’50” 6’59’30”	23.8
	Banyo	VoureYelel	11°55’45’’ 6°58’55’’	23.6
	Tignère	Woulnde	12°28’30’’ 7°26’10’’	74.0
	Meiganga	Yaisunu	14°48’20’’ 7°01’35’’	23.0
	Tignère	Burlel 2	12°01’25’’ 7°29’25’’	25.4
	Tignère	MalamJubairu	12°03’50’’ 7°28’15’’	23.3
	Tignère	Mamdugu	12°04’20’’ 7°29’25’’	26.0
	Tignère	Mberduga	12°09’20’’ 7°30’00’’	33.0
West	Manjo	Abang	9°45’50’’ 4°56’40’’	25.2
	Bangen,	Ahio-Ekanjo	9°41’30’’ 4°56’30’’	28.0
	Mamfé	Ayukaba	9°08’50’’ 5°41’55’’	28.6
	Bamenda	Bambui 2	10°15’25’’ 6°14’50’’	26.0
	Mélong	Bare 1	9°58’00’’ 5°00’35’’	25.8
	Mélong	Bare 2	9°57’20’’ 5°00’30’’	26.5
	Mélong	Ebuku	9°58’10’’ 5°02’50’’	26.4
	Bamenda	Fongakie	10°15’45’’ 6°03’25’’	23.4
	Foumbot	Fossette	10°38’40’’ 5°29’25’’	29.0
	Wum	FoundongMeteuf	10°14’20’’ 6°19’25’’	25.0
	Foumban	Kuchuantium	10°38’55’’ 10°50’10’’	23.8
	Foumban	Koutaba	5°36’45’’ 5°42’10’’	24.4
	Ekundu Titi	Lobe	9°05’25’’ 10°15’00’’	49.0
	Nkongsamba	Manengouba	9°53’10’’ 9°55’20’’	25.2
	Mélong	Mbuedum	4°51’20’’ 5°08’30’’	24.6
	Melong	Melong	9°59’05’’ 10°18’20’’	26.6
	Wum	Ndi	5°9’45’’ 6°26’30’’	25.2
	Bangen	Ndibisi	9°45’00’’ 9°46’10’’	28.5
	Manjo	Ngol	5°06’00’’ 4°51’45’’	31.0

	Njinikom	Nilli	10°16'30'' 9°49'55''	33.3
	Manjo	Nsoung	6°02'00'' 5°00'00''	35.0
	Nwa	Ntem	11°00'00'' 10°17'55''	27.0
	Wum	Nyos	6°20'00'' 6°27'15''	24.8
	Mamfé	Ebinsi	9°09'15'' 5°41'20''	28.0
	Mamfé	Mbakan	9°08'55'' 9°01'25''	25.0
	Mamfé	Akan-Mbe"	5°40'40'' 5°42'55''	27.6