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Identification of Water Reservoir Sites by Remote Sensing and Geographic Information System in Far-North Region of Cameroon

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ABSTRACT

The present work has for objective calling on remote sensing and Geographic Information System to identify favorable sites for the implantation of water retentions in the Far-North Region of Cameroon so as to answer to the problem of lack of water in this zone. To achieve this goal, satellite, geologic, hydric, topographic data, amongst others, have been used. The works took place in two phases; the first phase at the lab, where Shuttle Radar Topographic Mission images have been acquired and treated using the softwares QGIS, 3DEM and Global Mapper, to be able to study the drainage basins and the topography of the study zone and pre-selected potential sites. Secondly, field work has been carried out, taking in consideration the human, geologic, pedogenic, topographic parameters and the availability of geotechnical material amongst others, to select potential sites for the implantation of water retentions. This has enabled identify in the Far-North Region of Cameroon, forty-eight (48) sites, of which; six (6) are the most excellent, seven (7) good and thirty-five (35) fairly good. These sites are principally distributed in four divisions, which are; the Diamaré, Mayo-Tsanaga, Mayo-Sava and Mayo-Kani.

Key words: Water Retention, Satellite Data, Geographic Information System, Remote Sensing.

INTRODUCTION

Access to water in the Far-North Region of Cameroon, notably in the rural zones, constitute a real obstacle course. Water that is an essential resource to man fundamental needs is a primordial factor in economic development and amelioration of population living standard. In the Far-North Region, water is scares in the dry season, while it always almost provokes damages through inundations in the rainy season. Storing surplus water during rainy season for use during dry periods should be a solution to this double problem. This seems to be more logical because, in the dry season, a significant part of precipitation runoff very fast in few days. Intercepting this surplus water therefore enables increase mobilizable resources in the drainage basin (Chocat, 2014). This for various uses: irrigation, watering of animals, cleaning after treatment, supplies the phreatic table. Above boreholes which are insufficient and dries out in the dry season, water retention dams appear important and capital to fill the gap, not just that of water shortage in the Far-North Region, but also constitutes a solution for the problem of frequent inundations in the zone.

For the choice of favorable sites for the implantation of these water retentions, reliefs of which downstream, constitute a lock, and through which a water course crosses in mountainous zones, and water tides in plain zones which are most search for. But it locating these places that is a difficult step, whereas, very important and decisive for the construction of future dams. While with the advent of remote sensing that offers the advantage of coupling various multicriteria data, it possible to skip the prospection stage that is useless on the field. It at right tittle therefore that we call on this efficient and rapid prospection tool.

It questions in the present work to call on remote sensing and GIS technics to identify favorable sites for the implantation of water retentions in the Far-North Region of Cameroon, to ameliorate conditions for population access to water.

STUDY FRAME

The Far-North region of Cameroon has as headquarter Maroua. It one of the ten regions that counts Cameroon. Situated between latitude 10° and 13°North and longitude 13° and 15° east. It covers a surface area of 34246km² and extends on over 325km from Soudanese countries up to Lake Chad seashore (Figure 1). It limited to the East by Chad, to the west by Nigeria and South by north Cameroon region (Atlas, 2000).

The Far-North region is dominated by three (03) main geomorphologic unites (Morin, 2000); mountainous landscapes with piedmonts of altitudes superior to 1600m.These hills are constituted of ancient eruptive and intrusive rocks (L'hote, 1998), floods plains in the north and east, of altitude inferior to 400m, between the two precedent geomorphologic entities, we find in the center and south of the region, the glacis zone of altitude comprised between 400 and 1000 m.

Water courses in the far-north region are characterized by temporal flows (Ngounou Ngatcha and *al*. 2001). Their regime is more linked to the dry season than the modesty of annual precipitations generally comprised between 600 and 1000mm.The hydrologic region of the far-north is thus essentially made up of seasonal water courses (Olivry, 1993).

Geologic studies of the far-north reveals the presence of two formations; sedimentary formations and the Precambrian crystallin basement (Dumort and Peronne, 1966). Sedimentary formations extend from the Mandara piedmonts, the Diamaré plain situated in the east, up to the Chadian plain situated in the east, up to the Chadian plain. The Precambrian crystalline basement flush in a continuous way in the mountainous zones of the west and south peneplain and in a sporadic manner at the inselberg in the central zone.

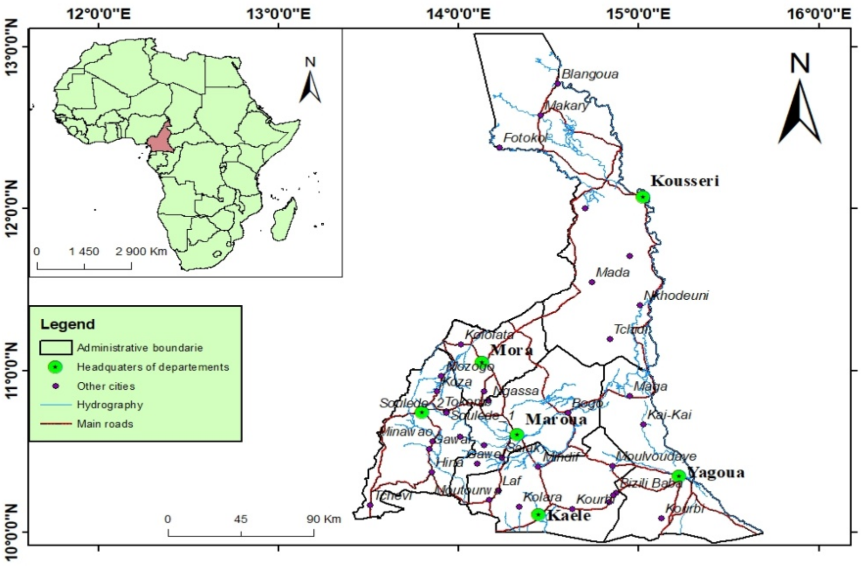

Figure 1: Localization of study zone

MATERIAL AND METHOD

The choice of the site for the dam results from studies carried out following various stages. For this work, the following stages are adopted, acquisition, analysis and treatment of satellite images, recognition of the field by geologic and topographic studies, estimation of field structure using the geologic prospection, test of permeability, estimation of water flow mechanism and verification of hydrologic and meteorologic data, such as pluviometric and water courses debit to determine the necessity and practicability of the dam.

Laboratory work

The study of drainage basins in the study zone, which is the preliminary phase has been done by Global Mapper and has enable characterize the zone on the view point of water flow in function of the type of geomorphology and hydrography of the drainage basin. The delimitation of the surface of the drainage basin on a map then precedes the delimitation of the hydrographic network and different soil types. The surface area is determined as from the delimitation of the drainage basin on the maps or on aerial photos by planimetry. This delimitation is done following the watershed.

The treatment of SRTM images has consist of managing contour lines as well as water courses in the study zone using Global Mapper 17.0 (Figure 2). This stage has as objectives to locate the sense of flow or identify water tides. For upstream retentions, hills crossed by water courses and who’s downstream constitutes a lock, is choose as site where the construction of dike does not need much means (Figure 3). Nevertheless, SRTM images are also used in 3D on QGIS for the choice of the dame's sites (Figure 4). The coordinates of identified site are consigned on an excel sheet and then important in the shape file format on Google Earth and QGIS for detailed studies.

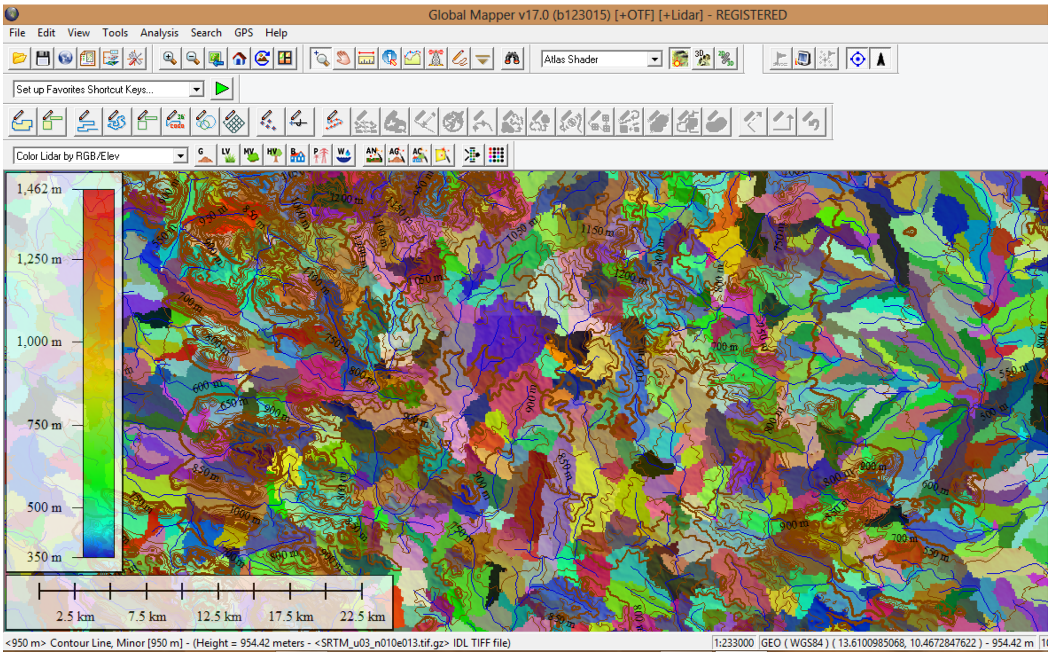

Figure 2: Study of drainage basin by Global Mapper

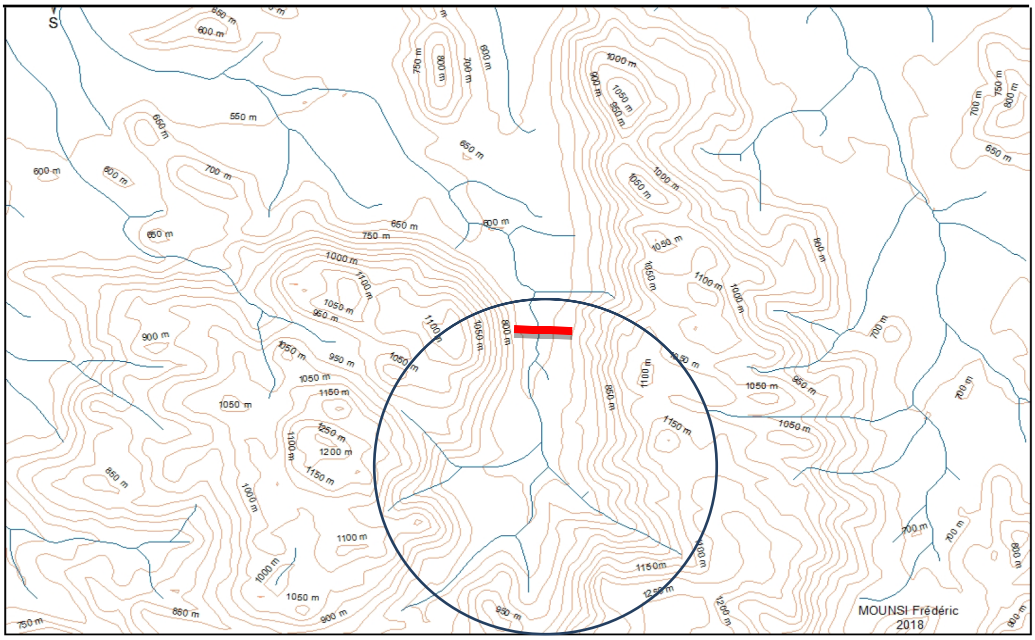

Figure 3: Choice of the dam site thanks to contour lines generated on Global Mapper

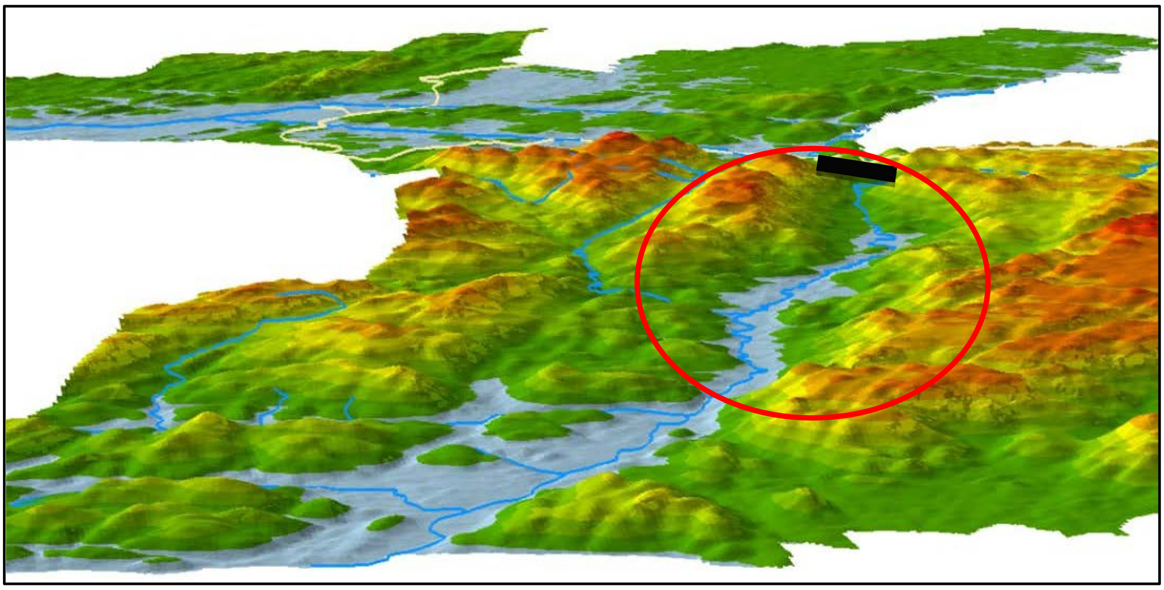

Figure 4: Choice of the dam site thanks to the 3D

Fieldwork

The sites identified by computerized tools have then been object of a field visit to verify information furnished by satellites. Inview of obtaining a profile with no lacune of the whole substratum, closer trenches are made at proximity of the minor bed, cause the risks of heterogeneity are more significant (Durand and *al*, 1999). In each trench, samples are made. Datelines are disposed in a spiral around the fossa as to easily situate each sample in the field profile. This enables characterize materials destined for the leveling of the future dam. After evaluating the availability of material for the backfill at proximity of potentially chosen sites, surveys in the assumed landed field zones are carried out. In the trenches, eventual water seepage in the foundations is noted. If their slow, the trenches are left opened many days to best evaluate them. During the opening of the trances, the characteristics of materials destined for the backfill of the future handiworks are determined. The following tests have been carried out; the granulometry test. It judged by separating the visible elements at necked eyes. For fine elements, Atterberg limits are replaced by shakes (Durand and *al*, 1999). We take a sample of saturated soils in our palms and apply shakes to it. We then mash the ball within our finger-tips, the resistance dry, we mold a quantity of soil, and we allow it dry under sun and mash it within our finger-tips. If it almost impossible to mash the sample, it plastic clay, and if it resistant and weak, it refers to a very fine sand or a lime, the plasticity is equally carried out. Here, we form scrolls of about 3mm of diameter, then we remodel to form a new ball. If the scroll is fragile and the remodeling impossible, the plasticity is weak.

RESULTS

Meteorological and rainfall data

The analysis of temperature and precipitation data (Figure 5) from the Far North Region shows that the months of July, September and especially August are the wet months with the precipitation figures greater than double the temperature figure. These months correspond to the only months during which the water is permanent in the rivers and where the dams would retain a large amount of water.

Analysis of rainfall data over 35 years (Figure 6) for the Far North Region reveals that the Mayo-Tsanaga department, which is located in a mountainous area, is the one that receives the most rainfall, this department which is nevertheless victim of the glaring lack of water in the dry season which lasts almost nine months. The construction of water reservoirs in this department will allow the retention of a large amount of water that runs out unnecessarily in the rainy season for use in the dry season. Mayo-Tsanaga is followed by the department of Mayo-Kani, Diamaré, and then Mayo-Sava, which also face the problem of lack of water. The least watered department is Logone-Chari.

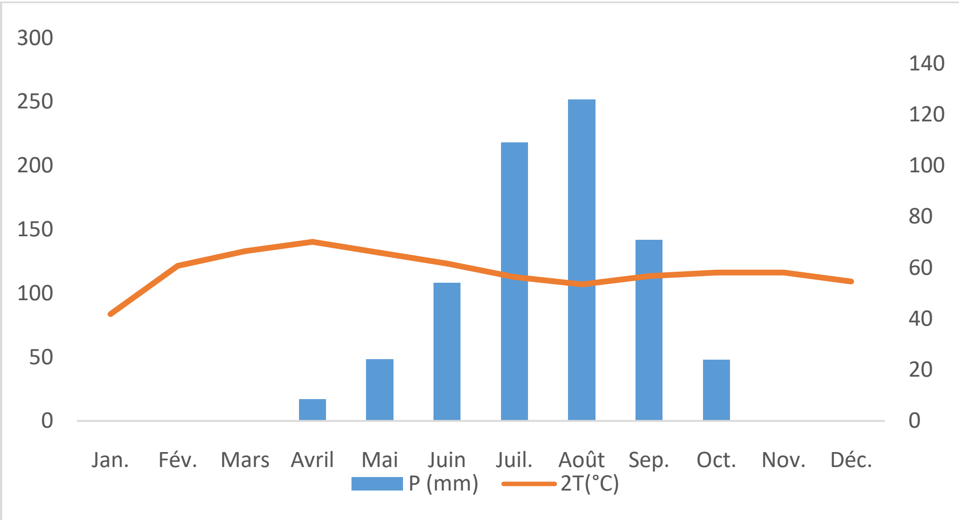

Figure 5 : Ombrothermal diagram of the Far North Region

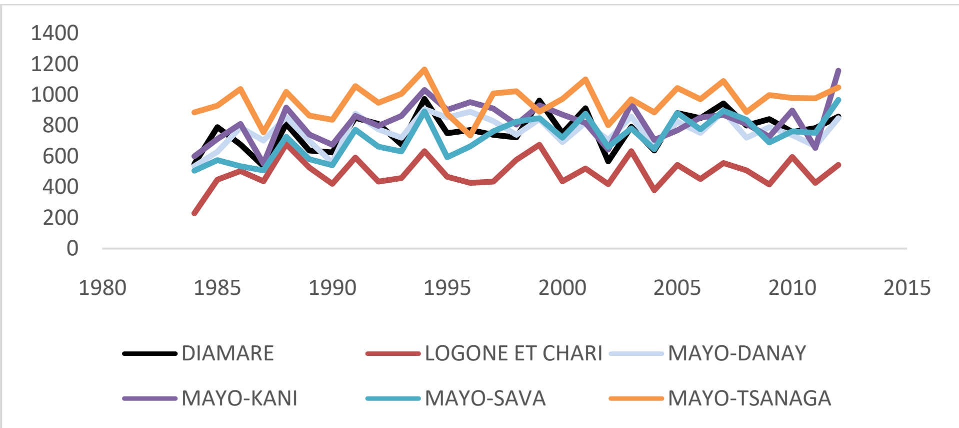

Figure 6 : Evolution of annual rainfall in the six Departments of the Far North Region

Investigations on satellite images

After a first survey on satellite images and topographic map, forty-eight (48) potential implantation sites for the water retentions (Figure 7) have been identified in the far-north region. Geographic coordinates of the preselected sites after been consigned on an excel sheet, and then transformed in to shapefile form are imported on QGIS and presents as shown on the map below.

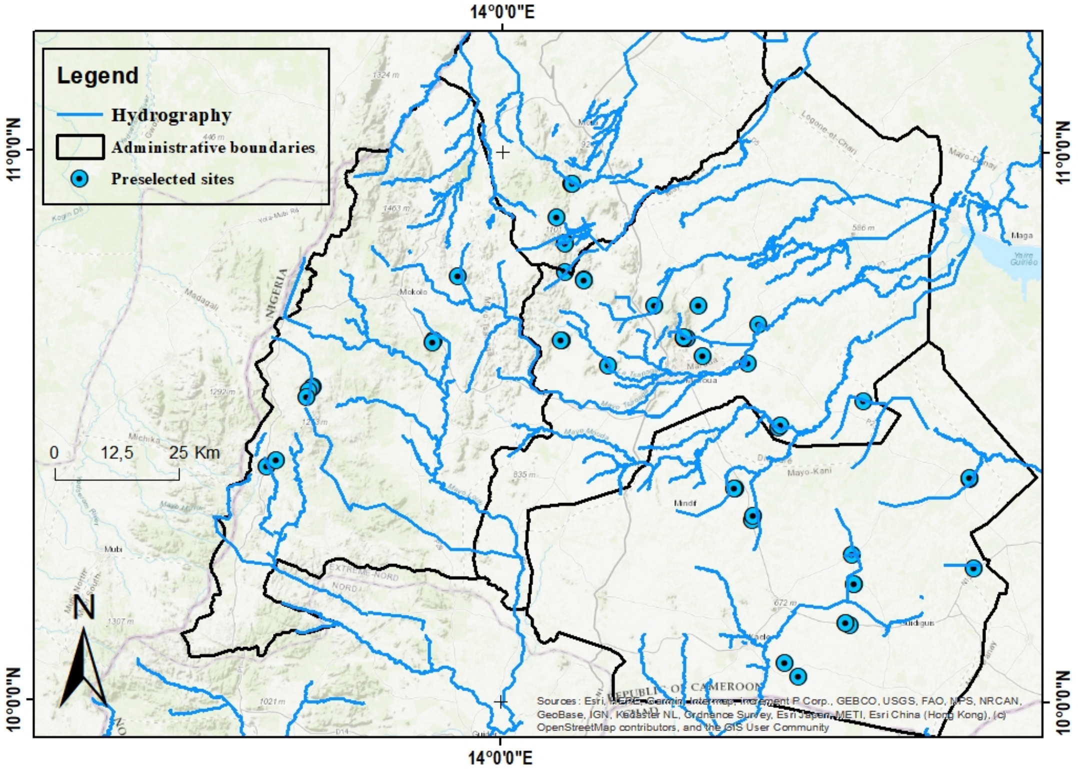

Figure 7: Map of 48 preselected sites.

Choice of the most favorite sites

More detailed studies carried out on Google Earth enabled to classify these sites by order of significance. Are taken in consideration, parameters such as, the proximity of the site to habitation zones and to needs expressed, volume of water stored and number of persons susceptible to benefit from the future handiwork, amongst others. On this base, 13 of the 48 sites (Figure 8) are finally retained.

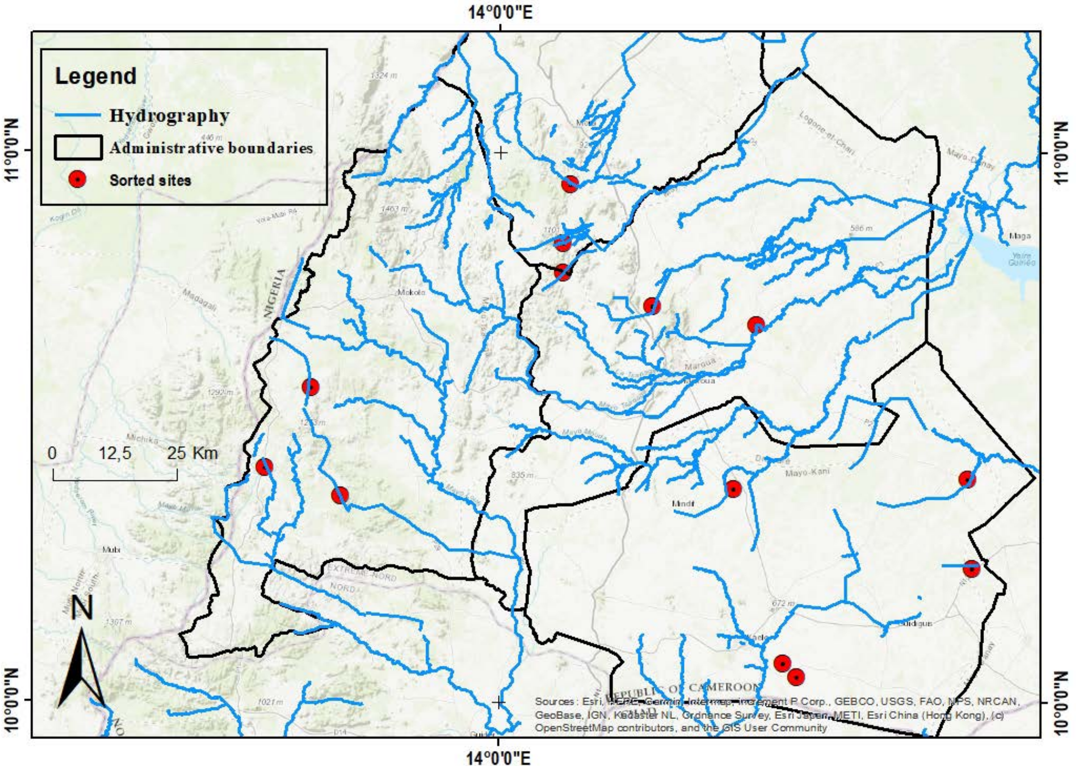

Figure 8: Localization of the 13 sites.

Fieldwork results

Fieldworks have again, enabled a further successive elimination of some sites. The socio-economic study is further accentuated. It carries on the estimation of the surface area and thus, of the potential volume of the retention and the number of population susceptible to use the water of the retention. On the field, various parameters are taken in to consideration. It refers amongst others to dangers that represent these water retentions for the riverain population, activities practiced around the sites, the geology of the site, also the soil type. The geotechnical material at proximity of the sites is the most searched indices. It convenient to note that, all these parameters are not always all gathered together in the chosen sites. Some are privileged at the detriment of others in function of sites. The six most favorable sites (Figure 9) are the Pohri site, the Mayo Ngaska Gniwa (plane zone), site Hina, Godela Winde Ganki, Balaza Akali and Mayo Ouldeme (mountainous zone).

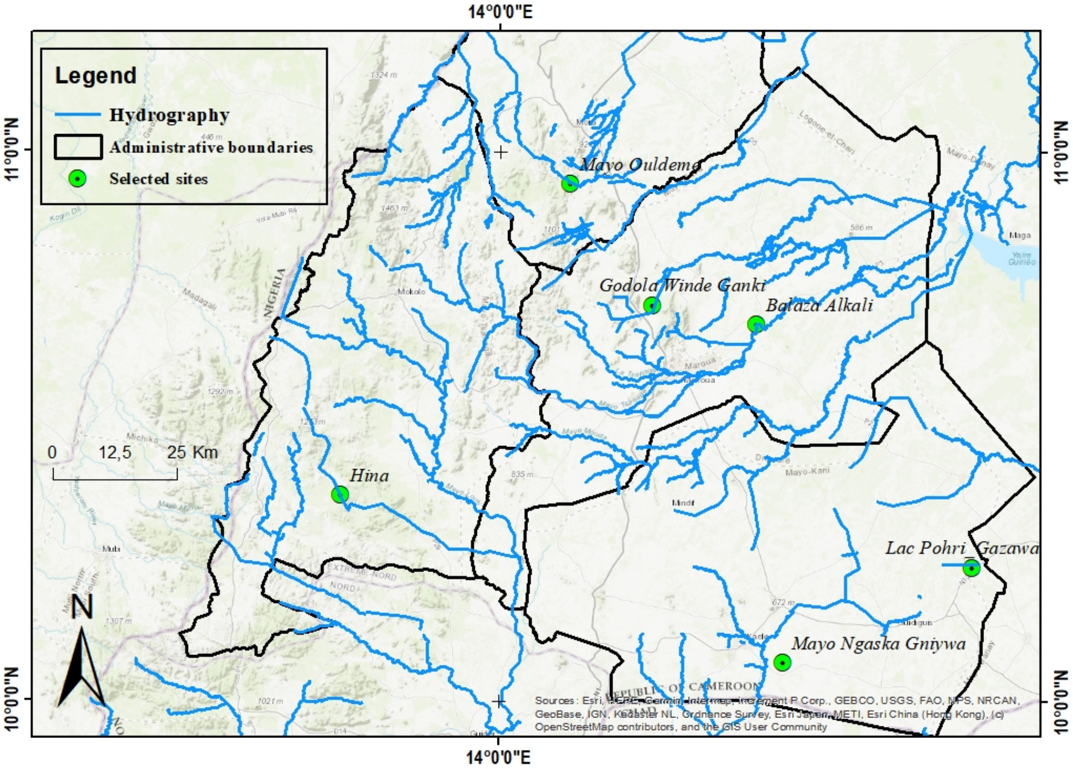

Figure 9: The most favorable zones

DISCUSSION

Security criteria

Dams constituting enormous water resources releases brutally following a rupture, they always have devastating effects on large zones downstream (Carrière, 1991). This justifies the importance given to security in the choice of sites in the present work. Security is thus, the first quality of a dam. As such, sites capable of causing enormous damages linked to the rupture of the handiwork; inundations, are object of particular attention. It refers to the case of Mayo Djarengol Kodek, situated at the heart of Maroua town, Kossewa and Kourbi closest to Taloum. In effect, a good site should neither be too far nor too close to habitation zones. It should not be far to ease access, neither should the site be too close cause of hydric illnesses they could generate and possible resulting damages in case of the rupture of the dike.

A dam enables store a given volume of water. This enables amongst others to limit the severity of inundations downstream. This function of limiting floods can only be fulfilled if the available storage capacity in the retention at the moment the flood arrives is superior to the volume of flood to be retained (Chocat, 2014). In effect, for security purpose, water level in the retention should be checked. If the water quantity surpasses the maximum value, the dike risks breaking with catastrophic consequences. In this case, flood outlets should be envisaged to avoid surpass this security limited and most importantly, be able to anticipate the flood.

But, if we poorly anticipate the flood, the dam would be full. In this case, water outlets should be opened and water left to flow through when the debit is higher. In this sense, the dam would not have played any role to limit risks of inundations. It can instead aggravate the consequences, cause the rise in debit is instead more rapid. The management of water outlets should be very technical. If not, it might give a false feeling of security. We might think domesticating a river and we develop urbanism in the exposed downstream zones. The vulnerability of these spaces increases and when flood arrives, its consequences are more significant.

Socio-economic feedbacks

In a large sense of satisfaction of the populations expressed needs in terms of water, good dams are those whose construction should be easy and exempted from dangers, those whose exploitation is economically profitable and conformed to expectations, finally, those that minimally perturbates the equilibrium of water courses on which their installed and surrounding environment(Durand and *al*, 1999).On this base, the site of Torock whose construction does not only seem difficult due to the scarcity of lent materials, might perturbate the equilibrium of the water course and might on the other hand be of negligeable economic profitability because of a weak human population all round. Closer to it, lake Pohri site at Gazawa Bizili that equally present access difficulties at the level of geotechnical materials, chosen because of the importance of economic activities like agriculture, rearing and fishing practiced all round, but equally and mostly because it a natural lake and thus, do not perturbates the hydric regime of the zone. Its strategic position between two towns, Touloum and Kalfou is by the way an important strength.

Topography and risks

On the topographic plan, the site of a dam is placed on a lock, retightening of the valley situated just at downstream of a susceptible natural cuvette, once closed, to constitute a reservoir of sufficient volume (Carrère, 1991). Topographic studies have enabled condition the quality of material to put in place for the construction of the dam and to this effect, equally condition the relationship volume of stored water/volume of necessary water. The estimation of supply by the upstream drainage basin by a source, has enable show the values found in relation to need. These parameters are used for the choice of sites in the mountainous zones, as the site of Hina, of Godola Winde Ganki and of Mayo Ouldeme.

Erosion is the principal factor at the origin of the filling of certain site. The solid matter produced by this phenomenon is collected and deposited in the site. Climate is the alteration of dry and rainy season. It participates in increasing the instability of the soil structure by limiting pedogenesis. In the dry season, longest period of the year in the far-north region of Cameroon, vegetal species disappears and soils loosens, soils left necked and crumble, stays without protection against the actions of first rains. To this adds trampling of the dry season by animals that loosen more the soil, and makes the first horizon of the soils crumble, exposing them to erosion during first rains.

Anthropic activities equally have some environmental impact. It principally refers to agricultural practices around the sites. In effect, fertilizers used for agricultural output are rich in nitrates and phosphorus transported by water from flows and colonization of lac by phytoplankton. This phenomenon known as eutrophication, is accelerated (Figure 10). The soil been sandy clay and thus weak in permeability, infiltration is weak. In case of strong rains; the zone is generally exposed to risks of inundations in the months of August-September.

Figure 10: Sedimentation and Eutrophication of lake Pohri.

Geologic and geotechnical data

On the geological plan, the imperviousness of the site is taken in to consideration. In effect, the construction of a water retention derives from a massif in which it situated, the minimal properties in terms of natural imperviousness, cause in effect, it would be very closetful to generalize artificial sponging to all the basin depth. The type of underground, quality of materials, their distribution, would be important factors for the composition, quality and imperviousness of the handiwork (Carrère, 1991).

When the substratum is known permeable on a strong thickness as the case of the Hina site, the realization of the handiwork would need important investments. In effect, the means that would be necessary to employ to artificially ensure imperviousness would be enormous in relation to the water volume estimated to be stored. If on the substratum on the contrary, the substratum is sponge up as the site of Pohri and most of the sites of plain zones, the cost of realization of the handiwork would be less. This supposes that the thickness of the alluvions is not very significant to the right of the handiwork (5 to 6 m max). This last criterion can lead to the elimination of various sites for which we cannot reasonably affranchise the thickness of the permeable cover (Couturier, 1985). Moreover, we can jot down most hydrogeological information: situation of source, leakage, losses, resurgence on the water course that we envisage to block. If possible, we shall verify if there exist a water table in the substratum, eventually, it positions and if exchanges with the future water plan can be reduced.

The lithological types observed on most sites are most often affected by soft deformations (Schistositis; folds and lineation) and or breakages (fractures, cleft, shearing). The geologic contexts of these localities present important accidented tectonics able of being stable or not, what can have a negative impact for the realization of the water retention handiworks. It the case for all sites in mountainous zones.

These zones, by occurrence, sites of Hina, of Godola Winde Ganki and of Mayo Ouldeme present geologic and pedogenic characteristics of a permeable site. At the actual state, losses in water would be considerable given the alluvial nature and mega fractures observed on the outcrop. This could lead to leakages or rapid drain of water in the retention. A deep survey should be realized so as to determine the nature of the sub-soil to identify clay zones that have a strong water retention potential, as well as deeply fractured rocky banks. The choice of the site is also tributary to the availability of lent material (Durand and *al*, 1999; Carrère, 1991). The distance of supply should equally be reduced as much as possible (Durand and *al*, 1999). It the case of the sites of Godola Winde Ganki, Hina, Balaza, Ouldeme. These environments present various materials (rocks, alluvial, lime, sands …) available that would be used in the constitution of the water retention body in backfill. This, while, survey studies at the drill should be realized so as to estimate the quantity and quality of backfill material in these zones. Contrary to this category, some sites of plain zones as that of Dargala bridge Djoulgouf of Torock amongst others, present difficult access to geotechnical material, where their qualified less good than those cited above.

Choice of site in function of needs.

We construct a dam in view of constituting a water reserve that could satisfy agricultural, pastoral, human, touristic or industrial needs (Durand and *al*, 1999). For the present work, emphasis is layed on the agropastoral and human, more, touristic needs (case of Pohri site). In this sense, various losses in water should be taken in account: infiltration and evaporation. Taking in account this parameter and equally those cited above (topography, geology, geotechnics, hydrology, economy), the choice of the site is tributary to the needs expressed, capable of satisfying demand. To this tittle, the site of Gazawa Bizili, of Hina and Mayo Gnaska Gniywa are very illustrative. In effect, in these zones are practiced agriculture and rearing which are confronted to problems of lack of water.

CONCLUSION

The choice of the site of the water reservoir is a very decisive step for the next life of the handiwork. The present work is a construction to the selection of favorite sites for the implantation of water retention dams in the far-north region, a region confronted to a double water problem. To achieve this, we called on remote sensing and GIS technics. Acquisition and treatment of satellite images have been by appropriate software's that have first of all enable to select sites on a vast extend, then thanks to detailed studies by software, the most favorite sites are retained. Then, field works have once more enable to choose the most potential sites, taking in account field realities. The method of choosing sites for the implantation of water retentions used in this work enables to skip the preliminary prospection stages which could be very costly.

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