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Spatial analysis of reforestation sites in the far-north region of Cameroon

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Abstract

Following the great drought which struck the Sahel countries including the northern part of Cameroon in the mid-1970s, Cameroon, like the other states of the sub-region located on the edge of the Sahara, decided to implement implement drought control activities. This study taking place in the Far North region of Cameroon, generally fits into the field of characterization of natural environments. It aims to structure and highlight the situation of certain reforestation sites in the far north region. Therefore, to achieve the expected results, we used two specific methods of data collection, namely: the in situ method (floristic inventories using the plot method) and the indirect method (downloading of iconographic data on the SOGEFI platforms, COPERNICUS, ATLAS and GEOFABRIK), for remote sensing analysis purposes with a Landsat OLI/TIR image from November 13, 2023 and photogrammetric shots with Pix4. The inventory data and measurements taken in the field were recorded in CSV and/or XLSX formats for the purposes of statistical analyzes (PAST, Excel) or cartographic operations (Qgis versions 3.22 and 2.18). To this end, the field surveys collected in situ made it possible to carry out thematic mapping using the inverse distance interpolation (IDW) method. The processing of remote sensing data consisted of assembling satellite images using "mosaicking", radiometric and geometric corrections, and spatial filtering using ENVI and SAGA Gis software. The analysis of these images consisted of calculating vegetation indices (the NDVI adjusted to the ground). It thus appears that the reforestation sites have a deciduous population, a natural habitat composed of shrub savannah, tree savannah, grassy savannah, steppe and meadow. Reforestation sites are sometimes less drained, sometimes very poorly drained due to the unfavorable structure and texture of the soils, in certain sites in the region. In addition, only the sites of Djiddel and Gawel 2 among the Diamaré sites have a better level of canopy, with an average regeneration rate of 36.11%. In Mayo-Kani, only the sites of Moumour, Kéra, Bipaing, Piwa, Mindif and Laf have a better level of canopy, with an average regeneration rate of 47.70%. In Mayo-Tsanaga, only the Boula-Mokong site has a better level of canopy, with an average regeneration rate of 44.66%. In Mayo-Danay, only one site has a better level of canopy, namely the Daiba-Kalfou site. Furthermore, sites in this department have an average regeneration rate of 49.25%. In Logone and Chari, most of the sites have an acceptable level of canopy since no site in this department has a very appreciable level of canopy. However, sites in this department have an average regeneration rate of 39%.

Keywords: Geomatics; Characterization; Remote Sensing; Far North; Cameroon

1. Introduction

For thousands of years, the world has been in constant change and is undergoing modifications of various kinds on a planetary scale [1,6]. Climate change is one of the major factors that modifies the parameters of the globe through negative or positive radiative forcing on a geological time scale [7,16,17]. However, problems related to the management of the environment and natural resources constitute major challenges facing humans today [2,6]. However, the degradation of forest ecosystems constitutes one of the elements [7,17]. Indeed, tropical forests have

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declined significantly under various anthropogenic pressures [4,5]. Moreover, more global data indicate that the rate of annual global deforestation, which amounted to 8.868 million hectares per year between 1990 and 2000, is today estimated at 7.317 million hectares per year [4]. Thus, the surface area of global forests increased from 4.077 billion hectares in 1990 to 3.952 billion hectares in 2005 [4,17]. Indeed, in Africa in general and in Cameroon in particular, vegetation has been progressively degrading for several decades [2,12,18]. In recent years, vegetation zones and agricultural lands in several sub-Saharan cities have experienced a decline in relation to urban sprawl and the progressive subdivision of land for agricultural and construction purposes [14,5]. Faced with this situation, it is wise to find out the status of the "Operation Sahel Green" reforestation project set up in the far-north region of Cameroon.

1.1. Study area

The study is taking place in the Far North region of Cameroon. It extends from 10.0° to 13.5° of North Latitude (southern shore of present-day Lake Chad) and from 13.0° to 15.0° of West Longitude. The Far North is made up of two geomorphological units which structure the relief of the region and all the associated physical elements: the Mandara Mountains to the West and the lowlands to the East. More specifically, the study is taking place in 5 of the 6 departments in the far-north region, namely: Diamaré, Mayo Kani, Mayo Danay, Mayo Tsanaga and Logone and Chari. The map below illustrates the study area.

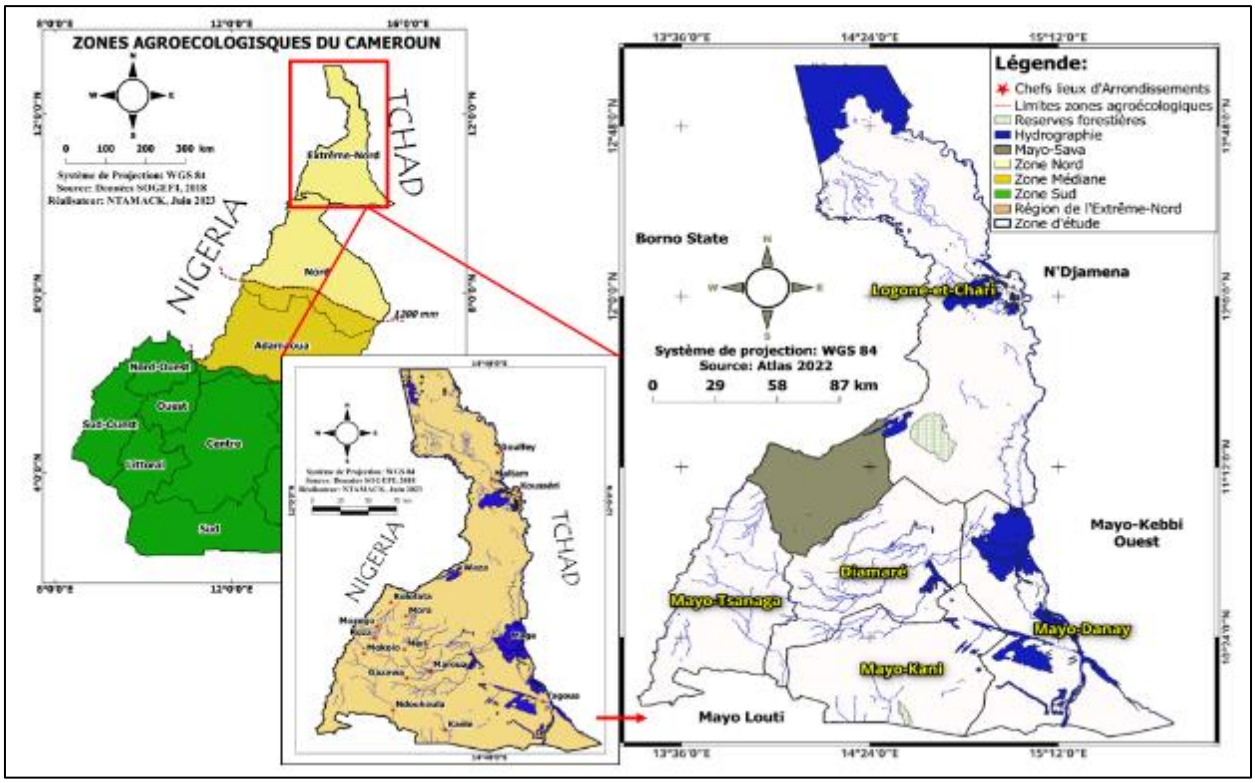

Figure 1 Location of the study area

2. Material

The equipment used for the characterization and evaluation of these reforestation sites consists of the following tools and/or elements:

2.1. Inventory and measurement tools

- 01 "Digital Compass" brand Android compass for orienting plots and measuring azimuths;
- 01 GPS for taking geographic coordinates of the "Garmin 82" brand and precision to the 100,000th, producing 3D geographic coordinates (longitude, latitude and altitude) in DMS format;
- 01 UNT Power Tape brand graduated tape, of Chinese origin (7.5 m) for measuring diameters (≥ 10 cm) at breast height (DBH) of woody plants;
- 01 machete;
- 01 marking post;

- 01 Brightly colored ribbon (red) for marking;
- Very solid 60 cm wooden sticks for marking plots;
- 02 Waterproof bags for measuring instruments and cards;
- 01 Photographic apparatus;
- 01 List of species (vernacular and scientific names);

2.2. Iconographic tools

- Landsat OLI/TIR satellite images (Doua, 2011);
- Cartographic data (CSV, raster and vector) from Sogefi, Earth Explorer, Copernicus and Atlas;
- Climatic data from the Maroua-Salak meteorological station;
- IRD soil data.

2.3. Methods

2.3.1. Data collection

Floristic inventories using the plot method

- **Sampling plan**

The sampling plan adopted for the evaluation of the floristic resources of the sites is systematic. The plots are distributed regularly at the tops of a square mesh grid, the dimensions of which are fixed according to the number of plots desired and the surface area of the site to be inventoried [3]. Depending on the number of plots chosen, we will determine the distance between each central point of the plots according to the formula:

$$D = \frac{\sqrt{(Sx10000)}}{\sqrt{n}}$$

With: D being one side of the square mesh, S the surface area in ha and n the number of plots previously chosen.

- **Marking of plots**

Several data on the location of the marker are recorded in order to be able to find the mark and the start of the plot in the future. For this purpose, a description of the landmarks is given in the plot map below. It sufficiently illustrates the data collection points (plots) in the study area [9].

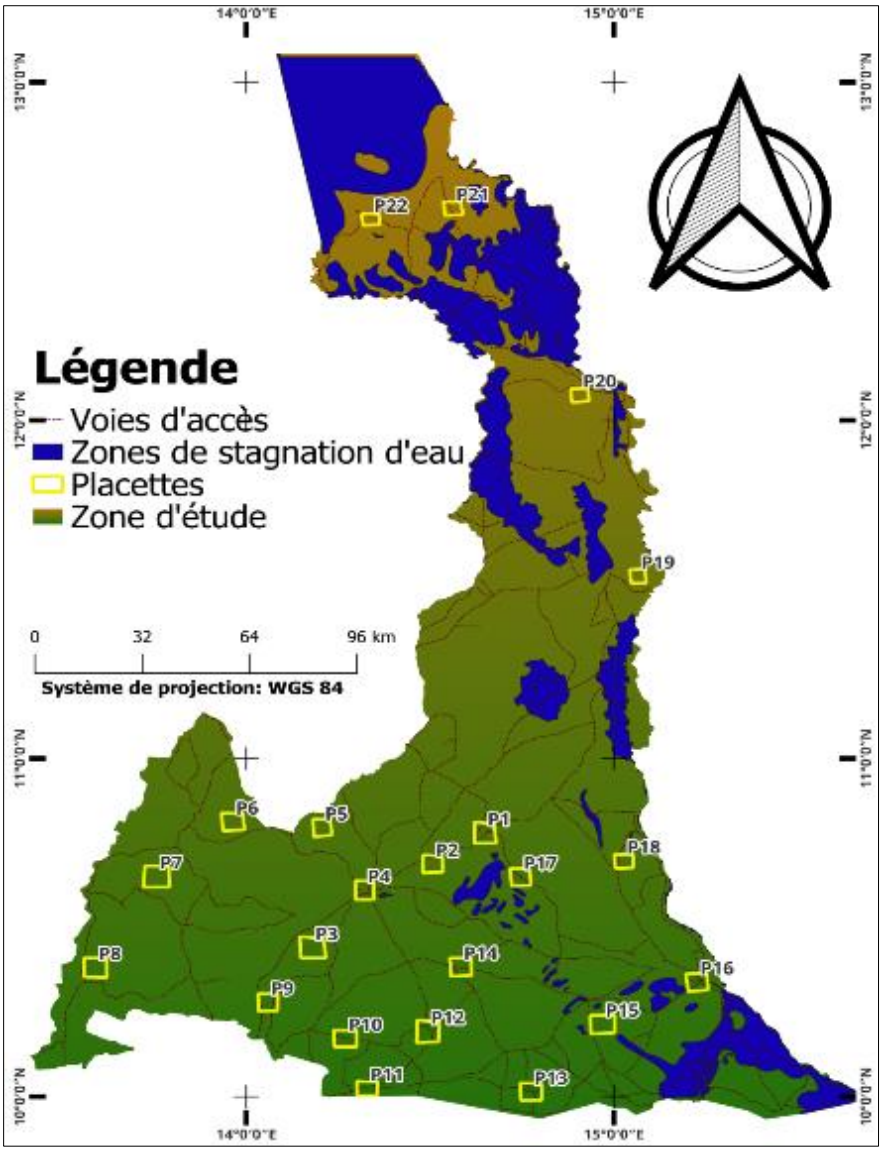

Figure 2 Map of plot layout in the study area

2.3.2. Downloading iconographic data and satellite images

Indeed, vector-type cartographic databases under the shapefiles (shp) extension are downloaded to the Sogefi, Copernicus and Geofabrik platforms, under a zipped Winrar package. In addition, we downloaded the remote sensing data via the United States Geological Survey (USGS) website, in the form of Landsat 8 images (OLI image from November 24, 2023) [11].

2.3.3. Data processing

- **Decompression, conversion and classification of iconographic data**

This involves the processing of map data collected by downloading. The downloaded databases are (for vector type data) decompressed using the "winrar" software package to make them usable in Quantum gis version 3.22 and 2.18 [9]. The geographic coordinates collected by GPS are converted in the "Long/Lat to UTM" application to navigate between the different coordinate typologies (DMS to Decimal Degree) [10].

- **Assembly of satellite images by "Mosaiking"**

When the extent of the area to be mapped exceeds the scope of an aerial photograph or a remote sensing image, it is necessary to resort to ''mosaicking'' which is an operation of automatic assembly of satellite images. This image fusion method allowed us to use several cut-out images and render them into a single, spatially very enlarged image [7,10,13].

2.4. Data analysis

2.4.1. Statistical analyzes

The data is analyzed in SPSS and Excel software. To this end, descriptive statistics and inferential statistics are applied. This software allowed us to analyze Position and dispersion parameters [20].

2.4.2. Analysis of homogeneity and determination of statistical indicators of dispersion

We determined the variance, standard deviation and coefficient of variation. To this end, once the standard deviation was determined, a correlation was made with the mean to measure the dispersion of the population in the reforestation sites [19].

2.4.3. Cartographic operations following the interpolation method

The maps designed come mainly from data collected in situ. The method used is inverse distance weighted (IDW) interpolation. IDW interpolation is a method that estimates unknown values using weighting inversely proportional to the distance between known data points and the estimation point [14,15,21]. The closer points have a greater influence on the interpolated value. The mathematical formula for IDW is:

$$Z(\boldsymbol{x_0}) = \frac{\sum_{i=1}^{n} \frac{Z(x_i)}{d(x_i,x_0)^p}}{\sum_{i=1}^{n} \frac{1}{d(x_i,x_0)^p}}$$

with :

- •Z(x0) is the interpolated value at the estimation point x0.
  - Z(xi) is the known value at point xi.
  - d(xi,x0) is the distance between the known point xi and the estimation point x0.
  - p is a parameter that controls the power of the weighting.

2.5. Remote sensing analysis for maps obtained by interpolation

The analysis of the cartographic data after processing is done in the Qgis software. This consists of interpolating toponymic field data from reforested areas in the different sites [11,8,13].

3. Results and discussion

3.1. Identification and determination of reforestation sites

Of around thirty reforestation sites set up as part of the OSV project, only 27 still exist in Diamaré. It is noted that in the Diamaré department, reforestation sites are mainly present in the district of Ndoukoula. To this end, table 1 below presents these sites, as well as analyzes linked to the diversity per site, the basal area of each site, the regeneration rate and the level of plant cover in each Diamaré site.

Table 1 State of Diamaré reforestation sites

Names Sites	Diversity	Basal surface area (m^2/ha)	regeneration rate	Traces of anthropic activity	Canopy level
Djiddel	22	39	80 %		Very Good
Ouro Yaya	18	21	40 %		Average
Bagalaf	16	19	15 %	X	Bad

Badjwal	18	18	15 %		Bad
Miziling	12	28	55 %		Bon
Beguele	12	22	40 %		Average
Beguele 3	16	21	40 %	X	Average
Mayel Ibbe	10	17	15 %	X	Bad
Maroua	10	17	15 %	X	Bad
Kaliao (Beguele 2)	16	16	15 %		Bad
Kaliao 2	16	17	15 %	X	Bad
Kaliao 3	16	21	40 %		Average
Bolmoyo 1	18	29	55 %	X	Good
Bolmoyo 2	18	22	40 %	X	Average
Tchakidjebe	20	27	55 %		Good
Djebe	16	17	15 %	X	Bad
Zakalliao	18	26	55 %		Good
Ouazzang	22	29	55 %		Good
Gawel 1	22	28	55 %		Good
Gawel 2	22	36	70 %		Very Good
Loulou 1	20	27	55 %		Good
Loulou 2	20	26	55 %		Good
Ndoukoula	22	30	55 %		Good
Goudoum	18	18	15 %	X	Bad
Gawel 3	22	28	55 %		Good
Goudoum 1	18	16	15 %	X	Bad
Zongoya	20	17	15 %	X	Bad

It thus emerges from this table 1 that only the sites of Djiddel and Gawel 2 have the best level of canopy. On the other hand, sites such as those of Goudoum, Djebe, Goudoum 1 or that of Kaliao 2, not only have a poor level of canopy, but also are troubled by the infiltration of certain anthropogenic activities (agricultural fields or transhumance bases). The average regeneration rate of sites in this department is 36.11%.

Furthermore, in Mayo-Kani, out of the twenty-eight (28) reforestation sites set up as part of the OSV project, only 24 still exist. It is noted that in this department, reforestation sites are mainly present in the district of Kaélé. Table 2 below presents the situation.

Table 2 State of Mayo-Kani reforestation sites

Names Sites	**Diversity**	**Basal surface area (m^2/ha)**	**regeneration rate**	**Traces of anthropic activity**	**Canopy level**
Going 1	22	22	35 %		Average
Going 2	22	23	39 %	X	Average
Gouada	18	22	36 %		Average
Moumour	28	36	75 %		Très bon

Kéra	22	33	72 %		Très bon
Goussor	20	23	35 %		Average
Bipaing	24	34	76 %		Very Good
Berkédé	22	11	23 %	X	Bad
Lamtari-Kaélé	20	30	55 %		Good
Matchoualta-Lara	16	20	37 %		Average
Gabane-Lara	12	13	21 %	X	Bad
Boboyo II-Kaélé	16	28	57 %		Bon
Matchoualta II	18	20	35 %		Average
Kilguim-Lara	18	27	56 %		Good
Moudjoui	16	11	24 %	X	Bad
Moudjoui 2	16	21	38 %	X	Average
Berkédé 2	18	23	35 %		Average
Piwa	24	36	77 %		Very Good
Beungel-Boboyo	22	22	35 %	X	Average
Mindif	22	35	79 %		Very Good
Loubour	22	27	54 %		Good
Goundaye	24	12	22 %	X	Bad
Missiliam	20	26	55 %		Bon
Laf	20	34	74 %		Très bon

It thus emerges from this table 2 that only the sites of Moumour, Kéra, Bipaing, Piwa, Mindif and that of Laf have the best level of canopy. Conversely, sites such as those of Goudaye, Moudjoui, or even that of Berkédé, not only have a poor level of canopy, but also are troubled by the infiltration of certain anthropogenic activities (agricultural fields or transhumance bases). The average regeneration rate of sites in this department is 47.70%.

The department of Mayo-Tsanaga, for its part, has 6 reforested sites that are still operational. As for the Mayo-Danay department, it has 8 sites still operational. Tables 3 and 4 present the state of the sites in these departments.

Table 3 State of Mayo-Tsanaga reforestation sites

Names Sites	**Diversity**	**Basal surface area (m^2/ha)**	**regeneration rate**	**Traces of anthropic activity**	**Canopy level**
Zouvoul	22	22	35 %	X	Average
Gaboua	20	21	32 %	X	Average
Boula-Mokong	22	34	69 %		Very Good
g	22	28	45 %	X	Good
Zidim	22	29	51 %		Good
Zidim 2	20	21	36 %	X	Average

Table 4 State of Mayo-Danay reforestation sites

Names Sites	Diversity	Basal surface area (m^2/ha)	regeneration rate	Traces of anthropic activity	Canopy level
Daiba – Kalfou	22	22	71 %		Very Good
Guissia	20	21	58 %		Good
Doukoula	22	34	47 %		Average
Boubaye	22	28	52 %	X	Good
Tchatibali	22	29	56 %	X	Good
Guirvidig	20	21	46 %		Average
Werféo 2	20	21	25 %	X	Bad
Tcherfeke-Yagoua	20	21	39 %		Average

It thus emerges from this table 3 that only the Boula-Mokong site has the best level of canopy. However, no site has a deplorable level of canopy in this department despite the presence of certain anthropogenic activities in some of these sites. The other sites have average canopy levels. These are the sites of Zouvoul, Zidim, Zidim 2, Boula-Mokong 2 and Gaboua. The average regeneration rate of sites in this department is 44.66%. Regarding the Mayo-Danay sites, table 4 shows that only one site has a better canopy level (Daiba-Kalfou). However, sites such as Doukoula, Guirvidig and Tcherféké have average canopy levels; only the Werféo 2 site has a low or poor canopy level. The average regeneration rate of sites in this department is 49.25%. Speaking of the department of Logone and Chari, it takes its name from the two main rivers which cross it, namely the Logone river and the Chari river. The reforestation sites in the Logone and Chari department number 06 sites. Table 5 below presents the situation of these reforestation sites.

Table 5 State of Logone et Chari reforestation sites

Names Sites	Diversity	Basal surface area (m^2/ha)	regeneration rate	Traces of anthropic activity	Canopy level
Mada	22	22	44 %	X	Good
Maltam	20	21	31 %	X	Average
Katikimé-Darack	22	34	33 %		Average
Djénéné-Goulfey	22	28	40 %	X	Good
Karéna	22	29	32 %		Average
Kousséri	20	21	56 %	X	Good

It thus appears from this table 5 that only the sites of Mada, Djénéné and Kousséri have the acceptable level of canopy. However, no site has a deplorable or very low level of canopy in this department despite the strong presence of certain anthropogenic activities and the high temperatures which predominate in some of these sites. The average regeneration rate of sites in this department is 39%.

3.2. Plant Physiology and Phenology

The physiology and phenology of the plant species observed in the different reforestation sites show that these plants have the following characteristics: a deep root system developed to capture water in depth, leaves of small size or deciduous to limit transpiration and persistent foliage or thick bark to protect the aerial parts. This is the case for acacias (Acacia spp.), neem (Azadirachta indica) and combretums (Combretum spp.). These deciduous forest stands, although less dense and more open than in wetter areas, play a very important ecological role in the study area. We therefore observe that the basal area for many sites is between 25 and 37 m^2/ha, which indicates a good density. However, the

average volume of tree trunks sampled in the different reforestation sites is 0.13 m3. A cross-analysis between the height and the usable diameter of the plant species in these sites shows that the standard deviation between the usable heights is much narrower while that of the usable diameters is very considerable (as presented in Table 6).

Table 6 Cross analysis of tree diameter and height

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Average	Standard Deviation
Usable Height (m)	38	0	38	3,020	5,210	3,760	0,688
Usable diameter (Cm)	38	0	38	7,000	27,000	16,818	5,820

In summary, the relationship between the two variables is a causal relationship between the two variables. Because the observation in the field shows that, the more a tree has a very considerable height, the less its diameter is large. Therefore, the vertical growth of trees in these different sites is inversely proportional to its usable diameter.

3.3. Tree health analysis

A cross-analysis of the quality of the wood, the state of health of the tree and the causes of the damage observed shows that externalities mainly influence the peaceful growth of plant species in place (case of the Bolmoyo 2, Going 1 sites). , Gaboua, Zouvoul or even that of Doukoula). To this end, a cross-analysis of the variables x (cause of damage) and y (state of health) allowed us to determine a skewness and a kurtosis varying between -2 and 1 as presented in table 7 below.

Table 7 Analysis of skewness and kurtosis between the causes of damage and the state of health of the plants

	Cause of damage	State of health
Diversity	38	38
Average	2,40909	1,54545
Standard deviation	1,29685	0,509647
Coeff. of variation	53,8315%	32,9772%
Minimum	1,0	1,0
Maximum	4,0	2,0
Range	3,0	1,0
Stnd. skewness	0,282767	-0,375722
Stnd. kurtosis	-1,68373	-2,07585

It thus appears that at 95.0% confidence intervals, the standard deviation of Cause of damage is [0.997733; 1.85328]; that of the state of health is [0.392098; 0.728319] with a ratio of variances being between [2.6883; 15.5956]. The F Test to compare standard deviations is then F = 6.475 with P Value = 0.0000707283 for alpha = 0.05. The skewness of the distribution is between -0.375722 and 0.282767, this indicates that the distribution is relatively close to symmetric or slightly skewed, but with relatively little skewness. This means that the causes of damage from one site to another are generally distributed relatively evenly around the average health of the trees in these different sites. This may suggest that the values are relatively less extreme and less widespread compared to a normal distribution. The plate below 3 sufficiently illustrates some tree distributions in certain sites in the study area.

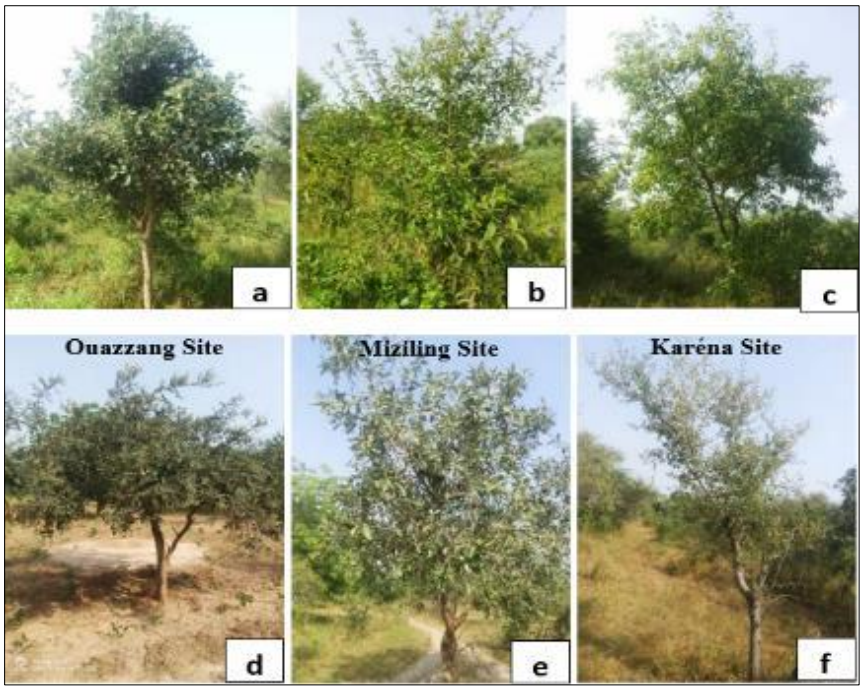

Figure 3 Plant physiology by site

This fig 3 thus gives the framework, in an indicative manner, of the distribution of plants in these reforestation sites. Some sites have a uniform distribution and others a disparate and scattered distribution.

3.4. Spatial analysis of reforestation sites

It aims to spatialize the object of study, following a very holistic approach. The figure below 5 shows the layout of these reforestation sites in the study area.

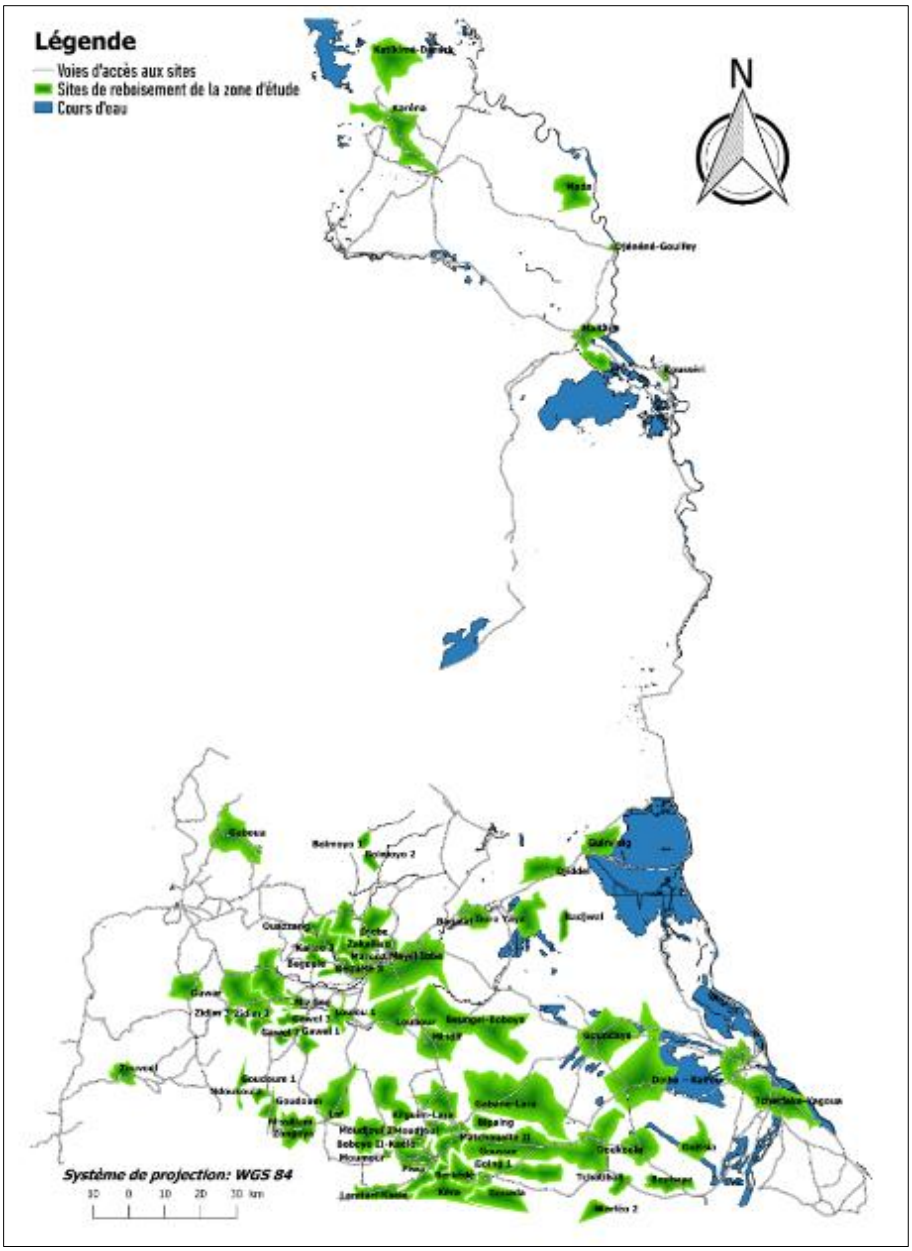

Figure 4 Distribution of reforestation sites according to the study area

3.5. Analysis of climatic parameters of reforestation sites

The climate of the study area is Sudano-Sahelian. It is characterized by a dry season which lasts seven months and a rainy season which lasts five months. From November to February, the region experiences colder months, followed by months of increasing heat until the rains arrive. Therefore the study area is dominated by an absolutely very high temperature for almost 8 months per year. Figure 5 below shows the temperature variation in the study area.

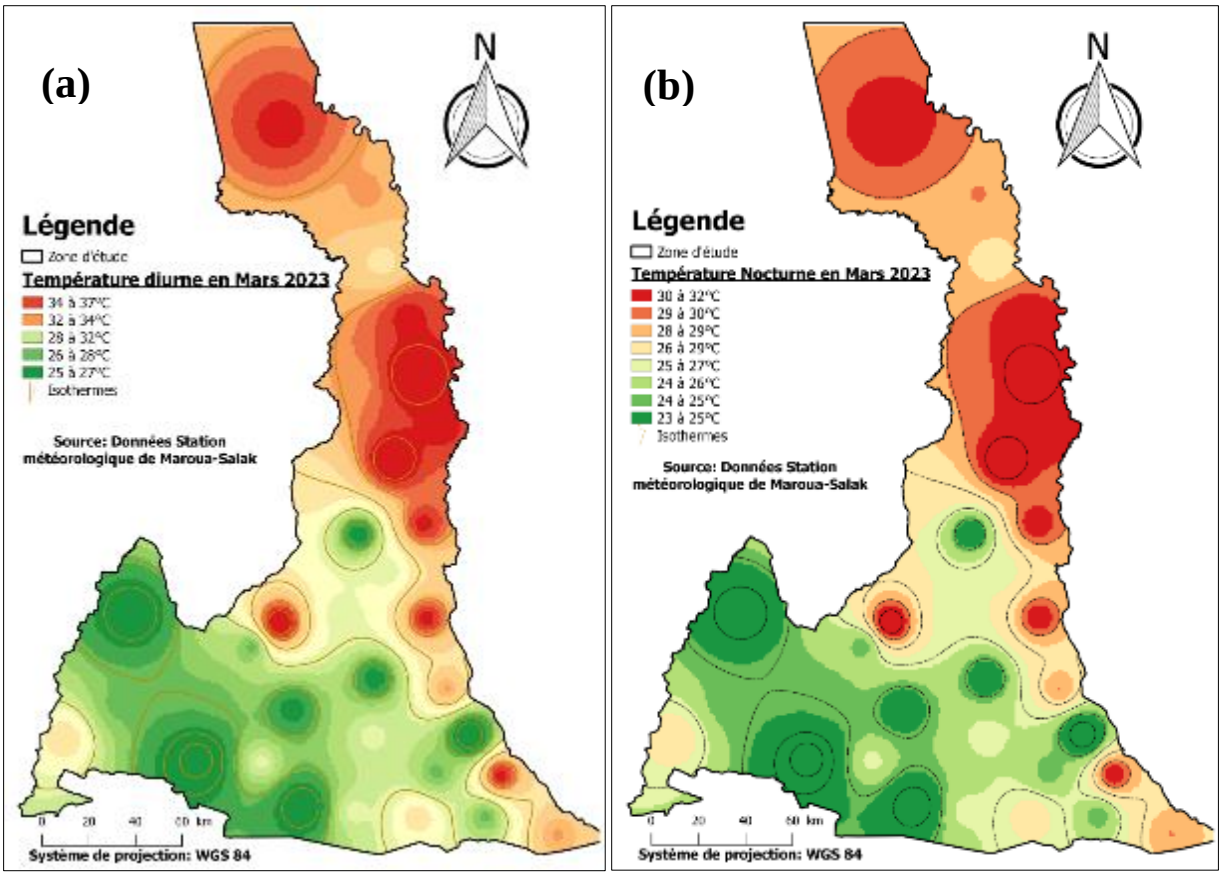

Figure 5 Average temperature of the study area: (a) daytime temperature (b) nighttime temperature

It is clear from these maps that in the dry season, temperatures are very high in the study area. In addition, we note that during the night, the peak temperatures are between 30 to 32°C; However, during the day, this peak reaches up to 37°C. So the average temperature of the study area is around 36°C. Therefore, according to the isotherms observed, the most extreme temperatures are specific to the reforestation sites located in the Logone and Chari department and relatively in certain sites in Mayo-Danay. Furthermore, the sites of the other three departments are in a slightly lower temperature zone (23 to 32°C). These are in fact the sites of Diamaré, Mayo-Kani, Mayo-Tsanaga and certain sites of Mayo-danay.

The observation made in the field shows that, in January, the relative humidity is generally low, with an average of 40% to 60%, which is considered pleasant. In February, the climate remains favorable, with around 1 mm of precipitation and maximum temperatures reaching 38°C. From March to May, during these months, the relative humidity is less favorable. Temperatures rise to 41°C, and it rains around 42mm each month. From June to July, the climate is very acceptable. Maximum temperatures reach 34°C, and you can expect 204 mm of precipitation per month. In August, although less favorable, the climate remains correct. The temperature rises to 31°C, and it rains around 310 mm. From September to November, the climate is favorable, with average temperatures of 36°C and around 1 mm of precipitation each month. Finally in December, the humidity is ideal, with temperatures ranging from 21°C to 34°C and no significant precipitation. In summary, these reforestation sites benefit from a semi-arid climate, characterized by high temperatures and periods of drought. Figure 6 below shows the rainfall map (a) and the hygrometric map (b) of the study area.

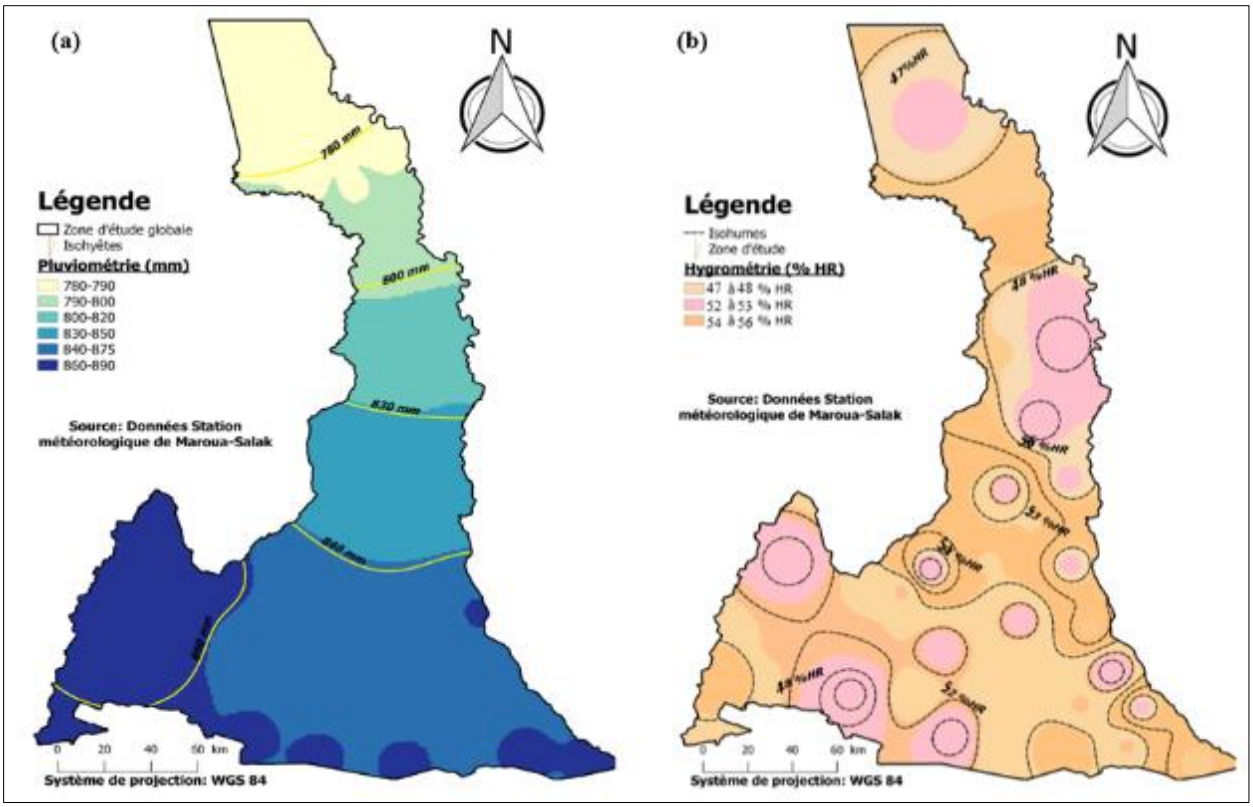

Figure 6 Rainfall variations in different reforestation sites

3.6. Analysis of edaphic parameters of reforestation sites

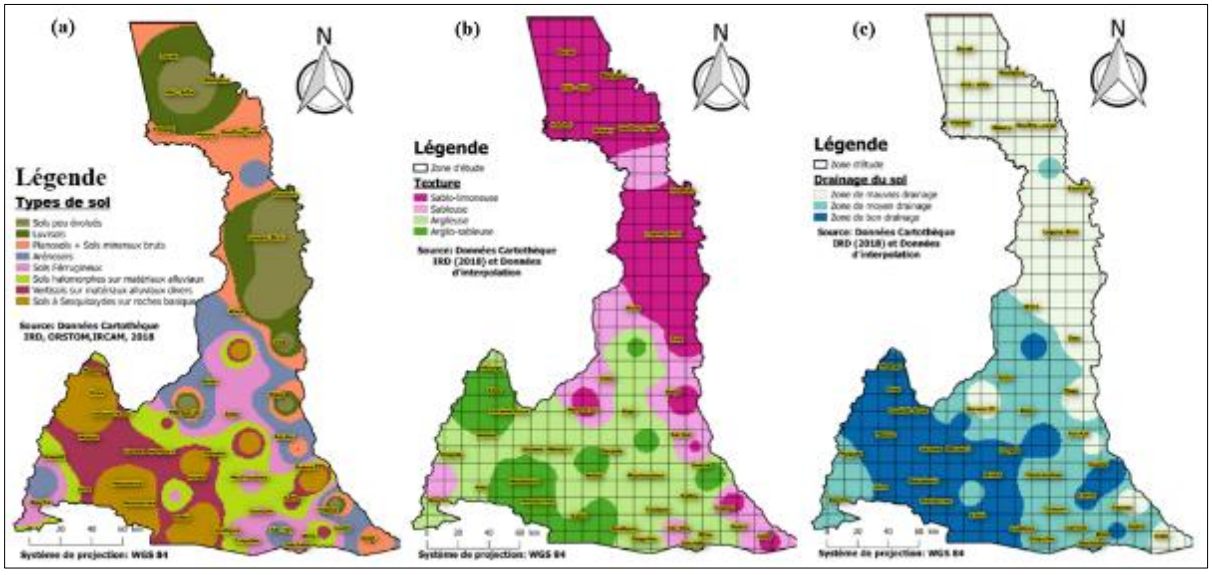

Figure 7 Pedology (a), permeability (b) and drainage (c) of the study area

Indeed, the study area presents specific soils, requiring careful management to preserve their fertility and support silvicultural activities. It appears that vertisols are dominant in all the sites of Diamaré, in certain sites of Mayo-Kani and Mayo-Tsanaga. Sesquioxide soils on basic rocks, as well as halomorphic soils on alluvial materials, are also present on the sites of these three aforementioned departments; but in a disparate and minority way. Ferruginous soils and Arenosols, for their part, are present in the Mayo-Tsanaga and Mayo-Danay sites and slightly in the Mayo-Kani and Logone-Chari sites. Speaking of less evolved soils, planosols, Luvisols and raw mineral soils, they are mainly on the Logone and Chari sites. Furthermore, the textural situation of the study area thus corroborates the result on the soil

types present. Indeed, the soils of the study area are progressively less porous from the South side to the North side of the study area. In fact, the more sandy a soil texture is, the more porous its structure; and the more clayey a soil has a texture, the less porous its structure is. The geology of the study area is mainly composed of the Chad sedimentary basin, which is a vast sedimentation basin. Consequently, soil drainage from one site to another varies depending on these two major factors, namely: the structure and texture of the soil present. Thus, the areas of good drainage are the plateaus located in the north of the Matakam mountains in Mokolo and the Mogodé massif, the southwest plain of Diamaré and a large part of the Mayo-Kani basin; because the soils in these areas can better absorb water and avoid stagnation. The medium drainage areas are circumscribed by the Logone basin, Mayo-Kani basin, up to the Mayo-Danay plain. The areas of poor drainage, on the other hand, are circumscribed by the Méri mountain range passing through the Koza basin. Figures 7 below present the soil map (8a), the textural map (8b) and the drainage map (8c) of the study area.

3.7. Analysis of topographical parameters of reforestation sites

The study area includes the Mandara Mountains to the west, the Danay-Logone flood plains to the east (yaéré), the Mayo-Kebbi peneplain running as far as Mayo-Kani to the south, swamps, wet/dry areas, seasonal lakes and Lake Chad in the north. The vast majority of the study area belongs to the endorheic basin of Lake Chad. The slopes in this area are characterized by low inclinations. Indeed, they tend to have a relatively low inclination in Diamaré, Mayo-Kani, Mayo-Danay and Logone and Chari, unlike the mountainous area of Mayo-Tsanaga. Gentle slopes are more common, with slope angles generally less than 10 degrees. This is due to the relatively flat relief and the characteristic geological formations of the territory. Figure 8 below presents the topographical structure of the study area.

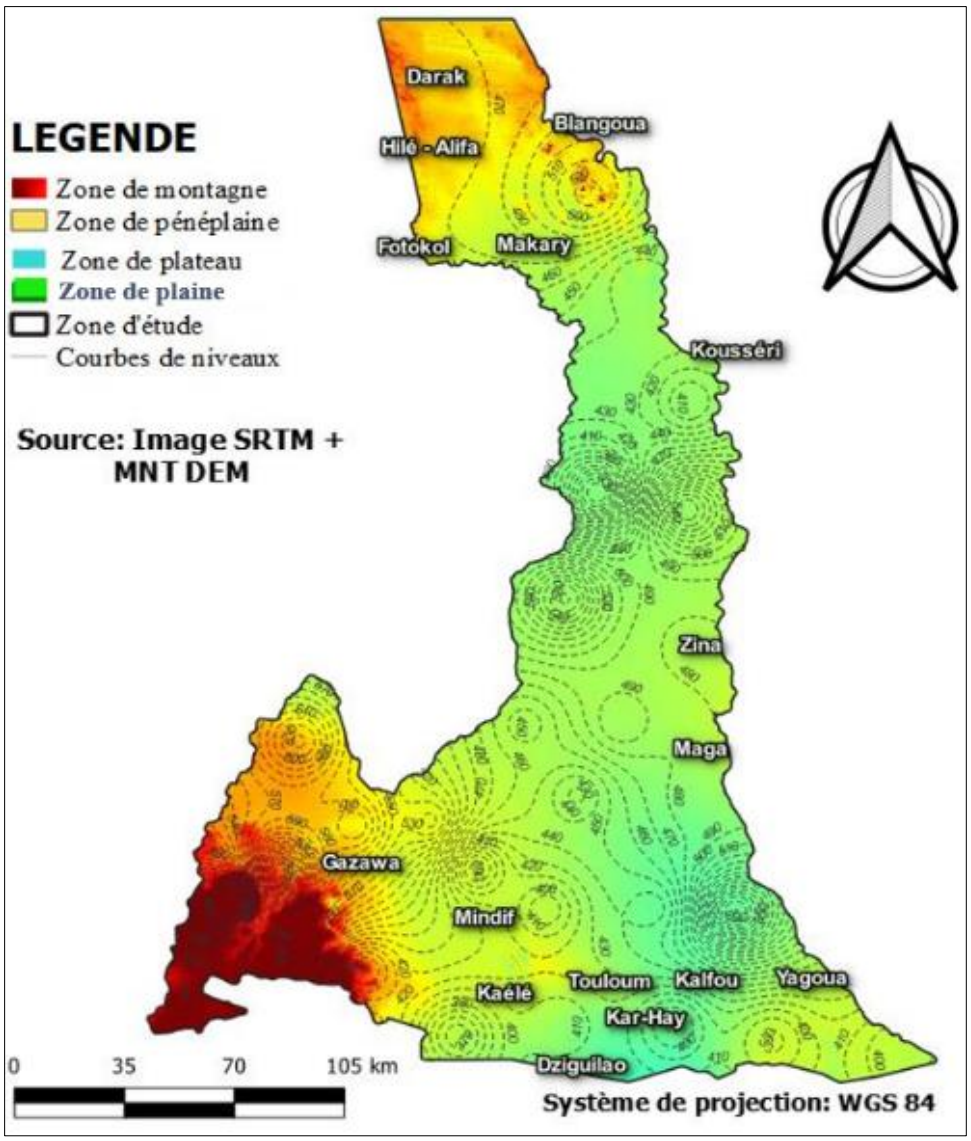

Figure 8 Drainage map of the study area

3.8. Natural habitation of the study area

The current state of the natural habitat in the study area is of concern due to various factors, including agricultural expansion, deforestation, increasing population pressure and the effects of climate change. These factors lead to significant modifications to the natural ecosystem of sites at stratified levels, with negative effects for biodiversity. The natural habitat of the study area is mainly composed of meadows, shrub savannahs, tree savannahs, steppes and rarely grassy savannahs (see fig. 9).

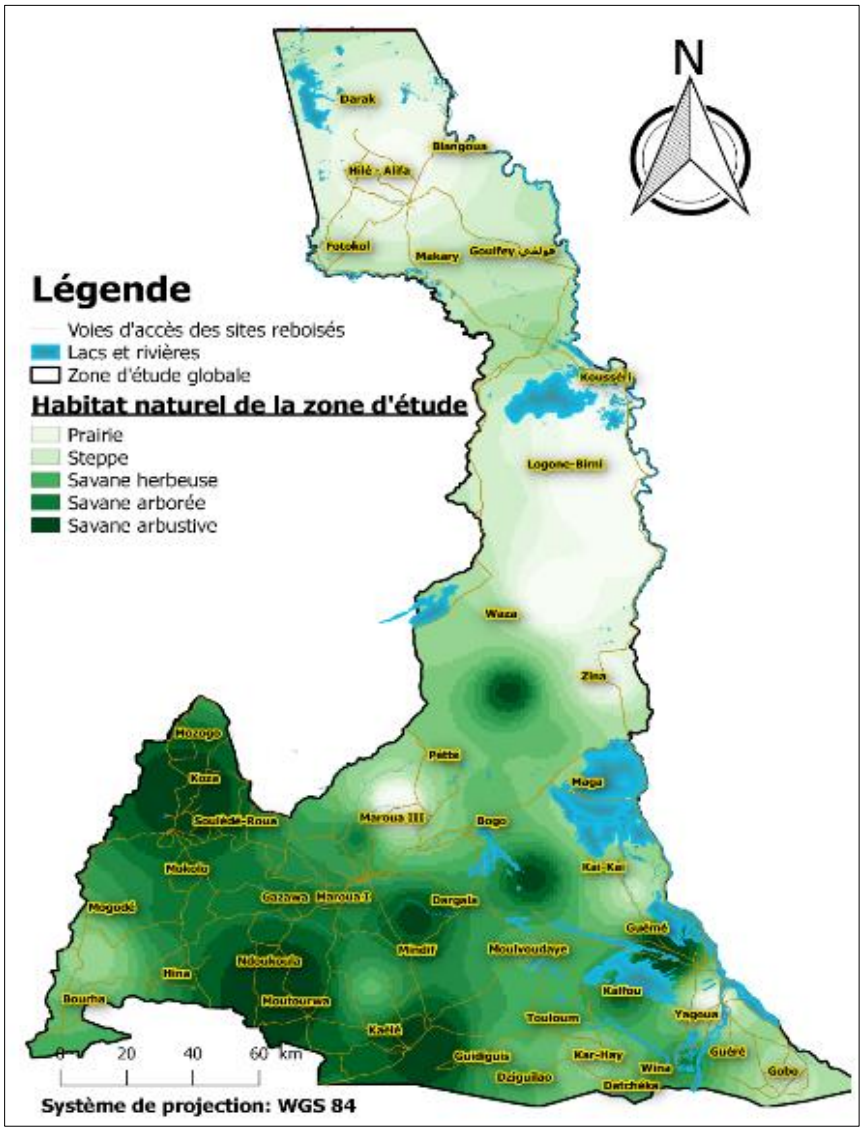

Figure 9 Natural habitation of the study area

He clearly observed that the stand is more leafy when we leave the northern part of the study area for the southern part.

4. Conclusion

Having reached the end of this research work, it was a question for us of characterizing the reforestation sites of the "OSV" project in 5 of the 6 departments of the far-north region. However, the climate of the study area is Sudano-Sahelian, with a rainfall regime characterized by precipitation which varies according to latitude, ranging from 900 mm in the south to 700 mm in the north. Therefore, in January, relative humidity is low, with an average of 40% to 60%. In December, the humidity is ideal, with temperatures ranging from 21°C to 34°C and no significant precipitation. Vertisols are dominant in all the sites of Diamaré, in certain sites of Mayo-Kani and Mayo-Tsanaga. As for ferruginous soils and Arenosols, they are present in the sites of Mayo-Tsanaga, Mayo-Danay and slightly in the sites of Mayo-Kani and Logone-Chari. Finally, the study area includes the Mandara Mountains to the west, the Danay-Logone flood plains to the east

(yaéré), the Mayo-Kebbi peneplain extending to Mayo-Kani to the south, swamps, wet/dry areas, seasonal lakes and Lake Chad in the north. The vast majority of the study area belongs to the endorheic basin of Lake Chad. The natural habitat of the study area is mainly composed of meadows, shrub savannahs, tree savannahs, steppes and rarely grassy savannahs. In perspective, we plan to evaluate the effectiveness of the reforestation action in this area.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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