IDENTIFICATION AND CHARACTERIZATION OF LOWLANDS IN THE OUADDAI REGION USING LANDSAT AND SRTM IMAGES

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Abstract: In arid and semi-arid zones, the use of lowlands has considerably increased in number and surface area, due to the fertility of their soils and their hydromorphic character. The aim of thisarticle *is to* identify and characterize lowlands in the Ouaddaï region using satellite imagery. The methodological approach is based, on the one hand, on the semi-automatic method that took into account vegetation indices (NDVI) and parameters (slope and water accumulation) generated from Landsat OLI TIRS and SRTM images. On the other hand, field surveys confirmed the results of the spatial analyses. Analysis of the NDWI for 2022 clearly shows thathigh values in the range -0.18 to 0.59 are observed almost everywhere in the mapped area. TheNDVI calculation enabled us to estimate the water content of the foliage of the vegetation cover,which is between -0.15 and 0 for the lowlands in the dry season. A reclassification of slopes enabled us to categorize slopes (1% to 3%). The reclassification of slopes enabled us to distinguish a broad plain in almost the entire area of the region, rich in lowlands. The field method enabled us to categorize the lowlands: primary lowlands with intense rural activities (Ouadi Biteha, Ouadi Hamra, Ouadi Chok etc.) and secondary lowlands where activities are limited.

Keywords: Identification, Landsat, SRTM, Remote sensing, Biogeography, Ouaddaï, Chad.

IDENTIFICATION ET CARACTÉRISATION DES BAS-FONDS DANS LA RÉGION DU OUADDAÏ À L'AIDE DES IMAGES LANDSAT ET SRTM

Résumé : Dans les zones arides et semi-arides, l'exploitation des bas-fonds a considérablement augmenté en nombre et superficie en raison de la fertilité de leurs sols et de leur caractère hydromorphe. Le présent article a pour objectif d'identifier les bas-fonds à partir des Images satellitaires dans la région du Ouaddaï et de les caractériser. L'approche méthodologique est basée d'une sur la méthode semi-automatique qui a pris en compte les indices de végétation (NDVI) et les paramètres (pente et accumulation d'eau) générées à partir des images Landsat OLI TIRS et SRTM. D'autre part, les enquêtes de terrain ont permis de confirmer les résultats des analyses

spatiales. L'analyse du NDWI de 2022 nous montre bien que les fortes valeurs de l'ordre de -0,18 à 0,59 sont observées un peu partout dans la zone cartographiée. Le calcul du NDVI a permis d'estimer la teneur en eau du feuillage du couvert végétal, qui est compris entre -0,15 et 0 pour les bas-fonds, et ceci en saison sèche. Une reclassification des pentes a permis de catégoriser les pentes (1% à 3%). La reclassification des pentes a permis de distinguer une large plaine au dans presque la totalité de la surface de la région, riche en bas-fonds. La méthode de terrain a permis de catégoriser les bas-fonds : les bas-fonds primaires avec d'intenses activités rurales (Ouadi Biteha, Ouadi Hamra, Ouadi Chok etc.) et les bas-fonds secondaires où activités sont limitées.

Mots-clés : Identification, Landsat, SRTM, Télédétection, Biogéographie, Ouaddaï, Tchad

Introduction

In massive and xeric zones, lowlands are agrosystems. They are exploited because of the fertility of their soils and their hydromorphic character. These lowlands are therefore of great interest in an environment marked by climatic variability and changing agricultural land use patterns (Souberou et al., 2016:78). According to Oloukoi (2005:63), lowland ecosystems have emerged as a set of resources whose development is becoming an imperative necessity for the development, intensification and diversification of agricultural production. In the Ouaddaï region of Chad, located in the Sahelo-Saharan zone, inland valleys are a major asset for the development of agricultural production. What is the lowland potential of the region? Development of these lowlands requires knowledge of the available potential through their spatialization. Based on a field approach, inland valleys in the region are environments with complex characteristics. They can be explained by their pedogenesis and fair agro-pedological potential, their particular hydrology and their abundant and varied pastures. Inland valleys in the region are characterized by their hydro-agricultural development and farming techniques in a changing social context. The identification of the potential of the lowlands through field surveys is limited. It is in this sense that identification and characterization using remote sensing is necessary to have a systematic source of information on these agrosystems. The present study is intended as a contribution in this direction. Its aim is to identify and characterize lowlands in the Ouaddaï region using satellite imagery.

1. Methodology

1.1 Geographic research framework

Ouaddaï is located in eastern Chad, more precisely between 13° 20'00" and 14° 00'00" north latitude and between 20° 00'00" and 22° 10'00" east longitude (Figures 1). Ouaddaï comprisesthe departments of Ouara, Abdi and Assounga. It covers an area of 3,0196 km^2 (INSEED, 2009:56)and is home to an estimated population of 731,679, 607,854 of whom live in rural areas (RGPH2[1], 2009:87), i.e. 6.5% of Chad's total population. The region's demographics are characterized by a dominant female population (51.7%), with an imbalance between rural and urban areas, at 16.9% and 83.1% respectively (RGPH2, 2009:88). The region is home to a numberof ethnic groups, largely dominated by the Maba. In addition to this population, there are 103,017 Sudanese refugees (OCHA, 2012:3) from Darfur. The Ouaddaï region offers a contrasting relief, characterized by an altitude of between 400 and1000 m, drained by a dense hydrographic network consisting solely of temporary

watercoursescommonly referred to as "*Ouadi*". This spatial contrast influences the edaphic factor and determines the distribution of vegetation according to the humidity of the area (Pias J. 1970:154). The geological substratum consists of infrequent metamorphic rocks and dominant granitic rocks. All these formations are essentially Precambrian in age and cover the entire region. Therugged landscape features a variety of facies. As for the sedimentary formations, they result from the accumulation of detrital materials of varying grain size, brought by rivers from the massifs (Pias J. 1970:15).

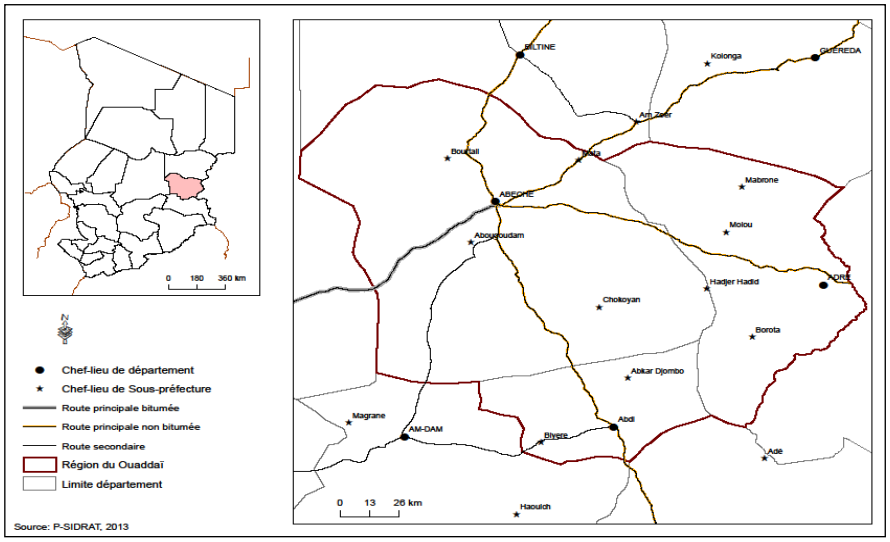


Figure 1: **the Ouaddaï region of Chad**

The Ouaddaï region belongs to the Sahelian climatic zone, which lies between isohyets of 200and 500 mm. The climate is characterized by the alternation of a very long dry season (9 months), generally marked by hot temperatures and drying winds, and a short rainy season (3 months) marked by irregular rainfall. Rainfall is the main physical factor influencing land use in the region.

1.2 Data and methods used

-The data

The data used for this study are:

- A Landsat OLI TIRS satellite image scene
- The Srtm digital terrain model
- A topographical map, sheets of Adré, Biltine and Abéché
- A geological map of the Ouaddaï region
- A geomorphological map
- Climatological statistics (precipitation, temperature)
- GPS (Global Positioning System) geolocation points of the lowlands exploited in the region
- The types of hydro-agricultural management implemented in the lowlands were assessed onthe basis of direct field observations.

-Data analysis and processing

The data processing method involves a series of stages leading to the inventory of lowlands

inOuaddaï province.

2. Results

2.1 Identification parameters

-Vegetation index

Analysis of figure 2 shows that areas with watercourses and low relief have high reflectance. These areas of high reflectance (figure 3) show the high density of vegetation in wetlands, as well as soil moisture levels containing a good quantity of biomass. The Ouaddaï RegionVegetation Index (NDWI) was used to characterize the chlorophyll activity of the vegetation. Analysisof the 2022 NDWI shows us that high values in the range -0.18 to 0.59 are observed throughout the mapped area. This indicates the presence of vegetation characteristic of lowland ecosystems.

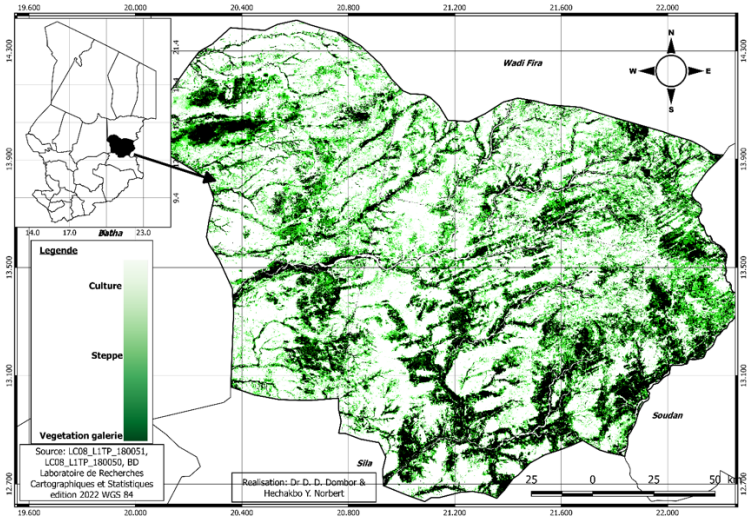


Figure 2: Extraction of areas with high NDVI values in the Ouaddaï region

The NDVI calculation was used to estimate the water content of the canopy foliage, which is between -0.15 and 0 for the lowlands in the dry season.

Spectral signatures

The aim of this section is to determine spectral profiles for different land-use units. Theaim is to determine the different luminance values (gray levels) for each of the main landscape units: lowlands, gallery formations, bare ground, crops, watering holes, cultivated areas, etc.

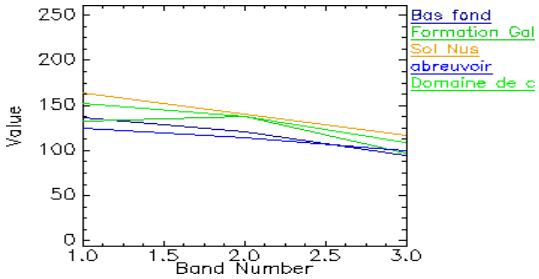


Figure 3: spectral signature

Figure 4 shows some of the spectral profiles determined on selected landscapefeatures. Signatures are quite different in bands 1, 2 and 3.

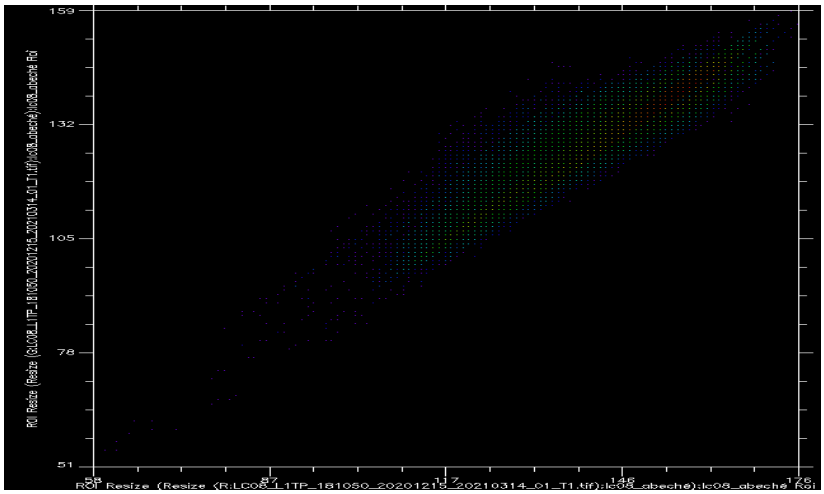


Figure 5: Spectral profiles of landscape features

The two-dimensional histogram expresses the distribution of all pixels in the image in the plane constituted, for example, by red on the x-axis and near infrared on the y-axis. These two bands are those in which there is the greatest contrast between the various landscape units,as seen in the spectral profiles.

-Slope levels

The slope map (figure 6) is obtained from the digital terrain model, which shows the different topographic facets (high and low spots) and the main drainage axes (direction of flow) of the Ouaddaï region. Analysis of figure 6 shows that slopes vary from 0 to 100%, indicating the presence of undulations that contribute to the establishment of lowland ecosystems.

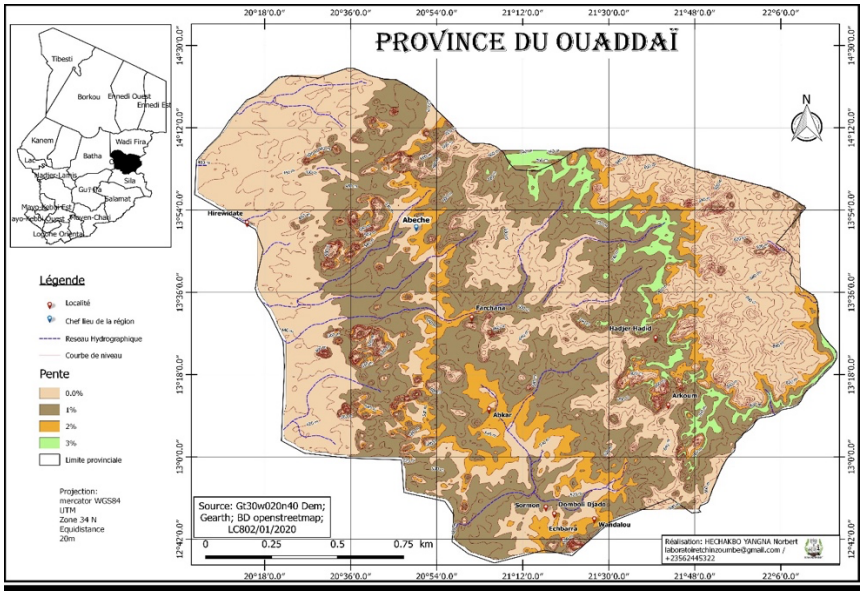


Figure 6: Slope map

Reclassification of the slopes revealed a broad plain covering almost the entire area, rich inlow-lying areas.

-Stagnant water surface

Water accumulation areas are generated from the flow direction map and are considered as surfaces on which water stagnates for a time before infiltrating or flowing towards temporarywatercourses (drains). The value of water accumulation surfaces varies from 0 to 1431 and indicates the degree to which the surface receives water from nearby slopes (Figure 7).

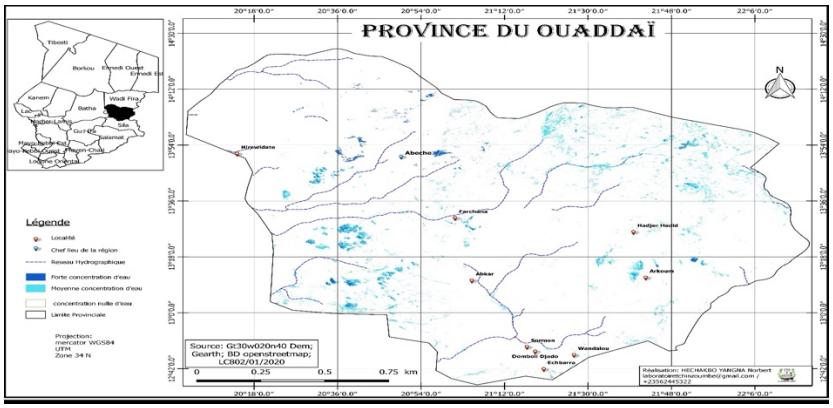
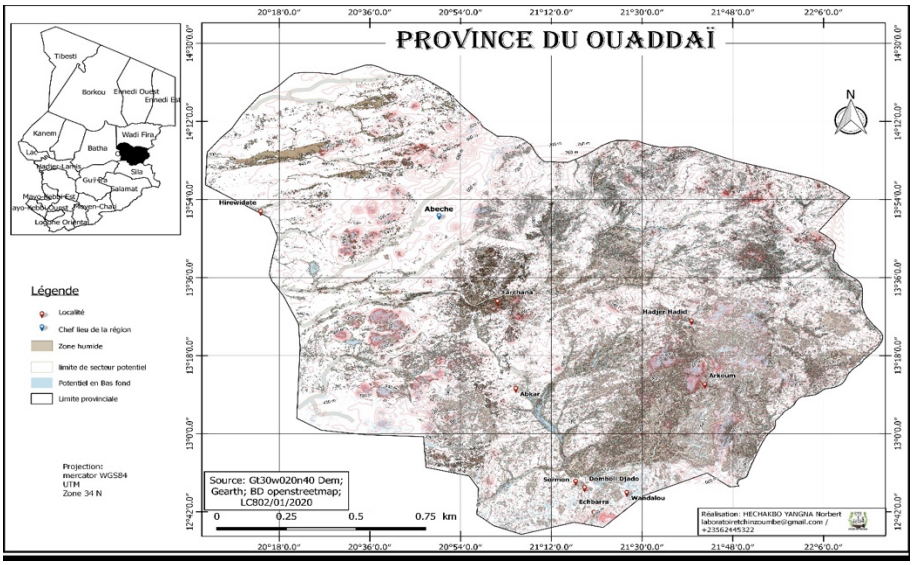


Figure 7: Map of water accumulation zones

2.2 Potential lowland areas

The inland valley potential (figure 8) is extracted by intersecting the cartographic results of thepreviously established identification criteria. A multi-criteria analysis of the previously established indices and parameters for selecting lowland areas, using Boolean superposition (intersection, union), revealed the lowland potential of the Ouaddaï region (figure). The Ouaddaï region is endowed with lowlands covering an area of 3,015.47 Km^2 , or 9.98% of the total surface area. It can be seen from the above that Ouaddaï has large

wetlands.



2.3 Lowlands identified by field method and their characteristics

In order to compare the results of the spatial analysis, multiple observations of the study area have enabled us to inventory a number of lowland types with multiple but complex characteristics linked to the evolution of their banks or the denaturation of their flood beds.

-Primary lowlands: areas of intense rural activity

Primary lowlands are places where market gardening, fruit-growing and livestock production are developed and diversified. The simultaneous practice of these agricultural and pastoral activities can be explained by the availability of favorable land resources, shallower water tablesand abundant pastures. This is how they differ from one another:

✓ *Bitéha lowland*

Also known as Ouadi Bitéha, is located between 13°31'29"N and 20°54'07"E. It is oriented east-west, with an altitude of between 400 and 500 m. It stretches over virtually flat terrain, from which it derives its Arabic name "couché au ventre" ("lying on one's stomach"). It is concave- convex from upstream to downstream, where its cross-section flattens out. The lowland is characterized by the impressive width of a well-marked sandy minor bed ranging from 200-900m, bounded by banks of between 0.80 and 1.5m in height, used in the dry season for watering livestock thanks to wells and artificial ponds built by farmers. The river is marked bya major bed whose width varies between 50-450m on both sides. During the rainy season, the watercourse is fed by the Mandjobo and Amlayouna rivers, which are junction ouadis. The soilhas a sandy-loam texture and is of average fertility. The average water table is 2 m deep. However, this depth varies according to the position of wells and sumps in the lowlands. Upstream, the width of the major bed narrows to zero meters (0m) due to isolated knolls. The lowland is intensively farmed. Market gardening, fruit growing and livestock farming are practiced. The exact total surface area is difficult to estimate due to the scattered nature of the cultivated plots. In terms of plant cover, it consists of a forest gallery whose dimensions are shrinking due to clearing for the extension or installation of agricultural plots. The Ouadi Bitéhais crossed by the road linking the town of Abéché and Goz Beida. Crossing this large sandy Ouadi is made easier by the

existence of the riffle. To the west of the riffle are three (3) boreholes drilled in 1992 by the German cooperation agency, but destroyed by water currents.On the high slope to the east of this location is the pumping station for the water supplied to thetown of Abéché from boreholes drilled in 2012 by MUNIRCAT.

✓ **Ouadi Hamra lowlands:**

It is located between 13°14'21"N and 21°14'11"E. This low-lying area is oriented east-west andrises from an altitude of 500-800m. It is irregular in shape, with convex upstream and concave downstream slopes. The well-marked minor bed (ranging from 40-100m) describes meanders whose morphology changes according to the magnitude of floods, as a result of excavation, construction of micro-terraces or sandy strips in the flow axes. Marked banks with signs of undercutting are between 0.50 and 2 m high. The width of the major or flood bed narrows upstream but widens downstream, with dimensions ranging from 80-200m. The soil has a silty-clay texture, making it ideal for market gardening and fruit-growing, thanks to the 2 to 3 m highwater table. Despite clearing for cultivation, the vegetation, dominated by woody plants, is wellstocked downstream, but degraded upstream on the Hadjer Hadid side, where the two large camps for Sudanese refugees from Darfur are located.

✓ *The Ouadi Chok lowlands*

It is located between 13°49'32"N and 21°01'6"E. This ouadi flows from northeast to west and rises on a topography of between 400-700 m in altitude. It is convex-concave in shape. The well-marked minor bed (oscillating between 10-30 m), describes meanders. The banks are 1-3 m high. The major bed varies in width from 0 to 300 m, due to the existence of the dyke linkedto the spreading sill bordering the hill upstream and the dam downstream near the village of Matar. The major bed bears traces of functional gullies, while the minor bed is undermined by bank erosion upstream and in its median section. The soil is hydromorphic to pseudogley witha sandy-loam texture, and is currently used for rain-fed and market gardening. The water tablevaries from 3 to 8 m as one moves away from the banks. Despite its depth in the lowlands, thewater table enables crops to be irrigated and water to be supplied to the surrounding villages. The landscape is characterized by sparse vegetation, dominated by thorny species from which the ouadi takes its name "chok".

✓ *Mandjobo lowland*

Located between 13°47'7"N and 21°12'13"E, this low-lying junction runs north-south. Itstretches across a rugged terrain with heights ranging from 600-800m. Deriving its meaning from the Maba language "Mandjobo means: he brought water", the lowland describes a sinuousshape. The minor bed measures between 100-200m and describes meanders whose morphologychanges according to the extent of the floods by digging, construction of micro-terraces or sandy cordons in the flow axes. The banks, which measure between 0.50-1m, are bordered in places by fruit trees. The width of the major or flood bed is reduced by the frequent appearanceof mounds or rocky outcrops in its middle section, but widens to between 100 and 150m both upstream and downstream. The soil has a silty-clay texture. The average water table is 2m, enabling crop irrigation and water supply to farmers. Upstream, farmers intensively cultivate market garden crops. In the middle, the silting-up process is an obstacle to market gardening. In this sector, however, farmers grow cereals. The landscape is characterized by very isolated trees. The Moura village side of the lowland is crossed by the national road linking Chad to Sudan.

✓ *Amlayouna lowland*

Like the previous one, this is a junction ouadi that flows into the Bitéha. It is located between 13°46'N and 21°21'E and stretches over an altitude of 600-800m. Upstream it's called Amlayouna, but downstream it's called ouadi Dalal. It has a complex orientation: first from eastto west, then from the crossing of the national road, it turns south. The name of this low-lying area derives from the name of a large village that is now the capital of the Amlayouna sub-prefecture. The minor bed is 100-200m wide, and meanders with a morphology that changes according to the magnitude of the floods, as a result of hollowing and the construction of sandystrips in the water flow axes. The banks, which measure between 0.50-2m, are bordered in places by a wide band of mango trees, giving it a magnificent backdrop for travelers. The widthof the major bed measures between 20-100m and is covered by a soil characterized by a sandy-clay to silty-clay texture. The water table is between 2 and 3 m high, enabling irrigation of market garden crops upstream and downstream of the lowland. Upstream, the lowland is farmedby Sudanese refugees from the Gaga camp, who rent the land, and downstream by local people.

✓ *The Farchana lowland*

The river is located between 13°34'09"N and 21°48'60"E, at an altitude of 700-900m, and flowsfrom northeast to southwest. The minor bed is 30-200m wide, and meanders with a morphologythat changes according to the magnitude of floods by digging or building sandy strips in the flow axes. Bank heights range from 0.50-3m. It is bordered in places by dense mango groves, providing a magnificent backdrop for travellers crossing the lowland on the national road to Sudan via the town of Adré. In the dry season, wells drilled into the bottom of the minor bed are used to water cattle and supply the local population. The major bed is 20-100m wide, linedwith sediments characterized by a sandy-clay to sandy-clay texture. In places, the major bed ismarked by siltation, traces of gullies and undercutting of the banks towards the plots. To the north of the national road, there are a number of brickworks, and to the west (approx. 1.5km), there are two (2) boreholes that pump water to Sudanese refugees who have been living in the Farchana camp since 2003 (the largest refugee camp in Chad). The land is farmed both by thelocals, who grow rainfed crops, and by the refugees, who grow market garden produce in widelyscattered plots.

-Secondary lowlands: environments of limited activity

Secondary lowlands are those where livestock are watered and grazed for a period of time. Theysupply the surrounding towns and villages with water all year round, and enable non- agricultural activities to be carried out in the dry season.

✓ *The Himeïmé lowlands*

Situated between 13°39'N and 20°44'E, its topography ranges from 400-600 m above sea level.It flows from east to west. The minor bed, which is well marked upstream with a bank height of 1-2m, disappears at the Abougoudam boundary before surfacing downstream as far as its junction with the Ouadi Chok near the Matar village dam. The minor bed is around ten meterswide and meanders. Upstream, it is lined with sands plucked from the upper slopes, and downstream with sandy-clay strands. The clay-loam major bed is occupied by wells and sumpsused for watering livestock and supplying water to villages and the town of Abougoudan (headof the nomadic sub-prefecture). The lowlands are home to scattered brickworks, which are undeniably useful in an environment characterized by extreme

poverty. The vegetation cover is very degraded, due to the very high number of sedentary herds and nomadic herds that transhumance seasonally.

✓ *Le bas-fond or ouadi chao or ouadi karano*

It is located between 13°51'N and 20°50'E. Its first name "chao" derives from the plant species known scientifically as *salvadora persica, which is* abundant and dominant downstream from the lowland. This plant species is useful in the region, as the local inhabitants use its roots to brush their teeth, providing significant economic benefits for those who market "natural toothbrushes". Its second name derives from the *Zizyphus spinachristi* dominance of the middlepart of the lowland, precisely on the outskirts of Abéché. It extends over a topography at an altitude of 500-600m, characterized by its longitudinal form. Its minor bed is 10-20m wide, in places occupied by sandy strips and sandy-clay terraces. The major bed, 400-500m wide on either side, is used to extract clay for pottery, which is found at the edge of the lowland's peripheral districts. It is also occupied by substantial brickworks and numerous boreholes, which are used for construction and to supply water to the city of Abéché (capital of the Ouaddaïregion and Ouara department). Some of these factories are veritable "cottage industries", with kilns capable of producing up to 100,000 fired bricks.

✓ *The shallows or ouadi Djilney*

It is located between 13°50'N and 20°45'E. It is elongated over a topography of 500-600m. It flows from north to south. As it crosses the sandy embankments, the 0.50-2m minor bed flattensout slightly upstream, but is clearly identifiable on the stony surfaces downstream up to its junction with the ouadi chao. The major or flood bed, 20-60m apart, is sandy-clay, with a watertable 5-8m deep. The vegetation cover is made up of sparsely planted areas. It is used to supplythe surrounding villages, and for watering and grazing cattle.

3. Discussion

Lowland management requires a solid foundation. These make it possible to identify and characterize inland valleys. According to Clément et al (2008), the design of any lowland development program requires a good knowledge of their location, morphological and hydrological characteristics, land tenure status and current use. Satellite imagery has enabled more precise mapping of these agro-ecosystems, complemented by field data. The identification and characterization of lowlands based on remote sensing data revealed the wealth of lowlands in Ouaddaï available from remote sensing images and on the basis of well-defined criteria following the elaborate computer-assisted automatic processing method. The same conclusion was reached by Chabi et al (2010:448) in a study on the inventory of lowlands in central Benin. For them, the estimation of lowland potential took into account three identification criteria: slope, NDVI and surface area. The use of Landsat imagery (ETM+, OLITIRS) combined with SRTM imagery provides the basis for identification studies of lowland wetlands. For Kafilatou et al. (2017:1618) this completed method is easy to implement from a computer point of view and offers a multitude of tools to help interpret the data, as it enables satisfactory results to be obtained. Lowland mapping using remote sensing data is a major assetfor selecting suitable lowlands for the implementation of farming systems. Although adequate and reliable, characterizing lowland potential using remote sensing and the Geographic Information System requires the use of very high-resolution images for accurate validation of potential lowland areas outside geolocation points (Kafilatou et al., 2017:1619).

Conclusion

The identification and characterization of lowlands combined vegetation indices and parameters (slopes and water accumulation). The analysis of these identification criteria showedthe potential for lowlands that could be easily developed in the Ouaddaï region. Ouaddaï's lowlands account for 9.98% of its total surface area. Whatever their characteristics, inland valleys in the Ouaddaï region depend on climatic conditions. However, the various climatic parameters influence water availability in the different lowlands. Several lowlands have yet tobe developed. Field work has shown that very few are exploited. Some of the lowland potentialidentified by image processing is unused. A more exhaustive inventory is needed to reconstitutea list of lowlands with their characteristics for efficient development.

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