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Changes in the Course of the River Komadugu Yobe during the 20th Century at the Border between Niger and Nigeria

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Abstract

The river Komadugu Yobe in the Lake Chad basin is a seasonal river, about 370 km long and with an average highest flow of 34 m^3/s during the time period of 1957 to 1976. The river is dynamic with plenty of meanders and oxbow lakes along its sides. Komadugu Yobe's thalweg (the line defining the lowest points in a riverbed) is the natural border between Niger and Nigeria and may change position with the river.

The objective of this study is to explore if and how the course of the Komadugu Yobe has changed during the 20th century and the impact this has on local inhabitants. Another objective is to look at similar examples in the world where the problem with a pending border exists and how this problem is dealt with. The study only concerns that part of the river constituting the border.

Maps and images on different scales and resolutions from the 20th century were compared in a GIS-program to identify possible changes. Subsequently, field observations were conducted in villages along the river together with officials representing local Niger government to permit verification of the observed changes and as a mean to understand the impacts. The results show various changes along the river: a meander that has been cut off, change in the course and erosion.

It is confirmed that the river has changed its course at numerous times during the 20th century and continues to do so. The most palpable influence of this change, as concerns local populations, is erosion of the riverbanks, which destroys and threatens houses and fields.

Key words: river, Komadugu Yobe, GIS, semiarid region, international boundary, thalweg, meander, Lake Chad basin

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First of all I would like to thank my supervisor Guillaume Favreau for giving me this interesting subject for my master's thesis and make my dream to carry it out in Africa possible. I want to thank him too for taking his time to go to Diffa with me and help me during the field visit; without his excellent skills of communication and observation of details, the results would not have been the same. I would also like to thank him and my supervisor Gerhard Barmen for their valuable comments throughout the project, on my report and the figures.

I would like to thank IRD in Niamey for welcoming me to work with them. Also, the field visit would not have been possible without their excellent driver Abdoulaye Oumarou who drove me safe and sound to and from Diffa and took me to the villages, which was not always easy.

I want to thank Ph.D. Yahaya Nazoumou at the Abdou Moumouni University in Niamey for helping me with the GIS-program and the georeferencing and also for giving me advices to my report.

I would like to thank the Ph.D. student Mathieu Le Coz for sharing information from his thesis with me and for taking his time to help me whenever I needed.

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I want to thank the technical assistant Monique Oï at IRD for taking her time to give me important data and to help me with the page layout of my report, in particular the layout of the tables and figures.

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I would like to thank the Ph.D. student Vincent Hiribarren for giving me a reference about international river boundaries.

I would like to thank my housemates Marie, Mathieu and Souleymane for enriching my life and experiences in Niger and for taking care of me.

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Last but not least I want to make a special thanks to François-Noël Cres for putting me in contact with his HydroSciences colleagues from IRD.

Preface

This project started in Montpellier 2009 during my Erasmus year in Polytech' Montpellier. In the spring, I encountered Dr. Guillaume Favreau who works at HydroSciences Montpellier in France and at IRD Niamey in Niger. IRD in Niamey has since the 1950s done research on the Lake Chad basin where the Komadugu Yobe is found. Other researches within IRD connected to the Komadugu Yobe is currently in progress, with several works dealing with the quantification of the recharge from the Komadugu Yobe to the underlying aquifer (for example Mathieu Le Coz, Ph.D. thesis in progress and Maïmouna Ibrahim, Ph.D. thesis in progress). Some of the results of Mathieu Le Coz have been used in this report. The work was also carried out in collaboration with the Department of Geology at University Abdou Moumouni in Niamey (Dr Ing. Yahaya Nazoumou, GIS/hydrogeologist). The French program ANR Sahelp and IRD provided funding for this study.

The study treats the river where it forms the border between Niger and Nigeria and whenever the river is referred to, this part is meant if nothing else is indicated.

Several of the figures in this report are in color. Some of them will be less comprehensible if seen in black and white.

Acronyms and Abbreviations

The report mentions acronyms for organizations and abbreviations. Here follows a list with an explanation to each of them:

Agrhymet : Centre de Formation et d'Application Agro-Hydro-Météorologique (www.agrhymet.ne). An interstate public institute specialized in the science and techniques applied to agricultural development, rural development and natural resource management. It is based in Niamey, Niger.

DRH : Direction Régionale de l'Hydraulique de Diffa. The hydraulic ministry representative in the Diffa region in southeastern Niger.

HydroSciences Montpellier: Laboratory focusing on water sciences (www.hydrosciences.org). Situated in Montpellier, France

IRD : Institut de Recherche pour le Développement (www.ird.fr). A public French research institute. Changed its name from ORSTOM (Office de la recherche scientifique et technique outre-mer) in 1998.

LEGOS : Laboratoire d'Etudes Géophysique et Océanographie Spatiale (www.legos.obs-mip.fr/). A research organisation based in Toulouse, France.

PADL : Projet d'Appui au Développement Local. It is a project focusing on development funded by the African Bank of Development, African Fund of Development, the Niger government and village communities.

SRTM DEM: Shuttle Radar Topography Mission, Digital Elevation Model (www2.jpl.nasa.gov/srtm/). DEM is a digital representation of the ground surface topography or terrain.

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1 Introduction

The Komadugu Yobe is forming the border between Niger and Nigeria from the village of Tam in Niger until its mouth into the Lake Chad. The border is one out of 238 international boundaries in the world that follow a river for at least a part of their course (International Boundaries Research Unit, 2008). There are various interpretations what Komadugu Yobe means: "river river", "river from Yobe" or "the big Komadugu" (Anderson, 2009, pers. com.).

The Komadugu Yobe basin is about 148,000 km^2 (Oyebande, 2001). It has its source in the plateaus of Kano and Jos in Nigeria (Ministère de l'Hydraulique, de l'Environnement et de la Lutte Contre la Désertification, 2002). The Hadejia river and Jama'are river in Nigeria together forms the Komadugu Yobe (Oyebande, 2001). The basin can be seen in figure 1.1.

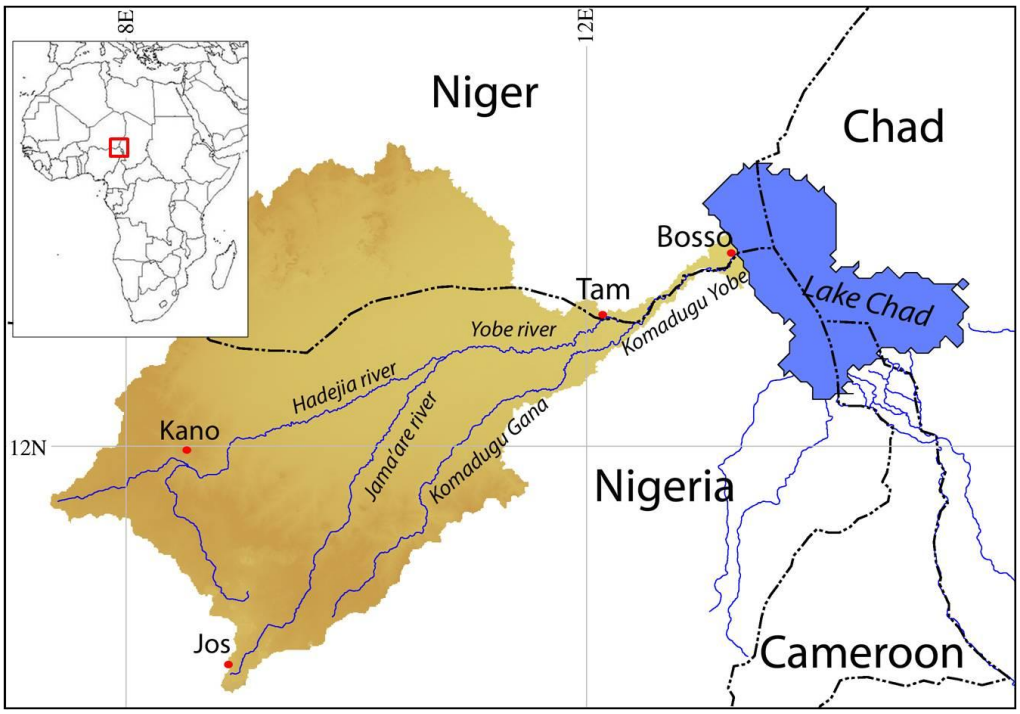

Figure 1.1. The Komadugu Yobe basin and its location in Africa (Revised from Le Coz, 2009).

The flow is dependent of the rainy season and the river is dry for some months each year. The downstream part forming the border is about 370 km long. The distance between the village of Tam and the river's mouth into the Lake Chad is about 150 km as the crow flies. The channel is about 20-40 meters wide.

The river loses water due to infiltration, dispersion to the oxbow lakes and the surroundings during the high water period, evaporation and also water catchments by the local inhabitants. Infiltration is the most important loss (Tidjani Ousmane, 2009). Sand deposits in the river were recently reported to make it shallower (Groupe Art & Génie, 2009).

1.1 Objectives

The Komadugu Yobe is meandering along its way to its mouth into the Lake Chad. Meandering rivers are dynamic and tends to evolve over time. The first objective is to find out if there are any changes in the river's course that have occurred during the 20th century and to identify the type of changes. This objective includes also the goal to quantify the changes by calculating the surface area difference along the river between different years.

The changes might have an impact on the local inhabitants. The second objective is to describe these impacts and to find out if there are any local organizations dealing with them. Another objective is to study what the law says about the border.

The Komadugu Yobe is not the only river in the world marking the border between two countries. The third objective is to study other similar rivers, preferably in Africa to get examples from the same continent. The examples will be used as a reference concerning problems that may occur with a pending border and changing river and how they are dealt with.

1.2 Description of the Komadugu Yobe

1.2.1 Map over the Komadugu Yobe

The next page shows a map of where the Komadugu Yobe forms the border between Niger and Nigeria. All the names of the towns and villages mentioned in the report are also marked in the figure.

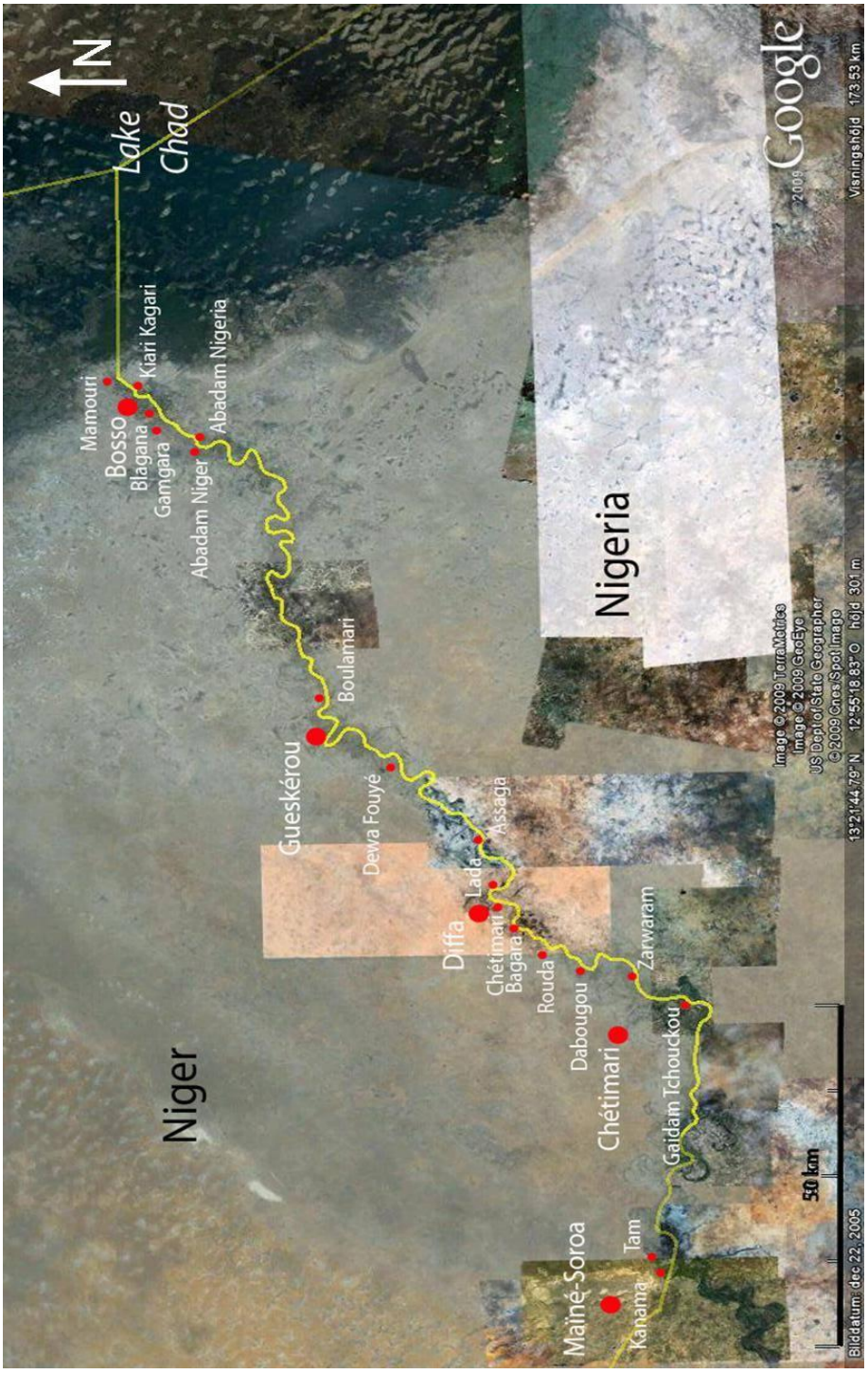

Figure 1.2. Composite satellite image from 2005 over the Komadugu Yobe with towns and villages mentioned in the report (revised from Google Earth, 2009).

1.2.2 Climate

The Komadugu Yobe is situated in the Sahel region in Africa, just south of the Sahara desert. The rainy season in this region is from June until September and the dry period is from October until May. The mean annual rainfall during the period 1981-2000 in Diffa is 250 mm. The mean annual rainfall in Maïné-Soroa is 374 mm during the period 1936–2000 while the mean annual temperature is 27.9°C between 1951 and 1990 (Gaultier, 2004).

There are two main winds; the monsoon and the harmattan. The harmattan is a northerly to easterly wind bringing sand-dust and blows during the dry season. The West African monsoon brings the rain in the summer (Warner, 2004).

1.2.3 Flow Characteristics

The daily flow in the river has been measured in Gueskérou between 1957 and 1976, with a few periods with no measurements (fig.1.3).

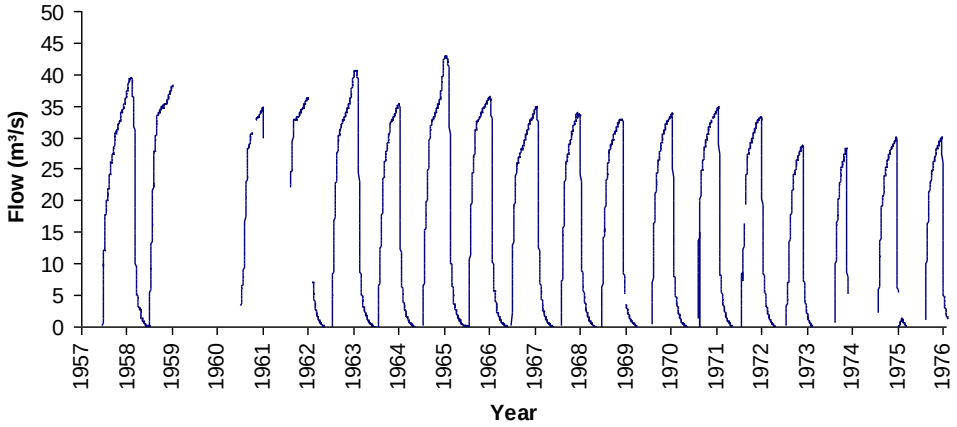

Figure 1.3. Daily flow in Gueskérou from 1957 to 1976 (Data obtained from IRD and DRH).

The annual runoff volume (fig.1.4) has been measured in Bagara from 1963 to 2002. Figure 1.5 shows the runoff volume converted to millimeter for the same years. The diagram indicates that the runoff volume corresponds to a runoff of two to seven millimeters each year for the Komadugu Yobe basin (the basin for the river in Bagara is considered 140,000 km^2).

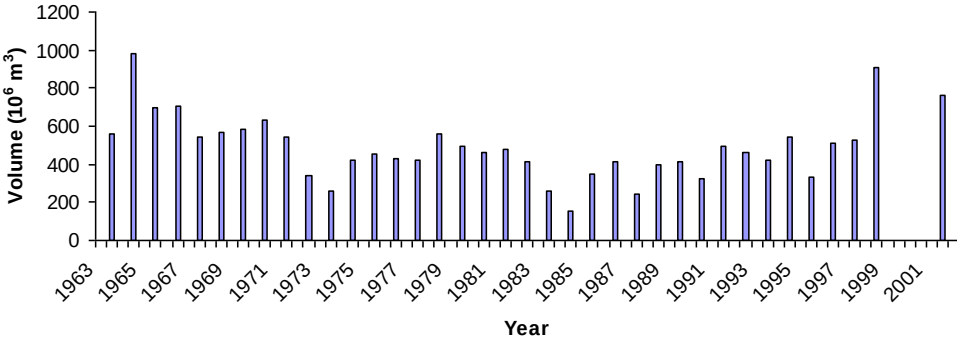

Figure 1.4. The annual runoff volume measured in Bagara from 1963 to 2002 (Data obtained from DRH).

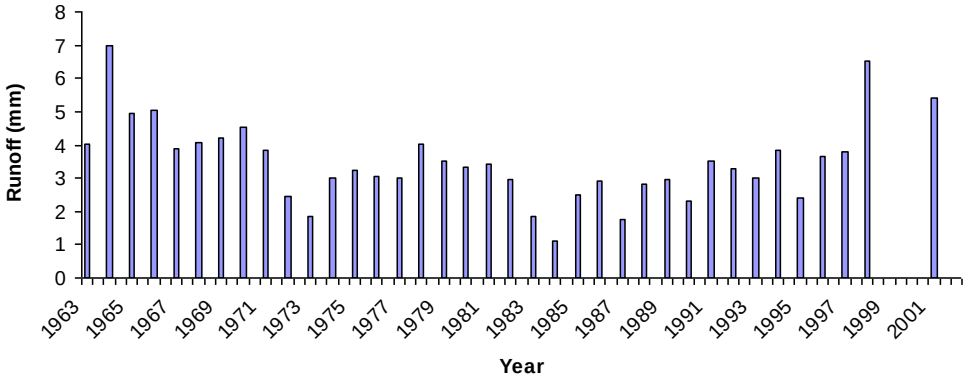

Figure 1.5. The annual runoff in millimeters for the Komadugu Yobe basin from 1963 to 2002. (Data obtained from DRH)

The period of which the river flows each year has been measured in Bagara from 1966 to 2002. The water in the river usually arrives in June or July (fig. 1.6). In 1970, 1973 and 1975 the water arrived in August. The water usually stops flowing in February or March (Data obtained from DRH).

Figure 1.6. Arrival of the seasonal Komadugu Yobe in Gueskérou, 21st of July 2009 (Photo by S. Anderson, pers. comm.).

1.2.4 Dams

Dams and reservoirs have an impact on the water quantity in the river. The three principal constructions in the Komadugu Yobe basin are in the Hadejia river system in Nigeria. The first dam, the Tiga Dam, was completed in 1974. The others were completed in 1992 (Oyebande, 2001).

1.2.5 Morphology

The riverbanks of the Komadugu Yobe consist mainly of fine sand and silt (Sogetha, 1962 a).

Figure 1.7 shows different cross-sections of the valley where the river flows. The valley is more significant upstream than downstream.

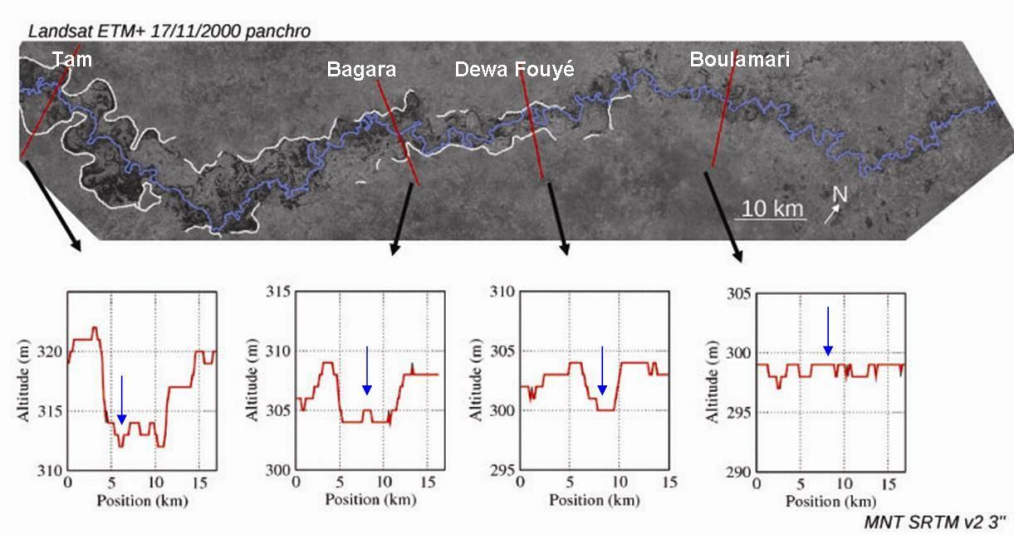

Figure 1.7. The changes in the cross-section of the Komadugu Yobe valley upstream to downstream. The blue arrows indicate the approximate position of the river's channel (revised from Le Coz, 2009).

Figure 1.8 shows the slope of the riverbed upstream to downstream. The altitude is measured from a 3" SRTM DEM (Shuttle Radar Topography Mission, Digital Elevation Model) which has an approximate resolution of 90 meters.

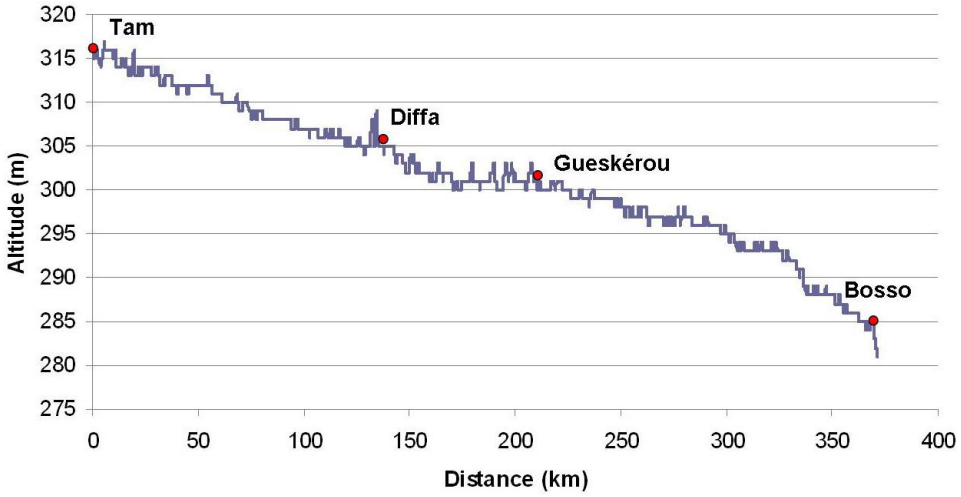

Figure 1.8. The slope of the riverbed from Tam to Bosso (Revised from Le Coz, 2009).

1.2.6 Water Use

The water from the Komadugu Yobe is mainly used by the local inhabitants for irrigation. The cultivators pump the water directly from the river or from the oxbow lakes. The oxbow lakes are replenished by the river during the high water period or from pumping from the river to the oxbow lakes. The oxbow lakes surrounding the channel along its course stocks water some months after the river has stopped flowing (Ministère de l'Hydraulique, de l'Environnement et de la Lutte Contre la Désertification, 2002). There is also a productive fishing activity in the Komadugu Yobe basin (Tanko, 2007).

1.2.7 Lake Chad's Influence

The water level in the Lake Chad is fluctuating (Olivry et al., 1996). The fluctuation has an impact on the river's course at the delta. Figure 1.9 shows the part of the lake where the river has its mouth, in different years. The yellow line is constant over the years and can be used as a reference for the changes.

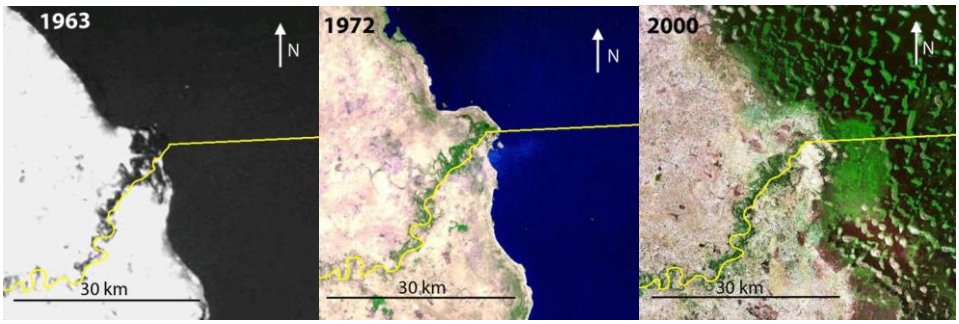

Figure 1.9. Komadugu Yobe's mouth in Lake Chad during different years (Google Earth, 2009).

Figure 1.10 shows the variation in the water level in Lake Chad from 1954 to 2004. The measures were extracted from three different places: water level observations in Bol and N'Guigmi, and estimated levels from the Topex/Poseidon satellite. Bol is a village situated in Chad from where the water level in the southern pool of the lake is measured. N'Guigmi is a village situated in Niger and from where the water level in the northern pool, where the Komadugu Yobe intersects, is measured. Topex/Poseidon is a satellite measuring the level in the southern pool. As seen in the figure, the water level has diminished since 1954 with a sudden drop in the 1970s.

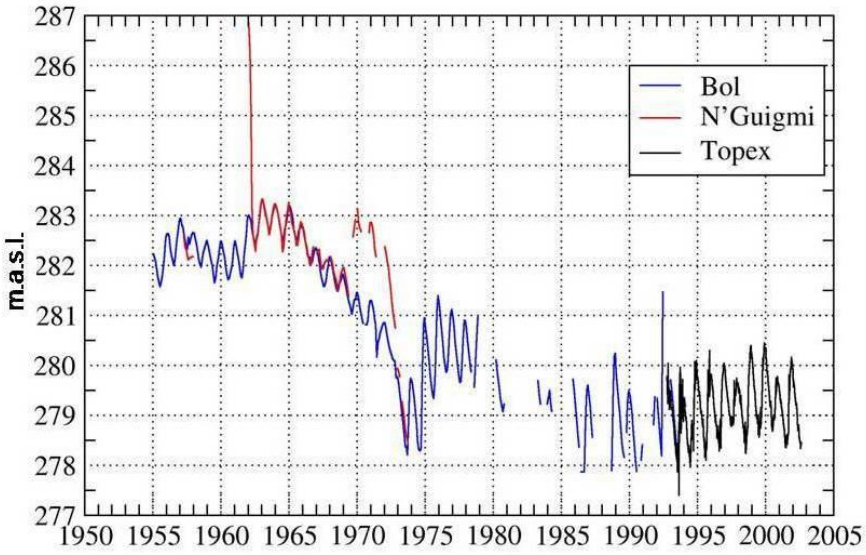

Figure 1.10. Lake Chad's altitude from 1954 to 2004 measured from three different places. (Le Coz, 2009. Data obtained from: Olivry et al (1996), ORSTOM and LEGOS).

2 Methodology

By studying maps and images from the 20th century, changes in the river's course were identified. After the inventory of maps and images had been made, the maps were georeferenced and imported in a GIS-program for digital handling. Finally the changes were verified by a field visit along the river. The following sections give a description of each of these phases.

2.1 Handling of Maps and Images

2.1.1 Inventory

First an inventory of the maps showing the Komadugu Yobe in the 20th century was made. Available maps and their information are described below in tables 2.1, 2.2 and 2.3.

Table 2.1. List of available maps at a scale of 1:500 000 and their information.

Scale 1:500 000		
Name	***Gamagarim-Mounio-Manga, Tilho mission***	***Nguigmi***
Published	-	1967
Publisher	-	I.G.N. Paris
Drawn from	Astronomic observations 1903-04	Maps, 1:200 000 scale, I.G.N. Paris : Kossatori 1965 Ngourti, 1965 Lagané 1964 Maïné-Soroa 1962 Maps, 1:200 000 scale, I.G.N. Dira 1961 Nguigmi 1961 Nokou 1960 Bosso 1959 Bol 1959
Coordinates	Paris meridian	-
Ellipsoid	-	Clarke 1866
Projection	Flamsteed	Lambert Conformal Conic
Part	Upstream, Tam to Gueskérou	Whole river
Source	The National Library of France, Paris. www.bnf.fr	Agrhymet, Niamey
Remarks	Has observations points with exact coordinates written on a table for certain villages and places. For more information from the Tilho mission see : *Documents Scientifiques de la Mission Tilho*, Imprimerie Nationale, Paris, 1910/1914	-

Table 2.2. List of available maps at a scale of 1:200 000 and their information.

Scale 1:200 000			
Name	***ND-33-VIII Boso***	***ND-33-VII Maïné-Soroa***	***ND-33-VIII Bosso***
Published	1959	1962	1979
Publisher	Geographic service in Brazzaville	I.G.N. Paris	I.G.N. Paris
Aerial photos	1950-51	1957-58	January 1975
Ellipsoid	Clarke 1880	Clarke 1880	Clarke 1880
Projection	UTM	UTM	UTM
Part	Downstream, Boulamari to the river's mouth	Upstream, Tam to Boulamari	Downstream, Boulamari to the river's mouth
Source	IRD, Niamey	I.G.N.N, Niamey	Geographic department, Abdou Moumouni University, Niamey

Table 2.3. List of available maps at a scale of 1:50 000 and their information.

Scale 1:50 000			
Name	***Maïné-Soroa 1 a***	***Maïné-Soroa 2c***	***ND-33-VIII Bosso 3a, ND-22-VIII Bosso 3b, ND-33-VII Diffa 2d, ND-33-VII Diffa 4b***
Published	1959	1965	1979
Publisher	I.G.N. Paris	I.G.N. Paris	I.G.N. Paris
Aerial photos	1950-51	1957-58	January 1975
Ellipsoid	Clarke 1880	Clarke 1880	Clarke 1880
Projection	UTM	UTM	UTM
Part	Downstream, around Tam	Downstream, around Diffa	Upstream, Dewa Fouyé to the river's mouth
Source	Geographic department, Abdou Moumouni University, Niamey	Geographic department, Abdou Moumouni University, Niamey	Geographic department, Abdou Moumouni University, Niamey

The month the aerial photos were taken is not noted on some of the maps as this information was not available. See figure 2.1 for an example of what the printed map from astronomic observations in 1903-04 looks like.

There was another map at a scale of 1:500 000 from 1907-08 (Tilho mission) available. The map had been scanned in black and white and does not show the Komadugu Yobe clearly. However, this map indicates the coordinates for the river's mouth: N 13°42'23"6, E 11°02'33"0. In the international Greenwich meridian, the coordinates are N 13°42'23"6, E 13°22'47"03.

The majority of the maps were available in digital format at the Geographic Department at Abdou Moumouni University in Niamey, Niger. Printed maps that were not digitalized were scanned either in A0 format at the Geographic Department in the Abdou Moumouni University in Niamey, or either in A3 format at Agrhymet in Niamey.

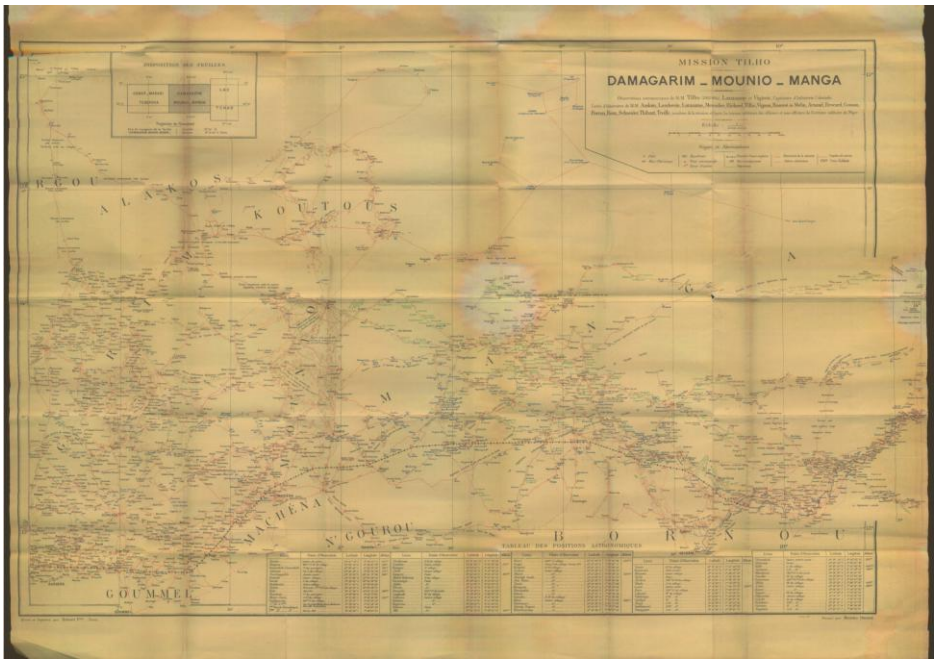

Figure 2.1. The printed map at a scale of 1:500 000 drawn from astronomic observations in 1903-04. The Komadugu Yobe can be found in the bottom right-hand corner of the map.

Besides printed maps, satellite images (table 2.4) and aerial photos over the river were available. See figure 2.2 for an example of a satellite image and an aerial photo.

Table 2.4. List of satellite images and their information.

Satellite	Date of image (yyyy-mm-dd)	Path	Row	I.D.	Resolution
Landsat TM WRS-2	1986-10-02	186	51	205-207	30 m
Landsat 5 TM WRS-2	1987-11-07	185	51	205-157	30 m
Landsat 7 ETM+ WRS-2	1999-12-10	185	51	036-742	14.25 m
Landsat 7 ETM+ WRS-2	2000-11-17	186	51	036-493	14.25 m

The satellite images were downloaded from the Global Land Cover Facility, www.landcover.org.

The available aerial photos are from January 1975. Together they cover the whole river. They are taken at a scale of 1:50 000 or 1:60 000. The maps drawn from aerial photos in January 1975 are made from the very same photographs. The access to the aerial photos was available thanks to collaboration with the University of Rouen in France.

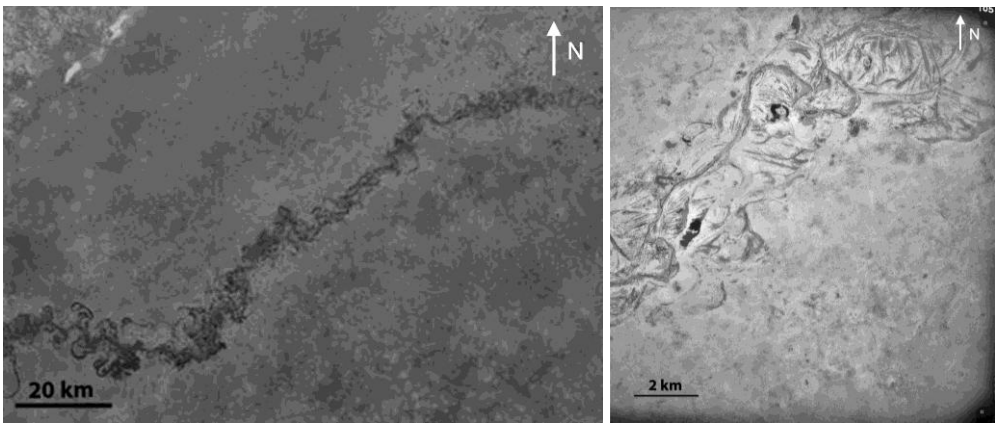

Figure 2.2. Examples of a satellite image and an aerial photo. At the left a Landsat image from 2000 showing the river from Tam to Bosso and to the right an aerial photo from 1975 showing a part between Diffa and Gueskérou.

2.1.2 Georeferencing

The scanned maps have to be georeferenced, i.e. giving the maps digital coordinates, to be used in a GIS-program. This is done by choosing points on the scanned maps, preferably tick marks, and give each point a coordinate. The georeferencing program then calculates (warp) the coordinates for the rest of the pixels on the image. The used georeferencing program was ENVI 4.2 (www.ittvis.com).

The maps were georeferenced to have a geographic latitude/longitude projection with a WGS-84 datum. A minimum of five points were chosen on each map. Together their RMS error was less than one before the warping process. For the map from 1903-04 it was impossible to obtain an RMS error less than one as fold marks had

deformed it (see fig. 2.1). More than five points were used to warp the map enough to have a satisfactory georeferenced image. For the warping process the triangulation method was used.

It was determined to have a resolution of ten meters to limit the size of the georeferenced image files. The riverbed is about 20-40 meters wide in reality. The pixel size to obtain this resolution is $9.00901*10^{-5}$ degrees in latitude/longitude. One degree in latitude is 110 km. One degree in longitude at 12° latitude was considered being the same length, for simplification (real length is 108 km).

For the map from 1903-04 it was necessary to convert from the Paris meridian to the coordinate system used today, the international Greenwich meridian. This was done by adding the difference to the longitude, 2° 20' 14,025" (Le Pape, 2009).

The Landsat images were downloaded georeferenced in a WGS 84 datum and a UTM Z 33 N projection.

Georeferencing the aerial photos showing the river (ca. 23 pieces.) would have been too time-consuming for the project. Instead the photos were used as a last verification for possible changes.

2.1.3 Comparison of the River on the Maps and Images

The river on the different digital and digitalized maps and images was compared by using ArcGIS 9.2 (www.esri.com/software/arcgis/). Polylines tracing the river were drawn manually on each map and image. By overlapping the different polylines the identification of the changes in the river's course could be made.

2.1.4 Surface Area Calculation

By using the polylines the surface area difference between different years could be calculated by the GIS-program. The polylines representing the maps at a scale of 1:200 000 from aerial photos in 1957-58 and 1975 and the Landsat images from 1986/1987 and 1999/2000 were used. The maps at a scale of 1:200 000 were chosen because together they show the whole river; the maps at a scale of 1:50 000 does not. The map at a scale of 1:500 000 from 1967 showing the whole river is a composite of maps at a scale of 1:200 000 and was considered less accurate.

Polygons with the same x and y coordinates in each corner, squaring the two different polylines from the maps at a scale of 1:200 000 were made. The polyline, representing the river, transecting the polygon was used to cut the polygon into two pieces, marked "A" and "B" in figure 2.3. The same procedure was done with the polylines representing the Landsat image from 1999/2000, with the same size and position of the polygons. When the polygons have been cut, the areas "A" and "B" from the different years were compared with each other. The same procedure was done when comparing the polylines from 1986/1987 and 1999/2000.

Example: $A_{1986/1987} - A_{1999/2000}$ = the surface area difference. The difference between $B_{1986/1987}$ and $B_{1999/2000}$ is the same, but with the opposite sign.

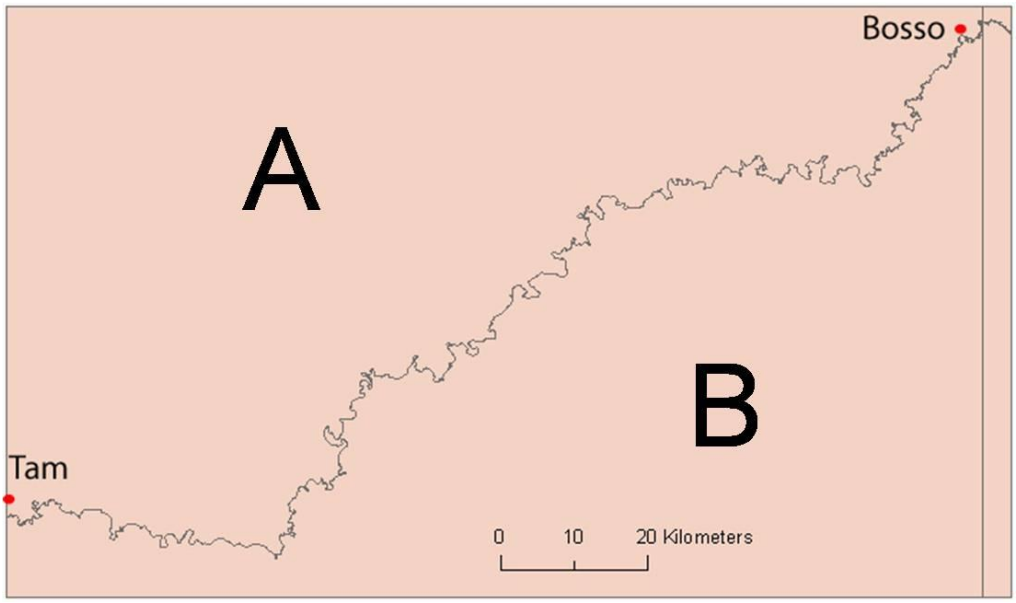

Figure 2.3. Example of a polygon squaring the polyline representing the river from the Landsat images from 1999/2000.

The surface area was calculated from the beginning of the river in Tam until downstream of Bosso, just before the river separates into two channels. The straight vertical line after Bosso in figure 2.3 shows the limit of the surface area calculation.

2.1.5 Calculation of the River's Sinuosity

The sinuosity of a river is the quotient between the river's length and the straight distance from the starting point and the end point of the river. The sinuosity gives an idea of how much the river meanders. The sinuosity for each polyline representing the river is a way to estimate how detailed the drawn/photographed river shown on the maps and images is. The more the sinuosity is close to the polyline with the best resolution, the more detailed the river on the map or image has been drawn.

The sinuosity was calculated by dividing the river into 13 different parts. A part is decided with either the beginning or the end of a polyline or either with an abrupt change in the course of the river. A straight line was drawn in each part. The length of the straight line and the polyline representing the river was measured. The quotient between the polyline representing the river and the straight line determined the sinuosity. Figure 2.4 shows an example of this; the length of the curvy line (a polyline representing a river) is divided with the length of the dashed straight line drawn from

the starting point to the end point of the river. The quotient is the sinuosity of the river.

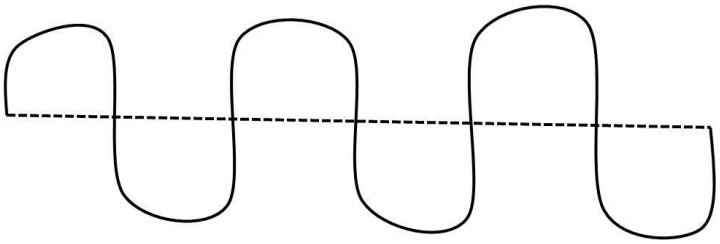

Figure 2.4. A polyline representing a meandering river and a dashed line representing the straight line from the starting point to the end point of the river.

2.2 Field Visit

2.2.1 Preparation

For the field visit a questionnaire was made with the help of Maï Mamadou Madou, (sociologist with a degree from the University Abdou Moumouni of Niamey, Faculty of Literature and Human Sciences). He has knowledge of the villages along the river and the problems the dynamic river causes the local inhabitants. The questions were supposed to give facts about if a change of the river has occurred and what impact such a change does. The original questionnaire was written in French. It has been translated into English (see appendix 2).

By a combination of the changes identified with the GIS-program and the villages the sociologist suggested, 14 places were chosen to visit. Special attention was made to have the places scattered along the whole river. For each village a document was written with maps on the surroundings attached to bring in the field. The chosen villages were: Tam, Gaidam Tchouckou, Zarwaram, Dabougou, Rouda, Bagara, Chétimari, Lada, Assaga, Dewa Fouyé, Boulamari, Abadam, Bosso and Mamouri (see fig. 1.2 for the location of the villages).

2.2.2 Field Work

The field visits took place from the 22nd to the 27th of October in 2009. This is during the high water period for the river (fig. 2.5).

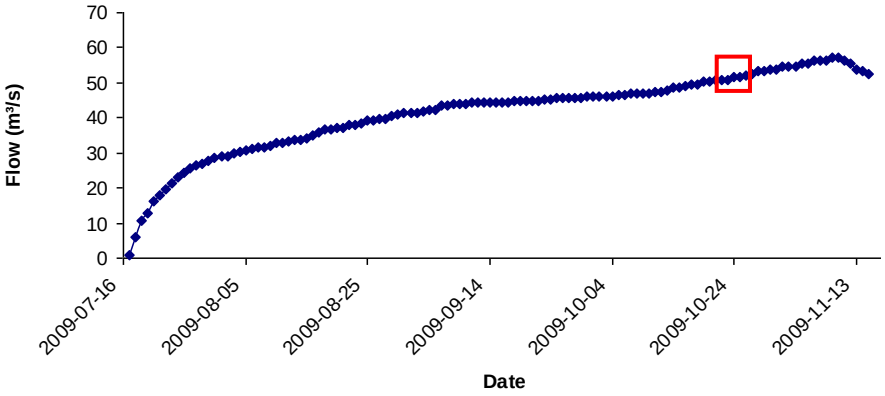

Figure 2.5. Diagram indicating that the time of the field visit (red rectangle) was made near the maximum flow at Bagara (Data obtained from DRH).

Once in the field it was clear that the questions could not be asked in the order they were written. The questions were instead asked in a semi-direct form; a specific question was asked to start the conversation, then the villagers were let to speak freely. Depending on what they said, the follow-up questions were developed. It was avoided to ask leading questions to be sure that the answer is something the villagers have thought about themselves. If the villagers did not talk about the changes that have been observed on the maps, they were asked this specific question, sometimes by drawing in the sand as help.

It was clear too that it was important to not use too much technical words. It was better to ask if fields had been lost than to ask if the river is eroding the banks. The sociologist Maï Mamadou Madou and Djibril Yacoudima at PADL, Diffa, did the interpretation the first and the second half of the field visit respectively.

The village chief or its representative is noted as the reference in this report even though he was not the only one who talked or gave the answers. It was most often a group of people, usually the oldest men in the village who discussed the answers with each other.

The travel to the villages was sometimes difficult (fig. 2.6) and Gaidam Tchouckou was not visited as it was inaccessible due to the river flooding the surroundings of the village (fig. 2.7).

Figure 2.6. Car stuck in mud outside Dewa Fouyé, 25th of October 2009 (Photo by G. Favreau, pers. comm.).

Figure 2.7. Water in front of Gaidam Tchouckou, 24th of October 2009.

Bagara was not visited due to shortage of time. The objective of visiting Bagara was to ask about houses being destroyed due to erosion of the riverbanks. As this problem already had been observed in Lada, it was not necessary to visit Bagara. Rouda was not visited either as it was clear after talking with the mayor of the Commune of Chétimari that the problems concerning the infrastructure in Rouda was not because of the river, but political problems that did not concern the river.

In addition to the villages, officials representing local Niger government who were available were also asked questions. In two cases the officials talked about villages which could be interesting to visit but were not initially planned to be visited. Those villages are Kanama and Gamgara and they were subsequently included in the field visit.

Besides visiting the villages and discussing with the villagers, the places where a change in the river had happened were visited. GPS-coordinates for each village and place were noted. The GPS used was a Garmin 60CSx.

The summary of the field visit is reported in appendix 3. The summary is quoting the answers given by the villagers. The answers might be confusing sometimes due to the villagers having a local view of the changes and the definition of words for different cultures.

3 Results

3.1 Comparison of the River on the Maps and Images

The different polylines representing the river does not overlap each other exactly (fig. 3.1 and 3.2). Because of this the comparison could not be used solely to prove that the river has changed its course. Instead the comparison was used as a help to identify

places where a change seemed to have happened. These places were further studied by observing the maps and aerial photos.

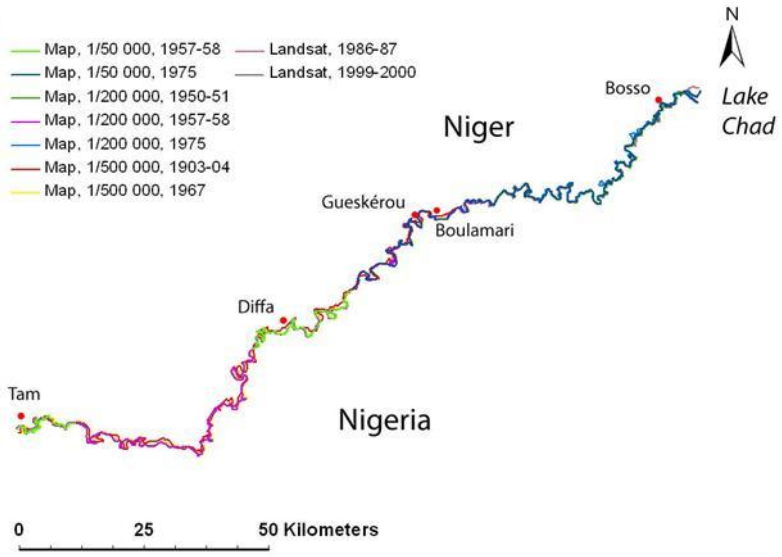

Figure 3.1. The polylines representing the different courses of the river.

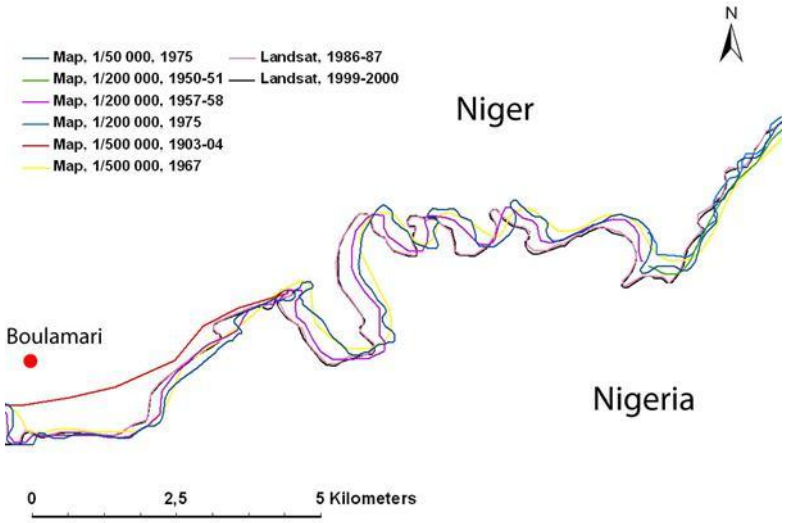

Figure 3.2. Zoom of the different polylines representing the river.

3.2 Surface Area Difference

The results of the surface area difference calculation show that between 1957-58/1975 and 1999/2000 the surface area difference is 5 km^2 between the two countries.

Between 1986/1987 and 1999/2000 the surface area difference is 3 km^2. It is the same country that has gained territory both times.

3.3 The Sinuosity of the River's Course

The Landsat image from 1999/2000 has a mean sinuosity of 2.16 (table 3.1). The image is considered as the most detailed of the maps and images as it has the highest resolution, and can be used as a reference for the other maps and images. Compared with the Landsat image, the map from 1903-04 is the least detailed followed by the map from 1967. These maps are at a scale of 1:500 000 and it is reasonable that the sinuosity becomes less when the scale is increasing.

Table 3.1. The mean sinuosity and the total mean sinuosity for the river on each map and image compared with other maps and images for the same parts.

Map or image	Part 1-2	Part 5-7	Part 1-9	Part 1-10	Part 8-13	Part 11-13	Total mean sinuosity
1/50 000 1957	1.85	2.11					**2.01**
1/50 000 1975					2.18		**2.18**
1/200 000 51						2.22	**2.22**
1/200 000 58	1.79	1.86	1.82	1.84			**1.84**
1/200 000 1975						2.20	**2.2**
1/500 000 1904	1.35	1.74	1.56				**1.56**
1/500 000 1967	1.66	1.73	1.71	1.70	1.78	1.86	**1.74**
Landsat TM 1986/1987	1.88	2.15	2.01	2.00	2.15	2.34	**2.08**
Landsat ETM+ 1999/2000	1.99	2.19	2.05	2.06	2.25	2.49	**2.16**

A complete table of the sinuosity for each part for the maps and images is shown in appendix 1.

3.4 Results from the Field Visit

The objective of the field visit was to verify, with the local inhabitants and the officials representing local Niger government, the observed changes from the comparison of the maps and images and to understand their impacts.

When asking the villagers if they have noticed any changes of the river they did not only talk about changes of the course, many talked about other changes as well. Some villagers (Boulamari, Assaga, Gamgara, Abadam) said the river flowed for a longer time in the past, around seven to nine months, compared to three to four months nowadays, or that the flow has diminished over the years (Zarwaram, Dewa Fouyé, Bosso, Mamouri). Many of them have also witnessed the river getting shallower because of sand depositing on the riverbed (Tam, Dabougou, Zarwaram, Boulamari, Assaga, Mamouri, Gamgara, Abadam). The villagers in Boulamari said that they have

bored "a well" in the riverbed to be able to reach the groundwater when the river is dry as the layer of sand has become thicker (fig. 3.3).

Figure 3.3. Pumping of outcropping groundwater in the riverbed during the dry season in June 2009 (Photo by G. Favreau, pers.comm.).

All villagers living along the river are aware of that the river is the border. Some said that when the river's course changes, so does the border (Tam, Dewa Fouyé, Abadam). The change of national territory concerning their property does not seem to be a problem as the lands would still be theirs on the other side of the border (Bagara, Assaga, Boulamari). The Nigerian villagers are also cultivating on the Niger side of the border. The biggest problem that comes with the dynamic river is when it destroys fields and sometimes even houses (Lada, Bagara, Gaidam Tchouckou). In Lada three or four houses have been destroyed recently (fig. 3.4).

Figure 3.4. Threatened houses at the riverbank in Lada, October 2009.

The river is used for irrigation, watering the livestock, fishing, transportation, sometimes for consumption and also for brick manufacturing.

The following subsections show changes in the river observed by doing the comparison of the maps and images and which were verified during the field visits, among with changes discovered on the field while talking to the villagers. The changes are divided into three categories: erosion, cut off meander and change of course. The complete answers from the villagers are quoted in appendix 3.

3.4.1 Erosion

In Tam the villagers showed a beacon that dates from ca. 1900 (fig. 3.5). The current beacon marking the border was placed north of the river by the Commission of the Delimitation of the Border around 2006, and about 300-400 meters north-westwards from the first one (fig. 3.6). The displacement of the beacon indicates the northward evolution of the river. The location of the beacons can be seen in figure 3.7.

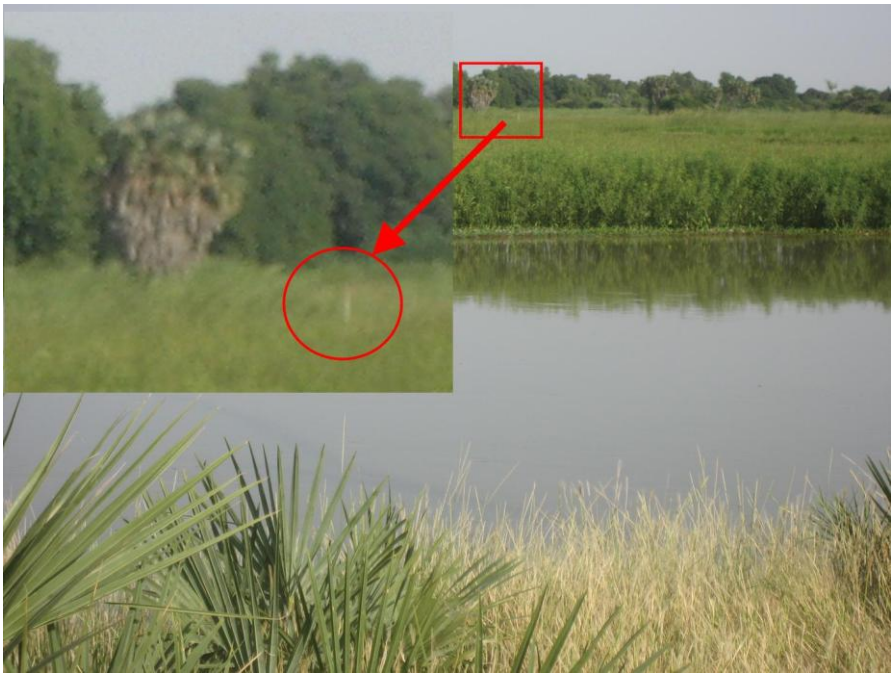

Figure 3.5. Photo of old beacon 148, October 2009.

Figure 3.6. Photo of new beacon 148, October 2009.

The river is eroding the banks surrounding the oxbow lake "Walou Minam" seen in figure 3.7. A dike has been built to protect the oxbow lake. The villagers at Tam said it would be a problem for them if the river connects to the oxbow lake. Other villagers along the river said they were not concerned about the changing border as they can continue to cultivate on their field, even if the river would move the field to the

opposite side of the border. The problem the villagers in Tam meant is probably connected to fishing. Today they can fish in the whole oxbow lake. If the river connects to it, they would only have the right to fish on their half. During the time of the visit, there was water flowing into the oxbow lake (fig. 3.8).

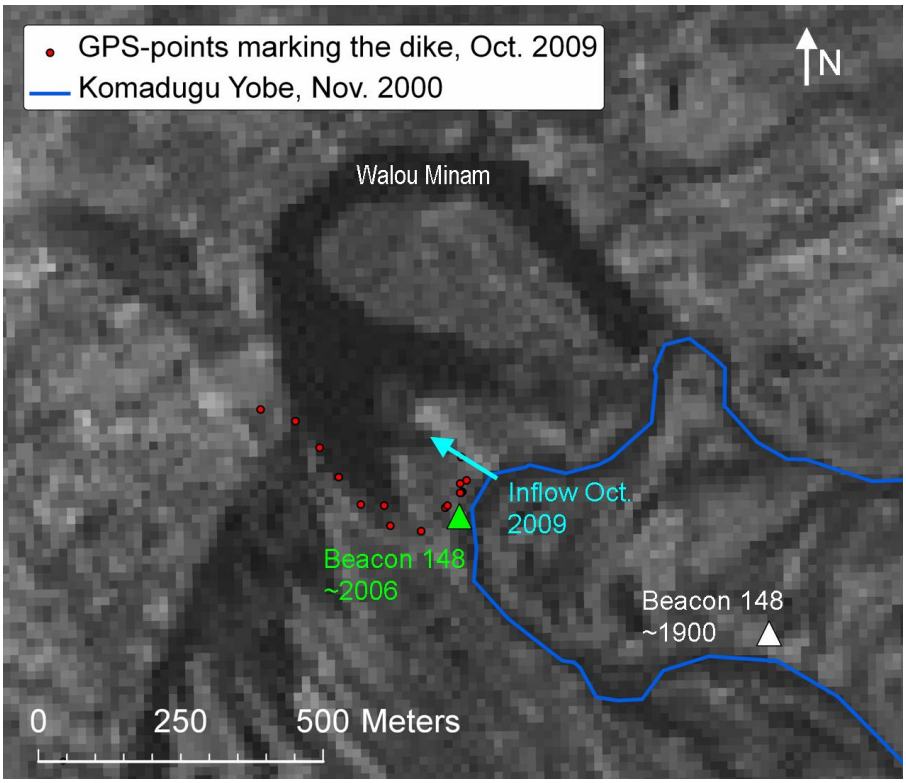

Figure 3.7. Location of beacons, dike and water flowing into the oxbow lake "Walou Minam" the 22nd of October 2009.

Since 1999, the river has moved ca. 40 meters into Niger territory according to the villagers. In-between where the Komadugu Yobe flows nowadays and the oxbow lake "Walou Minam" there was a village before called Baradi. The village had to move in the 1980s as the river came closer by eroding the riverbanks (fig. 3.9). The location of the village is indicated in Sogetha (1962 b).

Figure 3.8. Inflow to the oxbow lake "Walou Minam", October 2009.

Figure 3.9. Photo showing erosion on the banks and ash traces at the tip of the arrow from the old settlement of Baradi, October 2009.

The erosion is threatening numerous villages and houses along the river. In Bosso, the erosion on the meander is threatening the village and official buildings. The banks have been reinforced in 2009 by the local organization PADL (fig. 3.10).

Figure 3.10. Reinforcement of the banks of the meander, by the local organization PADL, at Bosso.

3.4.2 Meander Being Cut Off from the River

The meander close to the village Dewa Fouyé has been cut off. It happened after the colonisation according to the villagers. The village chief said that when he was young the meander was not cut off. It started during the highest water level the villagers have ever known and progressed during two to three years. Visually it happened when the river eroded through white sand. The maps from 1903-04 and 1957-58 show a non cut meander (fig. 3.11), while it is cut off on the aerial photo from 1975 (fig. 3.12). The flow measurements between these years (fig. 1.3) show that the biggest flow was in January 1965 (43 m^3/s). This indicates when the meander might have been cut off. When this happened the land inside became a part of Niger territory.

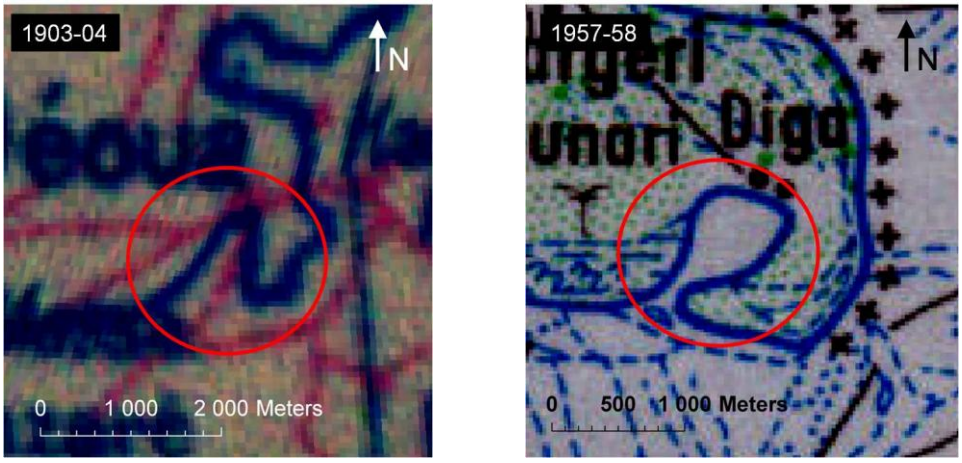

Figure 3.11. At the left, a map drawn from astronomic observations in 1903-04 and to the right, a map drawn from aerial photos in 1957-58. Both are showing a non-cut meander at Dewa Fouyé.

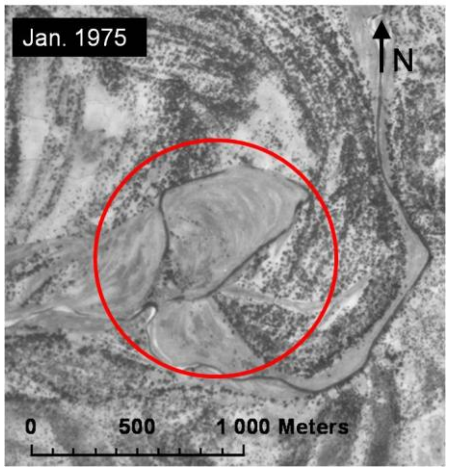

Figure 3.12. Aerial photo from January 1975 showing the meander being cut off at Dewa Fouyé.

3.4.3 Changes in the River's Course

The villagers in Zarwaram said the river flows in two channels at the tip of the meander east of the village. In the past there was only one channel. The change happened around 1999. It can be observed when comparing the aerial photo from 1975 with the Landsat image from 2000 (fig. 3.13).

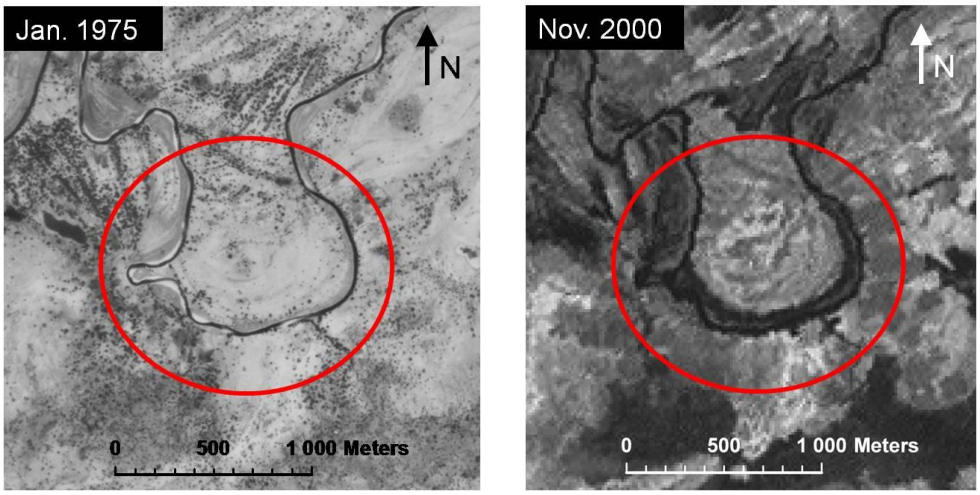

Figure 3.13. At the left, an aerial photo from January 1975 showing only one channel and to the right, a Landsat image from November 2000 showing two channels at Zarwaram.

In-between the village of Abadam in Niger and the village of Abadam in Nigeria the river has started to flow in a new channel. According to the villagers, the change happened around 1950 and for sure before the independence in 1960. The change came naturally. It happened at a time when the river was powerful and cut through white sand. Today it flows in the two channels, but more on the channel closest to Abadam in Nigeria (fig. 3.14). It has always flown more on this side since the river's channel was changed.

On the map and the aerial photo from 1975, the river flows in the channel closest to Abadam in Niger. A small channel close to Abadam in Nigeria can be observed, but the dominating channel is the one closest to Abadam in Niger. Therefore, the change can not have happened around 1950. See figure 3.15 for a comparison between the two channels. The villagers showed where the diversion of the channel happened. The GPS-coordinate at this place (N 13°37,314', E 13°15,515') corresponds to the location for the diversion seen on the map and Landsat image. The territory in the middle of the river belongs to Niger.

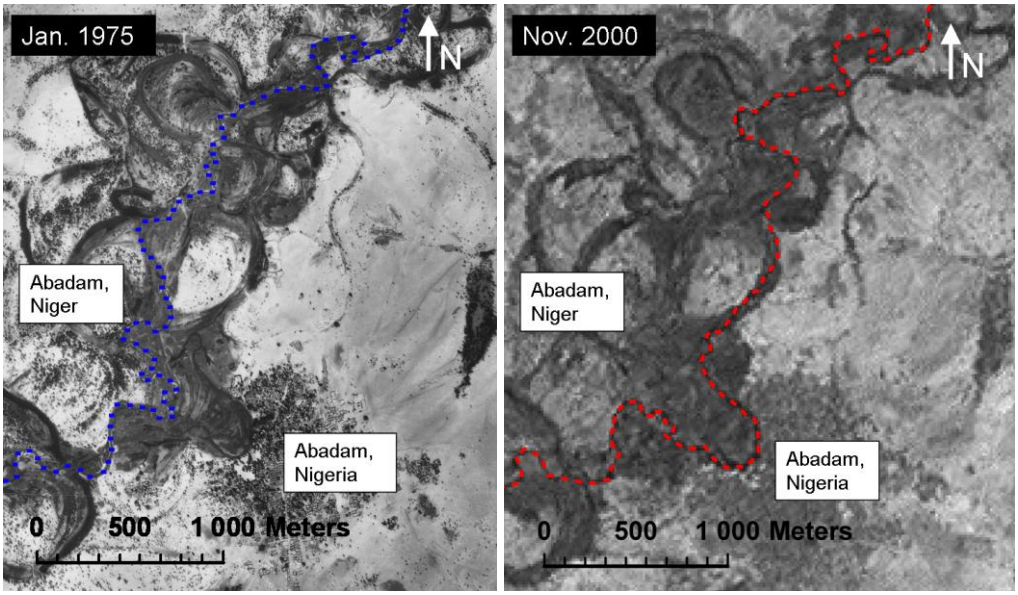

Figure 3.14. At the left, an aerial photo from January 1975 and to the right, a Landsat image from November 2000 showing the different channels between Abadam in Niger and Abadam in Nigeria.

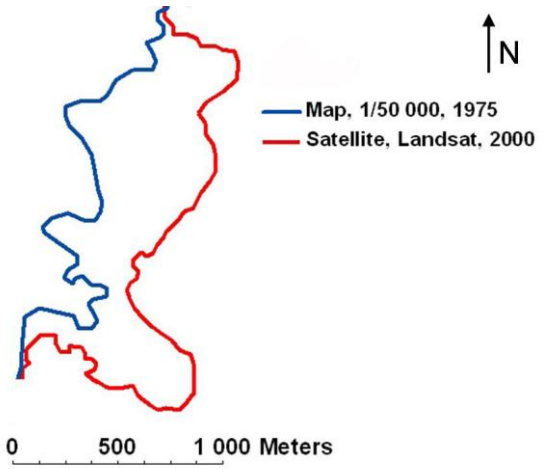

Figure 3.15. Polylines representing the two different channels at Abadam.

In-between Bosso in Niger and Kiari Kagari in Nigeria the river's course has changed. The change can be observed while comparing the map from 1975 and the Landsat image from 2000 (fig. 3.16 and 3.17). The Mayor of Bosso said the change is due to erosion and cultivation.

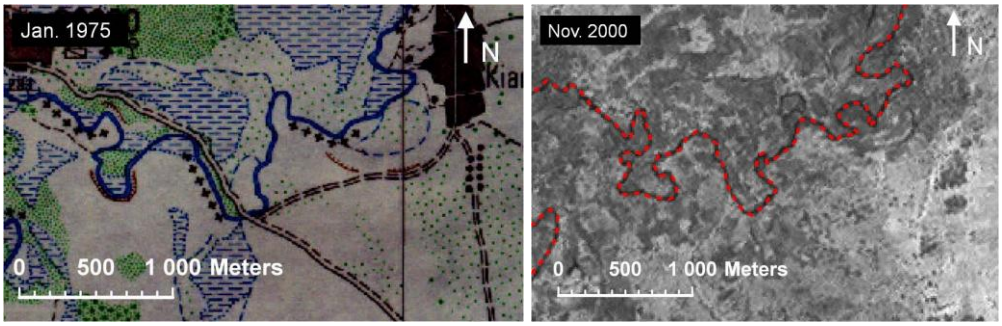

Figure 3.16. At the left, a map drawn from aerial photos in January 1975 and to the right, a Landsat image from November 2000 showing the river between Bosso in Niger and Kiari Kagari in Nigeria.

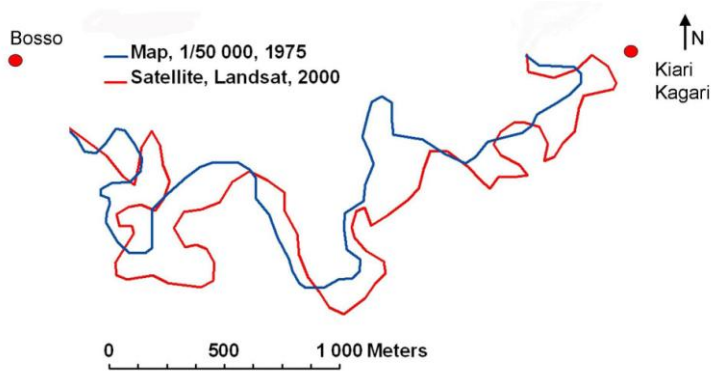

Figure 3.17. Polylines representing the two different channels between Bosso and Kiari Kagari in Nigeria.

At the outflow area there are two channels flowing out in the lake, one natural and one man-made. According to Hachirou Abdou (2009, pers.comm.), the responsible of water resources in DRH in Diffa, the man-made channel was dug around 1974-1976.

The two channels are seen in figure 3.18. The man-made channel (yellow) is present on the aerial photo from 1975. The natural channel (turquoise) does not flow the same way in 1975 compared to 1999. The change is probably due to the lake's fluctuations together with human activities (ex. diversion, agriculture).

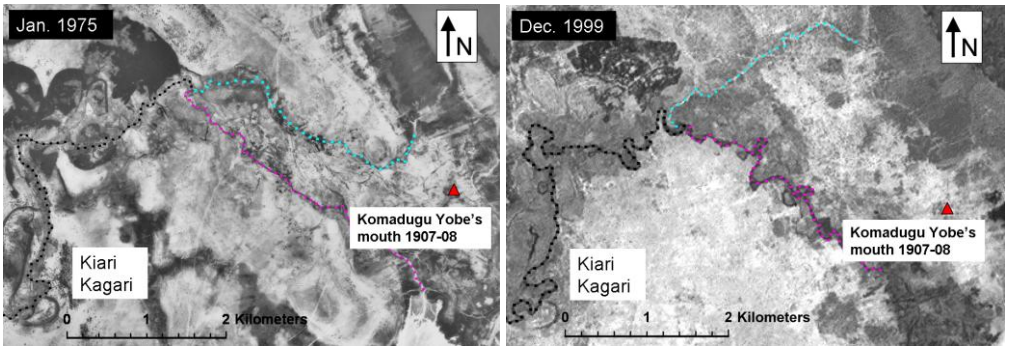

Figure 3.18. At the left, an aerial photo from January 1975 and to the right, a Landsat image from December 1999 showing the river's mouth into the lake. The turquoise dots mark the natural channel while the pink dots mark the man-made channel. The coordinates for the Komadugu Yobe's mouth in 1907-08 are written in section. 2.1.1.

The man-made channel is made by Nigerian villagers to lead water to their fields. According to the mayor of Bosso it was in 1992 the villagers started to dig between Bosso and Mamouri and now the river goes all the way down to Kaniram in Nigeria.

The Mayor of Bosso also says that the Nigerian authorities are aware of the problem by making another channel for the river. They have explained to the villagers in Nigeria that the river is the border and by diverting it southwards, Nigeria loses territory. They have also informed officials in Niger (through the Niger-Nigeria Mixed Commission) that they will make the river go back in its natural channel and close the passage the villagers have built.

The villagers in Mamouri showed the Komadugu Yobe on the field visit. The GPS coordinates for the river: N 13°43.185', E 13°21.091', was compared with the Landsat ETM+ image from December 1999. The coordinates correspond to the natural channel that seems dried out on the image. This shows that there is water flowing in the natural channel in October 2009.

3.5 Organizations Concerning the Managing of the Komadugu Yobe

3.5.1 PADL (Projet d'Appui au Développement Local)

The local officials are aware of the problems that the erosion is causing and have asked the local organization PADL, an organization focusing on development, to start a project to protect the riverbanks. PADL has identified Lada, Dabougou, Gaidam Tchouckou, Tam, Boulayi near Bosso, Bosso and Gueskérou as the most affected villages (PADL, 2007).

In Lada and Gaidam Tchouckou the erosion is threatening the houses. In Dabougou, Tam and Gueskérou, PADL want to protect the dikes separating the oxbow lakes with the river. This is to secure the water in the oxbow lakes during the dry season when there is no or little water in the river. In Boulayi they are planning to protect a water catchment in the riverbed. PADL have also identified the river being a threat to houses, a well and a customs building in Bosso (PADL, 2007).

In October 2009, it is only in Bosso where PADL have started their work. They have reinforced the riverbank with sandbags (fig. 3.10 on page 25) (Issaka, 2009).

3.5.2 Lake Chad Basin Commission

The Lake Chad Basin Commission (LCBC) includes Cameroon, Central African Republic, Chad, Niger and Nigeria. The aims of LCBC are "to regulate and control the use of water and other natural resources in the basin and to initiate, promote, and coordinate natural resource development projects and research" (Lake Chad Basin Project, 2010).

The Departmental Director of the Hydraulic Ministry of Maïné-Soroa recognizes that it is the LCBC that manages everything that concerns the water resources in the Lake Chad basin. It is the main organization concerning the managing of the water resources in the Komadugu Yobe.

3.5.3 Gamba Union

The villagers in Tam and Kanama as well as the Departmental Director of the Hydraulic Ministry of Maïné-Soroa mentioned the Gamba Union and its function. Gamba Union is a self-financed organization managing the Komadugu Yobe between Niger and Nigeria that measures the adaptation and change of the water resource. It was created in 2005. On the Niger side, the union includes the commune of Maïné-Soroa with the villages of Kanama and Tam. The union works on a village level. Kanama collaborate with Nigeria via the Gamba Union concerning the oxbow lake close to the village. The project is managing, among other things, the fishing in the river between Niger and Nigeria.

3.5.4 Niger-Nigerian Mixed Commission

Niger and Nigeria is collaborating through the mixed Niger–Nigerian Mixed Commission. Through this collaboration the states have made an agreement concerning the Komadugu Yobe. In the Sokoto agreement signed the 5th of October 1998 it is agreed about the equal division, the conservation and utilization of the water resources forming or transcending the border. It is further agreed that the two states have to inform and consult the commission before starting a project concerning the river that might influence the other state (Ministère de l'Hydraulique, de l'Environnement et de la Lutte Contre la Désertification, 2002).

3.6 The Law and the Border

The river was first mentioned as the border between Niger and Nigeria in the convention of 1904. The conventions in 1890 and 1898 were establishing the border, but very briefly and did not mention the Komadugu Yobe (Bureau of Intelligence and Research, 1969).

The convention of 1904 says as follows:

"(...) Thence the frontier shall follow in an easterly direction the parallel of 13° 20' north latitude until it strikes the left bank of the River Komadugu Waube (Komadougou Ouobe), [Komadugu Yobe], the thalweg of which it will then follow to Lake Chad. But if, before meeting this river, the frontier attains a distance of 5 kilom. from the caravan route from Zinder to Yo, through Sua Kololua (Soua Kololoua), Adeber, and Kabi, the boundary shall then be traced at a distance of 5 kilom. to the south of this route until it strikes the left bank of the River Komadugu Waube (Komadougou Ouobe), (...) The boundary will then, as before, follow the thalweg of the said river to Lake Chad." (Bureau of Intelligence and Research, 1969)

The thalweg is the line defining the lowest points in the riverbed.

In 1906, a delimitation convention between France and Great Britain described the border in detail:

"(...) From the last-named point the frontier will follow a line drawn parallel to and 5 kilom. to the south of the road from Gurselik to Adubur, which passes through Zumba and Judkorum, until this line strikes the thalweg of the river Komodugu Yobe, then it will follow the thalweg of the said river as far as Lake Chad." (Bureau of Intelligence and Research, 1969)

Finally, in 1910 the two countries agreed on a demarcation between the two states. The agreement contains a description of the frontier and a deflection of the 1906 delimitation convention. The deflection does not mention the Komadugu Yobe (Bureau of Intelligence and Research, 1969).

The description of the frontier contains a list of all the beacons marking the boundary. Beacon 148, marking the beginning of the natural border is describes as followed:

"Beacon 148 – On the left bank of the river Komadugu Yobe in the bush. An auxiliary mark, consisting of a telegraph pole, is placed on the right bank of the river." (Bureau of Intelligence and Research, 1969)

Beacon 148, the telegraph pole, is the beacon seen in figure 3.5.

Then the border is defined as:

"From beacon 148 the frontier follows a straight line bearing 90°, distance about 30 metres, till this line intersects the thalweg of the river Komadugu Yobe. From this point the frontier follows the thalweg of the River Komadugu Yobe as far as the mouth of the river in Lake Chad." (Bureau of Intelligence and Research, 1969)

The demarcation agreement is also conscious about the river being liable to changes and is giving a suggestion if this would happen:

"In the case of the river altering its course to the northward or westward so as to intersect the straight line between beacons 147 and 148 to the westward of the present point, the new thalweg of the river will constitute the frontier from the aforesaid new point of intersection." (Bureau of Intelligence and Research, 1969)

"In the case of the river altering its course to the southward or eastward so as not to intersect the line as described at 30 metres from beacon 148, the frontier will follow the thalweg of the river as now existing to the point where the thalweg of this old bed will join the thalweg of the new bed of the river." (Bureau of Intelligence and Research, 1969)

"From this point the frontier will follow the thalweg of the river as it may exist for the time being as far as the mouth of the river in Lake Chad. "(Bureau of Intelligence and Research, 1969)

"The mouth of the Komadugu Yobe has been marked by an iron telegraph pole, cemented at the base, situated in 13°42'29" north latitude, 8,250 metres east of the centre of the village of Bosso." (Bureau of Intelligence and Research, 1969)

Due to lack of time, no officials representing the Niger government were visited to obtain further information about the law concerning the border and the replacement of beacon 148.

3.7 Other Examples of Similar Rivers

3.7.1 Ruvuma River, bordering Mozambique and Tanzania

Ruvuma River is the international boundary for a part between Mozambique and Tanzania.

In the Anglo-Portuguese notes of 1936-37, it is agreed upon that the boundary follows the thalweg in the places where there are no islands. If the position of the thalweg is changed by a natural alteration in the bed of the river, the new course of the thalweg will mark the border. If the riverbed would undergo any alteration, the country affected by loss of territory shall have the right that within four years divert the river into its old bed. If it is not practicable, the affected country has the right to compensation by the benefiting country. If the states can not agree the Permanent

Court of International Justice will decide (Bureau of Intelligence and Research, 1964 a).

It is predicted by The Bureau of Intelligence and Research (1964 a) that the course of the Ruvuma river might shift which may lead to conflict over parcels of land.

3.7.2 Rio Grande and Colorado River, bordering Mexico and the U.S.A.

Rio Grande and Colorado River marks the border for a part between the U.S.A. and Mexico. In April 18, 1972 a treaty, regulating the pending boundary caused by the dynamics of the rivers, was entered into force.

In Article II, it is decided that in the limitrophe sections the boundary goes in the middle of the channel in normal flow. If there are two channels, the boundary goes in the channel with the greatest average width over its length in normal flows. Islands belonging to one country changes country if the channel divides them.

Article III is describing what to do when the river moves laterally and eroding one of its banks and is depositing alluvium on the opposite bank. In this case the boundary continues to go in the middle of the channel. If other movements than this occurs, the state that loses not more than a certain hectare or habitants can restore the river and the boundary by its own expenses.

In article IV it is dealt with the right to protect the banks to minimize the changes of the channel and the problems coming with it. Neither country has the right to make a construction within its own territory that deflects or obstructs the normal flow.

Article VI deals with how lands belonging to private owners and which are changing nationalities with the changing river should be treated. Compensation should be paid to the land owners by the delivering state and no payments should be done between the two governments for the value of the lands and improvements that are transferred.

3.7.3 Songwe River bordering Malawi and Tanzania

Songwe River is a meandering river prone to severe flooding (Shela, 2000). It marks the border for a part between Malawi and Tanzania. The location of the boundary is the thalweg of the river or the middle of the bed (Bureau of Intelligence and Research, 1964 b).

A 1901 border agreement between the two countries determines that whenever a piece of land is being cut off the land changes country as well as the residents living there. This is a problem for the local inhabitants (Shela, 2000). There are communities living close to the riverbanks that are alternating between being in Tanzania and Malawi when the river creates new channels around them (afrol News, 2009). In 1991, the problem was discussed between the two governments and it

resulted in a plan to stabilize the channel and construct dams and dikes to canalise the flows in the flood plain (Shela, 2000).

The Songwe River has its mouth in a fluctuating lake, Lake Malawi. The shore of the lake forms the boundary. As in Lake Chad, the water level is fluctuating which makes it difficult to make an exact delimitation of the shore (Bureau of Intelligence and Research, 1964 b).

4 Discussion

4.1 Uncertainty of the Maps and the Georeferencing

The printed maps used in this study are at a scale of 1:500 000, 1:200 000 and 1:50 000. This means that one millimeter on each map is 500, 200 and 50 meters in reality. The maps are printed on paper and paper might expand or contract because of changes in humidity. A change of one millimeter will deform the drawn river. The scanning of the maps might also have an impact on their accuracy. Even a very small deformation can move a specific point on a map several 100 meters from its actual position.

The map from 1903-04 is drawn from astronomic observations, but does not give any information of how the river has been traced. Also, the instruments used for astronomic observations at the time were less precise than the instruments used today. The other printed maps from the 1950s, 1960s and 1970s are drawn from aerial photos. There is no information on how they were drawn; the river can have been traced by hand or by help of an instrument. In either case, it is not first-hand information printed maps are showing, but a secondary.

Considering the scale of the maps, the error by using $9.00901*10^{-5}$ degrees for both the x and y direction of the pixel cell is not important. On the maps at a scale of 1:200 000, the river is drawn 0.3 mm wide, which would mean that the river is 65 meters wide in reality, and not 20-40 meters. The error by assuming one degree of latitude equal one degree of longitude is relatively small (ca. 2 dm. per 10 meter). One degree in longitude is about 108 km between 12° and 13° latitude. One degree in latitude is 110 km.

The Landsat images are georeferenced with a WGS 84 datum and an UTM Z 33 N projection. Most of the printed maps, with an exception of those at a scale of 1:500 000, were drawn referencing to the Clarke 1880 ellipsoid and with an UTM projection. However, in the used software ENVI 4.2, the only datum available for geographic latitude/longitude georeferencing is WGS 84. You can georeference in UTM, but as ENVI cuts off the area outside the points framing the image, parts of the river would have been missing. This means that the maps are georeferenced in a WGS 84 datum, while their ellipsoid is Clarke 1880.

The maps are georeferenced manually. The georeferencing was verified in the GIS-program by comparing what coordinates the tick marks have on the georeferenced maps. However, the coordinates shown did not always correspond perfectly with the coordinates for the tick mark. The measured distance difference between the coordinates for the tick mark and the coordinates the GIS-program showed are from 10 up to 100 meters. The distance difference is increasing with the scale of the map.

The polylines are traced manually on the maps and images. Sometimes it was difficult to follow the river due to the resolution of the images or that the river is not always visible on the maps (a village name might for example cover it).

The reason why the polylines representing the rivers from the maps and images has a continuous divergence compared with each other can be due to one or several errors listed above.

The conclusion of this discussion is that a study exploring how a river has changed over time can not solely be done by using maps and images. Additional information about how the maps have been done and their accuracy is needed. However, it is a helpful tool to easily identify important changes in a river's course.

4.2 Analysis of the Surface Area Calculation

The reason of which the polylines from 1957-58 and 1975 were merged together and considered as the same year for the comparison is because they were the maps with the least year difference to merge together to have a complete river. Also, when comparing the polygons squaring each polyline, one country gained territory for the first part of the river, but lost territory the second part. Merging these two polylines together was the only way to have a quantification of the total gain or lost for each country.

The results from this calculation based on the divergence between polylines from different years should be taken with caution. The accuracy of the surface calculation is affected by all the errors listed in section 4.1 including the fact that the maps used for the comparison are not first-hand information.

The polylines from the Landsat images have the least divergence between each other. They are also more accurate than printed maps because they represent first-hand information. However, the sets of images do have different resolutions; 14.25 m and 30 m (see table 2.4). The polylines on the images were drawn manually. Sometimes it was difficult to see the river due to the resolution. Therefore the accuracy of the comparison between the Landsat images should also be taken with some caution.

4.3 Analysis of the Field Visit

It was sometimes difficult to interpret what the villagers meant. Concerning beacon 148 at Tam, the villagers said that the present beacon has been there for three years and that the old one was replaced by the military in 2004. It was then moved six meters to the north. They are also mentioning that the replacement of the old beacon was done by the commission of the delimitation of the border.

The two different beacons have been seen on the field and it is verified that there are two. However, it is not a distance of six meters between them. The distance is approximately 300-500 meters. The interpretation of this is that the old beacon was first replaced in 2004 and moved six meters to the north. Then, in 2006, another new beacon was put into place and it is this one which now marks border.

The expression "island" used by some villagers can be discussed. Those villages who talked about an island at the village, Dewa Fouyé and Boulamari, do not seem to ever have been on an island. The expression probably means that the river is surrounding a big part of the village and/or may surround it completely during high water levels.

The villagers in Gamgara talked about a channel built 15 years ago, in 1994. The channel was also visited during the field visit. On the Landsat ETM+ image from 2000 but also on the map at a scale of 1:50 000 from 1975 the river flows in this channel, therefore it can not have been built in 1994.

The dates should be taken approximately if not a specific occasion that happened at the time is mentioned. The villagers in Abadam said that the river started to go in two channels in the 1950s with the dominant channel on the east side ever since. It is clear when observing the aerial photo from 1975 that the dominant channel is still on the west side. However, a channel on the east side can be distinguished. The interpretation of what the villagers meant is that the river did indeed start to go in the two channels in the 1950s, but the flow has not always been most dominant on the eastern channel.

There is no doubt that the meander at Dewa Fouyé has been cut off and that changes of channels at Abadam, Bosso and the river's mouth, have occurred; the villagers confirmed the changes and this can also be observed on the maps and images. The erosion on the riverbanks is also verified by seeing it at the site. In Tam they said the river has changed 40 meters laterally since 1999 because of the erosion. This should be seen as a verification that river moves laterally, but the distance can not be verified.

The villages along the river on the Nigerian side were not visited due to shortage of time during the field visit and due to administrative issues when making inquiries in another country. Because of this, only the perception of the changes of the river and its impacts by the local inhabitants and authorities on the Niger side is known. To

have a complete understanding and knowledge of the changing border and the issues coming with, the local inhabitants on the Nigerian side should be asked as well. However, the perception of the local inhabitants in Nigeria is probably not too different as the people living along the river are from the same ethnic group and sometimes the same family.

5 Conclusions

Studies of aerial photos, maps and satellite images together with verifications with the villagers during field visits prove that the Komadugu Yobe has changed its course during the 20th century and continues to evolve. The changes observed are changes of channels, a meander that has been cut off and erosion on the riverbanks. The calculated surface area difference due to variations in the position of the river is too uncertain to be used for quantification of the changes, thus this objective could not be fulfilled. However, the results give an indication that the river moves laterally.

The river's course from Bosso until its mouth into the Lake Chad is the most significant change. Today there are two channels, one man-made and one natural. However, the natural channel has changed its course over time. The fluctuation of the lake level is one reason for this change. It is concluded that the border follows the natural channel as both countries know that the other one is man-made and are trying to make the river flow in the natural channel.

There are other changes except those concerning the river's course. The water quantity in the river has diminished and the river is getting shallower because of sand being deposited on the riverbed. The reason of this sand deposit making the river shallower was not investigated; it may be due partly to increased erosion of the riverbanks, following increasing deforestation of the natural forest bordering the river.

The changes are not important in a large scale. In a smaller scale the changes have an impact on the local inhabitants. The erosion on the riverbanks is the most problematic among them. Houses and fields along the river have been destroyed or are threatened by the river. Changes of channels and the cut off meander are less problematic as the villagers, both in Niger and Nigeria, continues to be the owner of the field, even if the field would move to the other side of the border because of the river. An economic problem was expressed in the village of Tam where the villagers might lose the right to fish in the whole oxbow lake if the river would connect to it. All the villagers are aware of that the river is the border and when the river changes so does the border.

The most important organization concerning the management of the pending border is the Niger-Nigerian Mixed Commission. The demarcation agreement from 1910 between the two countries also mentions solutions how to deal with the pending border.

Another important international organization managing the water resources in the Komadugu Yobe is the Lake Chad Basin Commission. There are also local organizations; the Gamba Union and PADL. The Gamba Union is managing the water resources in the Komadugu Yobe between villages in Niger and Nigeria on a local level at the commune of Maïné-Soroa. PADL is working with the protection of the riverbanks to prevent houses and fields being destroyed when the river erodes the banks.

By studying three other examples of rivers being international borders, it is concluded that the best solution to avoid future conflicts seems to make agreements how to deal with different changes before they happen. To decide to have a fix border delineated by a meandering river may not be the best solution as the river might evolve to flow completely in one country and the other country would lose an important water resource.

6 Recommendations

It should be recalled that from an ecological point of view, erosion is a natural process of regeneration of land fertility and ecologically important for the fauna and flora (which determines the fish reproduction). A recommendation could be to help maintaining the banks by protecting and restoring vegetation on a standard distance from the thalweg to prevent excessive erosion and leave the river to change in a natural way. Apart from that, engineering protection of the banks is expensive and should only be chosen as a solution for protecting villages and houses.

Future work to continue this study would be to study the aerial photos from the 1950s. These and the aerial photos from 1975 can be georeferenced to have a more accurate source for the changes, especially for how the river has evolved laterally. It would also be of great value to get the opinion from the local inhabitants in Nigeria living along the river and from Nigerian officials.

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Appendix 1: Table of Sinuosity for the River on the Maps and Images from Tam to Bosso

Part of river		1	2	3	4	5	6	7	8	9	10	11	12	13	Mean Sinuosity
Map or image	Length of straight line (km)	8	4.7	26.5	23.2	5.5	9.4	11.5	22.8	5	6.2	24.3	15.6	7.8	
1:50 000 1957	**Length of river (km)**	20	5.6			14.3	17.6	21.5							**2.01**
	Sinuosity	2.5	1.19			2.6	1.87	1.87							
1:50 000 1975	**Length of river (km)**								52.6	7.1	14.8	61.6	33.5	17.7	**2.18**
	Sinuosity								2.31	1.42	2.39	2.53	2.15	2.27	
1:200 000 1951	**Length of river (km)**											57.2	30.9	18.2	**2.22**
	Sinuosity											2.35	1.98	2.34	
1:200 000 1958	**Length of river (km)**	19.2	5.5	43.3	46.2	11.3	16.8	20.1	51.2	6.7	12.5				**1.84**
	Sinuosity	2.4	1.17	1.63	1.99	2.05	1.79	1.75	2.25	1.34	2.02				
1:200 000 1975	**Length of river (km)**											61.2	32.5	15.7	**2.2**
	Sinuosity											2.52	2.08	2.01	
1:500 000 1904	**Length of river (km)**	13.7	4.6	44.4	32.6	13	12.9	17.2	42.1	6.1					**1.56**
	Sinuosity	1.71	0.98	1.68	1.41	2.36	1.37	1.5	1.85	1.22					
1:500 000 1967	**Length of river (km)**	18.4	4.8	40.8	44	10.1	16	19	47.9	6.6	10.4	51.2	27.3	13.5	**1.74**
	Sinuosity	2.3	1.02	1.54	1.9	1.84	1.7	1.65	2.1	1.32	1.68	2.11	1.75	1.73	
Landsat TM 1986/1987	**Length of river (km)**	20.1	5.9	45	51.6	14.9	17.4	21.9	52.6	8.1	12.2	60.8	34.1	18.2	**2.08**
	Sinuosity	2.51	1.26	1.7	2.22	2.71	1.85	1.9	2.31	1.62	1.97	2.5	2.19	2.33	
Landsat ETM+ 1999/2000	**Length of river (km)**	21.4	6.1	44.9	52.9	15.1	17.4	22.7	53.4	8.1	12.9	64.6	35.1	19.9	**2.16**
	Sinuosity	2.68	1.3	1.69	2.28	2.75	1.85	1.97	2.34	1.62	2.08	2.66	2.25	2.55	

Appendix 2: Questionnaire

QUESTIONNAIRE

A. Date of visit : _____/_____/_____

B. Region : _____

C. Departement : _____

D. Commune : _____

E. Village of : _____

F. Name of the person : _____

_____

_____

G. GPS coordinates : _____

1 When was the village founded?

2 Name of the village/other name

3 Has the village moved before being on this actual place?

If yes:

3.1 Did this happen before or after the colonisation?

3.2 How many times and in which parts at the river?

3.3 Why did you move?

4 What use do you make of the water in the river?

5 How are the fields limited close to the river?

6 What are the changes observed in the village and around it? Can you verify the changes I have seen? Have you noticed if the river is moving laterally?

7 Does the changing of the river make an impact in your life? Ex: losing or gaining fields, conflicts, your economical situation, problems with the agriculture...

8 Have you noticed any erosion? If yes, has this damaged your houses, fields or caused any other problem?

9 According to you, what is the border?

10 What difference do you make being from Niger or Nigeria?

For the mayor/authorities :

11 What is the border ?

12 Are there any beacons marking the border?

13 Are there any organisations managing the river between the villages in Niger and Nigeria? If yes, what do they do?

Appendix 3: Summary of Field Visit

Commune of Maïné-Soroa

Date of visit: 22nd of Oct 2009
Reference: Departmental director of the hydraulic ministry of Maïné-Soroa, Bagalé Tchiarima

There is an organization managing the river between Niger and Nigeria in this area, the Gamba union. The Gamba Union includes, among others, the village of Tam, the village of Kanama and Nigeria. There is no hydraulic representative; it works on a village level. The Gamba Union measures the adaptation and change of the water resource. It is auto-financed.

The Lake Chad Basin Commission manages everything that concerns water resources and the water around the Lake Chad. This is the main organization concerning the managing of the Komadugu Yobe.

The Komadugu Yobe is a natural border. It floods during the rainy season. There are sluice gates, installed 2003-2004, on two or three ends of the oxbow lakes at Tam.

Date of visit: 22nd of Oct 2009
Reference: Municipal secretary, Maï Lawan Gremah

The municipal secretary of Maïné-Soroa said that when it rains a lot, the oxbow lake gets filled-up with water. He also said that this year it has not rained so much.

Village of Kanama

Date of visit: 22nd of Oct 2009
Reference: Village chief Hassan Lawan a.k.a. Hassan Maïgari
Coordinates of the village: N 13°07,160', E 12°06,606'

The beacon at the oxbow lake at Kanama fell down four to five months ago. The beacon's old spot was at N 13°06,848', E 12°06,387'. The beacon was over 60 years old. The oxbow lake is not connected to the Komadugu Yobe. The upstream part of the lake belongs to Nigeria, the downstream part to Niger. The village collaborates with Nigeria via the Gamba Union concerning the oxbow lake. The villagers drink water from the well. The village has not moved during its history.

Village of Tam

Date of visit: 22nd of Oct 2009
References: Village chief Maina Moustapha, Amadou Moustapha, Kaoumi Bukari, Biri Moustapha,
Coordinates of the village: N 13°08,042', E 12°08,239'

The villagers witness a progress of the river to the north; the river is eroding the banks. The erosion is visible when the river is coming powerfully. Since 1999, the river has moved at least 40 meters laterally. When the oxbow lake, called "Walou Minam" is filled with water, the river connects to it. If the Komadugu Yobe would connect permanently to the oxbow lake, it will be a problem, as the land will become Nigerian. Nowadays this phenomena is accelerating as, besides the force of the river, there is sand being deposited on the riverbed and deforestation around the river. Today, the location of the river is at N 13°06,532', E 12°08,635'.

The village of Baradi was in-between the Komadugu Yobe and the oxbow lake but had to move as the erosion threatened the village. This happened in the 1980s. The village had about 20 habitants.

In the past, the Komadugu Yobe was narrow and little deep. Nowadays the riverbed is wider, as a result from sand, and shallower. The oxbow lake is replenished by rainwater.

There are people who are losing fields because of the river. This concerns Tam and surrounding villages like Igir, Abari, Gengari, Boulacoma and Chefori. The river is forcing the locals to find new fields. They either get help by the village chief or getting other help.

The Komadugu Yobe is the border from the beacon until Bosso. The villagers are aware of that when the river changes, so does the border. The present beacon has been there for three years. The old one was replaced by the military around 2004. At the same time, the beacon was moved six meters to the north. The commission of the delimitation of the border did this. The present landmark is a white pole. There is also a water level meter in the river. The first one was put there in 1999 by the DRH.

The villagers use the water for agriculture, fishing and for watering the livestock. Sometimes they drink it, but usually they drink water from the well.

The Gamba Union project in the Maïné-Soroa commune was created in 2005. The project is managing, among other things, the fishing in the river between Niger and Nigeria.

Commune of Chétimari

Date of visit: 24th of Oct 2009
Reference: The mayor of Chétimari, Djibrilla Malam Kalla

There was a drought from 1955 until 1974. Nowadays it is raining less and there is less water.

The border is the riverbed of the Komadugu Yobe. When the river is changing, so does the border. There has not yet been any problem about the border with Nigeria, but one day it might if both countries think a piece of land belongs to them. Before the colonisation, they were in the same country, a sultanate. Today people continue to cultivate on the other side of the border. The villagers in Bagara is for example cultivating in Nigeria. The customs consider the river as the border.

It is not clear to which country Dabougou belongs. Nigeria thinks it belongs to them. The problem started in the 1930s. The villagers at Dabougou say they are in Niger. Before 1950, a test was made to see which country the village belongs. A calabash was put in the river to determine where the dominant current goes, because this shows the principal channel of the river. The calabash went straight, and not taking the way into the meander, so this is were the border is, but Nigeria has still not approved of the border. People from Nigeria have come with documents to convince that Dabougou belongs to them. Today the two states has still not agreed to which country the village belongs. The village says Niger, and historically it belongs to Niger.

Around 1994 the Niger-Nigerian mixed commission was created. There is a committee for the delimitation of the border. They made a field visit on the spot concerning the border in 2004, after the election of the mayor. The man who supervises the committee is Colonel Mathmane Korou. They have worked in association with the communes.

At Gaidam Tchouckou, the river is eroding the banks on the southern part of the village. It has eroded 17 meters. People have had to move or move the houses. PADL will make a protection of the riverbank.

At Zarwaram, they are losing land. They can move a little to the north, but they want to stay where they are.

The Komadugu Yobe is moving, unfortunately to the Niger side. There has been a lot of deforestation and removing of the vegetation in Niger. In Nigeria, the trees and vegetations have been left alone. The deforestation is one cause of the erosion. Now there is also a lot of sand and the river is shallower.

In Dagaya, Lada and "Gogol" there are water catchments built by PADL around the 1980s. This was a problem for the Nigerians. The riverbed was not diverted. The

riverbed is sandy and has become narrower. This has transformed the series of oxbow lakes. It is in the big mares where you fish.

There is no collaboration concerning the river on a commune level.

Village of Dabougou

Date of visit: 24th of Oct 2009
References: The uncle of the village chief, Boulama Boudou, the representative of the village chief, Boulama Boukar
Coordinates of the village: N 13°15,331', E 12°33,469'

Dabougou was founded on its current spot about 400 years ago. In the beginning, the people lived in another village called Loumbouram. As they were attacked by the touaregs (an ethnic group), they moved. The trees and water served as a protection as the touaregs could not swim. The meander was there naturally and has not been made by humans.

Flooding was often a threat in the past, but nowadays this threat has decreased. The village built the dike crossing the two branches of the meander around 1959 to be able to cross the water easily. There is a tunnel under each dam to let water flow in to the meander. When the village was created there were no dams.

There is sand being deposited in the river and making it less deep. Before you could stand on the bottom and be completely covered by water, but not anymore. There were also trees around the river and the leaves touched the water. The wind is also carrying sand with it. The south is wooded.

Ten fields have been lost on the northern side, close to the northern branch. The villagers look for land further north when they are losing fields. This started 15 years ago. Before they did not have this problem. There is also an overexposure of the banks.

The water from the Komadugu Yobe is used for agriculture, like wheat, cereals, corn and pepper, and for fishing. They do not drink the water.

The Komadugu Yobe is the border.

The coordinates for the two branches are N 13°14,893', E 12°33,903' and N 13°14,728', E 12°33,866'. The coordinates at the tip of the meander are N 13°15,677', E 12°32,904'.

Village of Zarwaram

Date of visit: 24th of Oct 2009
Reference: The representative of the canton chief, Lawan Chétima
Coordinates of the village: N 13°09,090', 12°31,292'

Zarwaram has been on the current spot for 300 years. Before that, the village was at the meander just north of the village, but moved to get away from attacks.

There are enough trees around the river, but the villagers are aware of that in other zones with less trees, sand is being deposited in the river.

There is not as much water in the river as before. The villagers have noticed a decrease of the water level. In the past the river flooded, but not anymore. It has been 12 years (in 1997) since the last flooding. Before that, it was 30 and 60 years ago it flooded (in 1979 and 1949). There are dams upstream.

The river has not changed its course. The two meanders close to the village has the same course now as before the colonisation.

The river is eroding the banks and fields have been lost. The problem started 12 years ago (in 1997).

The meander southeast of the village has changed. Before it was only one channel at the tip of the meander, today there are two, with a distance of about 40 meters in-between them. This happened about ten years ago (in 1999). The original riverbed eroded. The change was brusque and was followed with a progressive change.

The Komadugu Yobe is the border from Kanama until the Lake Chad.

Commune of Diffa

Date of visit: 23rd of Oct 2009
Reference: Manager of the DRH, Laoualy Yahouza,

The Komadugu Yobe is the border. Everything depends on the river: water resources, fishing etc.

A big dam construction is scheduled in the Bauchi state, Nigeria, which will influence the downstream flow in the river. There was a meeting at Damatoru with the objective to discuss this between the countries, led by the Niger-Nigerian Mixed Commission.

Date of visit: 23rd of Oct 2009
Reference: The responsible for water resources at the DRH, Hachirou Abdou

The river's course has changed at its mouth at the outflow area. There are two branches flowing out in the lake. There is a natural course and a man-made. The man-made channel was made 30 years ago, around 1974-76. It is Nigeria who started this work. This means that Nigeria loses land. The Komadugu Yobe is the border until the Lake Chad.

At Gaidam Tchouckou Niger has lost land.

PADL is an organization focusing on the local development. It is a Niger organization financed by the African Bank of Development.

Village of Chétimari

Date of visit: 23rd of Oct 2009
Reference: The village representatives Moustapha Malam Mélé and Ousmane Makinta
Coordinates of the village: N 13°17,752', E 12°38,270'

The village was founded 300 years ago and has since then moved twice, to Nalea in the north and to Marera in the south. In the beginning, the village was where it is now. Around 1919 there is not enough room for everyone and most of the villagers moved, only seven families stayed. The villagers moved either to Diffa Nalea, or to Marera. In-between 1919 and 1939 some of them come back, but some are staying. In 1939, there is a flooding at Chétimari and once again, some of the villagers emigrate to Diffa Nalea. As there is not enough space at Diffa Nalea, some of them come back to Chétimari after the flooding.

There is a change in the rivers' course; it has moved and is eroding towards the north. As a result, fields are lost and you have to find new ones further north. The village is also gaining some land.

The Komadugu Yobe is the border. There is a landmark west of Tam where the natural border starts. Then it continues until the Lake Chad. The border is in the middle of the river and you can only fish on the Niger side.

The villagers are using the water in the Komadugu Yobe for fishing, drinking and agriculture.

Information obtained during the field visit in the surroundings with the village representative:

Taiwan has built a pump station (GPS points: N 13°16.989', E 12°35.723') in 1994 for irrigation. The villagers have also built a dam to prevent flooding. It has been 40 years, since 1969, that the villagers have understood that the water does not come as before. There was an exceptional high water level in 2001.

The villagers have never seen the Komadugu Yobe flow in the furrow, only at a high water level. The furrow is not man-made. They do not have any memory of the river ever flowing here. They have just concluded that in the past the river went here, as the furrow is not man-made. The GPS points along the furrow are: N 13°17.067', E 12°36.801' and N 13°17.094', E 12°36.864'.

Village of Lada

Date of visit: 23rd of Oct 2009
Reference: Village chief Boulama Mattamalambemi
Coordinates of the village: N 13°18,090', E 12°38,710'

The village was founded 800 years ago and has since then been situated where it is now. It moved to the current place from the oxbow lake 800 years ago.

There is no change concerning the river's course being observed except for erosion at the curves. It erodes every year. In the past, the houses had a garden in-between the house and the river, but no longer. When the river is approaching the house, you have to move. Three to four houses have been damaged recently. The river is progressing towards the houses each year. To prevent the erosion the villagers have put sandbags and/or bags with litter on the riverbanks.

The villagers are also losing fields; 15 to 20 fields have been lost. They have to find new land in the north. The dike between the river and the oxbow lake is sometimes flooded.

The Komadugu Yobe is the border and the border is on the middle of the river. Therefore, you can only fish on the Niger side. There is no problem with the local inhabitants on the other side of the river.

Commune of Gueskérou

Date of visit: 25th of Oct 2009
Reference: Mayor of Gueskérou, Bagalé Madou

The river is eroding the meander at Gueskérou, coordinates N 13°29,275', E 12°51,352'. How much depends on the rain and the flow each year. The mayor does not know how many meters it erodes every year, but it is visible. When a field is moved to the other side of the border due to the river, it still belongs to the same owner.

Village of Boulamari

Date of visit: 25th of Oct 2009
Reference: Village representative Koura Gassaou
Coordinates of the village: N 13°29,571', E 12°54,414'

The village is 300 years old. Before the village was at N'Guigmi in the north, but it was flooded so it moved down to the present place.

The river's course and flow is changing. Before, the water flowed for a longer time, eight to nine months. Nowadays it only flows for three to four months. It was 21 years ago (in 1988) when the villagers started to lose confidence in the duration of the flow.

The river is getting narrower and is also eroding fields. The villagers have built dams using sandbags to protect the fields. In the past, the river was deeper. Nowadays children can go in the river. As sand is depositing on the riverbed and is covering the outcropping groundwater, a well has been constructed to be able to reach it when the river is dry.

For about 55 years ago (in 1954), the village was on an island. The coordinates where a branch of the river was before are N 13°29,392', E 12°54,326' and N 13°29,673', E 12°54,363'. The river does not go here anymore because of sand deposits.

The Komadugu Yobe is the border. If the river would split the fields in two, the villagers would go to the other side of the river to cultivate.

Village of Dewa Fouyé

Date of visit: 25th of Oct 2009
Reference: Village chief Boulama Malam Mélé
Coordinates of the village: N 13°24,787', E 12°48,831'

Dewa Fouyé is 200 years old. One part of the villagers moved to Dewa Kargueri, just north of Dewa Fouyé. This happened the day after the independence in 1960. The people looked for a more opened space as Dewa Fouyé was on an island.

The river is changing but each year has its own particular change. The flow is decreasing. In the past water reached the banks of the village, but not anymore. One cause is the decrease of the flow, which is natural change. Another cause is that the exposure of the water is at its highest. The river is drained for cultivation.

The meander close to the village was cut off about 60-70 years ago, after the colonisation. The village chief remembers that when he was young the meander was not cut off. It happened when it was the highest water level he have ever known and progressed during two to three years. It was cut off during the changing of the

Governor Kazelma Omar to Kazelma Boukar. The land in the middle of the oxbow lake is not cultivable. Before you could cultivate there.

The water from the river is, among other things, used by the villagers for fishing.

The river is the border. When the meander was cut off, the land became Niger territory. There is no village on the other side.

Village of Assaga

Date of visit: 25th of Oct 2009
Reference: Village chief Boulama Boukar, Boulama Mélé
Coordinates of the village: N 13°18,862', E 12°42,526'

Assaga is 350 years old. The village has not moved since the colonisation. The village Assaga in Nigeria, on the other side of the river, moved from Niger in the depression of 1929. Before that, people moved away because they were forced to work. With Assaga in Nigeria, Assaga in Niger is in perfect harmony.

For about 50-70 years ago (1939–1959) the river flowed during seven to eight months each year. Nowadays it only flows for three months. It was in 1984, at the Buhari coup in Nigeria (1979-1983) it started to change. In the past, the river was deeper. Now the wind has carried sand into the river.

The river is the border, but those in Nigeria have a property in Niger and vice versa.

The water from the Komadugu Yobe is used for agriculture, to water the cattle, to manufacture bricks and for fishing.

Commune of Bosso

Date of visit: 26th of Oct 2009
Reference: The mayor of Bosso, Ibrahim Hassan.

The riverbed is no longer what it was before. It is because of erosion or because of the flow.

The villagers in Nigeria have diverted the river's channel. They have been explained to that the river is the border and they can not change it. It has been 17 years (in 1992) since Nigeria dug in-between Bosso and Mamouri. Now the Komadugu Yobe goes until Kaniram, Nigeria. They Nigerians did this for cultivation purpose. There is still water in the natural channel of the Komadugu Yobe, but not much.

It is it is the villagers have dug, not the Nigerian authorities. The Nigerian authorities have said that they will repair the diversion so the Komadugu Yobe flows in its

natural course. They have closed the passage the villagers have done. The villagers in Nigeria are not happy about this. They have put sandbags to prevent the repair, but luckily, the river continues its natural way.

The Komadugu Yobe is a natural border and the exploiters are trying to change this. This means that Nigeria is losing land. The Nigerian authorities have explained this to the villagers, that it is either water or land. It is Nigeria that has paid for the repair, as it is them who have lost land.

In Mamouri, they have almost no water left. The dig up is to the Nigerian advantage.

The force of the river has damaged the floodgate built by the villagers at Mamouri and the farmers have lost their corn.

In between Bosso and Kiari Kagari, the river's course has changed. This is because of erosion and cultivation.

The river has not changed in between Abadam Niger and Abadam Nigeria.

There are no organizations between the communes in Niger and Nigeria in Bosso.

The coordinates for where the riverbank has been reinforced are N 13°41,862', E 13°18,764'.

Village of Mamouri

Date of visit: 26th of Oct 2009
Reference: Village chief Boulama Mérémi
Coordinates of the village: N 13°43,469', E 13°21,100'

The village is 60 years old. In the beginning it was situated for about 100 meters further to the east from where it is now, at N 13°43,417', E 13°21,120'. The villagers moved to the present place 52 years ago (in 1957) as the Lake Chad was threatening the village. The old lake shore was at N 13°43,444', E 13°21,172'. Three years ago (in 2006) the lake was at N 13°45,055', E 13°22,129'.

The lake has changed. It is not the Komadugu Yobe who is threatening the fields, it is the lake. The river had its mouth in Nigeria, but since two years ago (in 2007) it changed to Niger.

While waiting on the arrival of the water, the villagers in Nigeria dig on the river furrow, this is what has changed the river's channel. It was two years ago (in 2007) it was regulated on a national level when it comes to the border.

There is more water now and it gets flooded. Therefore, you can no longer cultivate corn around the village.

The flow was bigger before than it is now. The villagers have started to cultivate pepper as the flow has diminished. It started to diminish around 1970. It is about 25 years ago, around 1987-88, the cultivation of pepper started.

The river is less deep now, because of sand coming in from the riverbanks. There are also fewer trees. When the lake retreated, the prosopis tree invaded the bottom of the lake. The trees along the river have been uprooted.

The fields have been on the same place since the village moved. The river is destroying parts of the fields.

The Komadugu Yobe is the border. Before one old man in the village was born, there were landmarks. When you cross the river, you are in Nigeria, even if there are landmarks that show the official border. The landmarks are made of iron and have been there since the colonisation. When one man of the villagers was young, he did not see the landmarks, as the lake was flooded. The beacon at the village of Tam has been moved.

There is no problem with the villagers on the other side of the river.

The river at the village has the coordinates N 13°43,185', E 13°21,091'. The coordinates from where the river is diverted are N 13°42,999', E 13°20,873'

Village of Gamgara

Date of visit: 27th of Oct 2009
Reference: Village chief Boulama Moustapha, Chérif Boubacar
Coordinates of the village: N 13°39,880', E 13°16,393'

A change has been noticed concerning the duration of the period of flow. It has changed from flowing during nine months, to four months. It was ten years ago (in 1999) the change started.

The river was deeper before. The water level has changed because of the wind and sand. The water does not come as powerful as before.

The river is following the course the lake left when it retreated. It was during the presidency of Ali Seybou (1987-1993) when the lake started to retreat . The river was then naturally progressing to the north. The coordinates for where the river goes today are N 13°39,202', E 13°16,675'.

Boulagana built dams 15 years ago (in 1994), that drained off the water. Gamgara and also Blagana in Nigeria have since then had problems to get water.

The Komadugu Yobe is the border.

The dried out oxbow lake between the two villages of the present Gamgara and the original Gamgara, had water in it the last time at the end of the presidency of Abacou, 1983-84. The oxbow lake's coordinates are N 13°39,818', E 13°16,451'. The village on the other side of where the river goes in October 2009 is called Yawa. The villagers dug a channel 15 years ago (in 1994). The coordinates for the channel are N 13°40,471', E 13°17,740'.

Village of Abadam

Date of visit: 27th of Oct 2009
Reference: Representative of the village chief Abdou Chétimami
Coordinates of the village: N 13°37,591', E 13°15,149'

The village is 560 years old. It has always been where it is now. From here, people moved to Abadam Nigeria because of politics. This happened after the colonisation, 80 years ago (1929).

The water is flowing in the river during a shorter period nowadays. In the past, it flowed for nine months, today only for three months. The river is also shallower now than it was before. This is because of sand coming in the river and a decrease of the water quantity.

The river changed channel between Abadam in Niger and Abadam in Nigeria before the president Seyni Kountché (1974-1987), around 1950. It was before the independence. The change was natural. When it happened, the river was powerful and there were white sand where it went through. The coordinates where the river diverted are N 13°37,314', E 13°15,515'. Today it flows on the two sides, but more on the side closest to Abadam in Nigeria. It has always flowed more on that side since the change. The territory in the middle of the river belongs to Niger. The villagers would like to dig in the channel closest to them to increase the water flow.

Nigeria built dams at the side of Abadam Nigeria. This was around 1950, when the river started to go there.

There are no problems with erosion and no fields have been damaged.

The water is used for transportation, agriculture and fishing.

The Komadugu Yobe is the border.