FOUTA DJALLON HIGHLAND WATER ATLAS

The Water Tower of West Africa

June 2017

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PREFACE

Looking at the West African water resources and their transboundary management, it is evident that the Fouta Djallon highland have a special and important role to play, which extends well beyond Central Guinea. The Highlands are the source of many international rivers, which include the Senegal, Gambia, Niger, Rio Corubal, and the Great and Little Scarcies Rivers. Eight countries (The Gambia, Guinea, Guinea-Bissau, Mali, Mauritania, Niger, Sierra Leone and Senegal) are thus directly or indirectly affected by these Highlands' water resources. Preservation and balance in the Fouta Djallon highland are therefore key issues for the entire sub-region. However, the Fouta Djallon highland have never really been studied through an integrated approach, even though they are the focus of many concerns. The Fouta Djallon Water Resources Atlas, produced by ECOWAS/WRCC with funding support from the World Bank, is a monographic synthesis of the Fouta Djallon highland, which aims to provide a comprehensive picture of both its physical components and its water resources, including their uses and the roles they play - more specifically their environmental roles.

The first sections of the atlas present the physical properties of the Fouta Djallon highland and attempt to clarify the multiple definitions found in the literature. For this specific objective, a study describing the topographic contours of the Fouta Djallon highland was undertaken, to examine their nature and how it differs from the other surrounding highlands. A study was also carried out to determine the basins and sub-basins. This has been supplemented by a summary of land use and climate characteristics. Finally, its water resources are presented as an exhaustive synthesis of the hydrological regimes of the main rivers originating in the Fouta Djallon highland, based on current knowledge.

The subsequent sections provide a view of the main human characteristics and water use in the Fouta Djallon highland, with the related constraints, issues or challenges that have been assessed or that will need special attention in the future. Based upon accessible data, these sections also address the areas that are dependent on the Fouta Djallon highland and, more generally, on the conditions at the heart of Fouta Djallon highland.

We wish to emphasize that this atlas is based upon data and knowledge that often come from a distant past, such as hydro-climatic monitoring data which, in some cases, dates back to the 1920s, and on the results of studies by D. Orange on the Hydro-Climatology of the Fouta Djallon (1990), by Y. L'Hôte and G. Mahé on Rainfall in West Africa (1995), or by Y. Boulvert on the Morphopedology of Guinea (2003).

The Water Atlas of Fouta Djallon highland is an initial basis for sharing knowledge among the stakeholders of countries that are interested by, or dependent upon, the water of these Highlands. It supplements the historical work of the Regional Program for Integrated Development (RPID) of the Fouta Djallon highland, which was started by the African Union in 1981. Producing this document also revealed how much work remains to be done in terms of knowledge, but also in terms of managing and capitalizing upon this information over the upcoming years. The importance of water resources for populations that depend upon the Fouta Djallon highland should encourage us to continue our efforts with regard to studies and publications that will reconcile socio-economic development with the preservation of the Highlands in the context of the climate and demographic challenges that characterize the sub-region.

ECOWAS/WRCC is a full and willing participant in this process and thus remains at the disposal of representatives from the countries that share the water resources of these Highlands. By making the Water Atlas of the Fouta Djallon highland available to decision-makers and stakeholders in these countries, our intention is to provide readers with knowledge and support, and we hope that everyone will greatly benefit from this document.

IBRAHIM BABATUNDÉ WILSON
Director of the ECOWAS Water Resources Coordination Centre (WRCC)

FIGURES

FOUTA DJALLON HIGHLAND

Natural region of Central Guinea in Guinea
4 countries directly concerned : Guinea, Mali, Senegal, Sierra Leone

AREA

47 000 km^2

MAIN ASSOCIATED HIGHLANDS

Guinean Dorsal: 89 000 km^2
Coastal Guinea highland: 29 000 km^2
Siguirini-Baléa region highland: 6 000 km^2
Manding mounts: 24 000 km^2

RIVER BASINS OF THE AREA

20 river basins
15 transboundary basins including Senegal, Gambia Niger, Rio-Corubal, Great scarcies and Little Scarcies

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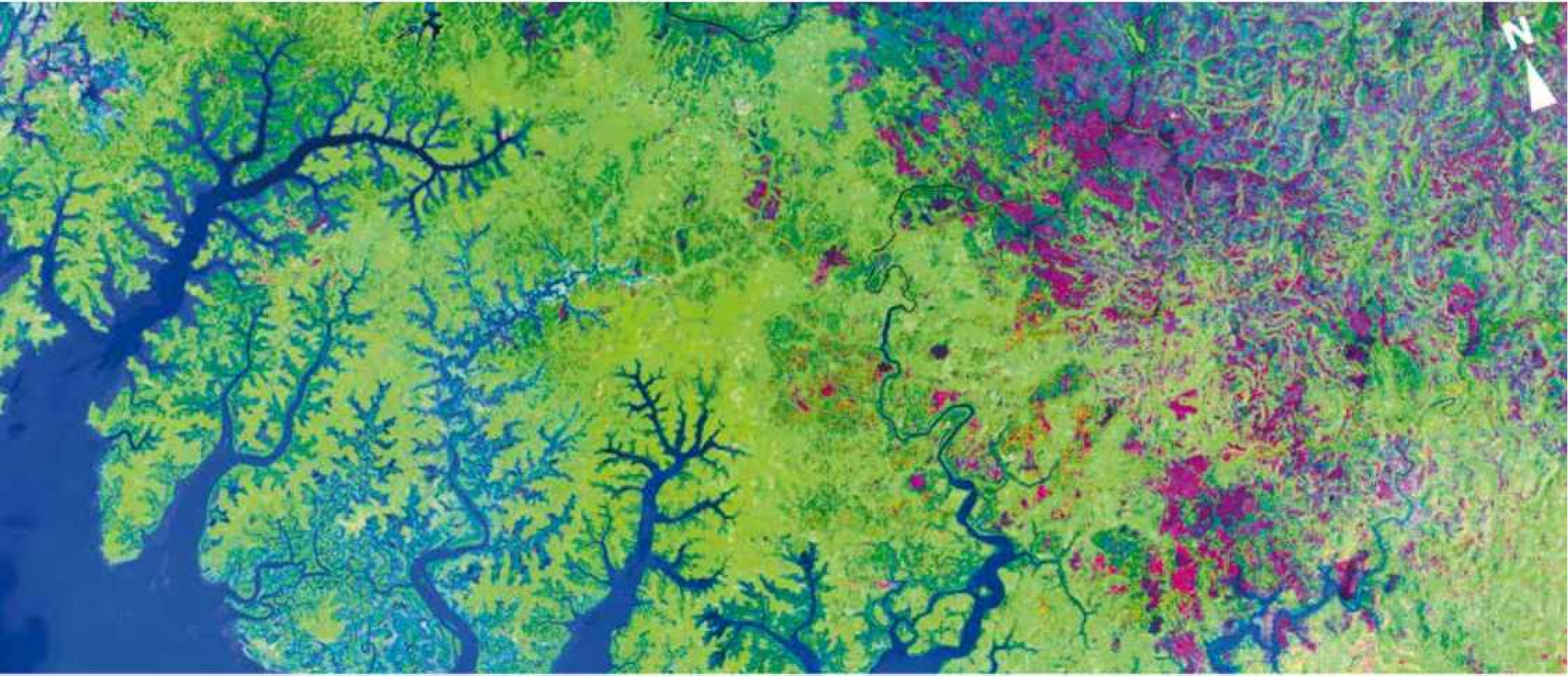
PREAMBLE



AN INFLUENCE ON ALL OF WEST AFRICA

This chapter introduces the Fouta Djallon highland, its various delimitations or interpretations and its role as «water tower» of West Africa.

AT THE ORIGIN OF FOUTA DJALLON

THE FOUTA DJALLON, A NATURAL AND CULTURAL MOUNTAINOUS AREA LOCATED IN CENTRAL GUINEA, IS UNANIMOUSLY RECOGNIZED AS «THE WATER TOWER OF WEST AFRICA», WITH REFERENCE TO THE MANY INTERNATIONAL RIVERS WHICH HAVE THEIR ORIGIN THERE. HOWEVER, IT IS SUBJECT TO MULTIPLE DELINEATIONS.

THE MULTIPLE DELINEATIONS OF FOUTA DJALLON HIGHLAND

Fouta Djallon is a powerful name which immediately invoke Guinea's topography. However, although it is a recognisable and a well-known natural entity, there is no precise geographical definition for Fouta Djallon (Orange 1990). There are currently several geographic definitions, with its actual definition remaining unclear. Whilst certain geomorphologists associate the Fouta Djallon highland with the Central Guinea topography, others associate it more with the Guinean Dorsal in Upper Guinea and Forest area of Guinea (map 1). There are also highlands on the south side of Guinea, which, depending on specific interpretations, may or may not be associated with the Fouta Djallon highland. In this water atlas, a comprehensive chapter on the sector's topography provides an initial definition between those different sectors whilst offering a more specific topographical definition of these landscape features.

In addition to these topographical approaches, the FAO also offers a geographical definition of Fouta Djallon which covers a larger zone including part of the Guinean Dorsal, the Coastal Guinea Highland, the extension of the highland from North-Eastern Guinea to Mali, as well as an extended area towards Guinea-Bissau and Southern Senegal. Based on different topographic and climate approaches, and river basins limit, this definition of Fouta Djallon by the FAO goes beyond the "natural" limits of the highland itself and covers an extended area around the Fouta Djallon highland which is consistent with several natural criteria.

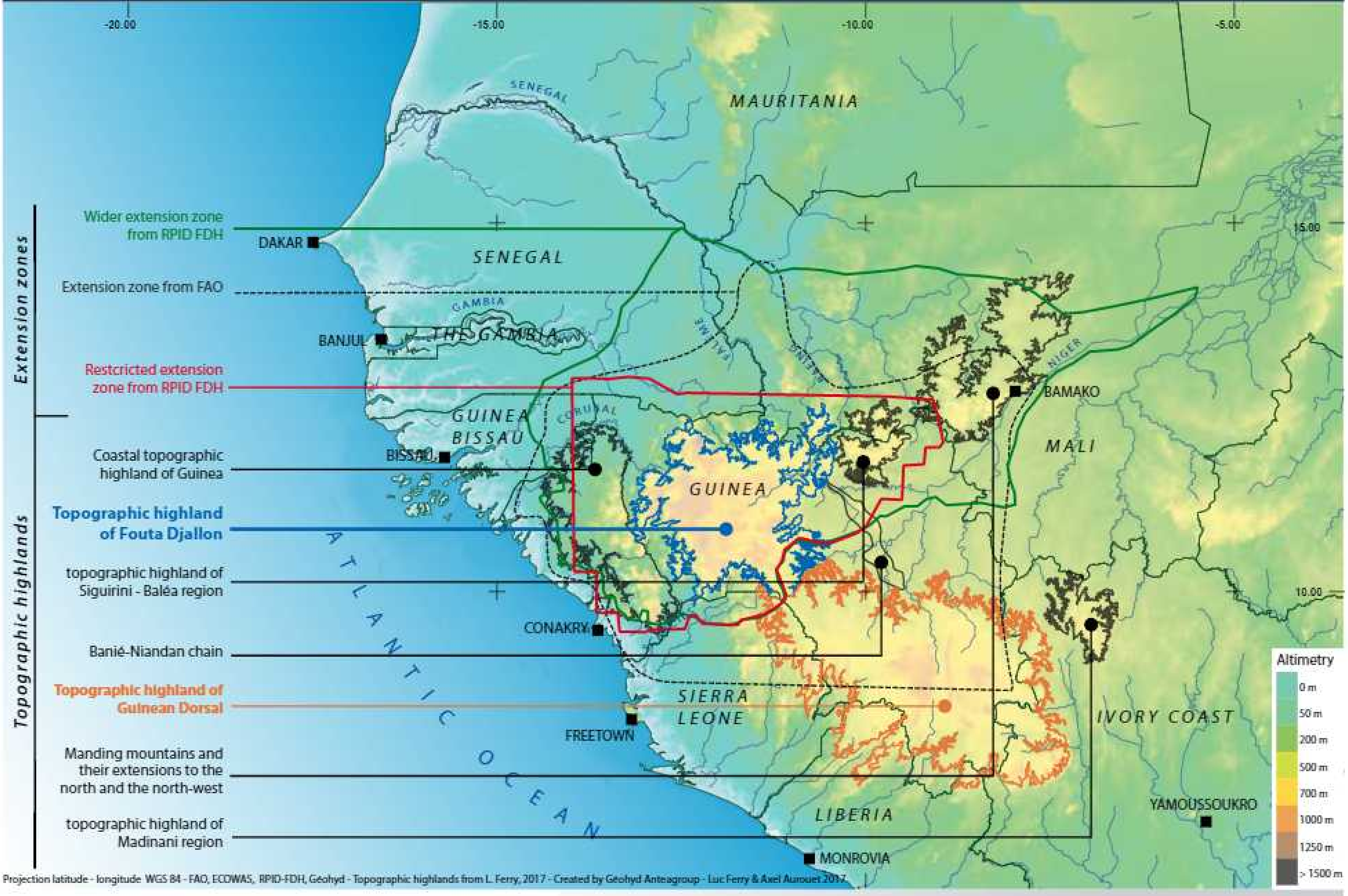
Finally, as part of the Fouta Djallon highland' regional integrated development programme (FDH-RPID) covering 8 countries (The Gambia, Guinea, Guinea-Bissau, Mali, Mauritania, Niger, Senegal, Sierra Leone), two suggested geographical boundaries are proposed. The first definition includes a "restricted" zone completely linked to Guinea and mainly based on Guinea prefectures influenced by Fouta Djallon (mainly from a hydrological and topographical point of view). A second, larger definition extends towards Senegal, Guinea-Bissau, Sierra Leone and Mali. This second zone, which we will call "the wider extension", includes the sector of Bakel in Senegal (site where the main tributaries of the Senegal river - Falémé - Bafing - Bakoye - meet), the sector of Markala in Mali (site where the main tributaries of the Niger river - Tinkisso - Sankarani - Milo - Niandan - meet), the Northern part of Sierra Leone corresponding to the upstream part of the Great and Little Scarcies rivers, the Eastern part of Guinea-Bissau corresponding to the upstream part of the Koliba - Rio Corubal and the Kolda-Tambacounda sector in Senegal, including the upstream sectors of the Kouloumtou river and the Gambia river before they enter The Gambia. All Fouta Djallon boundaries are shown on map 2.

There are therefore several interpretations of the Fouta Djallon highland which coexist in different literature, differences which sometimes create confusion regarding its actual definition. This confusion is accentuated by the origin of the highland's name. Etymologically, Fouta Djallon means "Country of the Djalonkés", Fulani farmers - giving an anthropological emphasis to Fouta Djallon. This emphasis is supported historically with the existence of a State of Fouta Djallon, which was created around the mid-18th century under the influence of a Foula leader which included eleven provinces (Timbo, Labé, Kolen, Koin, Kolladé, Fadé Hadji, Timbi Touni, Timbi Madina, Bani, Massi and Akolémadji) (Bouillet, 1893 – map 1). As a unique landscape, Fouta Djallon is therefore also at the crossroads between a significant ethnic and cultural history.

Map 1 > Natural region of Guinea

Map 2 > Delineation of Fouta Djallon highland, its extension zones and surrounding topographic highlands

Topographic highlands from Luc Ferry 2017



Projection latitude - longitude WGS 84 - FAO, ECOWAS, RPID-FDH, Géohyd - Topographic highlands from L. Ferry, 2017 - Created by Géohyd Anteagroup - Luc Ferry & Axel Aurouet 2017

ORIGIN


Esteam edge of Fouta Djallon nearby Mamou and Dalaba

FOUTA DJALLON OR FOUTA DJALON?

Both spellings are used in literature, although Fouta Djallon tends to be used in English literature and Fouta Djalon in French literature. It is usual to find both spellings in the same text, and in the oldest descriptions of Fouta Djallon from the 19th century, the spelling Fouta Djallon was used in French literature

THE WATER TOWER OF WEST AFRICA

Whilst the current definition of the Fouta Djallon highland is subject to various interpretations, nevertheless it is unanimously known as the "Water Tower" of West Africa, about the fact that various transboundary rivers and their tributaries have their sources in these highlands. It contains the source of the Gambia River, the source of the Bafing - Falémé - Bakoye complex which form the Senegal river after the Bafing - Bakoye confluence in Mali, the source of the Koliba which becomes the Rio Corubal in Guinea-Bissau, the source of the Kolenté which becomes the Great Scarcies in Sierra Leone, the source of the Kaba and Mongo which become Little Scarcies in Sierra Leone or even the Niger river and its left bank Guinea tributary, the Tinkisso (map 3).

In all hydrology-related monographs on river basin, the Fouta Djallon highland is highlighted in its role as a "spring" and this aspect gives it a key role around water issues for all transboundary river basins. As a result, a Fouta Djallon highland' Regional Integrated Development Programme (FDH-RPID) was established very early to preserve the highland from damage by bringing together 8 countries dependent on the Fouta Djallon highland' waters (The Gambia, Guinea-Bissau, Sierra Leone, Mali, Mauritania, Niger and Senegal). The geographical area covered by these 8 countries, although sometimes partially covered by the Fouta Djallon highland' waters, is therefore defined as the area of influence of the Fouta Djallon highland in different literature. This FDH-RPID project is specifically focused in spring protection (controlling erosion in particular) but also include a biodiversity protection and an evaluation of organic production potential components.

In shared recognition of its fundamental role in integrated water resources management of river basins (whether transboundary or not), the Fouta Djallon highland is now directly linked to three transboundaries organisations in the basin which are the Niger Basin Authority (NBA), the Senegal River Development Authority (OMVS), and the Gambia River Development Authority (OMVG). Those river basin organisations also cover the Fouta Djallon highland in their role of managing and planning water resources in the territory.

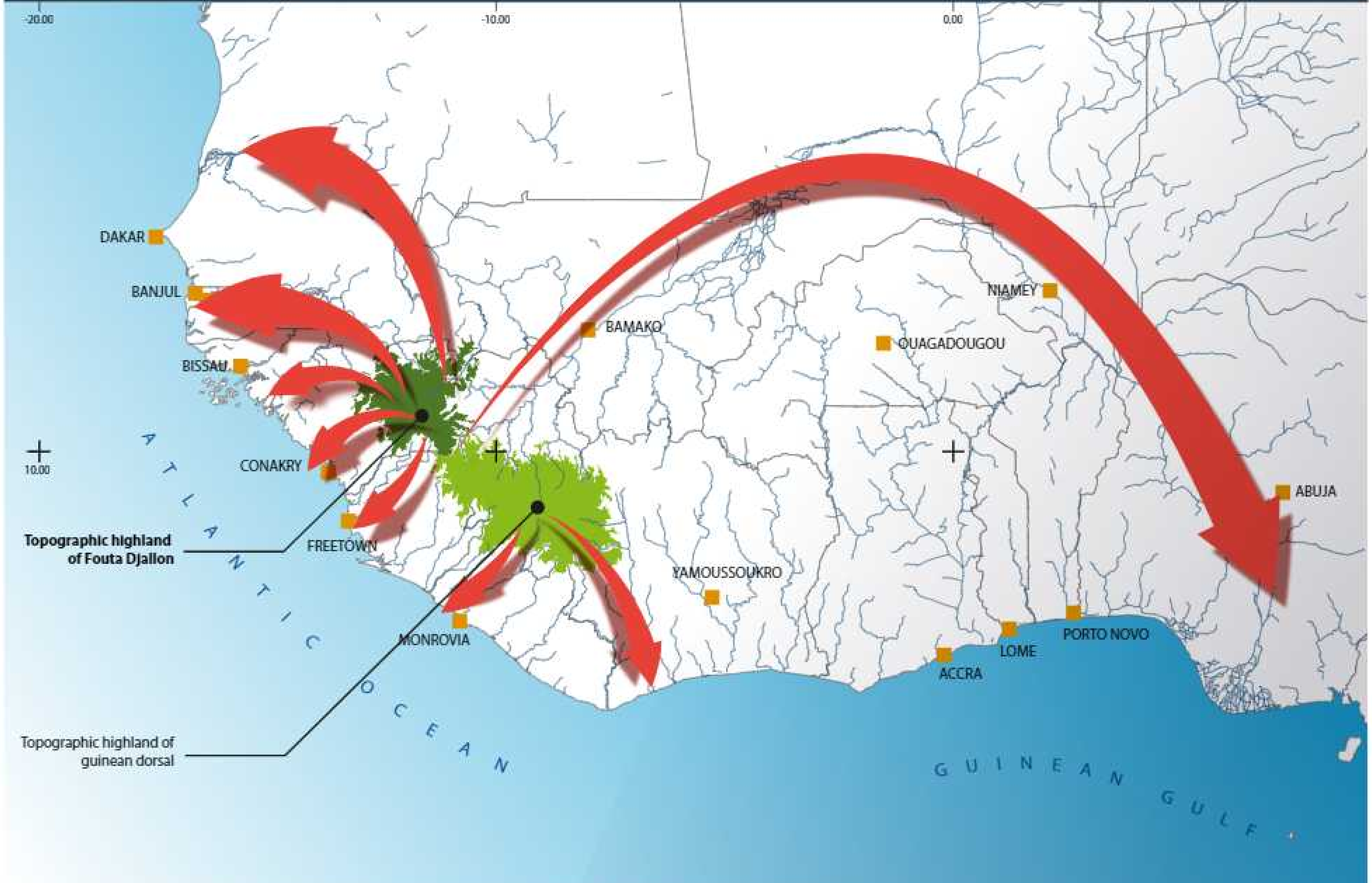
The Fouta Djallon highland therefore have an influence which goes beyond the limits of the Guinean Dorsal itself, and the population of a large part of West Africa, through transboundaries river basin, have some sort of connection with this highland (map 4).

This Fouta Djallon highland' Water Atlas aims to present the highland both from a physical and human point of view, and includes knowledge acquired over many years.

Map 3 > Main river basins of west Africa

Projection latitude - longitude WGS 84 - Géohyd - Watershed from L. Ferry, 2017 - Created by Géohyd Anteagroup - Luc Ferry & Axel Aurouet 2017

Map 4 > Area of influence of Fouta Djallon highland and Guinean Dorsal on West African rivers



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THE PHYSICAL ENVIRONMENT OF FOUTA DJALLON AND ITS EXTENDED AREA

AN ANCIENT LATERITIC LANDSCAPE

This chapter defines in a precise way the delimitation of the various highlands of the area and proposes a clear definition of them. It also deals on watersheds, which it inventories, as well as on land use, geology, geomorphological aspects and climate.

TOPOGRAPHY AND PHYSICAL DEFINITION OF THE FOUTA DJALLON HIGHLAND AND THE SURROUNDING HIGHLANDS

THE TOPOGRAPHIC MOUNTAIN RANGE OF THE FOUTA DJALLON BREAKS AWAY FROM THE GUINEAN COASTAL MOUNTAINS ON ITS SOUTHERN EDGE AND FROM THE GUINEAN HIGHLANDS ON ITS SOUTHEASTERN FRINGE. DELINEATED BY A 440 M CONTOUR AND WITH A SURFACE AREA OF APPROXIMATELY 47,000 KM², THE TOPOGRAPHIC MOUNTAIN RANGE OF THE FOUTA DJALLON LIES MAINLY ACROSS GUINEA, AND ITS BORDERS REACH MALI, SENEGAL AND SIERRA LEONE.

Map 5 > Topographic highlands of the area and position of altimetry profiles

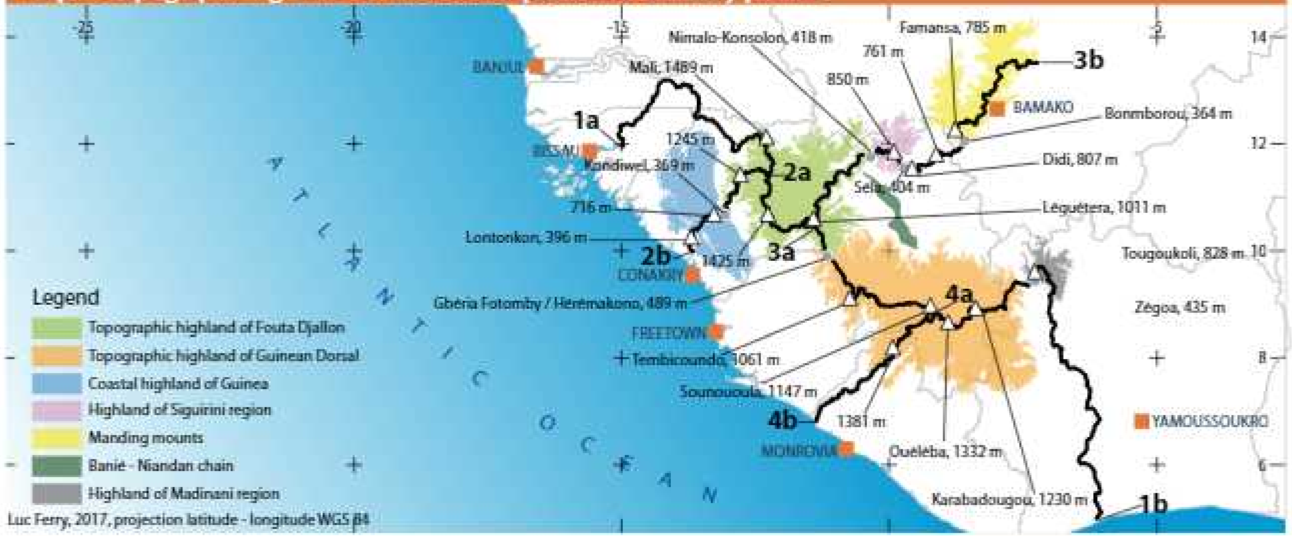


Table 1 > Main characteristics of highlands

Highlands	Area (km²)	Minimum Altitude (m)	MaximumAltitude (m)	Mean Altitude (m)	Mean Slope (%)
Guinea coastal highland	29 000	80	1 188	256	15.5
Guinean Dorsal	89 000	440	1 950	563	12.6
Fouta Djallon highland	47 000	406	1 538	686	16.3
Siguirini/Baléa highland	6 000	400	882	502	13.6
Manding mounts	24 000	360	785	420	6.6
Madinani region highland	6 000	420	914	472	9.8
Banié Niandan chain	(4 000)		859		

MANY HIGHLANDS AROUND FOUTA DJALLON

Mountains in the region, known as the "Water Tower of West Africa", have been poorly described. As an example, there is a strong confusion between the Fouta Djallon highland and the Guinean Dorsal. Some authors believe that the FDH are a sub-set of the Guinean Dorsal. For others, the Fouta Djallon highland and Guinean Dorsal are two separate geographic bodies (Boulvert, 1992; Ninot, 1994).

Yet Orange (1990) mentions that «Although it is a recognizable and recognized natural entity»…»There is no clear geographical demarcation of the Fouta Djallon. «. For others, the Fouta Djallon highland and the Guinean Highlands are two distinct geographical entities (Boulvert, 1992; Ninot, 1994; Diallo, 2010). In this atlas, the Fouta Djallon highland and the Guinean Highlands are considered to be two separate entities.

The map 5 shows three main groups: the Guinean Dorsal, the Fouta Djallon highland and the Guinea coastal highland. Four other smaller mountains, both due to their extensions and their altitudes, can also be distinguished: the Manding mounts, the small mountain in the regions of Siguirini/Baléa and Madinani. These four mountains, next to the area in question, are only briefly described here. Main features of those highlands are shown in table 1.

BOUNDARIES BETWEEN FOUTA DJALLON, GUINEAN DORSAL AND COASTAL HIGHLAND

The elevation profile of the water division line (figure 1) separating the Gambia, Senegal and Niger river basins (North-West to North-East) from other river basins from the Géba river basin to the Sassandra river basin (South-East to South-West) helps establish a boundary on this profile between the Fouta Djallon highland and the Guinean Dorsal. To fit the surrounding peaks into the central continuous highland, this limit is located at around 440 m at the Gbéria Fotomby/Hérémakono pass, names of the two villages located respectively in Sierra Leone and Guinea.

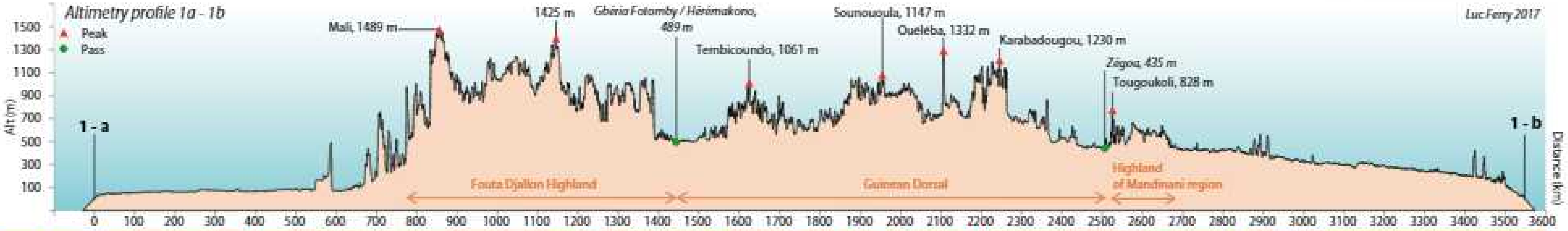


Figure 1 > Altimetry profile and drainage divided line between Fouta Djallon highland, Guinean Dorsal and highland of Madinani region (Profile 1-a 1-b map 5)

The Guinea coastal highland on the Atlantic coast cover mountains with an altitude above or equal to 80 m (figure 2). The boundary which differentiates between the Fouta Djallon highland and the Guinea coastal highland are established by the valleys of the Corubal, Konkouré and Kolenté rivers as well as the Tominé (Corubal DB), Bakolo (Fatala DB) and Kakrima (Konkouré DB) rivers; a limit passing through the Kondiwel pass between the Fatala and Konkouré rivers basins.

OTHER MOUNTAINS IN THE AREA

The highland of the Siguirini/Baléa and Madinani regions, as well as the Manding Mounts (and their extensions to the north and northwest) are delineated in the same way as the three previous highlands: boundary going through the passes identified for each geomorphological unit and use of the closest talwegs (figure 3). With boundaries that are not clearly delineated, the Banié Niandian range is approximately outlined here.

The very theoretical delineations of the seven highlands identified from elevation criteria obviously do not exclude other determining factors, especially historical and cultural ones, particularly in the Fouta Djallon highland and the Manding Mounts. Yet, let us underscore a relatively good match between the boundaries of the mountain highlands and the boundaries of the geological terrains or group of terrains.

Outside of these mountain highlands, the space is occupied by the low amplitude hills from which a few isolated peaks, rarely exceeding an altitude of 500 m, rise. Lastly, a non-negligible part of the landscape concerns floodplains with gentle slopes which include those located in the low valleys of the Niger, Senegal, Gambia and Rio Corubal rivers.

Figure 2 > Altimetry profile and drainage divided line between Fouta Djallon highland and Coastal Guinea Highland (Profile 2-a 2-b map 5)

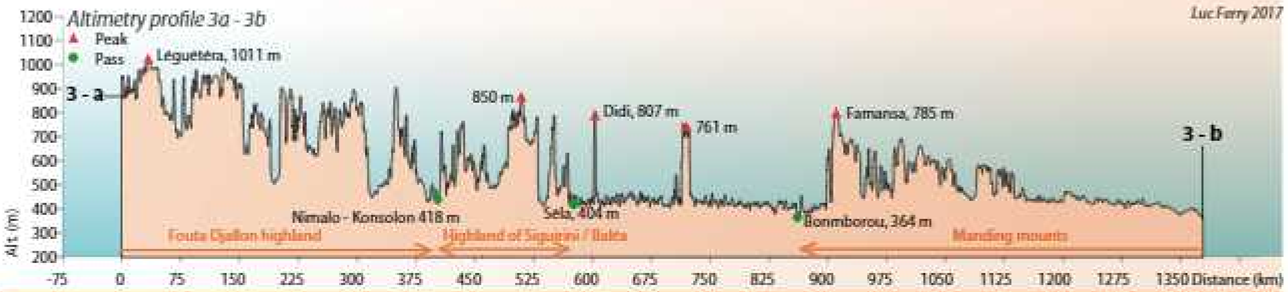
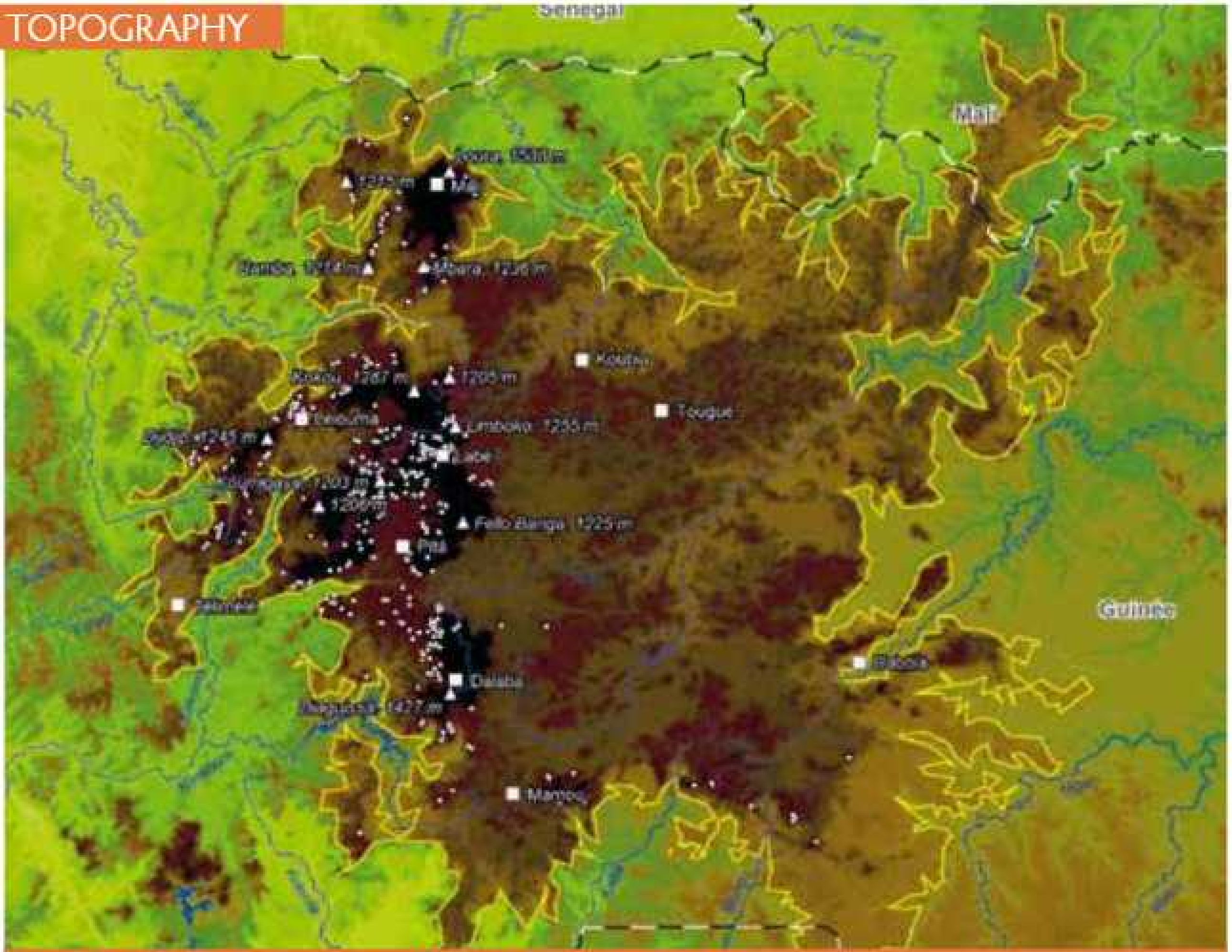


Figure 3 > Altimetry profile and drainage divided line between Fouta Djallon highland, Siguirini-Baléa highland and manding mounts (Profile 3-a 3-b map 5)

[1] Siguirini is a sub-prefecture of Guinea (not to be confused with Siguiri). Baléa is the chief town of the municipality of Koulou in Mali.
[2] Madinani is a department of Côte d'Ivoire.



Map 6 > Topographic highland of Fouta Djallon at 440 m above sea level From Luc Ferry 2017

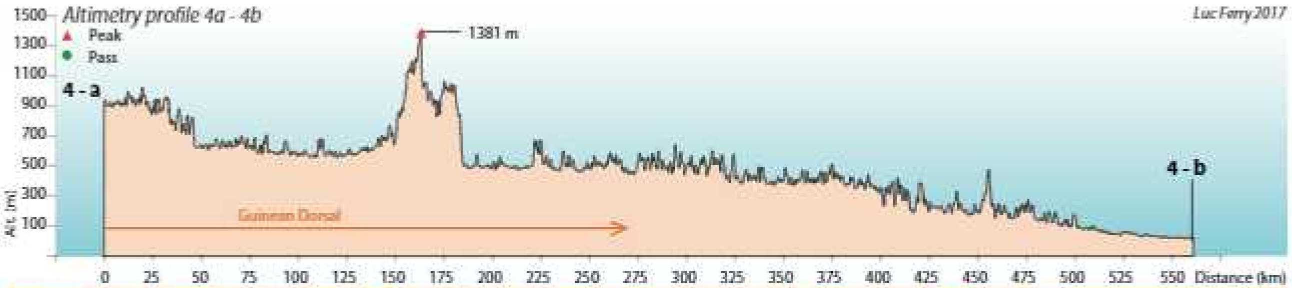


Figure 3 bis > Altimetry profile and drainage divided line of Guinean Dorsal (Profile 4-a 4-b map 5)

FOUTA DJALLON HIGHLAND TOPOGRAPHY

Above the neighbouring plains occupied by the forest and savannah, the Fouta Djallon highland (Map 6) have sheer cliffs surrounded by rivers which flow down the slopes. Based on topographical criteria, it has a surface area of nearly 47,000 km² and flows through Guinea (96%), Mali (3%), Sierra Leone and Senegal (<1%). It has quite clear borders, notably towards the west, and a tabular trend with a general decreasing gradient from west to east. The average altitude of the highland is around 686 m and its average gradient is 16%. Most mountains are between 500 m and 850 m tall (63%). However, mountains above 1,200 m, which are steeper, represent under 1% of the highland. Mountains over 1,100 m are nearly all located to the west of the highland where four groups can be distinguished:

- The neighbouring mountains in the prefecture of Mali which overhang The Gambia plains which are one thousand metres hight, with the following main mountains: Loura (1,538 m), Mbara (1,236 m), and Bamba (1,214 m); We also can find a peak well known as the "Lady of Mali" in reference to the shape of a face in the overhang when seen from a certain angle.
- The centre-west mountainous zone, the broadest and largest highlands, next to the prefectures of Lélouma, Labé and Pita, with mountains which rarely exceed 1,250 m in altitude: Kokou (1,287 m), Limboko (1,255 m);
- The Lélouma ridge in Télimélé including Djidjip (1,245 m);
- The Diagissa region (1,427 m) which is also the peak of the Senegal river basin.
- To the East, the plateau drained by the Bafing and the Téné rivers, at a lower altitude (750 m average altitude) and a less divided topography, are a pedestal for the powerful Haut-Fouta cliffs.

GUINEAN DORSAL TOPOGRAPHY

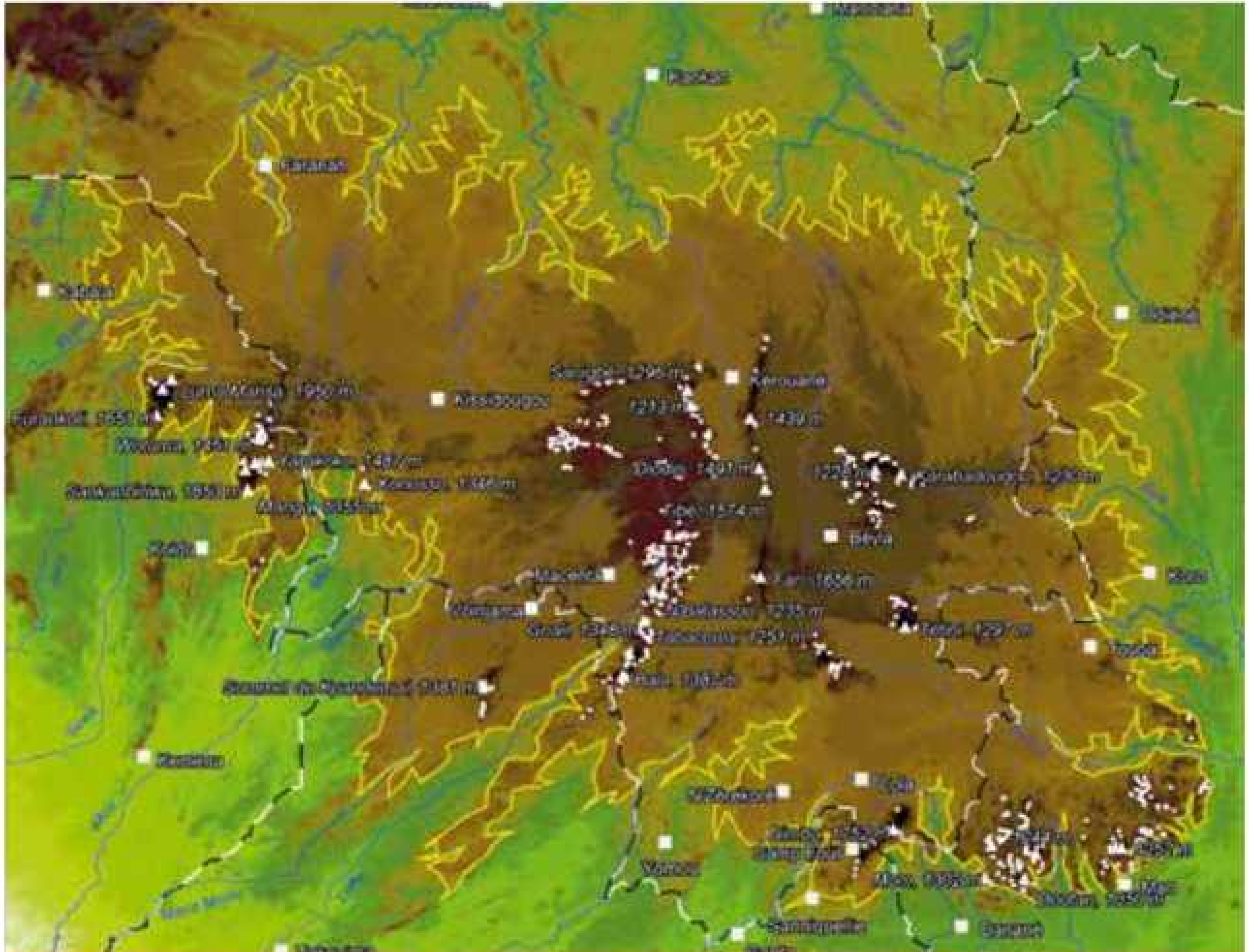
The Guinean Dorsal (Map 7) is formed of cristalline bedrock. Here, the Guinean Dorsal is distinguished from the Fouta Djallon highland. They cover four countries: Guinea (70%), Ivory coast (15%), Liberia (9%) and Sierra Leone (6%). There are various mountains over 1200 m, such as: Luma Manza (1950 m), Mont Nimba 1752 m and Fari (1656 m). Despite having some of the tallest mountains in the region, the average altitude and gradient of the Guinean Dorsal (563 m, 13%) are lower than the Fouta Djallon highland (686 m, 16%). The Guinean Dorsal is composed of a collection of mountains often separated by foothills between 440 m and 650 m high. This range of altitudes covers over 80% of the highland with an average gradient of around 10%. However, mountains over 1000 m altitude represent less than 1% of the entire highland but with an average gradient of 40%. From 1400 m altitude the gradients exceed 50% with maximums between 1650 m and 1850 m. Eleven mountainous sub-highlands can be distinguished between the Southern edge of the Guinean Dorsal and the central region of this dorsal.

SUB-HIGHLANDS ON THE SOUTHERN EDGE OF THE GUINEAN DORSAL

- The Luma Mansa highland (1950 m) and Farankoli (1651 m),
- The Tingi mountains, the peak of which is Sankanbiriwa (1853 m),
- The peak of the Kpandemai region (1381 m),
- The N'Balassou (1235 m), Gnali (1348 m) and Bala (138 7m) ridge,
- The Mont Nimba highland (1752 m),
- The summits of the Mom (1302 m) and Doutan region (1350 m),
- The summits located to the north of the town of Man (maximum around 1252 m) in the Dans mountains.

SUB-HIGHLANDS IN THE CENTRAL REGION

- The summits rarely above 1200 m altitude located to the east and north of the town of Macenta including Sanigbé (1296 m),
- The Simandou chain, which stretches nearly 100 km from north to south at a width of fifteen kilometres and several peaks exceeding 1400 m altitude including Diodo (1491 m), Tibé (1574 m) and Fari (1656 m),
- The summits located to the north of Beyla including Karabadougou (1230 m),
- The Tétini highland (1297 m).



Map 7 > Topographic highland of Guinean Dorsal at 440 m above sea level From Luc Ferry 2017

TOPOGRAPHY OF OTHER SURROUNDING HIGHLANDS

THE GUINEA COASTAL HIGHLANDS

The Guinea coastal highland (Map 8) is located to the south-west of the Fouta Djallon highland and are nearly fully located in Guinea with a small part in Guinea Bissau. From a geological point of view, the highland are relatively homogeneous with around: 85% sandstone, conglomerates, siltstones and argilites with gabbro, diorite and dolerite intrusions (7%). Outside of the coastal plain, the watershed for the Kogon and Nunez rivers are entirely located in the Guinea coastal highland. It is crossed by the Fatala and Konkouré rivers.

THE NORTH-EAST EXTENDED HIGHLANDS OF FOUTA DJALLON

The Banié Niandan chain crosses the Niger upper river basin from west to east. It has topography made of greenstone (ancient meta-volcanic rocks). We underline that the Fomi dam project is located at the crossing with the Niandan. The Sigurini region highland and the Mandingues mountains, located next to the Fouta Djallon highland, are mentioned here as a reminder but they have significant effect on the hydro-sedimentary operation of the Niger river and irrigated farming on the alluvial plains located on the left bank. These two highlands are separated by a narrow hilly area which marks the limit between the Niger and Senegal river basins.

Tinkisso falls near Dabola

FOUTA DJALLON RIVERS AND RIVER BASINS

THE WATERSHEDS OF THE SENEGAL, GAMBIA, RIO CORUBAL, LITTLE SCARCIES AND KONKOURÉ RIVERS ARE THE MOST DEPENDENT UPON THE FOUTA DJALLON HIGHLAND. THE NIGER RIVER BASIN DEPENDS UPON BOTH THE FOUTA DJALLON AND THE GUINEAN DORSAL. IN TOTAL, 20 MAJOR RIVER BASINS WERE IDENTIFIED BETWEEN THE FOUTA DJALLON AND THE GUINEAN DORSAL, INCLUDING 15 TRANSBOUNDARY ONES.

20 MAJOR RIVER BASINS IDENTIFIED IN THE GEOGRAPHIC AREA

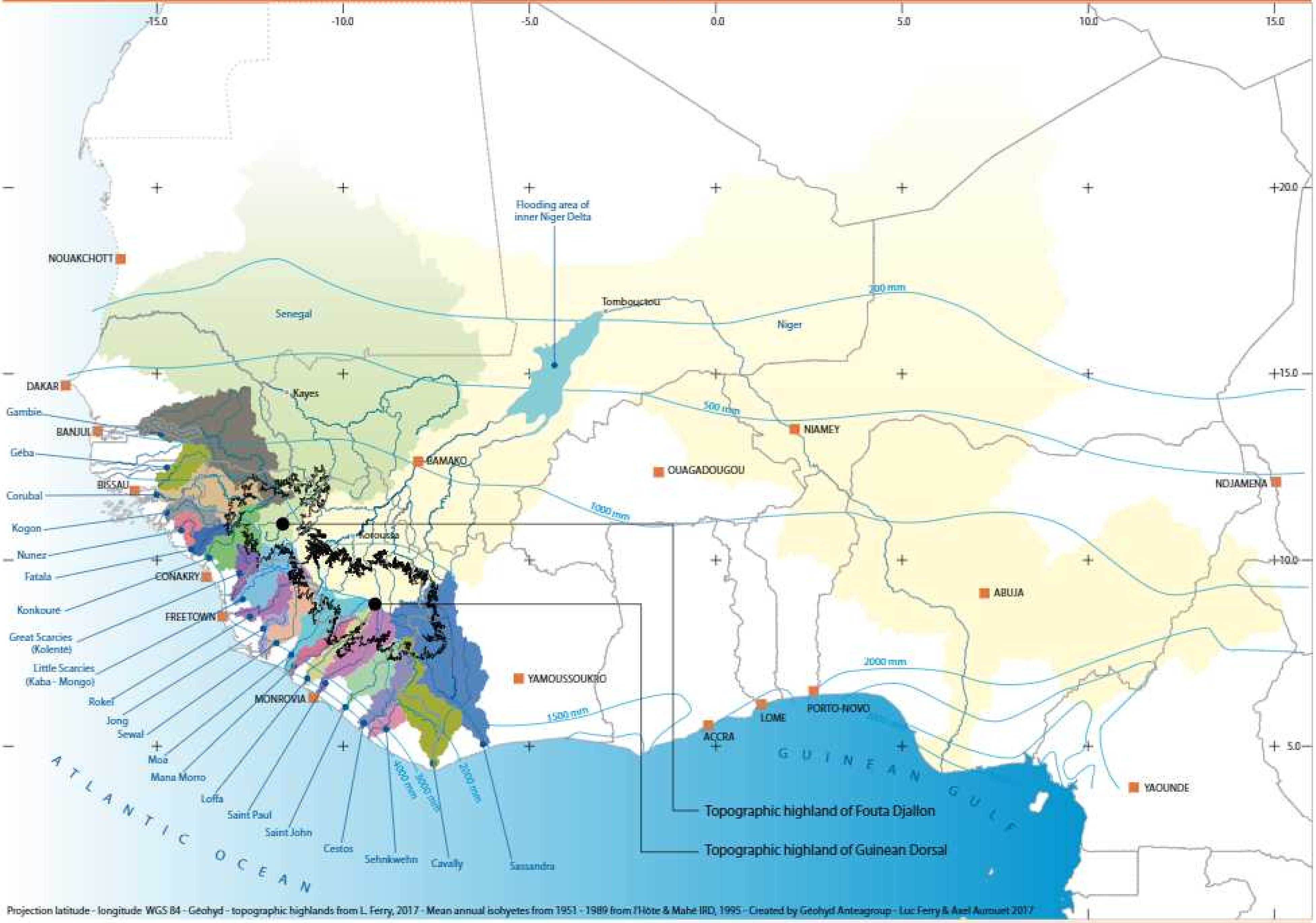
Amongst the infinite number of river basins and sub-river basins that it would be possible to map, only the river basins over 4000 km2 are described here, where the rivers have their sources in the West Africa water tower region (Heart of the Fouta Djallon highland and Guinean Dorsal). 25 river basins have been delineated which includes 18 transboundary basins. Amongst the 25 river basins, only 5 of them do not have their springs in the 7 identified highlands: the Cacheu (or Rio Cacheu), the Casamance, the Géba, the Jong, and the Sehnkwehn. We can underline that the Géba, at its outlet, shares the same outlet than Rio-Corubal and could be linked with Rio-Corubal river basin. Finally, it is 20 river basins that depend directly of highlands of the area of which 15 are transboundary (map 8). Related area of these river basins and by mountainous highlands are given in the table 2. The name given to each river basin, determined from maps at a scale of 1: 200 000 and 1: 250 000, is the name of the river at its mouth or its confluence with another river. Along their route, the rivers can have different names. Therefore, the longest talweg of the Senegal river basin has the name Senegal up to its confluence with the Bakoye, Bakoye up to its confluence with the Baoulé and finally Baoulé. We underline that the same river can have different names depending on the country in which they flow: Great Scarcies in Sierra Leone and Kolenté in Guinea, Cavalla in Liberia and Cavally in Ivory Coast. We also note that the names of the rivers are often the same in 2 different river basins: Bafing in the Senegal and Sassandra river basins, Baoulé in the Senegal and Niger river basins.

Finally, the definition and surface area of the Niger and Senegal river basins as well as the Bakoye river basin upstream from the Falémé (Senegal DB) are very inaccurate due to the presence of large dune areas located to the north of these three rivers; major inaccuracies which do not allow us to determine other physical characteristics of these three river basins.

Table 2 > Main characteristics of river basins

RIVER BASIN	SURFACE AREA (KM²)	LENGTH OF THE LONGEST TALWEG (KM)	RIVER BASIN COUNTRY	SECTOR HIGHLANDS ASSOCIATED WITH THE RIVER BASINS
Niger	> 2,000,000	4,260	Algeria, Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Guinea, Mali, (Mauritania), Niger, Nigeria, Chad	Guinean Dorsal, Fouta Djallon, Siguirini-Baléa highland, Banié-Niandan chain, Mandinani highland and Manding Mounts
Senegal	> 400,000	2,170	Guinea, Mali, Mauritania, Senegal	Fouta Djallon, Coastal Guinea Highland and Siguirini-Baléa highland
Sassandra	68,550	915	Côte d'Ivoire, Guinea	Guinean Dorsal and Madinani highland
Gambia	67,350	1,160	The Gambia, Guinea, Senegal	Fouta Djallon
Cavally (Cavalla)	29,600	775	Côte d'Ivoire, Guinea, Liberia	Guinean Dorsal
Corubal	24,700	815	Guinea, Guinea Bissau	Fouta Djallon and Guinea Coastal Highlands
St Paul	20,150	510	Guinea, Liberia	Guinean Dorsal
Moa	19,700	520	Guinea, Liberia, Sierra Leone	Guinean Dorsal
Little Scarcies (Kaba/Mongo)	18,400	445	Guinea, Sierra Leone	Fouta Djallon and Guinean Dorsal
Konkouré	16,750	385	Guinea	Fouta Djallon and Guinea Coastal Highlands
St John	16,150	455	Guinea, Liberia	Guinean Dorsal
Sewa	13,750	440	Sierra Leone	Guinean Dorsal
Cestos	12,550	470	Côte d'Ivoire, Liberia	Guinean Dorsal
Géba	12,300	415	Guinea, Guinea Bissau, Senegal	Outside of highlands
Rokel	11,300	455	Sierra Leone	Guinean Dorsal
Loffa	10,550	420	Guinea, Liberia	Guinean Dorsal
Kogon	7,860	450	Guinea, Guinea Bissau	Guinea coastal highland
Mana Moro	7,690	395	Guinea, Liberia, Sierra Leone	Guinean Dorsal
Great Scarcies (Kolenté)	7,650	305	Guinea, Sierra Leone	Guinea Coastal Highlands and Fouta Djallon
Fatala	6,180	240	Guinea	Guinea Coastal Highlands and Fouta Djallon
Nunez (Rio Nunez/ Tinguilinta)	4,830	190	Guinea	Guinea coastal highland

Map 8 > River basins linked with Fouta Djallon highland, Guinean Dorsal and Coastal Guinea Highland



Projection latitude - longitude WGS 84 - Géohyd - topographic highlands from L. Ferry, 2017 - Mean annual isohyetes from 1951 - 1989 from l'Hôte & Mahé IRD, 1995 - Created by Géohyd Anteagroup - Luc Ferry & Axel Aurouet 2017

THE SOUTH-WEST RIVERS AND RIVER BASINS

Apart from the Géba, Corubal, Kogon and Nunez (Rio Nunez/Tinguilinta) rivers, the South-West rivers in the study area have more direct paths to the sea. This includes the Fatala, Konkouré, Great Scarcies (Kolenté), Little Scarcies (Kaba, Mongo), Rokel, Jong, Sewa, Moa, Mana Moro, Loffa, St Paul, St John, Cestos, Sehnkwehn, Cavally (Cavalla) and Sassandra rivers (map 9). The South-West river basins in the study area (from the Corubal up to the Sassandra) receive rainfall between 1,500 mm/year and over 4,000 mm/year (1951-1989 period, L'Hôte Y., Mahé G., 1995). Six main river basins make up the hydrographic network of the oceanic front with sources linked to the centre and foothills of the Fouta Djallon highland. These are the basins of Kogon, Tinguilinta, Fatala, Konkouré (originating in Fouta Djallon), Kolenté which becomes Great Scarcies in Sierra Leone, and Kaba, which becomes Little Scarcies in Sierra Leone (map 9). These 2 latter rivers are therefore international.

KOGON AND TINGUILINTA RIVERS

The Kogon is a coastal river which originates in Coastal Guinea Highland in the South West of Fouta Djallon Highland. It has a relatively sustained slope (2m/km) for the first hundred kilometres (up to its first right bank tributary, the Linkourou). Then the Kogon spreads into various meanders into a huge alluvial plain before emptying into the ocean through a large estuary overrun by mangrove trees. The Tinguilinta is a coastal river draining the hills of the Boké region. The Tinguilinta has two small right-bank tributaries, the Bouroundou and the Batafong, and on the left bank the Bourouma. These basin heads have an average slope (0.5m/km), contrary to the downstream portions where the river and its tributaries flow into an alluvial plain.

FATALA AND KONKOURÉ RIVERS

The Fatala is a powerful river flowing from the foothills of the Fouta Djallon where it has its source close to Télimélé (1000 m). The slope of the Fatala is significant (over 3 m/km), its riverbed is broken up with rapids and waterfalls (Diou waterfall). At around 100 km from its source, its receives the Télébou on its right bank. The Konkouré is the most powerful river solely in Guinea, which starts close to Mamou in the Fouta Djallon highland at an altitude over 1000 m. In its upstream part, it is guided by rifs in the Fouta Djallon sandstone highland. The Konkouré, its tributaries and sub-tributaries (the Kakrima, the Kokoulo) have crossed deep valleys with impressive waterfalls. The gradients are more significant (3 m/km) on the upstream part. On the downstream part, the Konkouré is reinforced on the left bank by the Badi, the tributaries of which (Samou and Wantaba) flow down the main foothills from the south of Fouta Djallon to the south of Kindia. Next the Konkouré continues in an enclosed valley which narrows before arriving in a mangrove forest. The longitudinal profile of the Konkouré (and 19 of its tributaries with a catchment area of more than 200 km²) (figure 4) shows the often-important falls (from ten to sometimes a hundred meters) in the downstream part and a morphology favorable to the installation of hydroelectric structures.

GREAT AND LITTLE SCARCIES

The Kolenté is a boundary river with Sierra Leone, before entering the country where it becomes the Great Scarcies river. The upper basin of this river drains the Southern foothills of Fouta Djallon to the North-East of Kindia, where it receives a left-bank tributary: the Kara. Further downstream, its main Guinean tributaries are the Santa and the Kilissi. The slope of the upper portion remains very high (3m/km) then falls gradually. Finally, the high basins of Kaba and Mongo in Guinea drain the extreme south-east of the foothills of the Fouta Djallon. These two large river basins constitute the Little Scarcies that ends its race in Sierra Leone.


Kinkon falls Kokoulo

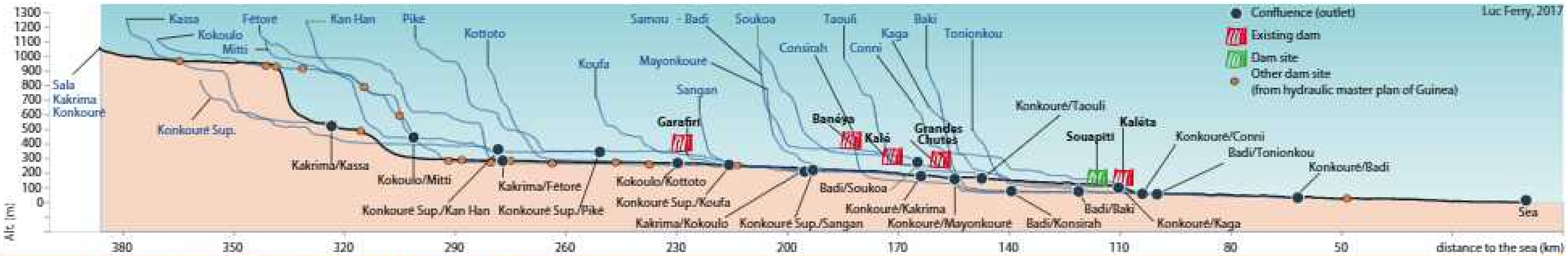
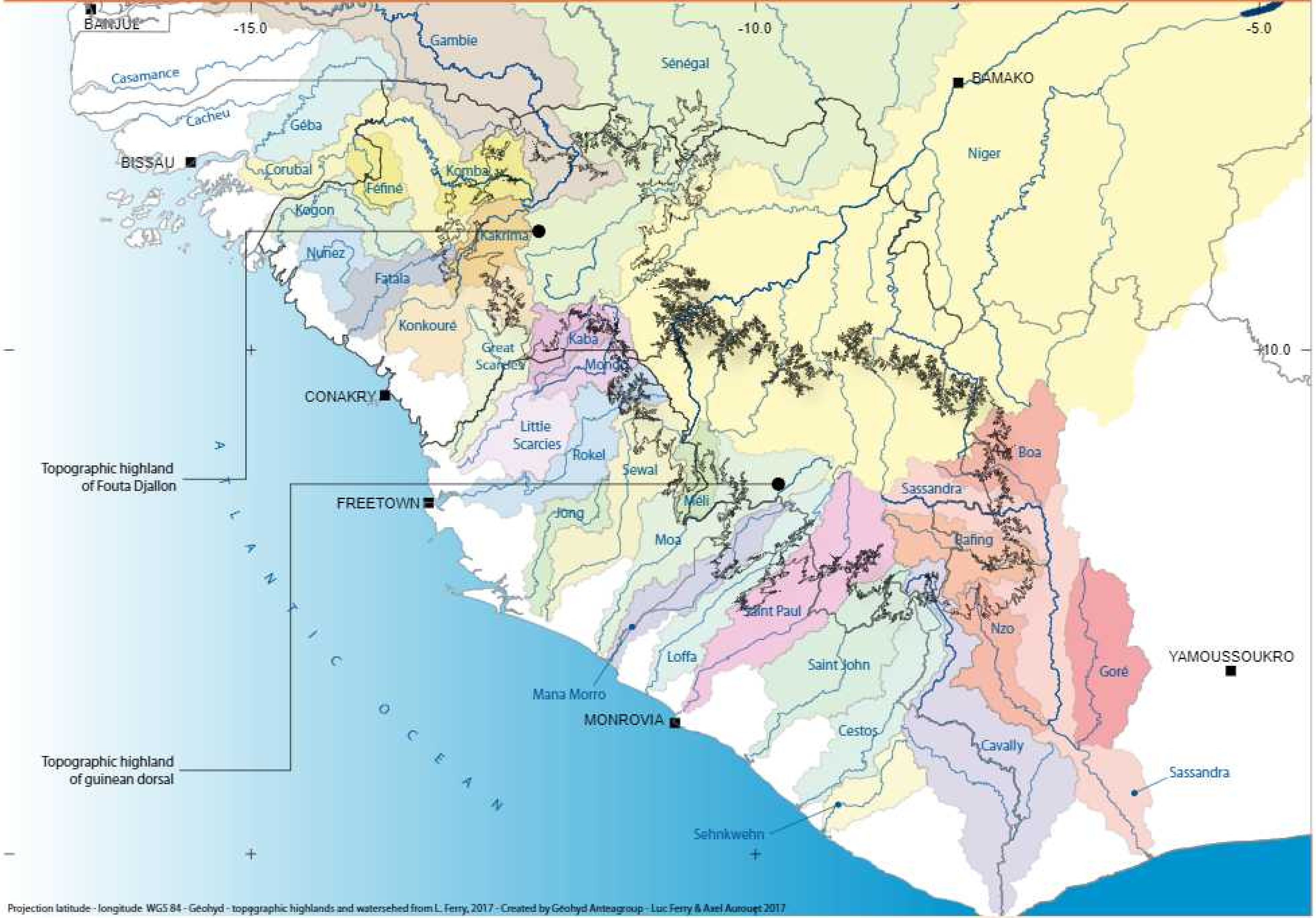


Figure 4 > Longitudinal profile of Koukoure and its main tributaries

Map 9 > Rivers and basins of south-west coastal area



INTERNATIONAL RIVERS FLOWING FROM THE HEART OF FOUTA DJALLON HIGHLAND

SENEGAL RIVER BASIN

Main description

The Senegal river basin crosses four countries: Guinea, Mali, Mauritania and Senegal (map 10). The Senegal and Niger river basin are identical in term of climatic regions (Guinean, South Sudanese, North Sudanese, Sahelian, Semidesert and Desert). The longest talweg of the river basin is composed of (from downstream to upstream) the Senegal river up to its confluence with the Bakoye river, the Bakoye up to its confluence with the Baoulé, the Baoulé up to its confluence with the Banangazalé and the Banangazalé. Further upstream, this river has several names: Koyo (or Koya?), Dyoumara, Koronglali, valley of the serpent (vallée du serpent), Gélédo, Fanta, Kolossa. With rainfall between 300 mm/year to the North and 800 mm/year to the South (1951-1989 period, L'Hôte Y., Mahé G., 1995), the flows of most rivers in the Bangazalé river basin are probably sporadic and rarely contribute to supplying the Senegal river. The Senegal river is mainly supplied by the Fouta Djallon highland (Bafing and Falémé DB) and to a lesser extent by the Siguirini/Baléa Mountains (Bafing and Bakoye DB) and the Mandingues Mountains (Bakoye and Baoulé DB). The longitudinal profile along the Senegal river and its main tributaries (Figure 5) show clear differences between the rivers which have their sources in the Fouta Djallon highland (Bafing, Falémé), the Siguirini/Baléa mountains (Bakoye upstream from its confluence with the Baoulé) and the Mandingues Mountains (Baoulé, Banagazalé). The longitudinal profile along the Bafing, "stepped", is like the longitudinal profiles along the Konkouré and some of its tributaries which also have their sources in the Fouta Djallon highland.

Bafing and Falémé at the source of the Senegal river

The Bafing is the main constituent of the Senegal and has its source near to Mamou (nearly 1,000 m altitude). It drains the entire Eastern part of the Fouta Djallon through the upper basin itself. Its main right bank tributaries are the Sokotoro, the Téné, the Dombélé, the Kioma and the Samenta. Its main left bank tributaries (Koukoutamba) are less significant. The upper basins of the Bafing (and its right bank tributaries) have spectacular rapids and waterfalls. The slope for the first 100 kilometres is intense and exceeds 5 m/km. After over 300 km in Guinea, the Bafing enters Mali for around fifty kilometres. It is still tumultuous in this sector and has narrow straight joints(figure 5).

The Falémé also has its source in the Northern foothills of the Fouta Djallon in Guinea and is a major tributary of the Senegal river which it joins at the meeting point of the Mauritania, Senegal and Mali borders, in the town of Ballou. In its upper course, its main left-bank tributary is the Koila, (the source of which is in the Northern foothills of Fouta Djallon) and on the right bank, a course formed by the confluence between the Koulounko and the Kounda Ko (sources in Guinea in the North-Eastern foothills of Fouta Djallon).

GAMBIA RIVER BASIN

With a surface area of 67,350 km², the Gambia river basin is the 3rd largest basin in the region (map 10). It is a transboundary river basin which covers The Gambia, Guinea and Senegal. Its average altitude and gradient are 131 m and 5.2% respectively, which are quite low. The Gambia river, initially flowing S E/NW and then downstream E/W, has its source in the Fouta Djallon highland at the approximate altitude of 1,150 m. Its main tributaries are Nianja Bolon, Sandougou, Kolountou and Niériko. The Gambia river basin is represented in Guinea by the upper basin of The Gambia and its tributary, the Kolountou. Upstream from the Kounsi, Gambia receives the Lili and then the Silame on the left bank. The upper basin of The Gambia drains the North of the Fouta Djallon plateau, without the waterfalls found in other rivers, but the slope is still steep (over 4 m/km for the first 100 km). The slopes are no more than 1 m/km at Kounsi. Several other tributaries from the northern foothills of Fouta Djallon, at the non-permanent flow on the Guinea portion, flow towards the Gambia river in Senegal, including the Kanta, Tiokoï and Diahra.

CORUBAL RIVER BASIN

The Corubal river basin (map 10) has a surface area of 24,700 km². Upstream, the Corubal river is formed by the confluence between the Komba and the Tominé, rivers with sources in the Fouta Djallon highland at 1150 m and 1050 m altitude respectively. Along its central path, on its left bank it receives the Féfiné, the source of which is located at least 400 m high in the Guinea coastal highland. In Guinea-Bissau, the river takes the name of Corubal, whereas in Guinea it is called Koliba, at least for its western portion. Before its confluence with the Tominé towards Gaoual, it is known as Komba. Then, the Komba (Kolimba) joins with the Tominé. The Tomine receives the Kokoni on the right bank which successively grows with the Bantala on the right bank and the Ouésséguélé on the left bank. The gradients of these upper basins are strong, there are many waterfalls and rapids, and the drained valleys are still embedded between the high cliffs of the Fouta Djallon sandstone plateaus. The different names of the river used in Guinea (Koliba, Komba, Tominé) before it becomes the Corubal in Guinea-Bissau illustrates the example of a sector which is rarely described in literature.

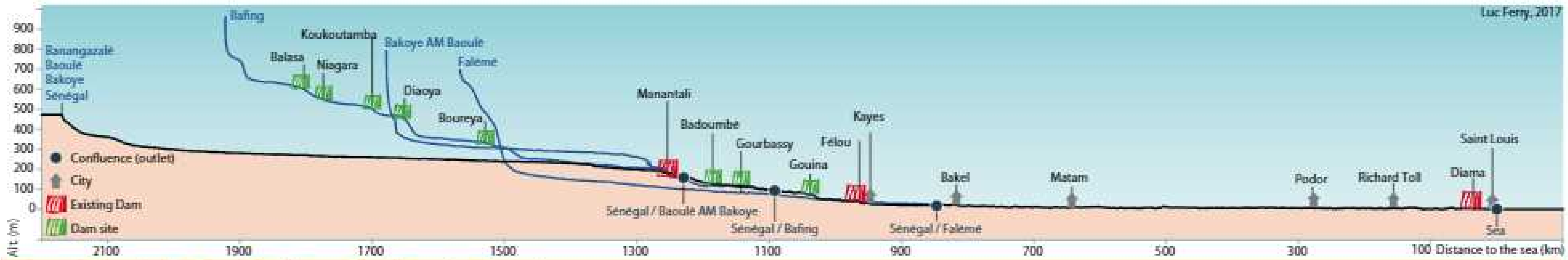
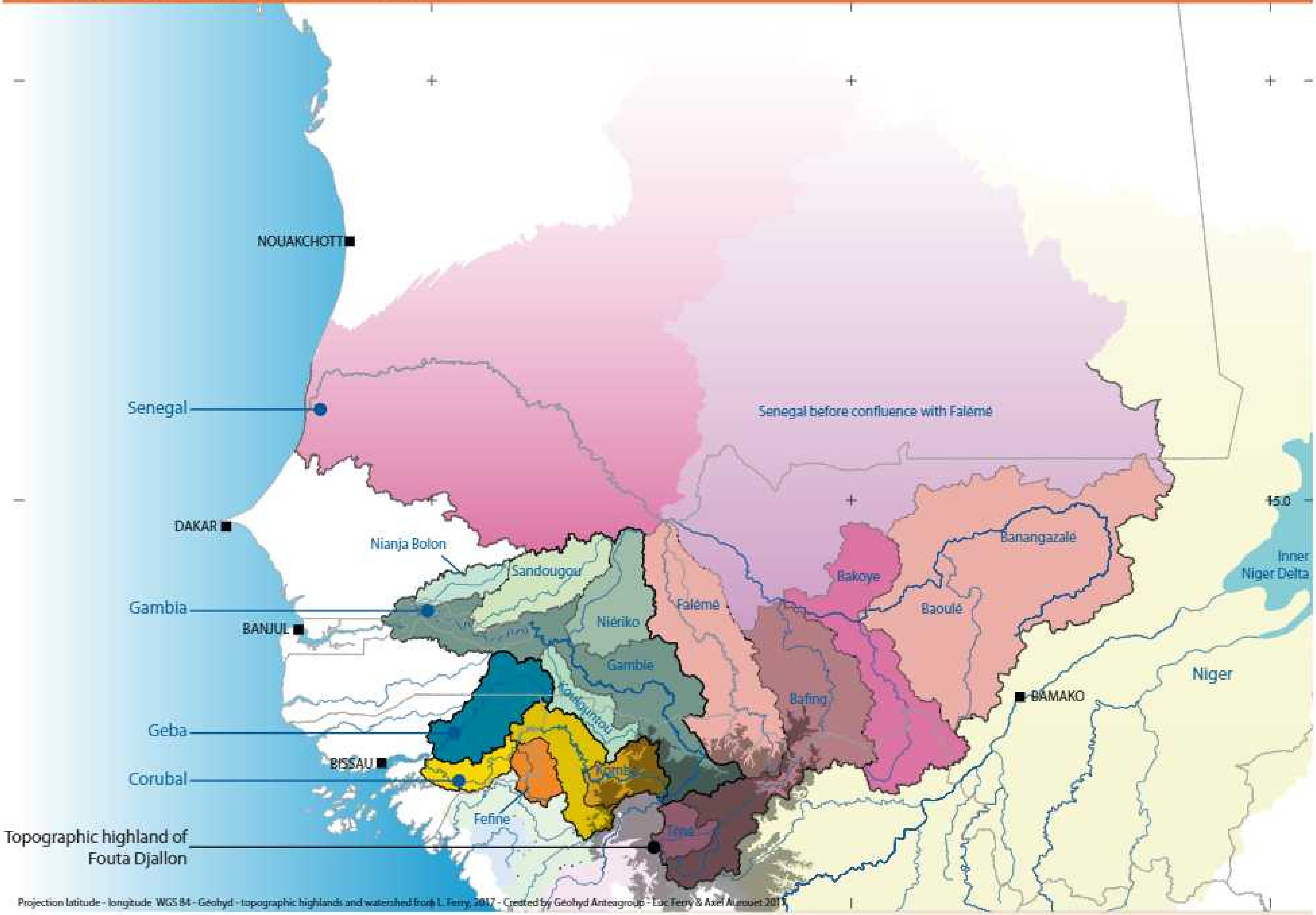


Figure 5 > Longitudinal profile of Senegal and its main tributaries

Map 10 > Rivers and basins of Sénégal, Gambia, Geba and Corubal



NIGER RIVER BASIN AND ITS MAIN TRIBUTARIES

This group is linked to both the Fouta Djallon highland, with the source of the Tinkisso, and the Guinean Dorsal. Most of the Niger River's tributaries also have their source in the northern foothills of the Guinean Dorsal (Niger, Sankarani, Milo, Niandan, Fié, Kouya, Mafou...). This large "basin" surrounded by the Fouta Djallon highland to the west and the Guinean Dorsal to the south is the upstream of the hydrological entity of the Upper Niger, an entity which flows to Mali upstream from the inner delta (between Ségou and Markala in Mali). The Niger river basin has a specific role due to the climate regions that it occupies (Guinea, South Sudanese, North Sudanese, Sahalian, Semidesert and Desert), the number of countries covered and the number of countries crossed by its river (Guinea, Mali, Niger, Nigeria) or bordered by its river (Benin, Nigeria); a river which is also noted as it crosses the Niger inner delta, the largest wetland in West Africa (map 11 and figure 6).

UPSTREAM PART OF NIGER RIVER

In its upstream part from the inner delta area, the Niger basin has two main basins, the Bani to the east and the upper Niger to the west. The latter has seven main branches: the Tinkisso, the Niger itself or Djoliba, the Mafou, the Niandian, the Milo, the Fié and the Sankarani. The slope of Niger river is important on the first 40 kilometers (7.5 m/km) and reduce around Faranah (figure 6). Its slope is stable even near tributaries flowing the Fouta Djallon highland (Balé, Koba, Niantan). After the junction with the tributary Mafou, Niger river shows important rapids and its altitude decrease from a dozen metres. Then, till Bamako, Niger river will keep a stable morphology, with high banks, flood plains, multiples islands with a smooth slope of 0.12m/km. In Guinea, it collects water from tributaries Niandan and Milo and right riverside. The latest and strong Guinean tributary, Sankrani cross Niger river in Kourouba, Mali, after feeding the massive Selingue dam.

It flows in the Niger inner delta area, with a surface area of around 50,000 km², with 20 to 30,000 km² flood plains, the inner delta is a complex system of channels and lakes. It is mainly supplied by the upper Niger river basins and to a lesser extent by the Bani. More than 40% of inputs are lost there by evaporation. Downstream from the Koryoumé, the river inputs flow back at the level of its left bank tributaries including the Gorouol, the Dargol and the Sirba. Downstream, the Niger river receives inputs from the Bénoué, a major tributary of the river's lower course.

THE MILO AND THE NIANDAN

The Niandan and the Milo have their sources in the Northern foothills of the Guinean Dorsal at an altitude of 700 m for the Niandan and 1,000 m for the Milo. The Niandan has a steep slope of 4m/km up to the Kissidougou station. The slope lowers to 0.5 m/km up to the Balé confluence at Sansanbaya. The Niandan then moves through a series of powerful rapids before receiving the Kouya on the left bank and settling into a large flood plain. It then passes through the narrowing of the Niandan-Banié chain, a narrowing where the Fomi dam project is planned, before emptying into the Niger around Koumana. The Milo itself loses 200 m in 30 km (6.7 m/km) before racing into a valley bordered to the East by doleritic mountains. It reaches the first flood plains around Kérouané before receiving its main tributary, the Baoulé, on the left bank. After a series of rapids, it has a similar appearance to the Niandan lower valley to join the Niger around Sansando.

THE TINKISSO, THE PORTION OF THE NIGER IN FOUTA DJALLON

This is the sole Niger tributary which starts in the Fouta Djallon highland. It starts at an altitude of around 850 m, races down a steep slope (5 m/km) and various waterfalls. At Dabola, it is only at 400 m altitude. From then, the slope slows quickly (0.5 m/km) until its left bank confluence with the Bouka. Its gradient slows a little more (0.05 m/km) until its confluence with the Niger towards Siguiri. It has many sinuosities leading to huge flood plains.

THE SANKARANI, AT THE EASTERN EDGES OF GUINEA

The Sankarani starts at the meeting point between the Gbanhala and the Kouroukélé, both from the Northern edge of the Guinean Dorsal. They arise at around 700 m altitude and meet after a series of small rapids in sloping desert valleys. The slope slows and the Sankarani receives the Kouraï on the right bank and above all the Dion on the left bank, its major tributary in this region. Upstream from the Sélingué dam in Mali, it receives another tributary, the Ouassoulou Balé, with its source on the border between Guinea and Mali.

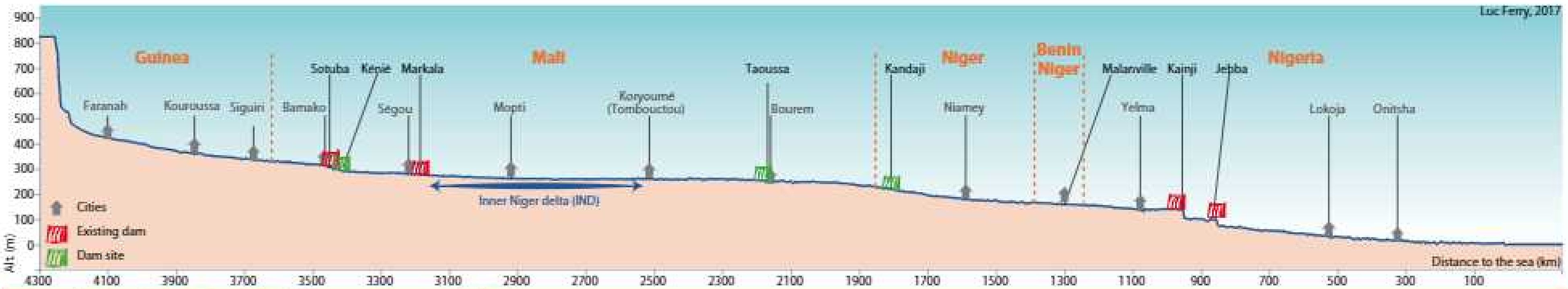
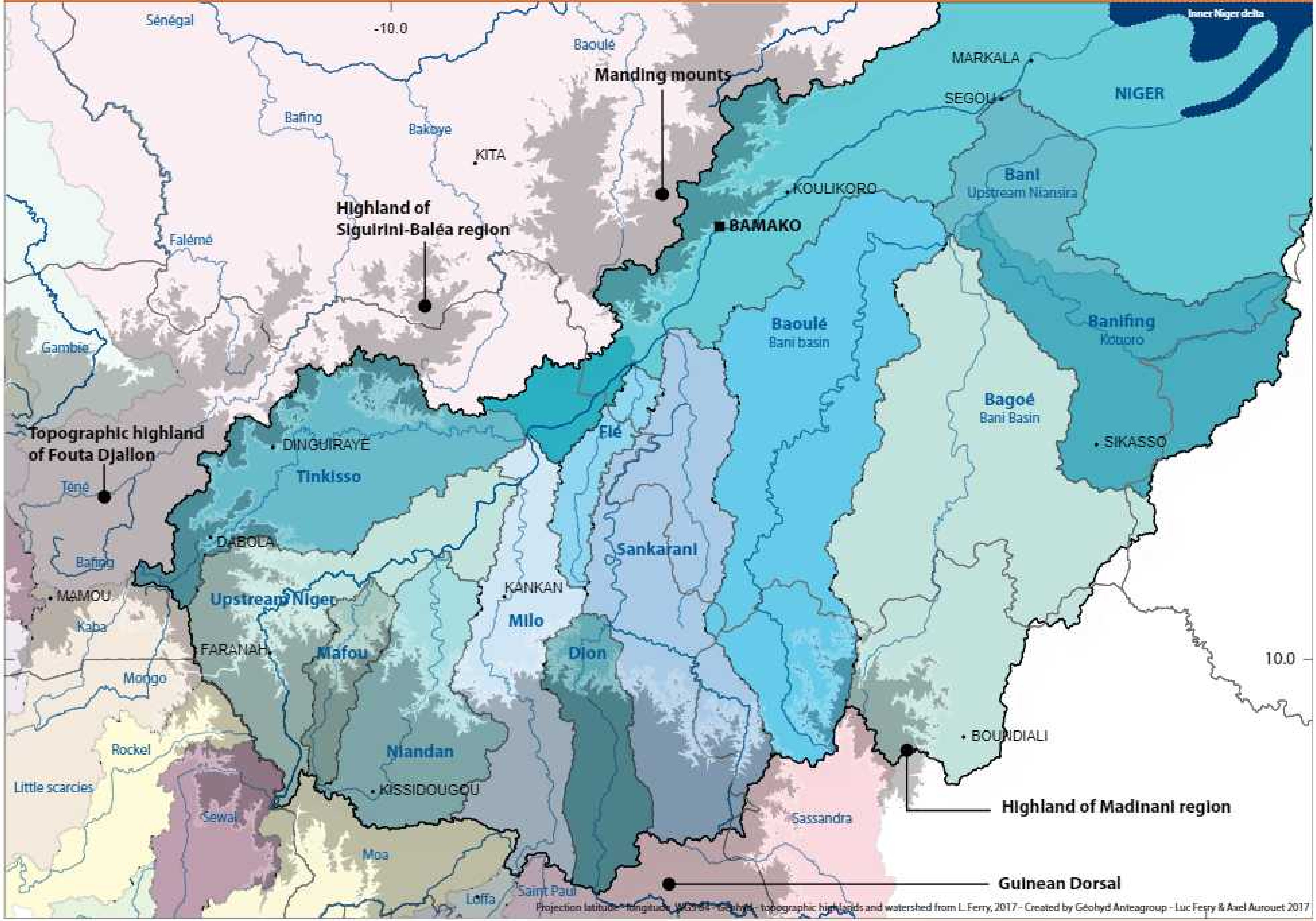


Figure 6 > Longitudinal profile of Niger and its main tributaries

Map 11 > Rivers and sub-basins of upstream Niger river



GEOLOGY OF FOUTA DJALLON AND ITS EXTENDED AREA

SHAPED OVER THE COURSE OF SUCCESSIVE TECTONIC CYCLES WHICH BEGAN MORE THAN 2 BILLION YEARS AGO, THE FOUTA DJALLON HIGHLAND ARE MOSTLY COMPOSED OF ACID ROCK (SANDSTONE, SHALE) WITH THE INTRUSION OF OLD REWORKED IGNEOUS ROCKS THAT ARE MORE BASIC (DOLERITE). THIS DOLERITE CORE CREATED THE POWERFUL TOUGUE-MALI RELIEF.

GEOLOGICAL HISTORY

The heart of the Fouta Djallon highland are located on the SW edge of the West African craton (map 12). This vast geological complex, stabilised at the end of the Eburnean orogeny, around 1800-1600 million years ago, is limited by mobile zones formed or rejuvenated during later orogenic phases, pan-African (660 and 550 million years ago), Hycernian (250 million years ago) or Alpine (60 million years ago) cycles. Standard thinking considers the West African craton as a continuous unit stretching from Mauritania to Algeria, to the North, and to Ivory coast and Ghana to the South (Bessoles, 1977). This cratonic platform is made of a bedrock ridge to the North (Réguibat-Algeria-Mauritania ridge) and another one to the South (Léo ridge), and between the two, a sedimentary covering (Taoudéni basin) with two bedrock windows (Kayes window and Kéniéba window). The main West African rivers flow in this vast geological unit: the Niger, the Senegal and the Gambia River.

GEOLOGY AT THE HEART OF THE FOUTA DJALLON HIGHLAND

This highland is divided into three equal parts, the soft sandstone to the West, granites to the South East and quartzitic sandstone to the North-East. The Lélouma-Pita-Labé-Dalaba-Télimélé group corresponds to the sandstone Fouta Djallon made up of soft sandstone and schist often injected with dolerites. The Mamou group corresponds to the crystalline Fouta Djallon, mainly made of granite bedrock extended from the Kankan basin with a thin alteration layer (table 3). Finally, the last doleritic Fouta Djallon group (Mali-Tougué and Koubia), also mainly sandstone and schist, but also marked by doleritic veins and dikes. In the last group, there is a doleritic core which makes up the heart of the mountain range. To the north of the Fouta Djallon highland, in Mali, there are soft Birimian schists to the very south of the Kéniéba window. The coverage of the southern fringe of the Fouta Djallon highland (Fria-Télimélé-Kindia) and south-west (Boke-Boffa) is made up of sandstones and schists with doleritic intrusions. The Gaoual Basin, towards Guinea Bissau, is characterised by sandstone with doleritic injections. The acid rock occupies 87% of the total surface area of Fouta Djallon. The most common lithographic class is sandstone. Conversely, greenstone (metamorphic volcanic-sedimentary rocks) is the least common. They are found in the watershed of the Niger (table 3), Falémé rivers and North of the Kayes in the Senegal river. The basic rocks are mainly represented by dolerites. The basins of Konkouré, Tinkisso and Milo are nearly monolithologic basins in sandstone or granite (table 3). The basins where the basic rocks are most common are the basins of the Gambia and Falémé rivers.

SUMMARY OF THE GEOLOGICAL GROUPS AROUND FOUTA DJALLON IN THE EXTENDED AREA

GEOLOGY OF THE GUINEAN DORSAL AND THE UPSTREAM BASIN OF NIGER RIVER

The Guinean Dorsal, the source of the Niger river and its tributaries (Milo, Niandan, Mafou, etc.), are marked by granites of the granite Archean bedrock with doleritic intrusions identified next to Beyla and some gneiss series with quartz in the Nzérékoré sector. The coverage of the granite bedrock extends into the Kankan, Kérouané basin. These granite coverages are found in the Forécariah-Coyah maritime sector, in the extension crossing Sierra Leone. In the downstream part of the Niger basin (Siguiri basin), there is a coverage of Birimian schist, sometimes injected with dolerites in the Northern part of Siguiri, which flows into Mali in its south-east part.

GEOLOGICAL FEATURES OF THE SENEGAL MIDDLE BASIN

On the northern part of the Fouta Djallon highland, entering into the Western part of Mali, there is a mainly sandstone infra-Cambrian sedimentary coverage in the extended areas of the Guinea Mali-Tougué formations and which is the start of the Taoudéni sedimentary basin. These formations are located up to Bamako (Sotuba sandstone formations) and constitute the geology of the middle part of the Senegal basin.

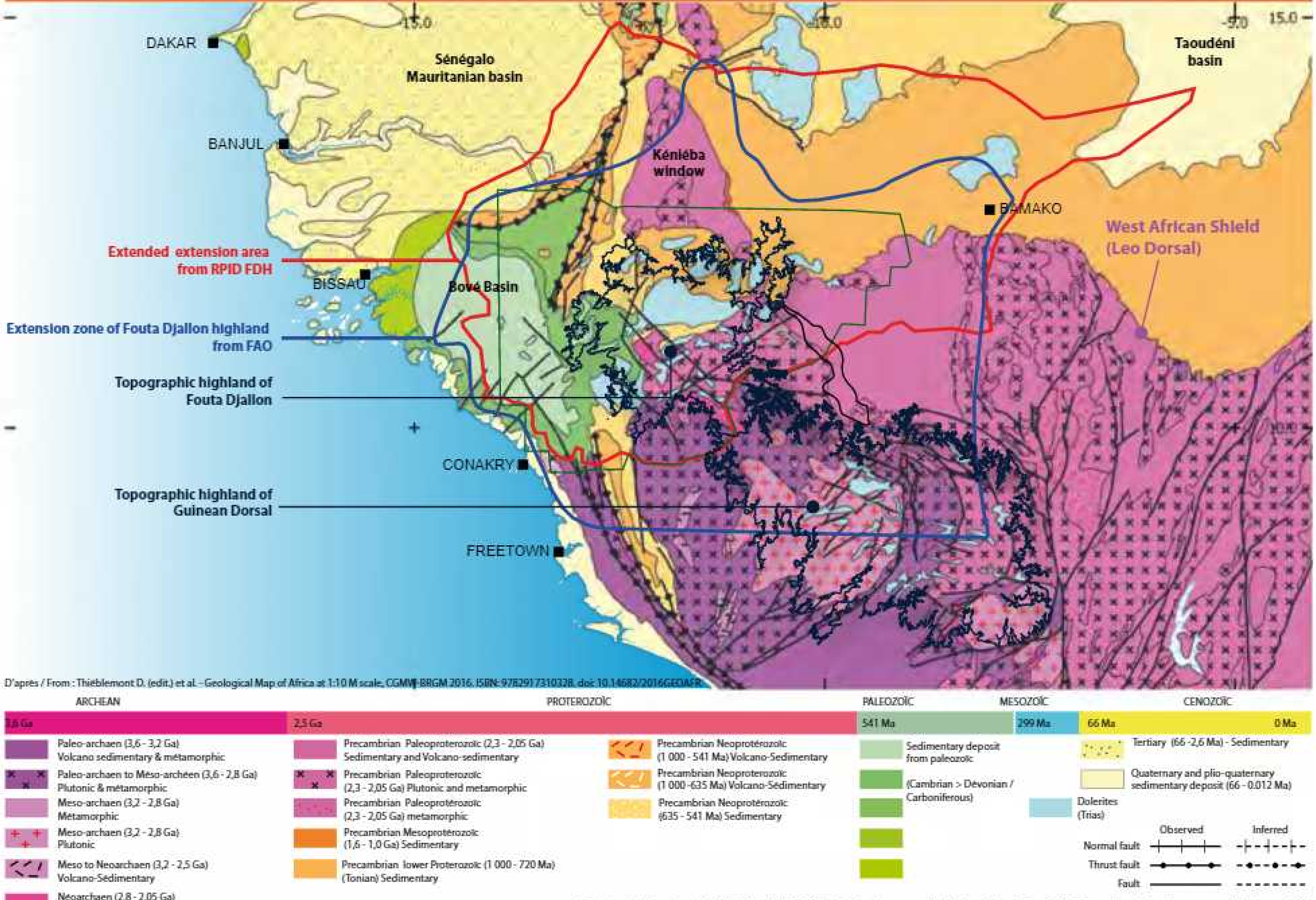
TERTIARY FORMATIONS IN THE INNER DELTA OF THE NIGER, SENEGAL AND GAMBIA RIVERS.

The most recent sedimentary formations are only located in the upper basin of Senegal river by a Continental Terminal outcrop, located to the east of Nioro at the limit between the Senegal river basin and the Niger river basin. The Continental Terminal is largely represented in the Senegal lower river basin and the middle portion of the Niger river basin (from the Markala surrounding area - Niger inner delta up to Gao). The Continental Terminal is composed of clayey sands in highly varied colours interbedded with clay or sandstone layers. Taoudéni basin main geological formation, the thickness of the Continental Terminal is variable depending on the structures of the sedimentary storage basin. From one hundred meters average depth in the Niger inner delta and up to 2000 m depth in the Gao rift.

Table 3 > lithological characteristics of few sub-basins

RIVER BASIN	OUTLET	LITHOLOGICAL CLASSES					
		Granites	Sandstone	Schist	Quartz sandstone	Dolerites	Greenstone
Bafing	Dakka Saidou	5%	6%	1%	9%	39%	0%
Falamé	Satadougou	8%	0%	16%	34%	42%	0%
Falémé	Kidira	15%	15%	36%	16%	2%	3%
Gambia	Kédougou	0%	18%	7%	45%	30%	0%
Konkouré	Konkouré	0%	98%	0%	0%	2%	0%
Milo	Kankan	91%	0%	6%	0%	3%	0%
Niger	Siguiri	69%	0%	26%	0%	2%	3%
Senegal	Bakel	7%	31%	7%	42%	12%	1%
Tinkisso	Tinkisso	96%	0%	0%	0%	4%	0%
Tominé	Gaoual	0%	86%	0%	0%	14%	0%

Map 12 > Geological context of Fouta Djallon and its extension zones



D'après / From : Thiéblemont D. (edit.) et al. - Geological Map of Africa at 1:10 M scale, CGMW-BRGM 2016. ISBN: 9782917310328. doi: 10.14682/2016GEOAFR

Projection latitude - longitude WGS 84 - BRGM, PRAI MFD, Géohyd - topographic highlands from L. Ferry, 2017 - Created by Géohyd Anteagroup - Axel Aurouet 2017

LAND COVER IN THE FOUTA DJALLON HIGHLAND AND ITS EXTENDED ZONES

FORESTS AND SHRUBBY SAVANNA COVER MOST OF THE FOUTA DJALLON HIGHLAND, EVEN IF THE FOREST OFTEN FOLLOWS MOSAIC PATTERNS. CUIRASSE OR LATERITIC PLATEAUS ARE ALSO A MARKER OF THE FOUTA DJALLON LANDSCAPE WHICH ORGANIZE THE TOPOSEQUENCES

GUINEA'S MAJOR FOREST ECOSYSTEMS

Seven major forest ecosystems are described in Guinea. This includes

- The Mangrove ecosystem (Amphibious forest ecosystem) in Maritime Guinea,
- The Guinea coastal woodland in Maritime Guinea along the river, along the banks of Marais and all rich soils
- Guinea and Sudan-Guinea savannahs resulting from the degradation of woodlands. They are present across the Guinea territory
- The Guinea dry forest which is the dominant category of the Fouta Djallon highland' plateaus and the upper Guinea plains
- The Guinea dense forest characterised by a closed formation where the vegetation is exuberant, the trees very tall with constant moisture
- The Guinea dense rainforests which are only remnants of forests, especially in the Forest Guinea sector (Macenta, Nzérékoré)
- The Guinea dry dense forest which occupies the north part of Guinea except Fouta Djallon highland.

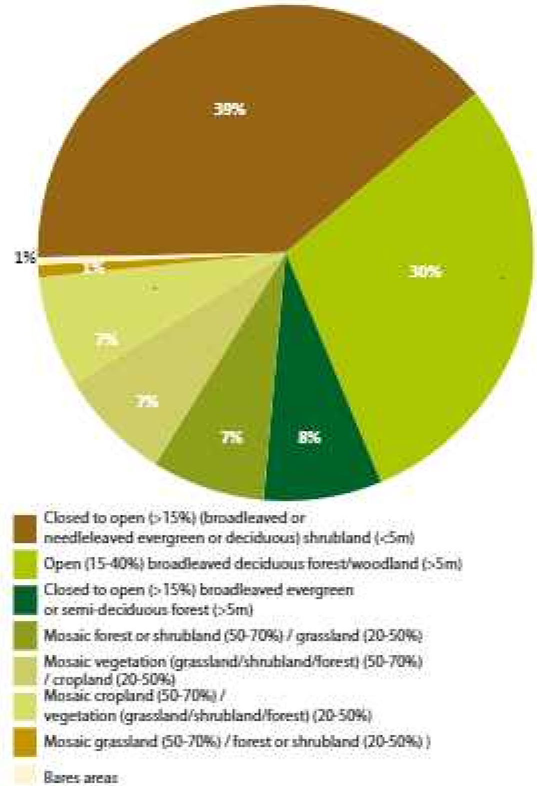
In literature, the environmental findings of land use in the Fouta Djallon highland sector notes a forest cloak which only covers 13% of the Central Guinea administrative region, i.e. 800,000 ha of dry dense forest and 50,000 ha of forest patches, remains of the former dense forest. It seems that there are no longer forest uplands outside of these small classified forests.

LAND COVER OF THE FOUTA DJALLON TOPOGRAPHICAL HIGHLAND BASED ON THE GLOBCOVER 2008 PROJECT

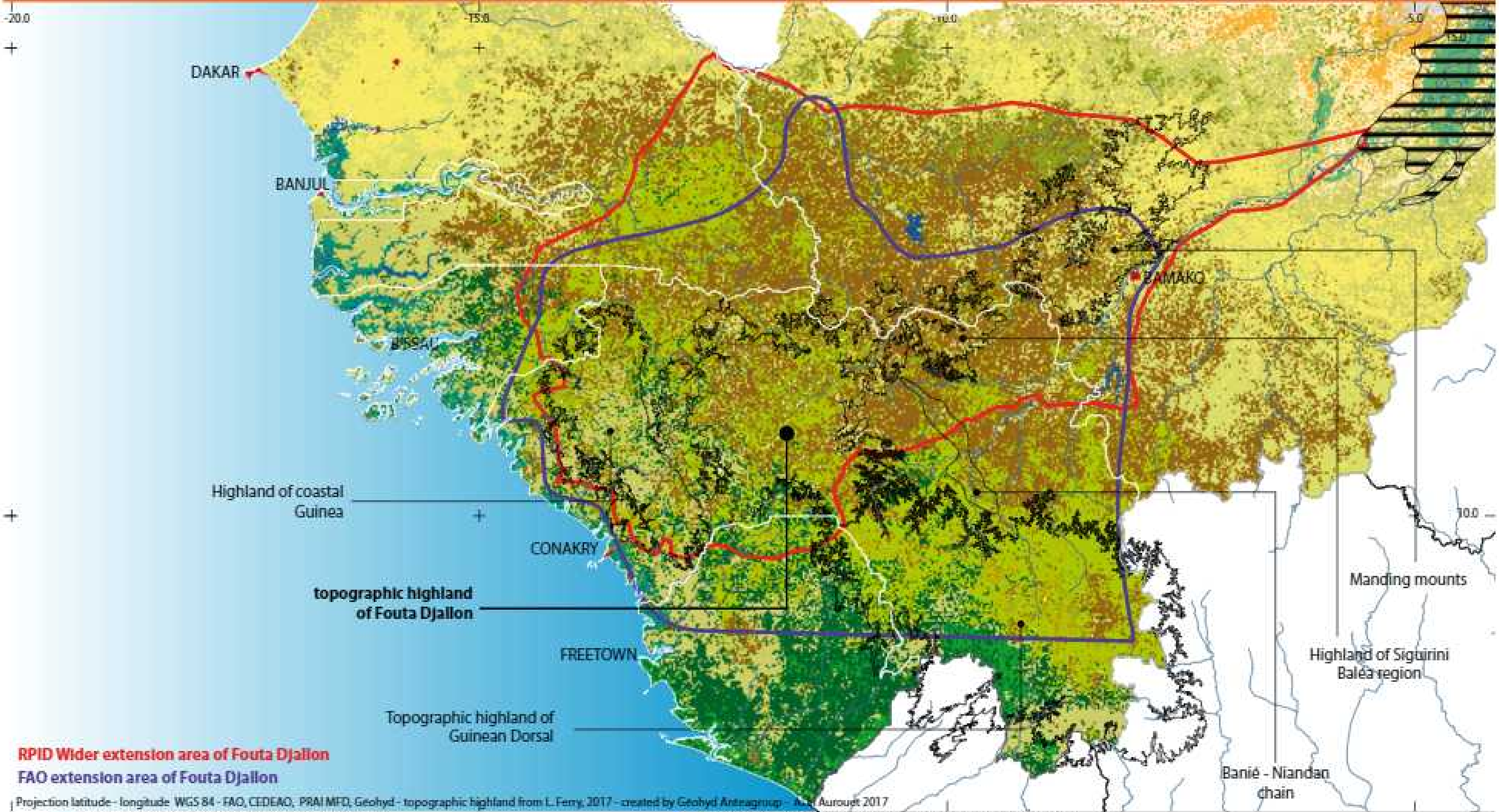
In the Fouta Djallon topographical highland, land cover associated with shrubby savannah and deciduous trees is the dominant land cover (39% - Figure 7), and distributed more on the edges of the topographical highlands than the centre, which is rather dominated by vegetation associated with open forest and wood. This class represents nearly 30% of land cover in the Fouta Djallon topographical highland. The other covers are marginal and mainly composed of patches of vegetation distributed between trees, shrubs, grasslands and crops. These patches of vegetation represent 30% of the surface area of the natural highland. Based on Globcover information in 2008, the bare land and low-land crops represent less than 1% of land cover in the topographical highland. From a spatial point of view, the natural patches of vegetation associated with the cultivation zones are mostly found on the Southern foothills in (Dalaba - Télimélé sector), the Eastern edges (Dabola - Dinguiraye), the specific Mali sector and the Western sectors of Pita – Labé (map 13).

Bowal and Dakoro's village nearby Bafing or «black river»

Figure 7 > Land cover distribution in topographic highland of Fouta Djallon (Glob cover 2008)



Map 13 > Land cover of Fouta Djallon highland and its extension zones (Glob cover 2008)



Projection latitude - longitude WGS 84 - FAO, CEDEAO, PRAI MFD, Geohyd - topographic highland from L. Ferry, 2017 - created by Géohyd Anteagroup - A. Aurouet 2017

Legend

- 11 Post-flooding or irrigated croplands (or aquatic)
- 14 Rainfed croplands
- 20 Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%)
- 30 Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%)
- 40 Closed to open (>15%) broadleaved evergreen or semi-deciduous forest (>5m)
- 50 Closed (>40%) broadleaved deciduous forest (>5m)
- 60 Open (15-40%) broadleaved deciduous forest/woodland (>5m)
- 70 Closed (>40%) needleleaved evergreen forest (>5m)
- 90 Open (15-40%) needleleaved deciduous or evergreen forest (>5m)
- 100 Mosaic forest or shrubland (50-70%) / grassland (20-50%)
- 110 Mosaic forest or shrubland (50-70%) / grassland (20-50%)
- 120 Mosaic grassland (50-70%) / forest or shrubland (20-50%)
- 130 Closed to open (>15%) (broadleaved or needleleaved evergreen or deciduous) shrubland (<5m)
- 140 Closed to open (>15%) herbaceous vegetation (grassland savannas or lichens/mosses)
- 150 Sparse végétation
- 160 Closed to open (>15%) broadleaved forest regularly flooded (semi-permanently or temporarily) - Fresh or brackish water
- 170 Closed (>40%) broadleaved forest or shrubland permanently flooded - Saline or brackish water
- 180 Closed to open (>15%) grassland or woody vegetation on regularly flooded or waterlogged soil - Fresh brackish or saline water
- 190 Artificial surfaces and associated areas (Urban areas >50%)
- 200 Bare areas
- 210 Water bodies

LAND COVER OF THE FOUTA DJALLON HIGHLAND'S EXTENDED AREAS BASED ON THE GLOBCOVER 2008 PROJECT

IN THE RESTRICTED EXTENDED AREA OF THE FOUTA DJALLON HIGHLAND'S RPID

In the restricted area of the Fouta Djallon highland's RPID, the land cover associated with shrubby savannah has quite similar proportions to the Fouta Djallon topographical highland (40%) with a more marked spatial distribution in the Upper Guinea plains to the East-North-East of the Fouta Djallon highland (map 13). Nearly 30% of the surface area in this zone is associated with "open forest" type trees or wooded vegetation. The patches of vegetation distributed between tree, shrub, prairie and crop vegetation covers 31% of the surface area in this zone and are largely in the Kindia - Fria - Boké zones (Guinea coastal highland sector). This land cover is less pronounced in the North-East part of the Fouta Djallon highland, although it is visible in the Siguirini sector. Finally, a class associated with the mangrove forest would appear at a proportion of nearly 0.1% in the coastal fringe of this extended area.

IN THE WIDER EXTENDED AREA OF THE FOUTA DJALLON HIGHLAND'S RPID

The proportions between shrubby savannah and cover associated with open forest and wood (41% and 21% respectively for this extended area) are like the previous zones, although the forest coverage is a little lower. The major difference between the land cover here and other spaces is the appearance of rain-fed cultivation areas (or low-land cultivation) dominant in the extreme north-east of the zone, beyond Bamako (map 13), which represents 3.6% of the land cover for this space. Finally, the artificial lakes caused by the Manantali dams, the Sélingué, Baneah and Garafiri dams and the free water surface area constituted of major rivers (Niger in particular) represent a little over 0.5% of the total RPID extended surface area, i.e. around 1,550 km².

GEOMORPHOLOGICAL MODEL OF THE FOUTA DJALLON LANDSCAPES

The plateaus and glacis are the main geomorphological features of the Fouta Djallon highland. Maignien (1958) and Michel (1973) identified three major crust levelling surfaces with successive steps, an intermediate crust relief of average altitude on the slopes and finally three very variable extended glacis.

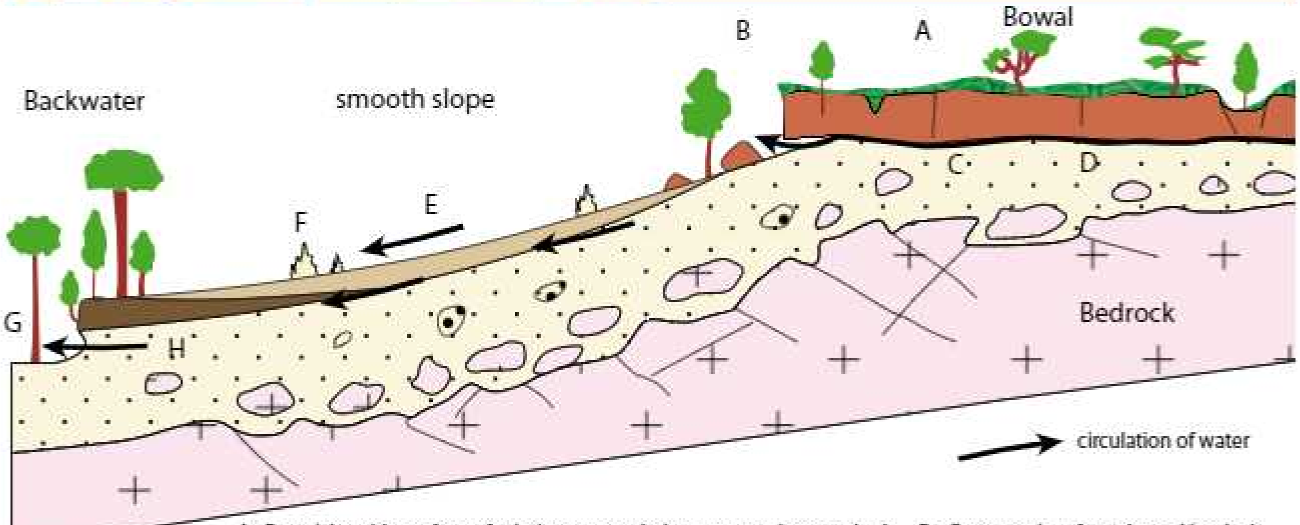
The diagram of the edge of the cuirasse plateau (figure 8) describes a landscape that is typical of the Fouta Djallon. On the Bowal's surface, vegetation is scrubby and conducive to grazing and logging. These almost impermeable surfaces only make water flow possible under the surface of the cuirasse's edge. Logging activities are thus much more detrimental to these surfaces, and the increased degradation of these spaces can lead to erosion during heavy rains. The most suitable cultivation areas are located on the slope rises, where soils are more hydromorphous in nature (spotted area) due to the associated water tables that can be found there and due to water movement in the ground.

HIGH PLATEAU OF FOUTA DJALLON

From the point of view of its geography and geomorphological shape, the entity of the Fouta Djallon highland is more specifically recognizable (map 14) in the central part of the highland. Morphological sub-units can be found in these high plateaus, such as:

- The plateau of Labé (approximately 1,100 m) with a central part that is massive and tabular. This plateau extends toward Dabola, and it is marked by dolerite intrusions. Encrustation is generalized with, in particular, outliers of the primary bauxite surface called Labé (P. MICHEL,1973). Two flats rises around Dankolo which mark the transition with the plateau of Tougué.
- The plateau of Dalaba is separated from the plateau of Labé by the upper Kokoulo valley. With an average altitude of 1,100 m between Bouliwel and Dalaba, these plateaus culminate around Diaguissa, at a height of 1,425 m. Bauxite cuirasse outliers punctuate this eastern escarpment. To the west, it reveals sandstone hills, testimonies of its decline due to erosion.
- The plateau of Mali Yambéring and the Mali escarpment: This plateau, with an altitude comprised between 1,100 m and 1,400 m, culminates at Mount Loma (near Mali), a mountain which is a dolerite sill and not an indurated outlier. It is not massive and alternates between little cuirasse plateaus and dolerite sills that are particularly numerous in that sector. In the north of Mali, the escarpment rises more than 1,000 m above the rise (slope of Madina-Kouta). To the west and northwest, the escarpment is less steep and displays intermediate flats or steps.
- The Mamou Highlands are born of the extension of the Diaguissa-Dalaba plateau which constitutes, according to Boulvert, the south end of the Fouta Djallon plateaus. Landforms do not reach 1,100 m in height, and the cuirasse interfluves are most often dismantled and limited.

Figure 8 > Edge of lateritic plateau (from Demangeot - 1976)



A : Bowal, lateritic surface of relative accumulation, more or less cracked
B : Edge of Bowal with screes
C : Spotted zone
D : Groundwater circulation between lateritic surface and spotted zone
E : Cemented surface shaped in glacis
F : Termite mound
G : plain with backwater
H : absolute accumulated lateritic surface

BOWAL : The term bowal (a bowal/several bowés) is a Peulh word. It is given to forms made of laterite surface crusts, once released by erosion. The first use and explanation of this term was by the geographer Jacques Richard-Molard in 1944 when describing Fouta Djallon Highlands in Guinea. Since then, the term has entered various dictionaries and entered French in geomorphological vocabulary and German in biogeography.

MORPHOPEDOLOGICAL ENTITIES ASSOCIATED TO FOUTA DJALLON PLATEAU

The following morphopedological sub-units are associated with the Fouta Djallon

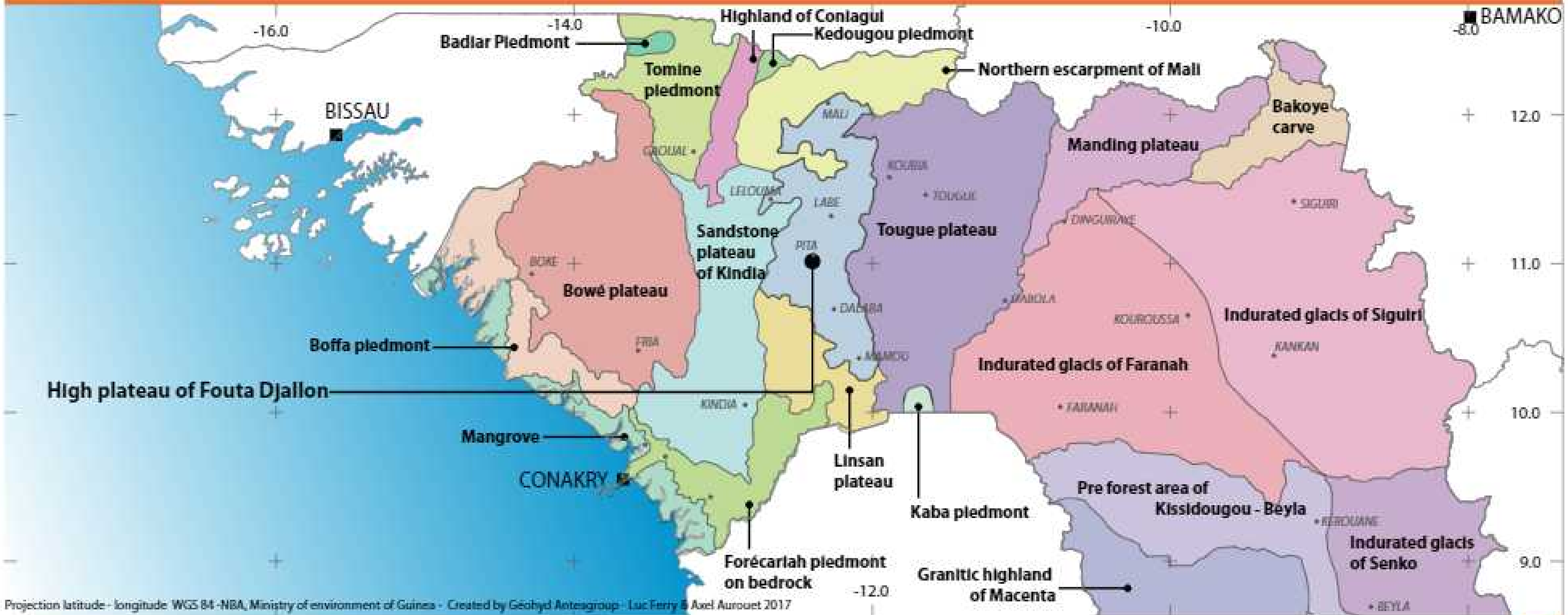
- The plateau of Tougué-Timbo is made up of the upper basins of the Gambia, Bafing and Tinkisso rivers. Encrustation is generalized and the plateau appears massive and monotonous with a succession of plateaus and cuirasse rises. Nonetheless, it is more or less dismantled by the vertical erosion of the Tinkisso and Bafing rivers. In the north, this plateau ends at the Guinea-Mali border, whereas in the south, between the Mongo and the Tinkisso Rivers, Mount Tandon (1,015 m) marks the southeast border of the Tougué-Timbo plateau. It is connected to the Mamou Highlands on its western side.
- The Rises - Flats of Linsan or of the Upper Konkouré River are an area of transition between the Fouta Djallon highland and the plateau of Kindia. This sector is a depression which overlooks the basins of the Kolenté and Kora rivers to the south. With an altitude of approximately 500 m, it takes the form of a cuirasse rise that is homogeneous and vertically eroded by the Kolenté River. Within this entitywe can see a shape with two large steps, with a slope-flat (Kolenté Piedmont) topped by sandstone plateaus.
- The Bassari Mountains, also identified as the Coniagui Highlands, represent the transition between the Fouta Djallon highland and the Tominé Piedmont. They are a set of small hills lined up like a chain. Active erosion uncovers rockbands in a SSW-NNE alignment.
- The Tominé Piedmont (or the Gaoual-Koundara Piedmont or the Youkounkoun basin) constitute a vast flattened area with an altitude of 100 m. The valley widens to a breadth of approximately one hundred kilometers, like a fan delta. Historically associated with the Fouta Djallon highland, this sub-unit remains very far from the geomorphology of the heart of the Fouta Djallon (Boulvert, 2003). Passage from the Bassari Mountains to this sub-unit involves a cuirasse slope that is virtually continuous over 50 km from Gaoual to Kifaya.
- The Badiar sandstone plateaus dominate the Tominé Piedmont. This landscape is described as a «sort of ovoid sandstone pancake» which stretches to the southwest beyond the border with Guinea Bissau.

SURROUNDING HIGH PLATEAU OF FOUTA DJALLON

The following morphopedologic landscapes can be identified around the Fouta Djallon:

- The sandstone plateau of Kindia - Télimélé, which more or less corresponds to the Bové basin described by geologists. This plateau, at a lower altitude, is composed of a complex alternation of coarse layers (sandstone and conglomerates) which is sometimes conducive to induration.
- The transition of the plateau of Bové with the sandstone plateau occurs in multiple tiered cuirasse steps. This plateau is vertically eroded by waterways but it retains a well established cuirasse surface.
- The Manding plateau, which is composed of a tabular relief fossilized by encrustation. It dominates the southern edge of the Taoudéni basin.
- The indurated slope of Faranah is covered by a generalized encrustation and there are several outliers that can be reconciled with the dismantling of the plateau of Tougué.

Map 14 > Morphopedological landscape of Guinea



Projection latitude - longitude WGS 84 -NBA, Ministry of environment of Guinea - Created by Géohyd Anteagroup - Luc Ferry & Axel Aurouet 2017

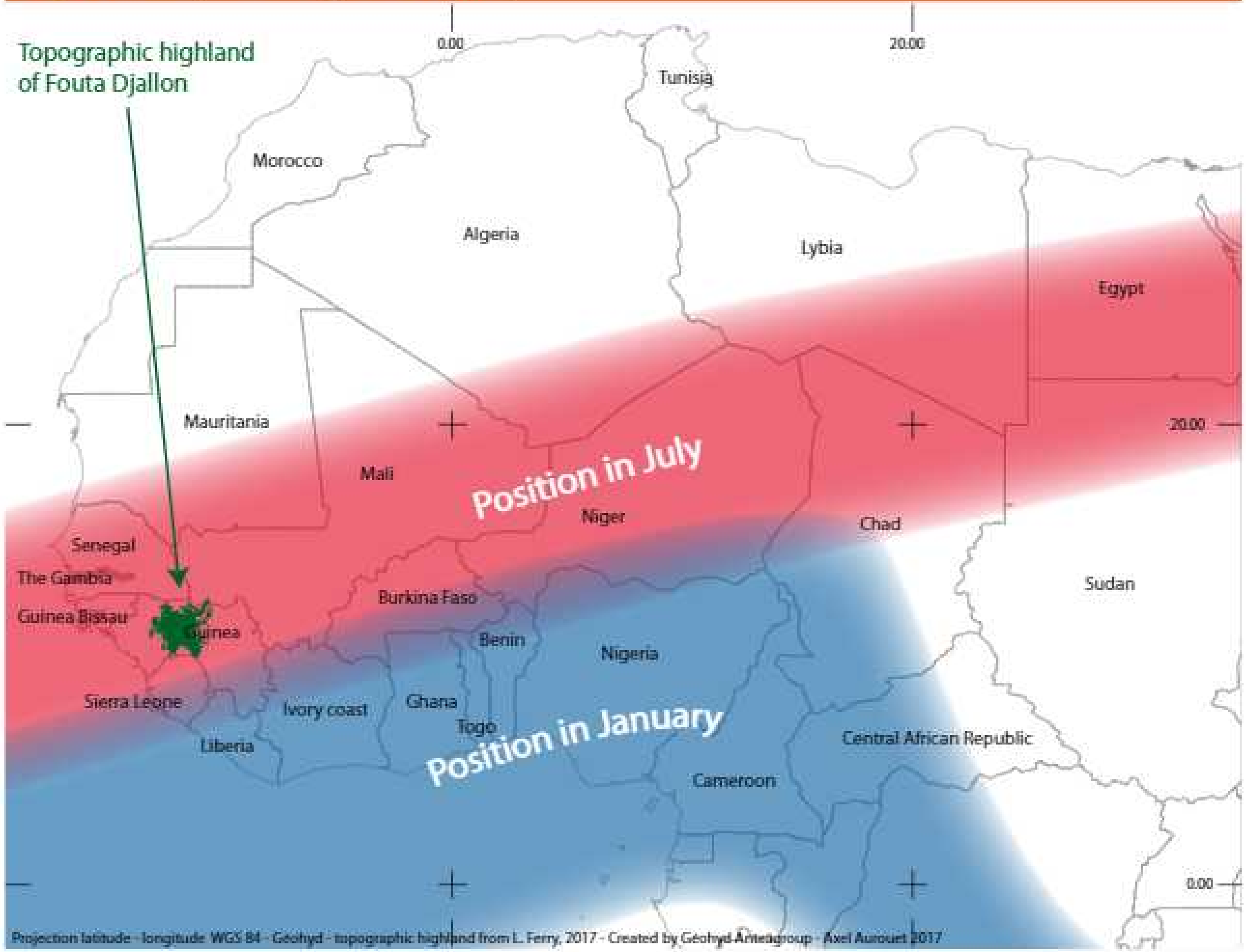
MAJOR CLIMATE FEATURES

THE SUDANO-GUINEAN CLIMATE, WHICH IS DOMINANT IN GUINEA, MARKS A TRANSITION BETWEEN A VERY HUMID CLIMATE OBSERVABLE IN THE SOUTH AND A DRYER «SUDANESE» CLIMATE TO THE NORTH. THE FOUTA DJALLON CLIMATE IS DIFFERENT FROM THE SUDANO-GUINEAN CLIMATE DUE TO ITS «MOUNTAINOUS» AND MUCH COLDER NATURE. ANNUAL RAINFALL AVERAGES 1,700 MM IN THE FOUTA DJALLON

A CLIMATE INFLUENCED BY THE INTERTROPICAL CONVERGENCE ZONE AND THE GUINEAN HIGHLANDS

The Inter-Tropical Front (ITF), now more commonly known as the Intertropical Convergence Zone (ITCZ), is a major feature of the climate in Guinea, the Guinea surrounding area and more generally West Africa. This "real front" (map 15) is a discontinuous surface between the continental tropical air mass, hot and dry, and the maritime monsoon tropical air mass, fresh and humid. Its movement is slow and is coordinated by an annual seasonal movement. In January, it is at its most southern point (a little north of Conakry) and in August at its most northern position (Nouakchott NE position towards the 20th parallel). These North-South movements during the southern and northern summers generate alternate dry and humid periods in the sub-region characterizing the seasons in this part of the world. More locally in the Guinea surrounding area, three major climate regions are described by Aubréville (1949). The Forest Guinea climate region including Sierra Leone, Liberia and Forest Guinea, the Sudan-Guinea region, which includes the centre of the Fouta Djallon highland and the majority of Guinea, and finally the Sudan-Sahelian region, starting at the Northern edges of Guinea. In view of previous knowledge, these major regions are further explained by Boulvert (1992) who suggests even narrower sub-divisions.

Map 15 > Intertropical Convergence Zone (ITCZ)



TEMPERATURES AND EVAPOTRANSPIRATION

TEMPERATURES INFLUENCED BY THE FOUTA DJALLON HIGHLAND

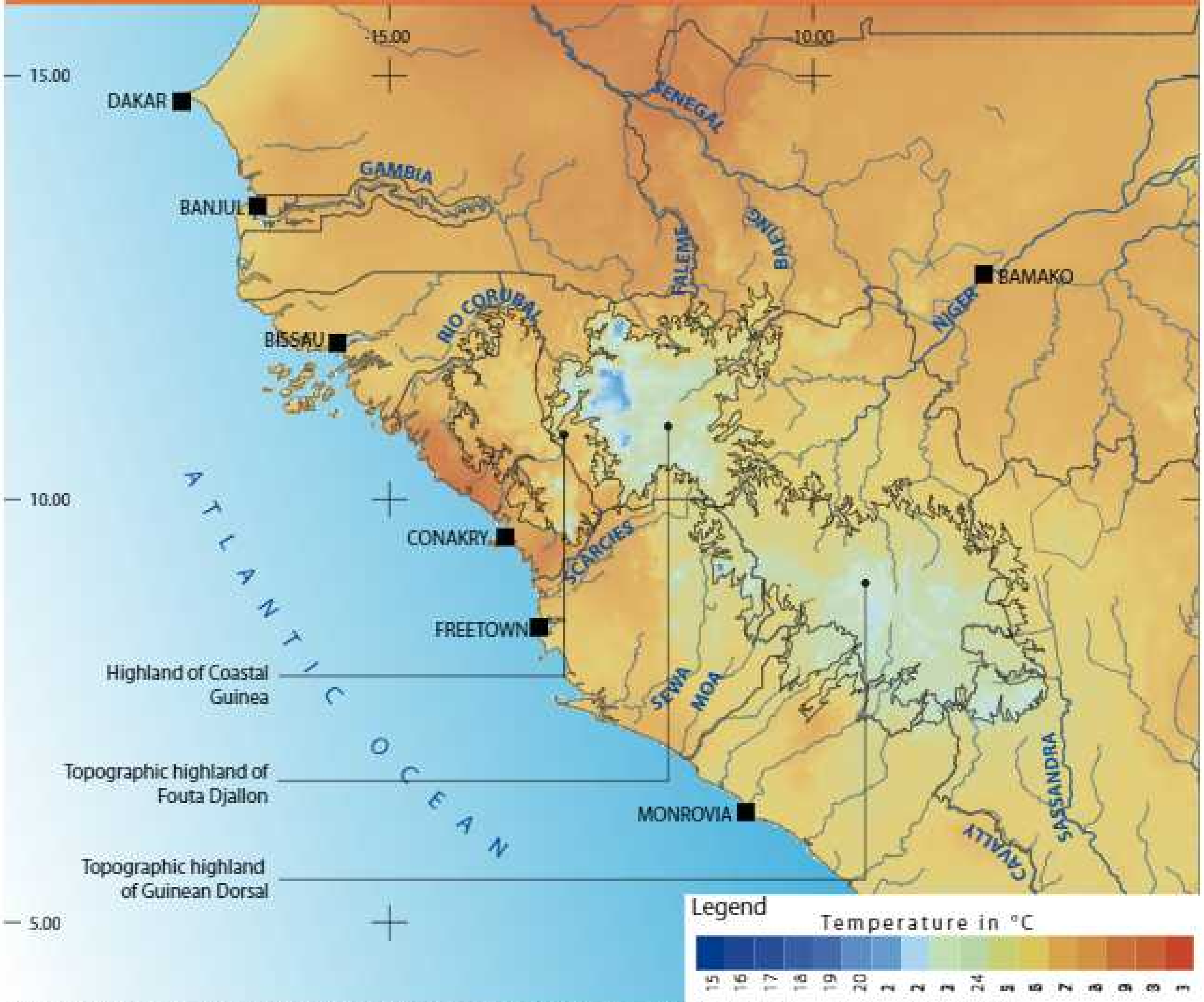
The average annual temperatures follow a growing progression from the south to the north (Map 16), alongside the reducing rainfall. This reducing "axis" is however skewed in Guinea, with the appearance of the Fouta Djallon highland' and the Guinean Dorsal. On the eastern edges of Guinea, temperatures change "normally" on a South-North axis of 24.5 °C on average at N'Zérékoré at 28.2 °C in Bamako, passing through 26.1 °C in Kankan and 26.8 °C in Siguiri. Next, the average temperatures above 27 °C are only observed in the north-west (27.2 °C in Boké and 27.9 °C in Youkounkoun) and the north-east of the country. At the level of the Fouta Djallon highland' and Guinean Dorsals', the average annual temperature falls below 25 °C and settles around 21°C in the Fouta Djallon highland (20.9 °C in Dalaba). During the warmest months (March south of the 9th parallel and April-May to the North), the temperatures in the north of the country are easily above 30 °C (Youkounkoun, Siguiri). In Fouta Djallon, the temperature in the warmest month is around 24 °C. The coolest months are observed during the winter period in July-August in the Fouta Djallon highland, settling around 18 to 19 °C (Dalaba, Mali). It is also during this same period that the coolest months are observed in the South of Guinea and the Forest Guinea area (22.8 °C in Beyla). Further North, the coolest month tends to be observed in December-January, along Guinea-Bissau and the upper basins of the Gambia, Senegal and Niger (up to Macenta). Boulvert notes out of curiosity that the absolute minimum temperature in Guinea would have been recorded in January 1906 at the sources of the Niger at 1 °C.

EVAPOTRANSPIRATION OR THE QUANTITY OF WATER GOING BACK INTO THE ATMOSPHERE

Evapotranspiration covers the notion of evaporation, representing the quantity of water transformed into vapour due to the temperature and wind, and the notion of transpiration linked to a plant's demand for water. This fundamental climate parameter in the understanding of hydrological and hydrogeological balances is expressed in millimetres of water evapotranspired. We can also distinguish the notion of potential evapotranspiration (PET, corresponding to a climate demand for water vapour) and actual evapotranspiration (AET), which includes the actual availability of water to be evapotranspired (including the water component in the soil). In the Guinea and surrounding Guinea geographic area, this PET varies from 1300 mm at the 7th parallel in Liberia to 2000 mm at the 13th parallel in Mali. The Guinea coasts cause a skew from the South-west to the North-east with a PET assessed at 1410 mm in Conakry and 1900 mm in Niagassola, near to the Mali border. The lowest PET values in Guinea are observed in N'Zérékoré (1322 mm in the forest area), the PET also decreases with the lower altitude and temperatures there. This is notably the case in the Fouta Djallon highland. The PET maximums are observed during the hottest month (March to the south of the country and the Fouta Djallon highland), when the sun is at its peak. For this month, the PET is assessed at 174 mm in Conakry and 171 mm in Dalaba.

September nearby Mamou

Map 16 > Mean annual temperature in West Africa



Projection latitude - longitude WGS 84 - PRAI - MFD, FAO, Géohyd - Topographic highlands from L. Ferry, 2017 - Réalisation Géohyd Anteagroup - Axel Aurouet 2017

THE CLIMATE TYPE OF THE FOUTA DJALLON HIGHLAND AND ITS EXTENDED AREA (FROM Y.BOULVERT – 2003)

Regional rainfall (map 17) shows that there are pronounced rainfall contrasts in the extension area of the Fouta Djallon highland, and more generally in the sub-region. There are thus three major climate areas concerned by the extended area, which can themselves be subdivided into sub-sectors.

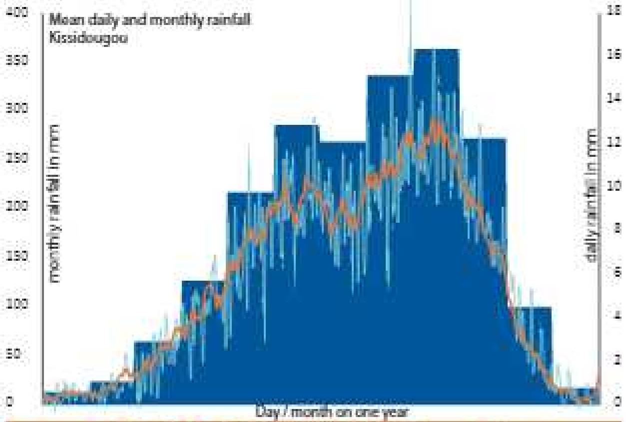


Figure 9 > Rainfall of «Forest Guinea» climatic domain

THE CLIMATE AREA OF FOREST GUINEA AND THE GUINEAN DORSAL

This area is initially separated from the Sudan-Guinea area by a line linking Freetown (Sierra Leone) to Ouré Beka (Guinea) along the Scarcies (or Kaba) then, forming a bend, by linking Ouré-Kaba to Touba (Ivory coast) by passing through Beyla (eastern edge of Guinea). This large climate region which covers the dense and damp forest is characterised by very uniform temperatures (24 to 27 °C with 4 °C thermal range) and its humidity. The rainfall is high with the heart of the rainy season in July-August on the coastal slope and in September in the Guinean Dorsale. Very exceptionally, minimum temperatures are observed in December (Macenta) and even in January (Kolahun in Liberia). This climate region can be subdivided into four sub-areas. Boulvert (op. cit.) notably distinguishes the Liberian sub-climate (only seen in Liberia and to the south of the 7th parallel) which is characterised by no dry months with a net slowing of rain in August; the Sierra Leone climate corresponding to the maritime district of Sierra Leone with abundant rainfall (2,500 to 4,000 mm/year), rainfall peaks in August-September and dry months in January-February under the influence of the Harmattan; the Guinean Dorsal sub-climate (figure 9), under the influence of the highland (Nimba mountains, Simandou mountains...) is characterised by slightly lower temperatures (between 22 °C and 29 °C), slightly lower rainfall (1,800 to 3,000 mm) with a peak during September, secondary peaks in June or July and a significant drops in other months. Finally, a final sector corresponds to the Edge of the dense Guinea forest and the Guinea surrounding area savannah sectors. This extends from Freetown to Touba via Musaï and Kérouané.

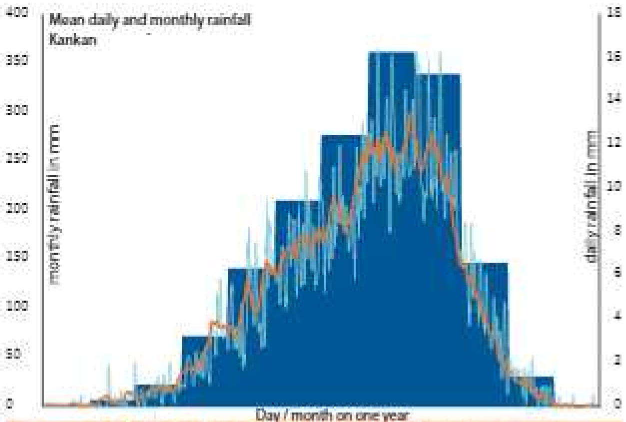


Figure 10 > Rainfall of «East Guinea» climatic domain

THE SUDAN-GUINEA AREA, THE HEART OF GUINEA AND THE FOUTA DJALLON HIGHLAND

Bordered to the South by the Forest Guinea climate region, the Sudan-Guinea region is bordered by the Sudan-Sahalian area to the north by a line passing through the Bolama-Bafata axis (Guinea-Bissau) up to the Gambia then generally following the Guinea Senegal-Mali border, joining the Sankarani-Niger confluence in Mali. This region is characterised by several rainy months (over 100 mm rainfall) for 5 to 7 months with dry months (rainfall under 30 mm) between 4 and 5 months. This climate region can be subdivided into three sub-areas. In addition to a sub-climate "typical of Eastern Guinea", there is also a Fouta Djallon sub-climate (see dedicated chapter) and the Maritime Guinea sub-climate.

East Guinea sub-climate

The "typical" Eastern Guinea climate (figure 10) is characterised by a fringe stretching from the West to East between the 9th and 12th parallel, starting with the Eastern foothills of the Fouta Djallon highland (Tougué-Kédougou in Senegal) and extending to the East, surrounding Kérouané to the South and Siguiri to the North. This climate is found in the upper basins of the Gambia, Senegal (Bafing) and Niger. The average temperatures vary between 23.5 °C and 27.7 °C with a relatively small thermal range between 4.4 °C and 6.7 °C. The average rainfall decreases along a SSW-NNE axis. The month with the highest rainfall is generally August, sometimes delayed into September. The rainfall starts in April and stops suddenly in November. Evapotranspiration varies between 1640 mm (Tougué) and 1900 mm (NE of Siguiri) with 120 to 176 d/year during when rainfall is higher than evapotranspiration (positive water balance).

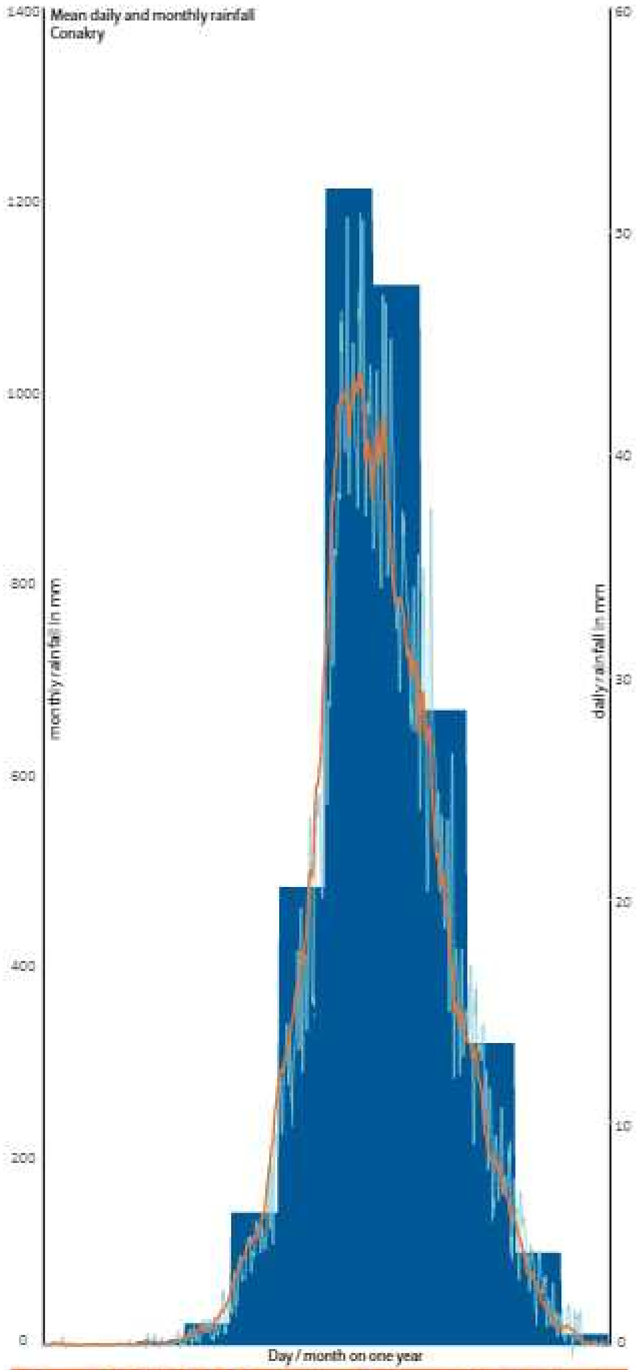


Figure 11 > Rainfall of «maritime Guinea» climatic domain

Maritime Guinea sub-climate

The Maritime Guinea Sub-Climate (figure 11)is very largely under the influence of the intensity of the Gulf of Guinea monsoon and extends from the North-West of Sierra Leone to the South-East of Guinea-Bissau. The contrast between the dry and rainy seasons is accentuated by the effect of the rain which appears suddenly in May, gets stronger in June to culminate in August and finally diminishes in September and stops in November. The rainfall is abundant (1934 mm in Gaoual, 2270 mm in Télimélé, 3 221 mm in Boffa and 4351 mm in Conakry) with a SE/NW decrease mainly linked to a more continental influence to the North-West. This continental effect is also felt on evapotranspiration which is presented inversely to rainfall with a decrease on the NW-SE axis (1,411 mm in Conakry, 1,529 mm in Boffa, 1,584mm in Télimélé and 1,733 mm in Gaoual). A sub-division of this climate can be bordered by an approximate line between Télimélé - Fria and Conakry to individualise a Conakry-Télimélé-Forécariah sub-climate and a Boffa-Boké-Gaoual sub-climate. Between these 2 sub-divisions, there is a slightly shorter dry season in the Conakry sector with rainfall divided in half between the Conakry region and Guinea-Bissau border. The number of days where rainfall is higher than evapotranspiration is significant: 177 to 198 d/year for Conakry-Télimélé and 155 to 172 d/year for Boké-Boffa.

Oceanic facade in Guinea

CLIMATE AT THE HEART OF FOUTA DJALLON, AN UNUSUAL FEATURE OF THE SUDAN-GUINEA CLIMATE

This "Fouta" climate (figure 12), individually explained by Boulvert, corresponds to the Fouta Djallon Highland and has a limited geographic extension from the Sierra Leone border to the South up to the Tamgué mountains (towards the Loura mountains) to the North. It is described as a mountain climate of the Sudan-Guinea area. However, it is intensely watered by monsoon rains and is subject to the drying influence of the Harmattan, whilst fog moderates dryness. In Mali, with the altitude, the annual averages fall below 24 °C down to 20 °C. The coldest month (December) normally noted in the Sudan-Guinea area is observed in August at the summits in Dalaba and Mali (around 18 °C). Under this climate, the hottest months are modest in temperatures (between 23 °C and 26.5 °C) and run from March-April. The thermal ranges are small during the year. The average annual rainfall is relatively high, around 1800 mm in Mali and 2250 mm in Dalaba, with a decrease due to the wind (1714 mm in Labé, 1590 mm in Ditinn). The first rains reach Dalaba in March, Pita in April and Mali in May. The maximum rainfall is observed in August with a return in October and some extra rainfall on highland in December. Evapotranspiration remains quite high, at around 1450 to 1625 mm. During 154 to 185d/year, rainfall is higher than evapotranspiration (positive water balance).

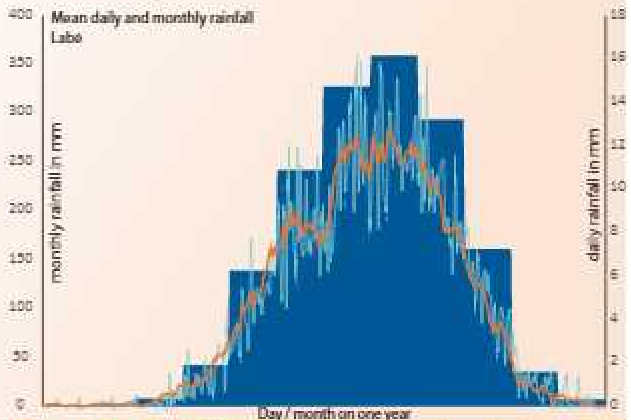


Figure 12 > Rainfall of «Fouta Djallon» climatic domain

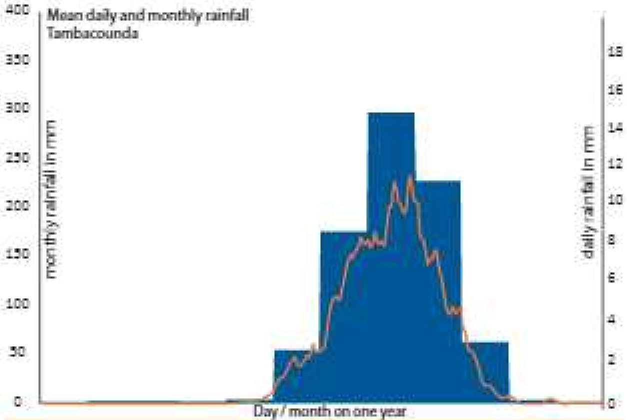
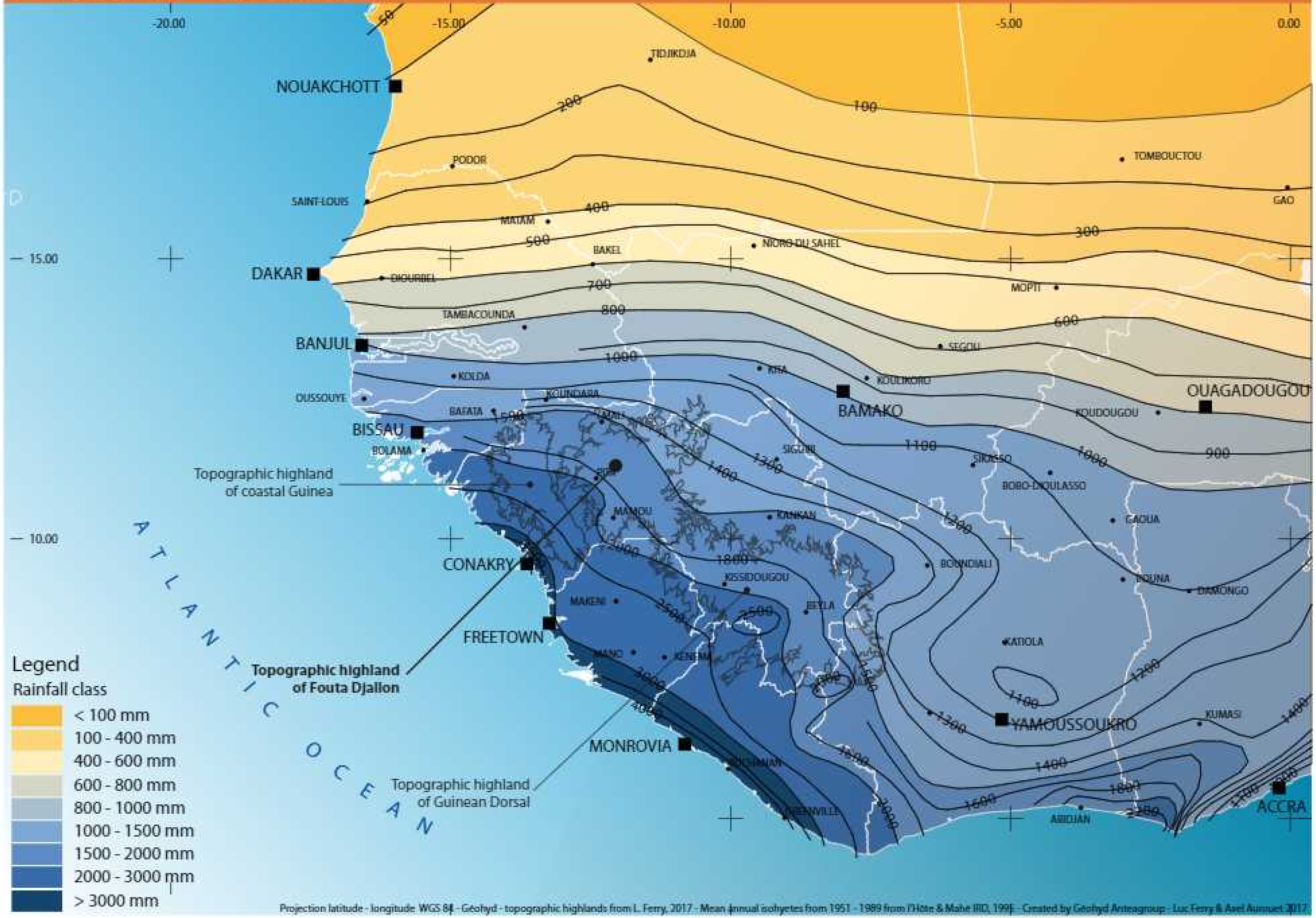


Figure 13 > Rainfall of «Sudanian» climatic domain

TOWARDS THE NORTH OF THE FOUTA DJALLON HIGHLAND, FROM THE SUDAN CLIMATE TO SUDAN-SAHELIAN CLIMATE

This climate region is positioned on the northern fringe of Guinea and reaches from West Africa (Senegal) to the Horn of Africa (Eritrea) with a clearly marked "continental" type. The specific feature of this Sudanese climate region is the fact that there are less rainy months than dry months (map 14). Boulvert proposes five sub-climates. The Sudan-Sahelian Southern variations (Youkounkoun-Kédougou) and the Banifing basin (South-East of Mali) are two very different sub-groups which are transition sectors between the Sudan-Guinea and Sudan-Sahalien areas. The rainfall varies there between 1100 sometimes to 2000 mm (Youkounkoun-Kédougou) for an evapotranspiration between 1700 mm and 1900 mm. To the west of the Youkounkoun sector, there is a "lower Casamance" climate sub-group where the maritime influence can be felt. It is made up of the Guinea-Bissau-Casamance and Upper Guinea sub-sector. Upper Gambia has lower rainfall (> 1000 m vs 1100 to 1500 mm Guinea Bissau-Casamance) as well as higher evapotranspiration (>1800 mm vs 1800 mm Guinea Bissau-Casamance). Finally, to the north of Guinea, on the fringe including Bamako in Mali, the climate sector is linked in reality to the continental Sahelian-Sudan climate marked by high average temperatures (> 28 °C on average with peaks higher than 32 °C in April-May), relatively low rainfall (1200 mm) and marked evapotranspiration (>1850 mm).

View on Coastal Guinea highland, near Kindia


NOUAKCHOTT
DAKAR
BANJUL
BISSAU
CONAKRY
FREETOWN
MONROVIA
BAMAKO
OUAGADOUGOU
YAMOUSSOUKRO
ACCRA
TIDJIKDJA
PODOR
SAINT-LOUIS
MATAM
BAKEL
NIORO DU SAHEL
TOMBOUCTOU
GAO
MOPTI
SEGOU
TAMBACOUNDA
KOLDA
OUSSOUYE
BAFATA
KOUNDARA
BOLAMA
KITA
KOULIKORO
KOUDOUGOU
SIGUIRI
SIKASSO
BOBO-DIOULASSO
KANKAN
MAMOU
GAOUA
BOUNDIALI
KISSIDOUGOU
BEYLA
MAKENI
KENEMA
BOUNA
DAMONGO
KATIOLA
KUMASI
ABIDJAN
Topographic highland of coastal Guinea
Topographic highland of Fouta Djallon
Topographic highland of Guinean Dorsal
ATLANTIC OCEAN
Legend
Rainfall class
< 100 mm
100 - 400 mm
400 - 600 mm
600 - 800 mm
800 - 1000 mm
1000 - 1500 mm
1500 - 2000 mm
2000 - 3000 mm
> 3000 mm
Projection latitude - longitude WGS 84 - Géohyd - topographic highlands from L. Ferry, 2017 - Mean annual isohyetes from 1951 - 1989 from l'Hôte & Mahé IRD, 1996 - Created by Géohyd Antea group - Luc Ferry & Axel Aumuet 2017

HISTORICAL TREND IN RAINFALL AND CURRENT TRENDS

ANNUAL RAINFALL AVERAGE IN THE FOUTA DJALLON HIGHLAND HAS DECREASED BY CLOSE TO 12% BETWEEN 1930-1960 AND 1970-2000. THIS TREND, GENERALIZED IN WEST AFRICA AT THE TIME, HAS REVERSED SLIGHTLY OVER THE PAST FIFTEEN YEARS WITH INCREASED PRECIPITATION IN COMPARISON WITH THE DROUGHT OF 1970-1990.

A MAJOR WIDESPREAD HISTORIC DROUGHT IN WEST AFRICA SINCE 1970

Deep-rooted trends on rainfall in West Africa and Central Africa were observed from the 1990s when distinct rainfall variations were demonstrated for the 1950-1990 period (Mahé et al., 2005; Descroix et al., 2009; Dezetter et al., 2010). After a rather rainy period observed for the 1950-1970 period, a very dry period followed (1970-1995), which is still well remembered. This "great drought" seems to start around the 1968-1971 period with the phenomenon spreading across the African Sudan-Sahelian fringe. During this period, rainfall deficits were assessed between 25% (Liberia and Senegal-Gambia) and 13% (Sierra Leone). In Guinea, the overall deficit for this period can reach the upper range (20%), as well as in Mali (23%), Guinea-Bissau (22%) and the Senegal-Gambia sector (25%). Against more recent data, a North-South gradient is observed in annual variations with deficit fluctuations not exceeding 20% in the Senegal Guinea basin, with deficits reaching 35% in the Mali basin (1983) and with deficits reaching nearly 60% in Mauritania.

A REGULAR DEFICIT IN THE HIGHLAND AND ITS FRINGE SINCE THE 1970'S

This period of drought in West Africa is shown in rolling 30-year rainfall studies at LABE, MAMOU, SIGUIRI, BAMAKO (Mali) and KEDOUGOU (Senegal) (table 4). At the centre of the Fouta Djallon, in Labé, the normal 30-year situation has moved from 1693mm (1931-1960) to just 1475 mm (1971-2000), a 13% fall from the normal situation. This drop is the same (12%) as at Mamou, falling from 1948 mm for the 1931-1960 period to 1722mm for the 1971-2000 period. To the North and East of the Fouta Djallon highland (Kedougou and Siguiri), the intensity of the falls is around 9 to 10%, falling from a standard of 1299.8 mm (1931-1960) to 1174.4 mm (1971-2000) at Siguiri, and falling from the standard for the same period from 1264 to 1153.2mm at Kedougou. Finally, moving away from the Fouta Djallon highland, at Bamako, the normal situation has fallen by nearly 19% from rainfall of 1127.7 mm (1931-1960) under the emblematic threshold of 1000 m to around 910 mm (1971-2000). Between 1970 and 1984, across the period for usable data from 1922 to 2001, at the Fouta Djallon highland itself, the Pita station has the 9 driest years.. The Labé station shows 7 out of the 10 driest years for the 1970-1989 period and the evaluation of its rainfall index between 1923 and 2007 (figure 15) clearly shows the impact of this drought in the Fouta Djallon Highland.

Table 4 > Trend of mean thirty-years rainfall in West Africa between 1931 and 2000 (JC Bader)

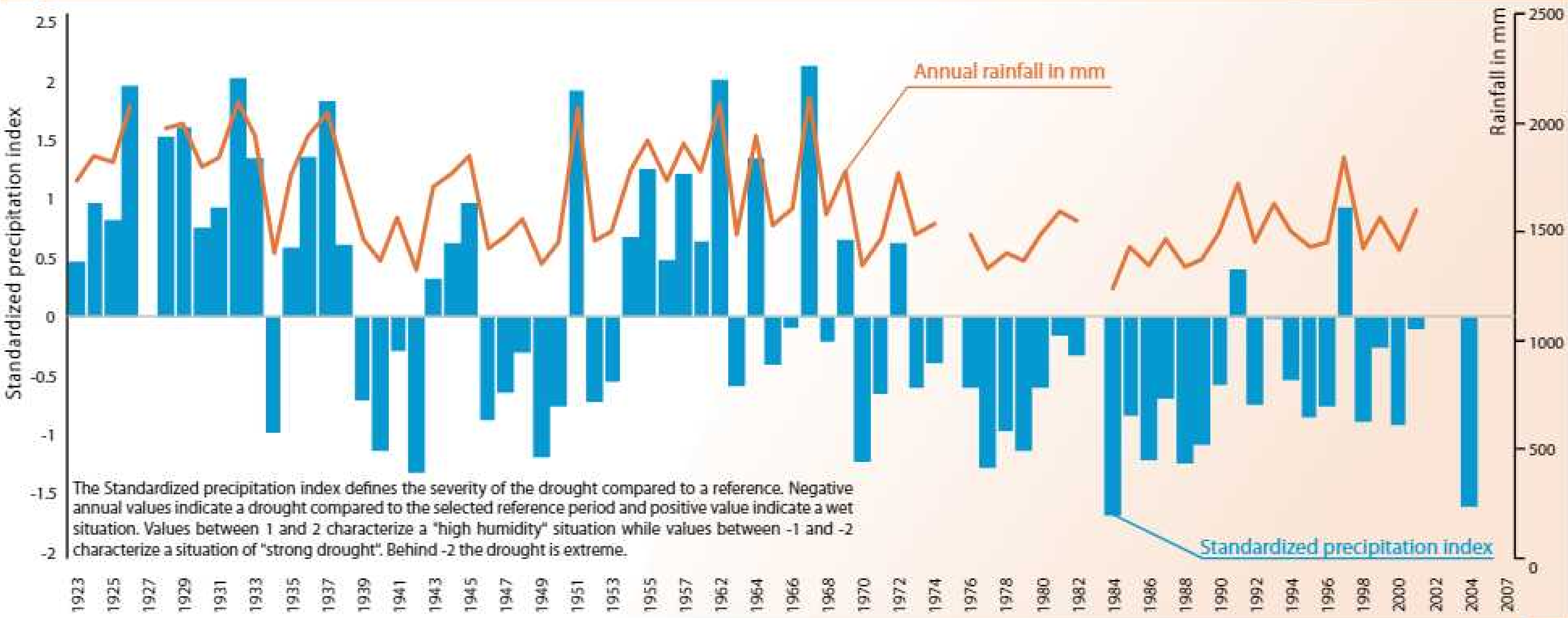
LOCALISATION	COUNTRY	AVERAGE ANNUAL RAINFALL OVER 30 YEARS IN MM					DIFFERENTIAL FOR PERIOD 1931-1960 AND 1971-2000
		1931-1960	1941-1970	1951-1980	1961-1990	1971-2000	
LABE	GUINEA	1,693.0	1,677.8	1,649.8	1,530.1	1,475.0	-13%
MAMOU	GUINEA	1,948.3	1,954.2	1,958.1	1,802.3	1,721.7	-12%
SIGUIRI	GUINEA	1,299.8	1,326.1	1,319.2	1,230.5	1,174.4	-10%
KEDOUGOU	MALI	1,264.0	1,266.9	1,282.1	1,178.8	1,153.2	-9%
BAMAKO	MALI	1,127.7	1,112.2	1,062.7	949.9	910.6	-19%
KAYES	MALI	799.7	768.5	695.4	630.9	615.5	-23%
KENIEBA	MALI	1,340.0	1,335.4	1,291.5	1,153.1	1,083.6	-19%
KITA	MALI	1,159.9	1,091.3	1,055.8	920.3	898.8	-23%
NIORO DU SAHEL	MALI	626.1	603.9	563.5	454.7	427.7	-32%
YELIMANE	SENEGAL	616.8	604.8	564.2	477.8	445.3	-28%
BAKEL	SENEGAL	505.9	518.0	503.2	499.1	481.0	-5%

Mabé's mountain on sandstone, Télimélé. In the foreground, *Elaeis guineensis* and *Terminalia glaucescens*

A RETURN OF RAINFALL IN RECENT YEARS?

The drought described previously and covering the period 1970-1990 with a "peak" in the 1980s was more or less uniform across the majority of West Africa. Nevertheless, the recent period seems to be characterised by more complex systems. At the Sahelian fringe (between the 11th and 16th North parallel), there seem to be more contrasted dynamics where the Eastern Sahel (around 10 °E longitude) has more rainy conditions since 1990, returning to the average levels for the 1950-1989 sequence. The Central Sahel saw a decline in the drought whilst remaining at rainfall levels lower than those observed for the 1950-1989 sequence and the western Sahel continues to experience persistent dry periods whilst remaining at the average levels seen in the 1970-1989 sequence. For the western Sahel sector, Descroix (2015) seems to demonstrate a return to the rainfall depth, notably showing an increase in the number of rainfall days with strong accumulation and an earlier arrival of the rainy season, whilst the end of the monsoon period does not seem to have changed. These recent studies also underline that whilst the returned rainfall reached the West (Senegal/Gambia) more than the Central Sahel (Middle Niger), it seems more pronounced, franker and more sustained whereas it does not seem to affect it inside the Sahel. Based on rainfall indexes focused on agricultural criteria, it is important to underline that this return of rainfall does not necessarily match up with the agro-climatic season. This is particularly true in the central part of the Sahel where there are years without organized agricultural monsoon in the 2000s, whereas rainfall did not change in this period. This observation tends to show the intra-annual modification of the temporal rainfall distribution. These "failed monsoons" based on the Sikavumar criteria are more adapted to the Sahel, logically decreasing on a North-South axis and the Sudan zones, to the northern fringes of the Fouta Djallon highland, with no "failed" seasons since 1951 (Kedougou and Kolda stations in Senegal a little under 13°N latitude).

Figure 14 > Rainfall Index at Labe Station



SUMMARY OF PHYSICAL LANDSCAPE

The Fouta Djallon highland are a singularity in the sub-region's relief. With a surface area of 47,000 km², they are defined (L. Ferry, 2017) as the Central Guinean Highlands located above a 440 m altitude. They stretch slightly into Mali and Sierra Leone along their borders. The Fouta Djallon highland is surrounded by other topographic highlands, the most emblematic of which are the Guinean Highlands located to the East-Southeast of the Fouta Djallon. With a surface area of 89,000 km², beyond Guinea, these also concern Sierra Leone, Liberia and Côte d'Ivoire. The other surrounding highlands defined by L. Ferry are the coastal Guinea mountains, the highland of the Siguirini-Baléa region and the Manding Mountains, which are all three extensions of the Fouta Djallon highland.

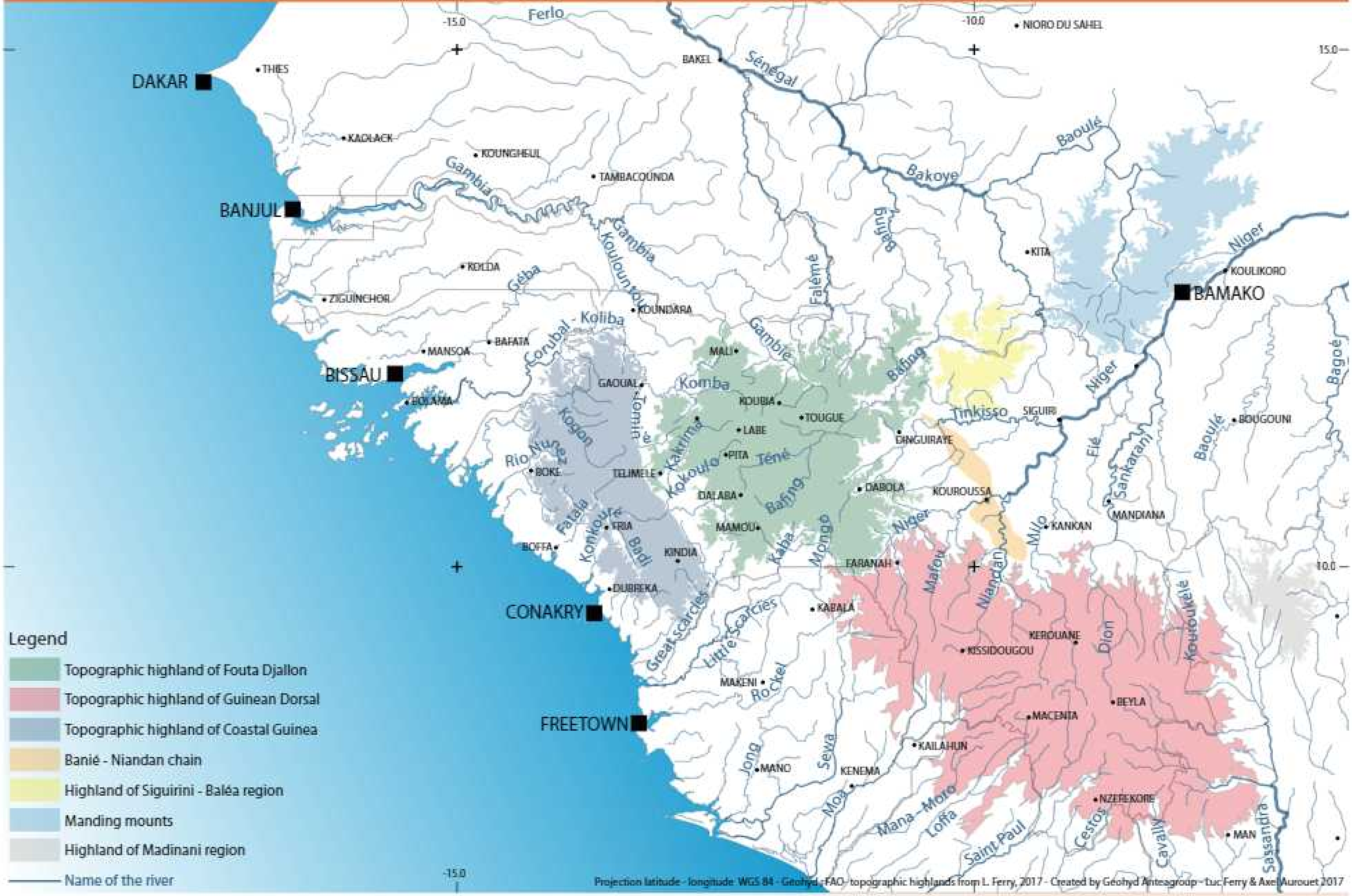
All of these highlands which characterize the region's landforms play a major role in the origins of the great rivers. The most emblematic of them are the Niger River - which has many upstream affluents that originate in the Fouta Djallon highland or in the Guinean Highlands - the Senegal River - which originates simultaneously in the Fouta Djallon highland, in the highland of the Siguirini-Baléa region, and in the Manding Mountains - and, lastly, the sources of the Gambia River which are almost entirely linked to the Fouta Djallon highland. There is also the Rio Corubal (near Guinea Bissau), the Great and Little Scarcies (near Sierra Leone) and the Konkouré - a river that is entirely Guinean and of paramount importance for the country due to the many hydroelectric developments in its watershed.

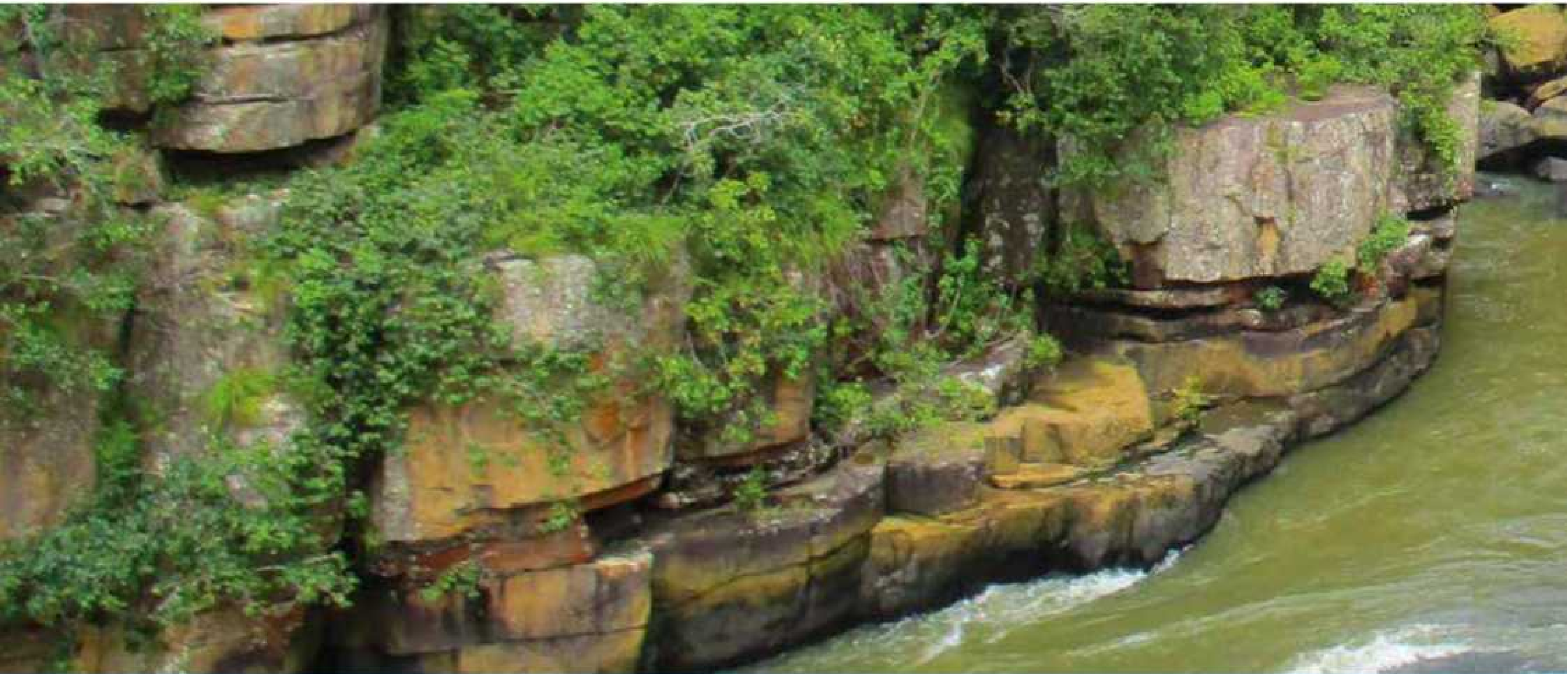
These highlands play a fundamental role in rainfall distribution on a regional scale. Both the Fouta Djallon highland and the Guinean Dorsals act as a real topographic barrier, and they determine the rainfall pattern that ranges from close to 4,000 mm per year in Conakry to almost 1,300 mm per year on the northern border of Guinea (some 400 km away). These highlands can be considered as having helped to mitigate the effects of drought on the southern fringe of the country during the 1970-1980 drought which impacted West Africa, even if the Fouta Djallon highland was not spared said drought.

Originating from a very old geology, the Fouta Djallon highland, like other neighboring mountains, is all marked by the presence of predominantly acid rocks. The rocks of the Fouta Djallon highland are essentially sandstone with dolerite injections. They stand out quite clearly from the granites of the Guinean Highlands.

In the Fouta Djallon highland, the landscape is made up of terraces consisting of primarily lateritic plateaus, also called Bowal, with savannas and tree vegetation being dominant. Literature emphasizes the «degraded» nature of these spaces with a reduction of dense forested areas in the heart of the Fouta Djallon highland. Beyond the Fouta Djallon highland, ecosystems remain rich with a dense and humid forest that can be observed on the relief of the Guinean Highlands (Guinea Forest Region) and mangrove ecosystems on the oceanic front.

Map 18 > Rivers linked with Fouta Djallon highland and surrounding highlands





WATER RESOURCES OF FOUTA DJALLON AND ITS EXTENDED AREA

TRANSITION TROPICAL REGIMES TOWARDS A PURE TROPICAL REGIME

This chapter describes the flows of the main rivers taking their sources from the Fouta Djallon highland, the Guinean coastal highland and the northern descent of the Guinean Dorsal. By proposing this reading, it redefines the main features of the hydrological regimes of the sector's rivers. It also gives a look at groundwater resources.

HYDROLOGICAL REGIMES OF THE FOUTA DJALLON RIVERS

HYDROLOGICAL REGIMES OF RIVERS UPON LEAVING THE FOUTA DJALLON ARE CHARACTERIZED BY A HIGH WATER PERIOD FROM JULY TO NOVEMBER, A LOWER WATER PERIOD BETWEEN MARCH AND MAY, AND ABRUPT FLOW CHANGES. THESE REGIMES ARE TYPICAL TROPICAL TRANSITION REGIMES. DOWNSTREAM, A SHORTENING OF HIGH WATER PERIODS CAN BE OBSERVED, BRINGING THE SENEGAL, NIGER AND GAMBIA REGIMES TOWARD BECOMING PURE TROPICAL REGIMES, THEN SAHELIAN ONES.

MAJOR FEATURES OF THE SENEGAL RIVER HYDROLOGICAL REGIMES

Senegal is described by Orange (1990) as a pure tropical regime with a succession of 3 regimes between the sources of the Bafing and Bakel in Senegal: the transition tropical regime, the pure tropical regime and the Sahelian regime (Frécaut & Pagney 1982). The transition tropical regime covers the upstream part (Fouta Djallon) of the Bafing, the Falémé and to a lesser extent, the Bakoye. This sector enjoys significant rainfall as well as abrupt flow variations linked to rainfall regimes and the steep gradients of the slopes of Fouta Djallon. The "pure" tropical regime covers the lower part of the Falémé, the Bafing, the Bakoye and the Baoulé. It is differentiated from the previous regime mainly by a shorter period of high water. Finally, the Sahelian regime covers the entire downstream basin of Senegal where the rainfall is lower than 700 mm and where the flows are more sporadic. From upstream to downstream, the specific flows decrease gradually. Downstream, the inputs have barely any influence on the hydraulicity of the Senegal river, the same as the transition tropical regime. Up to Bakel, it is a pure tropical regime, and then the descent of the Fouta Djallon, which influences the hydraulicity of the Senegal River. Along the river there is a very strong flow seasonality which marks the flow regime with monsoon rains (July to October) which cause flood flows and increasingly reduced inputs from upstream to downstream. During the dry season, a drying-up regime is put in place and the associated water tables are emptied. The rainfall drought observed during the 70-80s considerably influences the average annual flows observed on the Senegal which range from single (220 m^3/s 1984-1985 in Bakel) to six-fold (1349m^3/s 1936-1937 in Bakel). Finally, since its creation in 1987, the Manantali dam (on the Bafing in Mali) has modified the river's hydraulic regime by limiting downstream flood peaks and by offering low flow support during a dry period. In this atlas we will remain on Bakel to look at the Senegal, with bakel representing the Northern Fringe of the Fouta Djallon highland' extended area (map 19).

THE BAFING

The Bafing takes the name of the Senegal after its confluence with the Bakoye. The natural year-on-year average flow is currently (1987-2011 period) around 30 m^3/s in Sokotoro, 204m^3/s in Daka-Saidou, 235m^3/s in Makana and 258m^3/s in Manantali. These average flows have fallen considerably between the 1950-1969 and 1970-2011 periods under the influence of climate deterioration. The annual natural flood usually starts in June and has its strongest flows between August and late September. In Sokotoro, (figure 15) the nearest to the source of the Bafing, the maximum flood is identified in August 1958 with a flow of 428 m^3/s. The current maximum flood flows seem to be around 150 m^3/s. In Daka-Saidou, these flood flows can reach 2881m^3/s (August 1958) and approach 3000 m^3/s in Manantali (2976m^3/s in August 1906 and 2528m^3/s in September 2000). From October, the drying-up period returns, but lesser flood peaks can arise up to November. From March to May, the flows become very low or non-existent (Figure 15,16). Since 1987, the Manantali dam has modified the Bafing regimes but also the Senegal river (figure 20) by storing an equivalent volume to the average annual flow at the Manantali station, i.e. 8.2km^3. Therefore, a significant portion of the Bafing is currently stored every year to be carried over from one season to another. There are three main consequences of these modifications. They currently allow a good hydraulicity for downstream uses (irrigation, flood recession crops, drinking water and sailing), they allow significant hydroelectric power production, but they also limit flood strength and, consequently, their extended areas, sometimes beneficial for ecosystems. The guaranteed flow by the dam is around 120 m^3/s from January to July, 180 m^3/s in august, 120 m^3/s from September to November, and 100 m^3/s in December. It should be noted that the optimum sailing flow at Bakel would be around 200 to 300 m^3/s (OMVS), an impossible flow to provide with the current Manantali facilities. Since 2004, the flow released by the dam is still below 450 m^3/s and completely turbine-based, and no specific flow is released for flood support. In Fouta Djallon, we also note the Téné inputs with an average year-on-year flow around 65 m^3/s in Belebe as well as the Kiomo inputs with an average year-on-year flow around 13 m^3/s in Salouma.

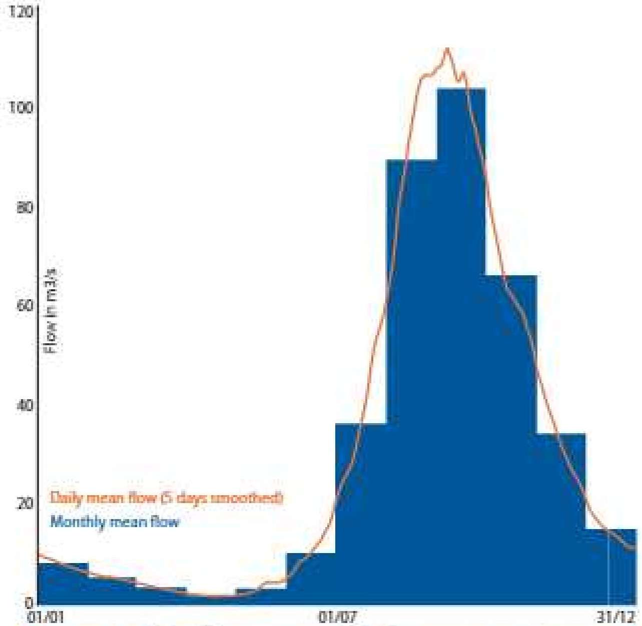


Figure 15 > Monthly mean and daily mean river flow on Bafing at Sokotoro / Period 1972 - 2016

BAOULÉ-BAKOYE, THE RIGHT BANK OF THE SENEGAL IN MALI

The Baoulé joins the Bakoye in Kita, Mali, to the east of the Badinko reserve. The Bakoye has its source in Guinea with a relative dependency on the Fouta Djallon highland. The Bakoye empties into the Bafing to form the Senegal downstream from the Manantali dam. The hydrological regime remains natural for these two rivers, and both have seen their hydraulicity fall following the drought in the 1970-1990s. In Oualia (Downstream Bakoye), the annual flood generally starts in July and ends in the first half of September. An overall fall in flow then follows, despite some flood peaks which can arise in October. Generally, the flow stops or nearly stops in January or February. In Oualia, 50 km before its confluence with the Bafing in Bafoulabé, the Bakoye has an average year-on-year flow around 81m³/s. It accounts for a little under 25% of the Senegal's flow.

THE FALÉMÉ

The Falémé has its source in the Fouta Djallon highland and runs along the border between Senegal and Mali. Its behaviour is the same as the Bafing and its average year-on-year flow in Gourbassi is positioned around 93 m³/s, the high-water period appears quite suddenly in July and extends to October-November with a peak in September (Figure 17). On average during the high water period, its flow is between 350 and 450 m³/s on average. The low water periods are very marked and the average flows are around 0.1 m³/s for the April-May period, the lowest water period. The contrast is strong between the 2 periods (2 m³/s on average between January and June against 171 m³/s between July and December).

Motorized dugout canoe on Senegal river

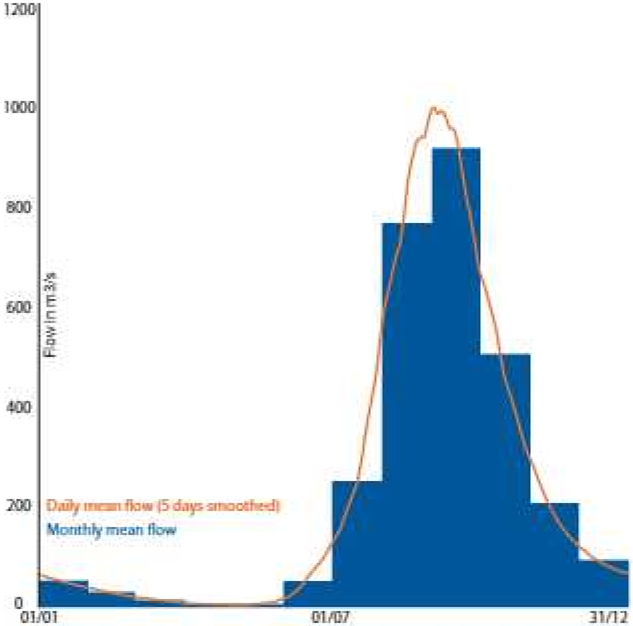


Figure 16 > Monthly mean and daily mean river flow on Bafing at Makana / Période 1960 - 2016

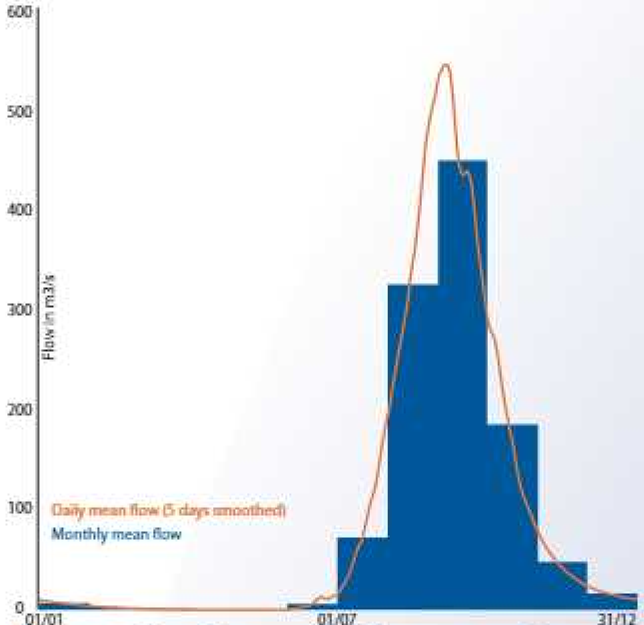


Figure 17 > Monthly mean and daily mean river flow on Falémé at Gourbassi / Période 1960 - 2012

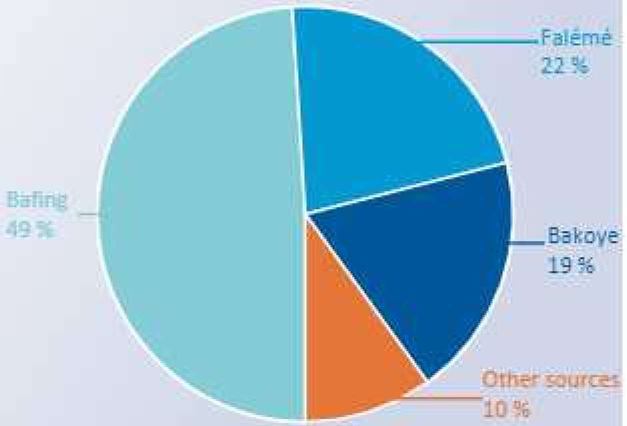


Figure 18 > Share contribution of tributaries of Senegal river at Bakel station

BETWEEN GALOUGO & BAKEL, THE SENEGAL REGIME UNDER INFLUENCE

The Senegal, for this portion, is directly subject to the influence of the Bafing and the Manantali dam (figure 19), despite not modifying the average date that the strongest flows appear. In Baking, flood control is significant for the peaks and flood durations are shortened despite improved flood peak generation in comparison to a natural regime. The lack of specific flows increases between 15 and 17% in relation to the natural regime and can even grow for a longer period (30, 60 or 90 days). The reinforcement of the low water flows by the Manantali dam also leads to a major modification by maintaining flows at 60 m^3/s whereas the latter would have been nil or practically nil for over 30 days/year in a natural regime. In a natural regime, the average flow of the Senegal in Bakel is estimated at around 507 m^3/s and, in a "modified" regime for the same period, at 469m^3/s. The lack of flow is mainly explained by the loss of evaporation caused by the extension of the water body at Manantali (16.3 m^3/s on average) and by the stored flow (10.8 m^3/s on average). We note that the climate deterioration in the 1970-1990s was felt significantly on the hydraulicity of this portion of the Senegal, reducing from an average flow of around 916m^3/s in Bakel (1950-1969) to nearly half that level, i.e. 413m^3/s approximately for the 1970-1987 period to result in 477m^3/s for the 1970-2011 period (figure 20). The recent period seems to be surplus with an average year-on-year flow of around 632 m^3/s (2011-2015). This observation would need to be confirmed with future series.

SUMMARY OF THE SENEGAL REGIME IN THE FOUTA DJALLON HIGHLAND' EXTENDED AREA

The flows of the regime observed in the period from 01/05/1950 to 31/04/2011 show that, on average, the volume flowing in Bakel comes from the Bafing for 49%, the Falémé for 22% and the Bakoye for 19%. The remaining 10% comes from intermediary inputs between Bakel and the Dibia stations on the Bafing, Kidira on the Falémé and Oualia on the Bakoye (figure 18).

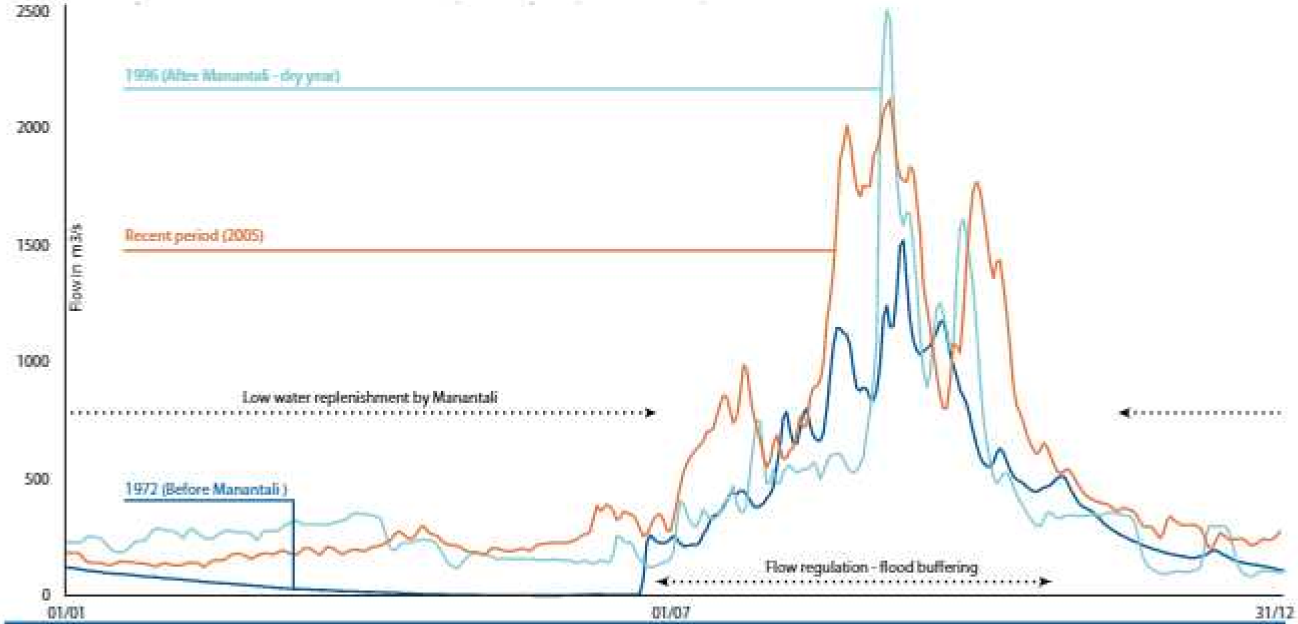


Figure 19 > Comparison of daily river flow before and after Manantali commossioning at Bakel station -Senegal river

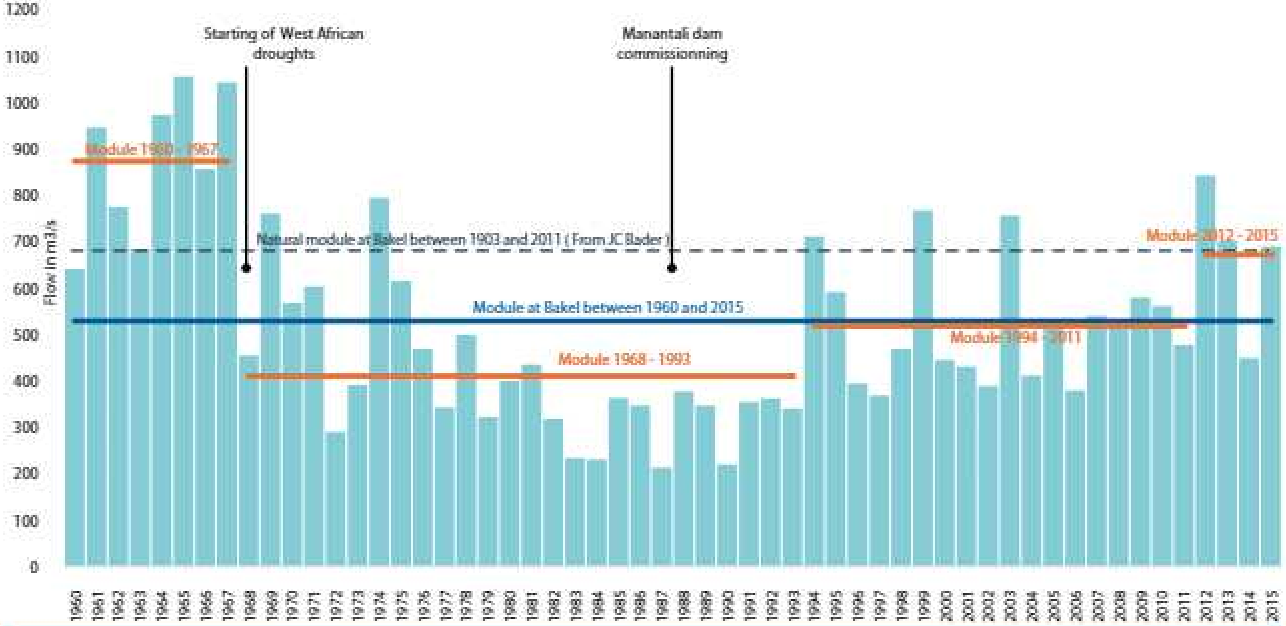
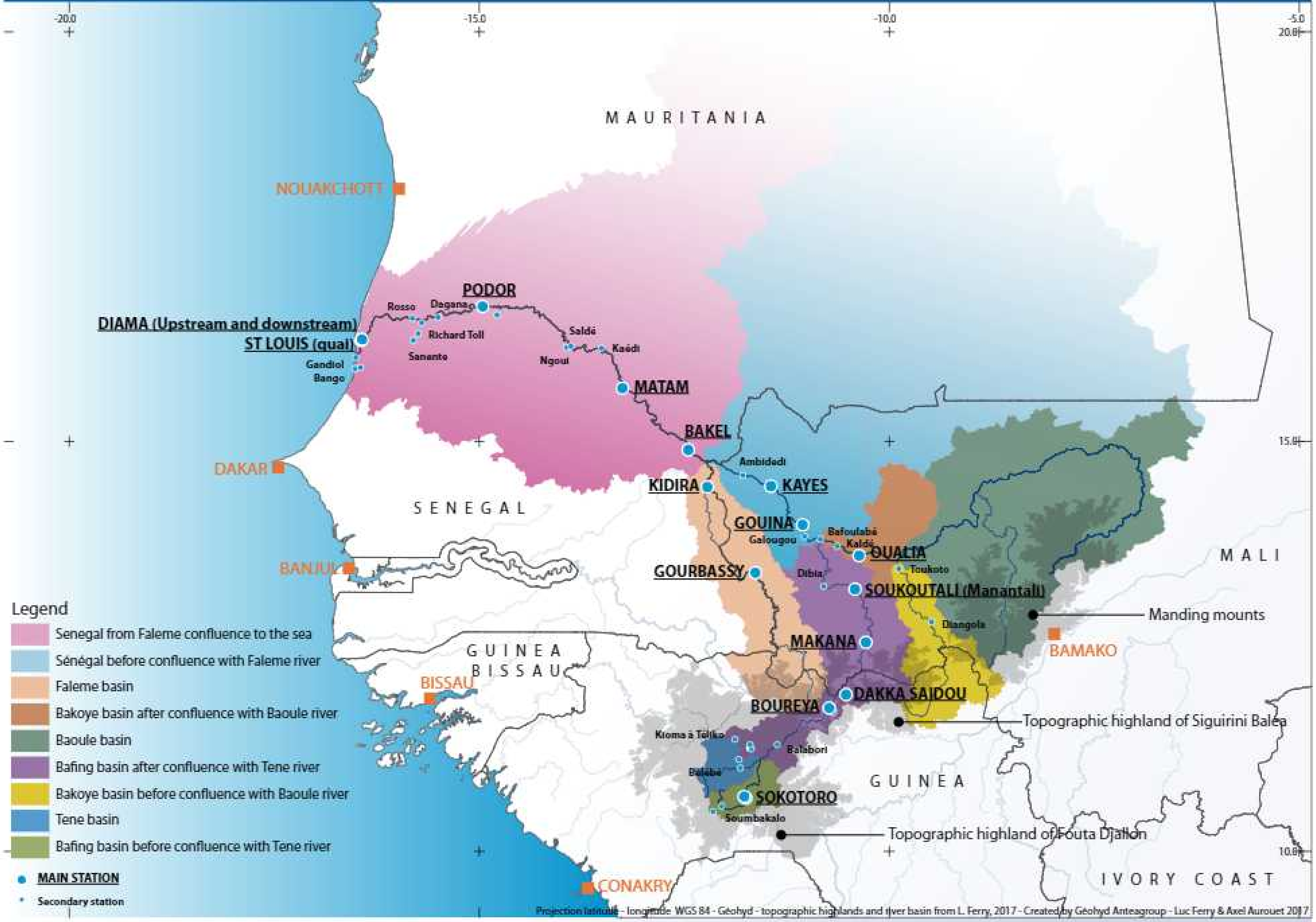


Figure 20 > Yearly mean river flow on Senegal at Bakel / Period 1960 - 2015

Map 19 > Main river flow stations on Senegal river basin



MAJOR FEATURES OF THE NIGER RIVER HYDROLOGICAL REGIMES

In comparison to the Senegal river, Orange describes the Niger regime as a transition tropical regime, notably due to the climate position of the two main tributaries, which are the Niandan and the Milo, with their long period of high water and their sources in the Guinean Dorsals. The Tinkisso, also a major tributary, flowing down the Eastern foothills of the Fouta Djallon highland, is described as being positioned in a pure tropical regime, with lower abundance due to severe low flows. This feature is largely compensated by more regular inputs from the Niandan and the Milo. The large flood plains in Upper Guinea play a role in controlling floods in the rainy periods. When leaving Guinea, at the level of the Siguiri, the Niger regime remains a transition tropical regime with a sustained low water flow and even longer high water periods. The Sankarani, a large tributary which meets with the Niger in Mali, after passing through the Sélingué dam, also has a transition tropical regime. Niger then receives the Faya, downstream from Bamako. The Kolikoro station plays the role of a "rain gauge" for the upstream portion of the Niger until it enters the inner delta, a zone over 40,000 km² where it loses a significant portion of its volume. It is joined there by the Bani, the source of which is in a much less rugged part of the Northern part of Côte d'Ivoire. After passing through the inner delta, the Niger continues its route in a Sahelian regime, crossing Niger, Benin and then returning to a more tropical regime in the south of Nigeria where it ends in the Gulf of Guinea. It is joined along the route by the Bénoué, where the sources in Chad increase its flow in Nigeria. At the end, the Niger is a "continental river" with a river basin which covers 9 countries (Guinea, Mali, Niger, Nigeria, Benin, Chad, Cameroon, Burkina Faso and Côte d'Ivoire) plus the southern part of Algeria, where the fossil networks of Azaouagh, to the south of Hoggar, could be included in this group. With the uncertainties linked to the definition of the river basin and the links with the Taoudéni aquifer, Ferry (2012) also suggests including Mauritania and Sierra Leone. In this Atlas, only the section of the Niger under significant influence of the Fouta Djallon highland and which is the Upper Niger before entering the inner delta is discussed (map 20).

TINKISSO, THE DIRECT LINK BETWEEN FOUTA DJALLON AND THE NIGER RIVER

In Tinkisso, on the upstream part of the Tinkisso river which has already covered approximately 150 km, the natural regime corresponds to a transition tropical regime with a period of high water focused between August and November (figure 21). The Tinkisso slowly rises in May-June then suddenly in July, then in August under the influence of the first intense rains, with its average flow between June and August by nearly 10-fold. Until December-January, it continues to rise and then dries as quickly as its rise. Since 1974 a hydroelectric dam (in reality a simple concrete weir with a fall height of 80 m - Olivry 2002) was built on the Tinkisso course. The probable consequences of this work on the hydrological regime are a delay in the first flows normally expected in June, a flood control effect during the high water period, and the supply of a more or less constant flow linked to the hydroelectric power production. To date, the silting of this dam seems to limit its electricity production capacity to a few hours per day. From the point of view of hydrological regimes, even if the latter have certainly been barely modified since 1974, in Tinkisso the September peak flow displays an average monthly flow around 250 m³/s. Between February and May, the flow is very low and stabilises between 7 and 10 m³/s. The average year-on-year flow increases to around 74 to 75 m³/s (1955-1983 period). During the drought period, this average year-on-year flow falls to around 50 to 55 m³/s (1971-1983 period) with years below 35 m³/s (1979). In Ouaran, just before its confluence with the Niger, the Tinkisso follows the regime observed upstream and it increased its average year-on-year flow 2.5 times (186 m³/s approximately). The specific flow (9.9l/s/km²) remains the lowest of the Niger tributaries in this geographical space and its input represents around 18% of Niger inputs at Siguiri before its entry into Mali.

THE NIANDAN

The Niandan meets the Niger just after the Baro station. Its regime is still natural for its entire course, even though the Fomi Dam project, planned for many years without any progress, could modify its regime in the future. Its regime is like a variant of the transition tropical regime. In Kissidougou, on its descent in the Guinean Dorsals, its average year-on-year flow is around 41 to 42m³/s, the water rising period starts from May (11 to 12m³/s approximately) and ends in September at around 113m³/s. The high waters are distributed over 5 months (July to November). From September, the drying-up period starts and ends in January-February. The months of February, March and April correspond to the lowest waters with flows below 5m³/s for March and April. During very dry periods, the average flow for these months can fall below 2 m³/s. At the Baro station (figure 22), the behaviour is strongly linked to the behaviour of the Kissidougou station, even though the period with the lowest water already tends to overlap into May. Also in Baro, the flows increase suddenly in July-August to reach an average flow of around 780 m³/s in September. The two months of low waters, March and April, have average flows of around 20 to 24 m³/s. During dry years, the flows in these months can approach 2 to 3 m³/s. Finally, the Niandan average year-on-year flow in Baro rises to nearly 250 m³/s with a specific resulting flow of around 20.6l/s/km². During the drought of the 70-80s, the average annual flow fell to nearly 38 m³/s (268 m³/s for the 1948-1964 period to 230 m³/s 1968-1974-1983). This deficit represents over 1.16km³/year on average at its outlet. At Siguiri, the Niandan contributes nearly 26% to the Niger flows.

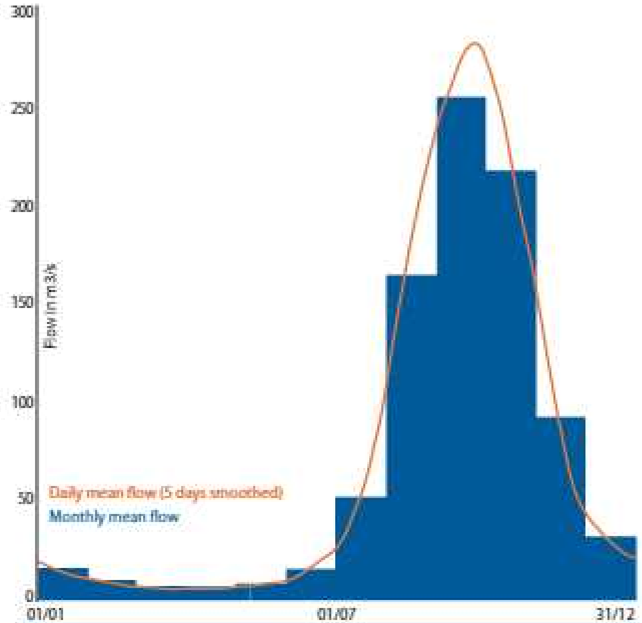
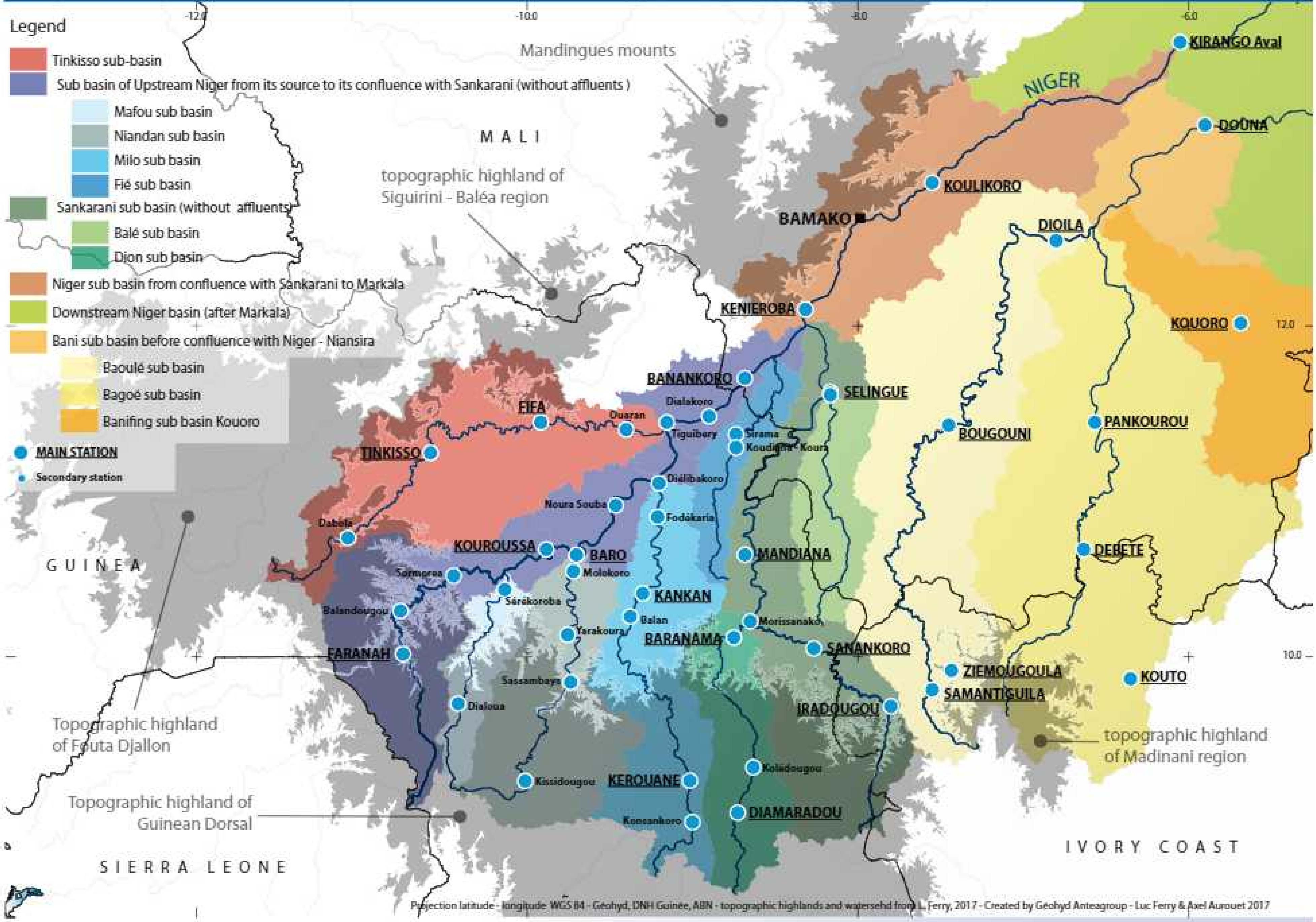


Figure 21 > Monthly mean and daily mean river flow on Tinkisso at Tinkisso / 1955 - 2009 period

Map 20 > Main river flow stations on upstream Niger river basin



Projection latitude - longitude WGS 84 - Géohyd, DNH Guinée, ABN - topographic highlands and watersehd from L. Ferry, 2017 - Created by Géohyd Anteagroup - Luc Ferry & Axel Aurouet 2017

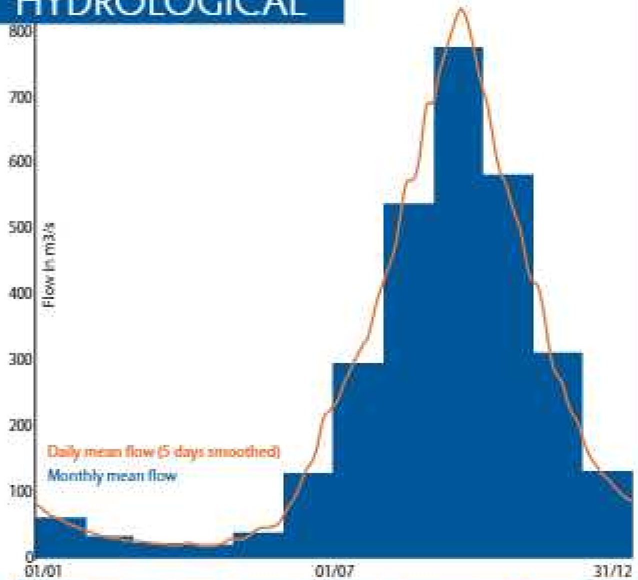


Figure 22 > Monthly mean and daily mean river flow on Niandan at Baro / 1948 - 1983 period

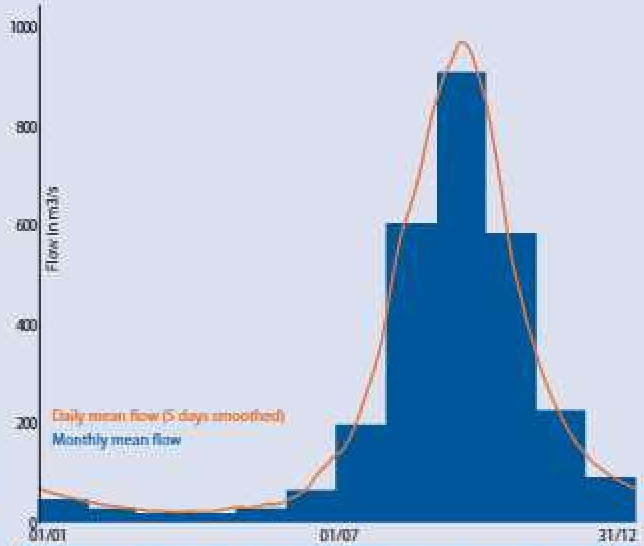


Figure 24 > Monthly mean and daily mean river flow on Sankarani at Mandiana / 1955 - 2006 period

THE SANKARANI

Whilst its source is in Guinea, the Sankarani has a hydrological regime which is slightly different in the sense that the low water periods are greater, and its high water peak seems restricted to 3 months (August to October). The ranges between the high waters and low waters are more marked. The rising water period starts in June (65 m^3/s in Mandiana – figure 24) and ends in September (910 m^3/s in Mandiana). The drying-up period ends in January and the lowest waters appear in February-April, sometimes May (19 m^3/s in Mandian on average). The average year-on-year flow is established around 249m^3/s in Mandiana, before leaving Guinea and after its confluence with the Dion. It continues its route until the Sélingué dam, a 2.17 km^3 capacity dam (equivalent to 69 m/s per year).

THE MILO

The Milo joins the Niger at Sassando, a little after the Kankan station, and has the same behaviour as the Niandan from the point of view of the hydrological regime. A transition tropical regime governs this river with a rising water period which starts slowly in May (27 m^3/s in Kankan) (figure 23) to end in September (540 m^3/s in Kankan) and a drying-up period which ends in January. February, March and April are the months with the lowest water with average monthly flows measured between 14 and 15m^3/s on average for these months. During the drought years, the flows for these months fell below 1 m^3/s at Kankan (10 times between 1985 and 1999). The high waters are between July and October. The Milo average year-on-year flow in Kankan rises to around 173 m^3/s for a specific flow equivalent to the Niandan (20l/s/km^2) but the average annual flow has varied significantly between the surplus periods (average annual flow 1940-1979 estimated at 196 m^3/s) and the dry periods (average annual flow 1980-2008 of 140 m^3/s). Finally this discrepancy of 56 m^3/s on average between these two periods represents a volume of 1.77 km^3 at the Milo outlet. The Milo represents around 20% of the Niger's inputs at Siguiri.

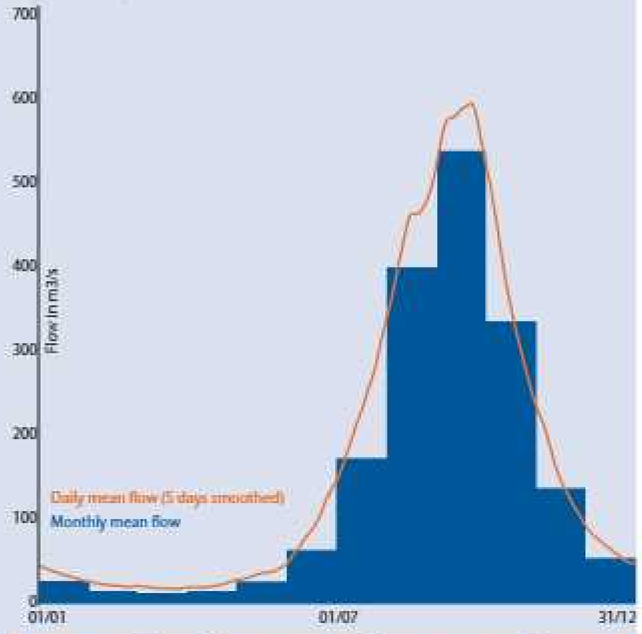
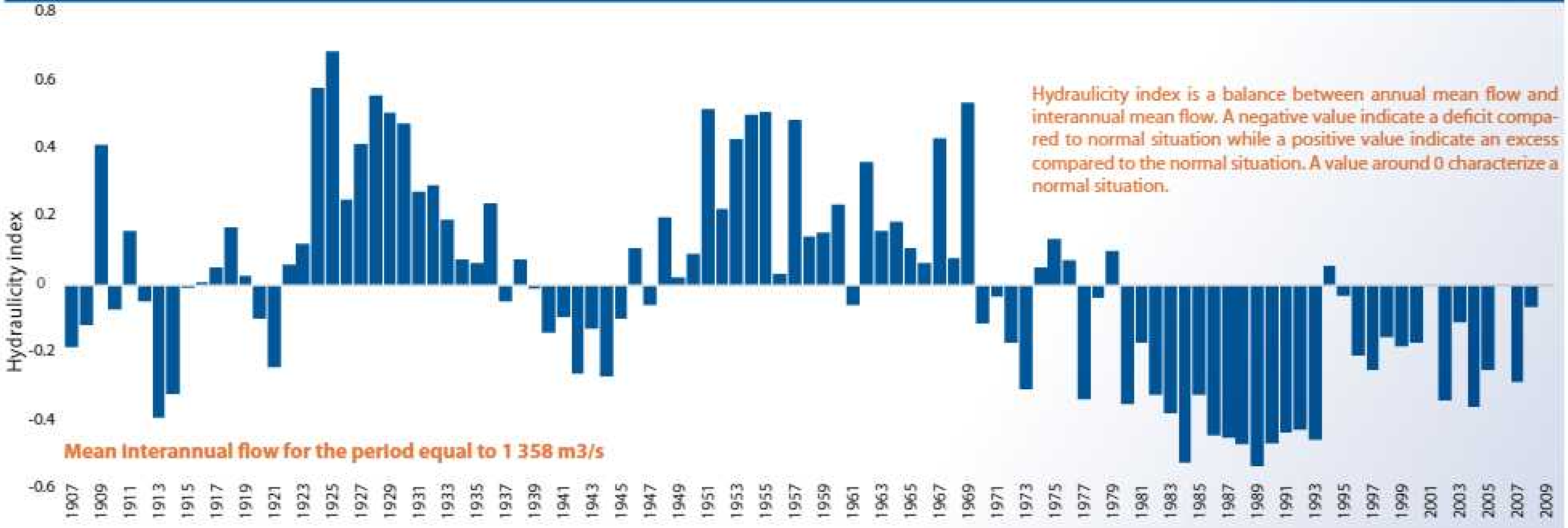


Figure 23 > Monthly mean and daily mean river flow on Milo at Kankan / 1940 - 2008 period

THE NIGER

In Faranah, it already has an average estimated flow of 60 m^3/s and its hydrological regime is still a variant of the transition tropical regime described for the Niandan and the Milo. The rising water period starts slowly in May (8.5 m^3/s in Faranah) to end in September (165 m^3/s in Faranah) and with its flood recession up to February. The lowest water period extends from March to April with a minimum in April. It is measured in Kouroussa, a little before its confluence with the Niandan, and has an average year-on-year flow around 185 m^3/s for the 1954-2008 period. Comparison works between the Kouroussa and Baro Stations (on the Niandan) by Orange underline that the flow in Kouroussa is underestimated by 30%, which would mean an average year-on-year flow more around 265 m^3/s. Orange estimates it at around 331 m^3/s for the 1950-1980 period. On leaving Guinea, after having received the Niandan, the Milo and the Tinkisso, the Niger average year-on-year flow reaches 784 m^3/s in Banankoro. Further away in Mali, at the Koulikoro station, after having received the waters of the Fié and Sankarani (now regulated by the Sélingué dam), the average year-on-year flow reaches 1358 m^3/s (Table 5). Ferry's hydrological studies (2015) show different hydrological periods through the Koulikoro station, where the very strong year-on-year variations demonstrate the effects of major climate cycles (table 5 and Figure 25). From

Figure 25 > Hydraulicity of Niger river between 1907 and 2009 at Koulikoro station (from Luc Ferry)



1907 to the present day, 1982-1993 stands out as a period with very low hydraulicity (average annual flow of 776m³/s in Koulikoro) and the 1922-1936 and 1948-1969 periods stand out as periods with very high hydraulicity. The recent period is noted by Ferry as a transition period. Finally, in Koulikoro, Ferry also demonstrates the influence of major facilities like the Sélingué dam on the hydrological regime of low waters, notably by raising minimum annual flows since 1982. Finally, it leaves Guinea at between 32 and 36m³/s towards the Niger river (Niger, Guinea tributaries and Sankarani) and during flooding episodes, nearly 3 days are needed to flow between Kankan and Koulikoro, whereas nearly 3 months are needed in Niger to drain this same Mali flood (Ferry 2015).

Table 5 > Hydraulicity periods of Niger river at Koulikoro station between 1907 and 2010 (from Luc Ferry)

PERIODS	YEAR	AVERAGE ANNUAL FLOW IN M³/S	MINIMUM IN M³/S	MAXIMUM IN M³/S
REFERENCE PERIOD	1907-2010	1,358	58	5,569
PERIOD WITH LOW HYDRAULICITY	1982-1993	776	84	3,335
INTERMEDIATE PERIODS	1907-1921	1,301	36	5,313
	1937-1947	1,245	33	5,333
	1970-1981	1,228	23	5,200
	1994-2010	1,164	96	5,008
	4 periods	1,231		
PERIODS WITH HIGH HYDRAULICITY	1922-1936	1,794	53	7,088
	1948-1969	1,694	66	6,679
	2 periods	1,734		

MAJOR FEATURES OF THE GUINEA COASTAL RIVER HYDROLOGICAL REGIMES

The Guinea coastal rivers are marked by the southern slope of the Fouta Djallon foothills with the most emblematic river being the Konkouré (map 22). This southern slope is what the majority of the hydroelectric power facilities rely on, such as the Garafiri and more recently Kaléta on the Konkouré, Kinkon on the Kokoulo (tributary of the Konkouré) and Banéa, Donkéa and major waterfalls in the Samou (tributary of the Konkouré, Badi basin). A modified hydrological regime is now observed on the Konkouré path. The Souapiti project, still on the Konkouré and upstream from the Kaléta, modifies the regimes a little more in this basin. On the upstream part of the Fatala, there are also small-scale hydroelectric power facilities, notably on the Samakou, a tributary of the Fatala around Télimélé.

THE NATURAL UPSTREAM OF THE KONKOURÉ BASIN

The Kakrima course is still natural in its course in the Fouta Djallon. Before its confluence with the Koukoulo, in Kaba (figure 26), its average year-on-year flow seems to be located around 82m³/s (1988-2014 period) Its general regime is similar to a transition tropical regime with a period of high waters which extends for 4 months (July to October) and a flow peak in August or September estimated around 250 to 270 m³/s on average. The hydrology of the months of August and September is quite similar. The lowest waters appear in March-April with average flows between 3 and 5 m³/s. The Koukoulo is very similar to the Kakrima, although slightly influenced by the Kinkon hydroelectric power facilities. Before its confluence with the Kakrima in Nianso, its average year-on-year flow is estimated at 67 m³/s (1999-2002: Kakrima estimated at 80.2 m³/s for the same period). Its regime is identical to the Kakrima with a high water period in August. The upstream Konkouré at Pont de Linsan (figure 27) is not modified by the Garafiri dam. It has an average year-on-year flow around 14m³/s for the 1955-2006 sequence and its characteristic regime of a transition tropical regime gives it a high water period extended over 4 months (July to October). The average flow peak seems to appear in August (47 m³/s approx.) with a similar character to September (41 m³/s). The overall regime is very similar to the Kakrima and Kokoulo with lower water flows in April-May with 1 and 2 m³/s on average.

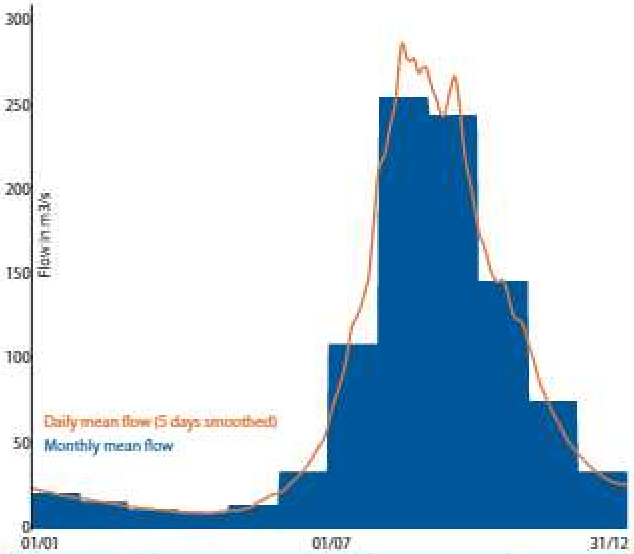


Figure 26 > Monthly mean and daily mean river flow on Kakrima at Kaba / 1988 - 2016 period

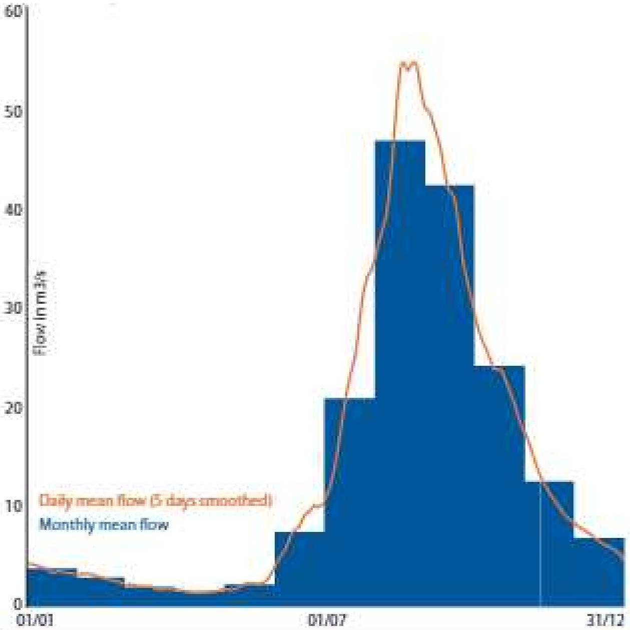


Figure 27 > Monthly mean and daily mean river flow on Konkouré at Linsan / 1955 - 2007 period

THE DOWNSTREAM REGIME OF THE KONKOURÉ WHICH IS CONSIDERABLY AFFECTED BY HYDROELECTRIC POWER PRODUCTION SINCE 2000.

The Garafiri dam was commissioned in 2000 with significant consequences on the low water flow regimes. Ferry et al. (2003) indicate that in the rainy season, modifications linked to the Garafiri are barely (or not) visible, notably due to year-on-year irregularity, but that the modifications from December to June are visible for the entire network up to the downstream Konkouré (figure 28). However it seems that the Garafiri dam plays a limited role during the highest water months (August & September). The Yékémato station, the most downstream on the Konkouré before the estuary, presents increased flows between 25% and 193% between the 1989-1998 and 2000 average for the period between January and June under the influence of the Garafiri. For low water, the freshwater inputs towards the estuary are considerably increased and the flows for the year are considerably smoothed out. The impacts of the Garafiri on hydrology are summarised thus by Ferry et al. (2013):

- In the dry season, the flows are much higher than the natural flows from Garafiri up to the Konkouré estuary.
- There is flood control, notably for the Konkouré segment between the Garafiri dam and the confluence between the Konkouré and the Kakrima.
- For the Konkouré segment between the Garafiri dam and the confluence between the Konkouré and the Kakrima:
  - The complete stop in flows between April 1999 and September 1999 perhaps had an impact on the aquatic life during low water (April and May).
  - The frequent operating stoppages (flow = 0 m³/s) could also have consequences on the aquatic ecosystem during the low water period.
- The sudden operating start-ups (from 25 to 100 m³/s) could be dangerous for those living downstream from the dam. This flushing phenomenon probably modifies the low-flow channel of the Konkouré downstream from the dam (collapsed river banks, suspended sediment...).

The recent presence of the Kaléta dam and its impact on the operation of hydrological regimes has not currently been studied in detail. With 3 times the production capacity of Garafiri, we could assume that the Kaléta facility will also slightly modify the Konkouré flow regimes, even if this run-of-river dam should have a lesser or even negligible influence. The Souapiti project has just been completed, and should largely influence the hydrological regimes of the river basin.

AN INFLUENCE ON THE BADI?

The Badi has also small hydroelectric power facilities on the upstream portion. Downstream on the Badi, before its confluence with the Konkouré, the average year-on-year flow for the 1951-58 period reached 193 m^3/s, with extremes from 155 to 230 m^3/s. For the 1998-2002 period, its average year-on-year flow is measured at around 144 m^3/s. The maximums are in August (701 m^3/s year-on-year 1951-1958 and 524 m^3/s for the 1998-2002 period) and the minimums in April (5.5 m^3/s year-on-year 1951-1958 and 14 m^3/s for the 1998-2002 period). We note here that the facilities on the Badi tributaries respectively date from 1969 (Banéah), 1965 (Donkéa) and 1953 (Grandes Chutes). The matter of the differences observed between the 1951-1958 and 1998-2002 sequences (reduction in flows in August and increase in flows in April) remains open regarding the reason, even if the trend for increased low water flows suggests that the facilities influence the hydrological regime which is non-negligible for this period of the year.

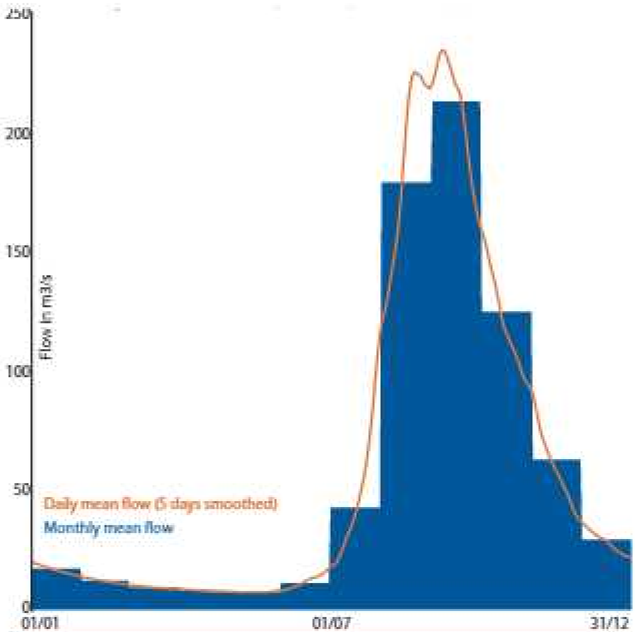


Figure 29 > Monthly mean and daily mean river flow on Kogon at Pont / 1957 - 2016 period

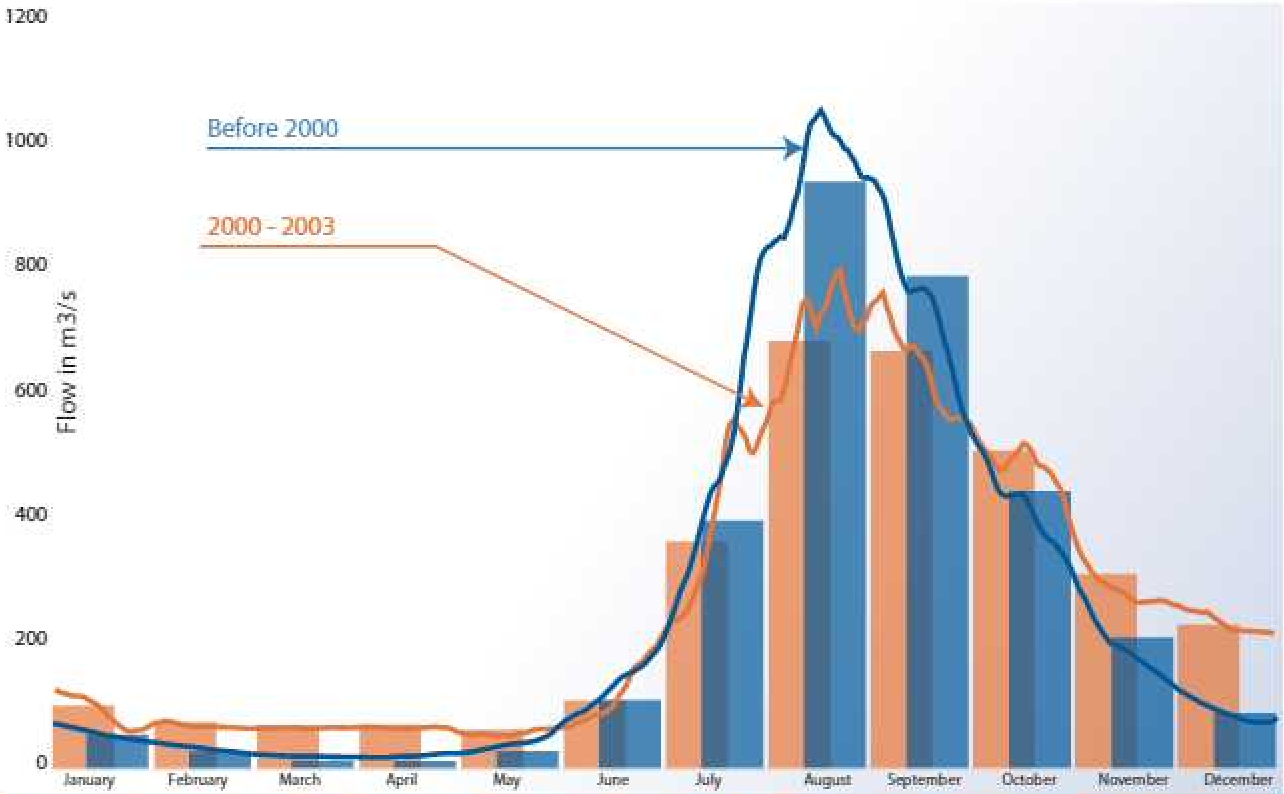


Figure 28 > Comparison of monthly mean and daily mean river flow of Konkoure at Télimélé before and after commissioning of Garafiri dam

THE FATALA AND KOGON

At the Bindan station, downstream from the basin and before its estuary outlet, the average year-on-year flow for the 1971-80 period reached 165 m^3/s, with extremes from 137 to 193 m^3/s. The maximums are in August (542 m^3/s year-on-year) and the minimums in April (0.8 m^3/s year-on-year). With the reservations linked to low water flows, it should be noted that there was a monthly low water in April 1973 lower than 200l/s. The observed daily maximum has reached 1701 m^3/s. The Kogon flow remains difficult to understand with data which often seems incorrect. On its upstream portion, the average year-on-year flow seems to establish around 70 m^3/s (perhaps a little more). The information available suggests a flow peak in September, with a similar average in August. On the Kogon, the period of high waters is focused on these 4 months, generally between August and November (figure 29), and slightly offset in relation to the most eastern basin of the Konkou.

Upstream the Salaa falls on kakrima river

MAJOR FEATURES OF THE GAMBIA RIVER HYDROLOGICAL REGIMES

Orange (1990) compares the Gambia river regime to a transition tropical regime for the section in the Fouta Djallon, therefore comparing it to the Niger and Senegal hydrological regime. In its upstream portion, it is monitored at the Kounsi station in Guinea, then at Kédougou in Senegal (map 21). The high water period is condensed into 3 to 4 months between August and October with a maximum in September (290 m³/s at Kédougou 1971-1999 – figure 30). The rising in the hydrological regime to high waters starts slowly in June. Between February and May, the period with the lowest waters, the flow is very low (< 1.6 m³/s on average for the 1971-1999 period in Kédougou). The flows are often nil during April and May. By compiling the data from Da Costa & Orange, a timeline of the average year-on-year flows from 1903 at Kédougou shows the wide variability of average annual flows (figure 31), in combination with known climate trends in West Africa. Since 1903 the average year-on-year flow is established around 107m³/s but the hydrological sequences have largely affected this average annual flow. For the 1972-1994 period, the average annual flow has fallen by 36% in relation to the average year-on-year flow (68.3 m³/s approx.) with a minimum annual average flow of 34 m³/s in 1984/1985 (68% deficit compared to the average year-on-year flow. Two surplus sequences (1918-1940 and 1951-1971) demonstrated average annual flows around 134 to 137 m³/s for the period. The hydrological year 1955-1956 is the year recorded with the highest average annual flow (193 m³/s). The Koulountou, another tributary of the Gambia which arises in Guinea, seems to have an average year-on-year flow of 15 to 16 m³/s (estimation for 4 incomplete years), without certainty, with previous studies mentioning an average year-on-year flow around 5m³/s. The hydrological regime for this portion of the Gambia should be modified in the future, notably by the Sambangalou hydroelectric power dam site, leaving Guinea and upstream from Kédougou, where a planned facility flow of 200 m³/s is being studied.

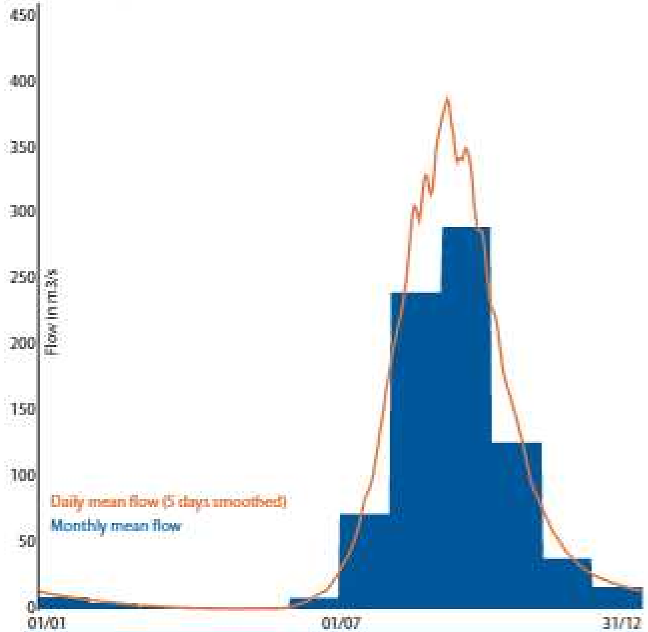
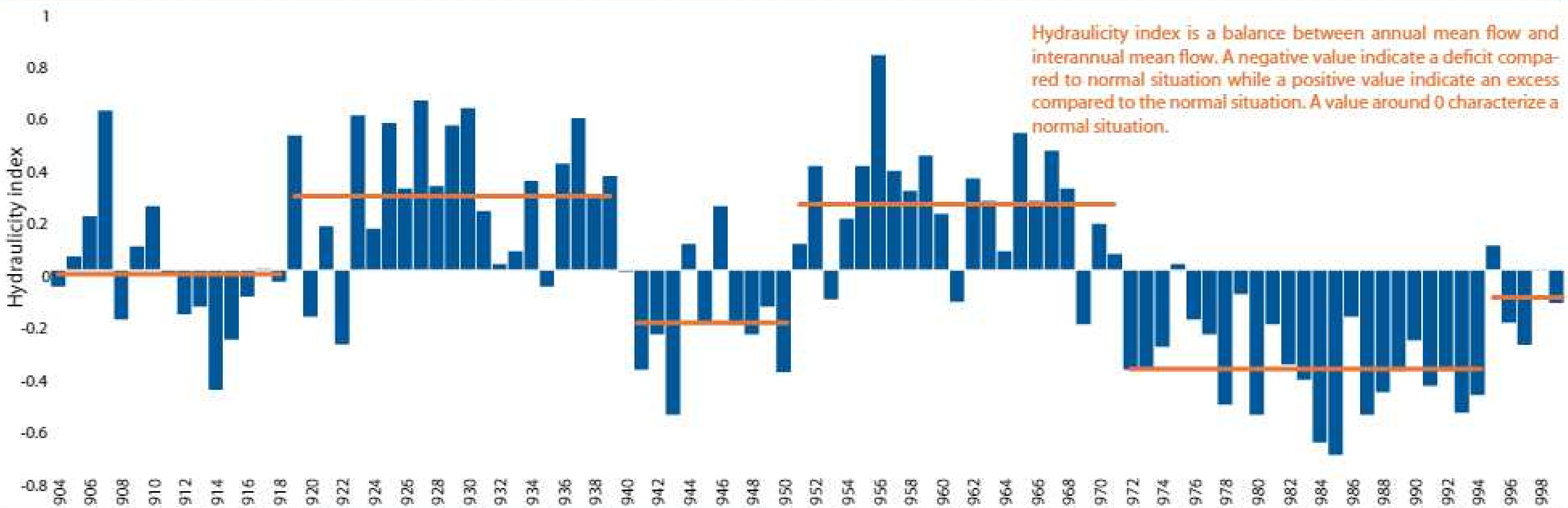
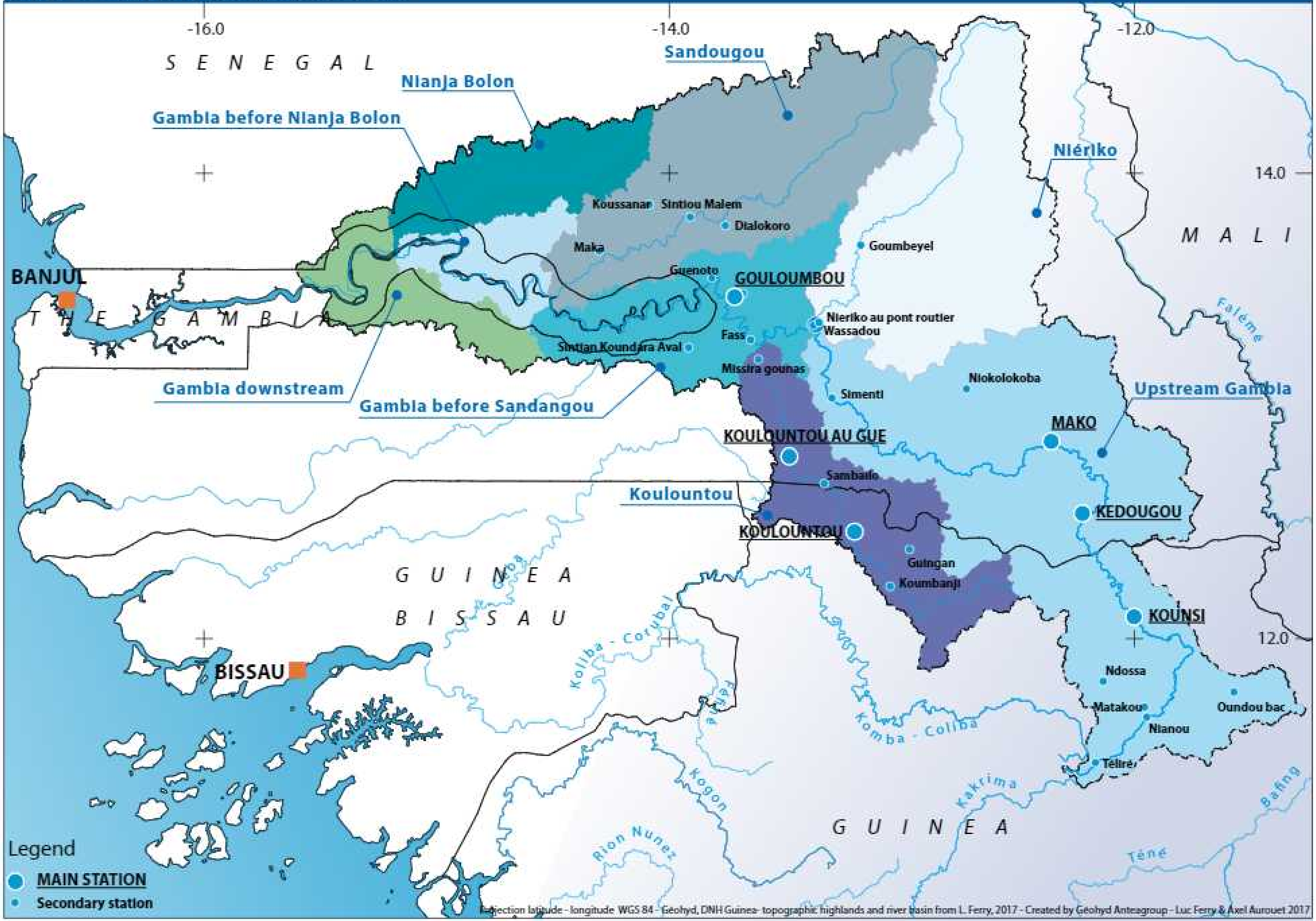


Figure 30 > Monthly mean and daily mean river flow on Gambia at Kédougou / 1970 - 2014 period

Figure 31 > Hydraulicity of Gambia river between 1904 and 1999 at Kédougou (reconstructed from Orange and Da Costa)



Map 21 > Main river flow stations on Gambia river basin



MAJOR FEATURES OF THE KOLIBA-CORUBAL RIVER HYDROLOGICAL REGIMES

The hydrological regime of the Kolima (Komba in Fouta Djallon) in its upstream portion remains poorly understood. The origin of these sources, not far from the source of the Gambia (map 22), lead us to link its regime with that of the Gambia. The other major tributary of the Koliba is the Tominé, with the source to the south having a similar regime to the intermediary between the Konkouré and the Gambia. Hydrological data is available for the "Tominé at Gaoual" in the DNH banks (Figure 30). In view of the variable names between Koliba, Tominé or Komba, it remains difficult to say if this station effectively represents the Tominé at Gaoual or rather the Koliba after having received the Tominé and the Komba. These data between 1971 and 2014 propose an average year-on-year flow around 180 m³/s whereas it has been estimated by Orange (1990) at around 150 m³/s for the 1979-1987 period. In the Komba basin, before its confluence with the Tominé, the average year-on-year flow seems to establish around 100 m³/s (BCEOM et al.). The "Tominé at Gaoual" timeline emphasises a period of high waters which extends across 4 months between August to November included (month with average flow > average year-on-year flow). The flow peak appeared in September with an average flow of around 565m³/s for this month (1971-2014). The hydrological regime in the low water period is also more sustained with an average flow in April-May of 27.5m³/s without ever approaching a negligible flow. In its lowest recordings for these months, it remains at a flow level of around 13 to 16m³/s.

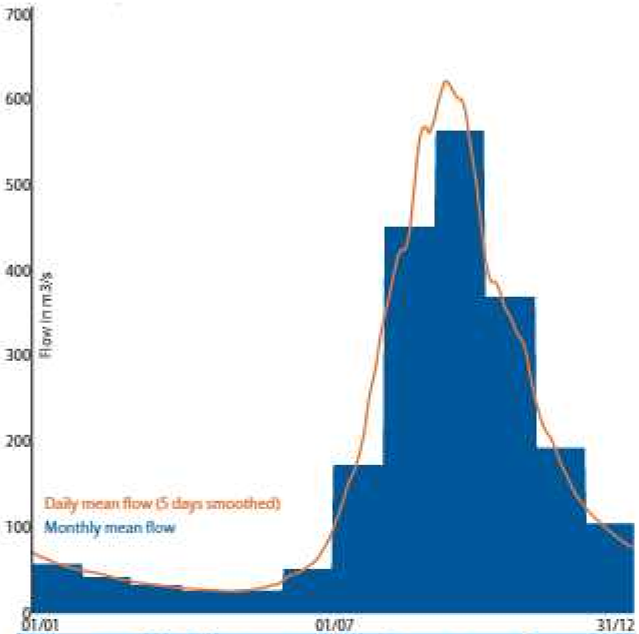


Figure 32 > Monthly mean and daily mean river flow on Tomine at Gaoual / Période 1970 - 2014

MAJOR FEATURES OF THE SCARCIES RIVER HYDROLOGICAL REGIMES

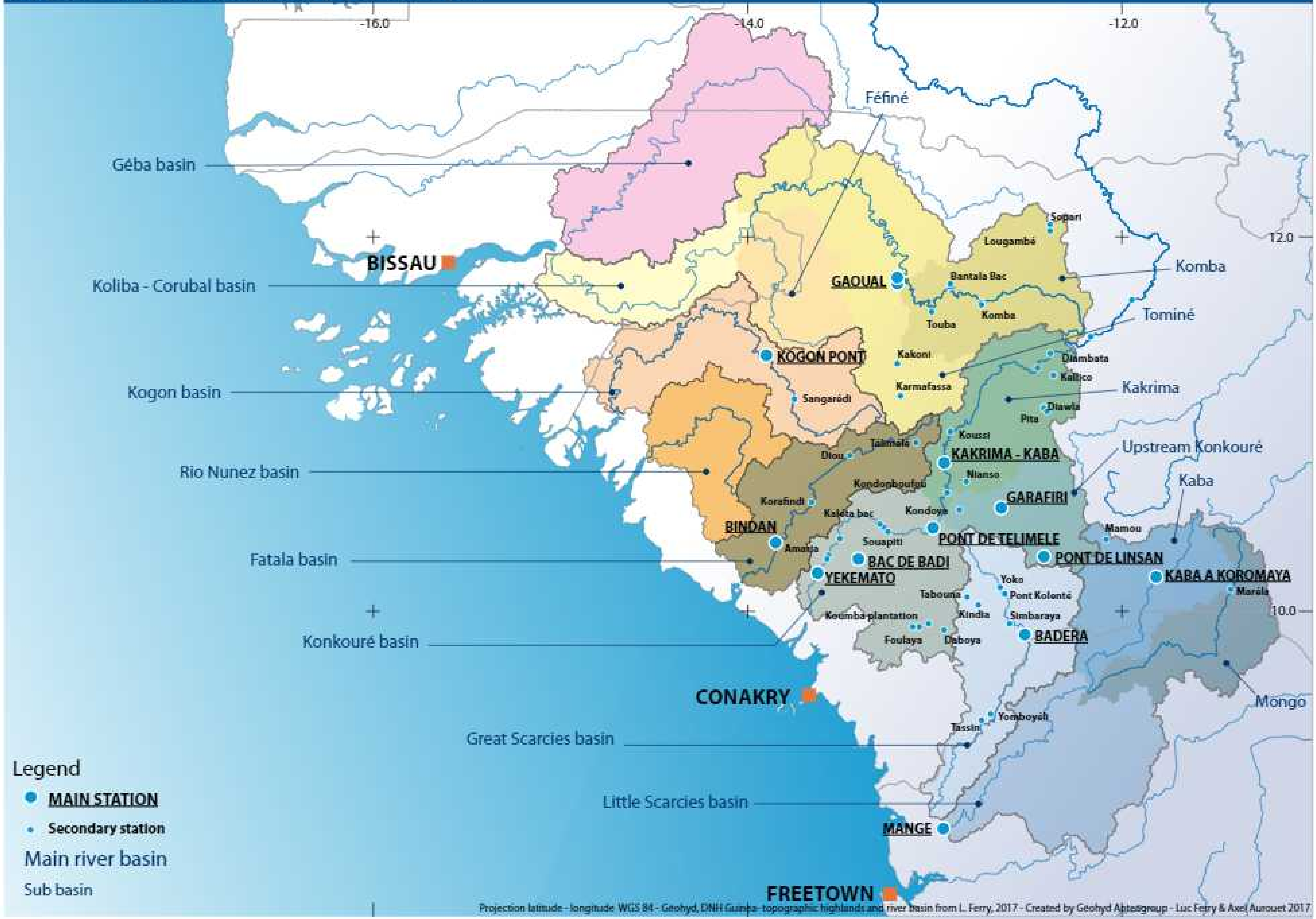
The Scarcies are formed by the Kolenté (Great Scarcies) and the confluence between the Kaba and the Mongo (Little Scarcies). All have their sources in Guinea (southern foothills of the Fouta Djallon for the Kolenté and south-east of Fouta Djallon for the Kaba and the Mongo – map 22). There is few information available on these rivers. The Kaba in Guinea, in Koromaya, well before its confluence with the Mongo in Sierra Leone, seems to have an average year-on-year flow around 30 to 35 m³/s (1981-2016 period). Based on raw information available for this station, it seems that the high water period lasts around 5 months from July to November included, positioning its regime as a transition tropical regime. The available data seems to indicate that this period can sometimes be extended to June during specific years. The water rise starts in May and ends in September, sometimes August, at around 80 m³/s on average (sometimes 30 to 40 m³/s during the 1980s and 202m³/s in 2006). The drying-up period then lasts until February-March. The lowest water months are March and April with an average estimated flow between 3 and 5m³/s. In the 1980s, the average flow for these months seems to be under 1m³/s. Mahé (1993) suggests an estimated average year-on-year flow for Little Scarcies in Mange (Sierra Leone), after the confluence between the Kaba and the Mongo, of around 600 m³/s (rebuilding of the flow between 1951-1989). In the Kolenté basin (Great Scarcies), the average year-on-year flow in Badera a little before the Kolenté forms the border between Guinea and Sierra Leone, the average year-on-year flow is estimated at 83m³/s for the 1967-1980 period with a maximum of 102m³/s and a minimum of 37m³/s. The monthly average flow is also reached in September (312m³/s 1967-1980). The lowest flow months are March and April. In the 1970-1980s, the observed flows were systematically below 100l/s.

SUMMARY ON HYDROLOGICAL REGIME AT THE OUTLET OF FOUTA DJALLON HIGHLAND

The Senegal, Konkouré and Koliba basins have the largest year-on-year average flows from the centre of the Fouta Djallon highland. On leaving Guinea, it is the Niger river basin which represents the most significant water export with a stronger dependency on the Guinean Dorsals than the Fouta Djallon highland. The southern slopes, which are more rugged, logically have average year-on-year flows with a greater effect on the outlets. Finally the Gambia basin receives the least water in general with a more reduced river basin influence on the highland in relation to other river basins in the sector (map 24).

"Voile de la mariée" site (bride's veil), near Kindia

Map 22 > Main river flow stations on South-west coastal river basin



HYDROGEOLOGY AND GEOCHEMISTRY

GEOLOGY IN THE HEART OF THE FOUTA DJALLON IS HARDLY CONDUCIVE TO THE PRESENCE OF GENERALIZED GROUNDWATER. GROUNDWATER MAINLY FLOWS ALONG GEOLOGICAL FRACTURES AND IN SURROUNDING FLOOD PLAINS. WELLS AND BOREHOLES THEREFORE HAVE LIMITED PRODUCTIVITY. THAT WATER HAS A LOW MINERAL CONTENT AND TENDS TO BE MORE ACIDIC.

A LACK OF GENERALISED GROUNDWATER IN THE CENTRE OF THE FOUTA DJALLON HIGHLAND

The materials present in the Fouta Djallon highland are, in a raw state and not reworked, materials with very poor aquifer capacity. The granites and sandstones are hard rocks where water can only circulate through fractures, fissures or alternating permeable and impermeable layers. Dolerites and quartzes are totally impermeable rocks. Only schists and greenstone can have aquifer layers but they are only marginally present in the Fouta Djallon highland. The fundamental feature of the Fouta Djallon centre is therefore the lack of a generalised groundwater (Orange, 1990). There is no deep groundwater, the only existing ones are those in the alteration zone, never exceeding 100 m depth, sedimentary covering and recent formations (alluviums, elluviums and laterites). These aquifers are discontinuous and have a strong vertical difference depending on the stratification of permeable zones, leading to semi-captive or captive groundwater (Blot, 1970; Sow, 1984; Traore, 1985). The Fouta Djallon is impermeable but has small and very localised groundwater. The refilling is essentially ensured by infiltration of some rainfall and water pumping is made up by rivers and sources, and evaporation of lowlands where the groundwater is flush to sub-flush. Despite this, wells and boreholes are located locally with general productivity which translates well into the "usability" of different geological sectors and confirm the greater productivity of schists and mica schists (flow often usable above 2.5 m^3/h) in comparison to soft sandstone and dolerites (flow generally usable between 0.7 and 1.4 m^3/h and granite sectors (flow generally usable between 0.7 and 2.5 m^3/h). The growth in drilling depths does not seem to improve productivity of drilling and beyond 50 to 60 m for sandstone, dolerites and granites, it even seems to decrease productivity. For schists and mica schists, greater depths sometimes offer much greater flows.

FROM DISCONTINUOUS OR SEMI-CONTINUOUS AQUIFER SYSTEMS TO GENERAL AQUIFERS IN THE EXTENDED AREA

The aquifers in the extended area of the Fouta Djallon highland, to the east of the Fouta Djallon highland, in the Kankan basin, and on the southern fringe of Mali, are fissured aquifers from infra-Cambrian crystalline formations. The flows are generally weak and groundwater circulation is restricted by the fissure network. We can however find very productive zones locally on underground circulation networks and in the surface alteration zones which generally are thin. The average flows for these formations are estimated at between 4.2 and 6.5 m^3/h. Around Bamako and in an extended area which flows to the west to Senegal, there are Cambrian sandstone formations encrusted with schist which are semi-continuous aquifers. These aquifers are more productive than those noted previously but generally remain unsatisfactory. From Ségou (Mali) to beyond Gao, the formation of Continental Terminal/Quaternary represents the so-called "general" aquifers (Taoudéni basin – map 23) with good permeability linked to its sandy clay substrate with support from the surface water. The aquifer formation of Continental Terminal/Secondaire-Tertiaire is also present in the eastern and south-eastern part of Senegal (Senegalo-mauritanian basin) and presents interesting potential in terms of flow which can rise up to 50 m^3/h in some sectors.

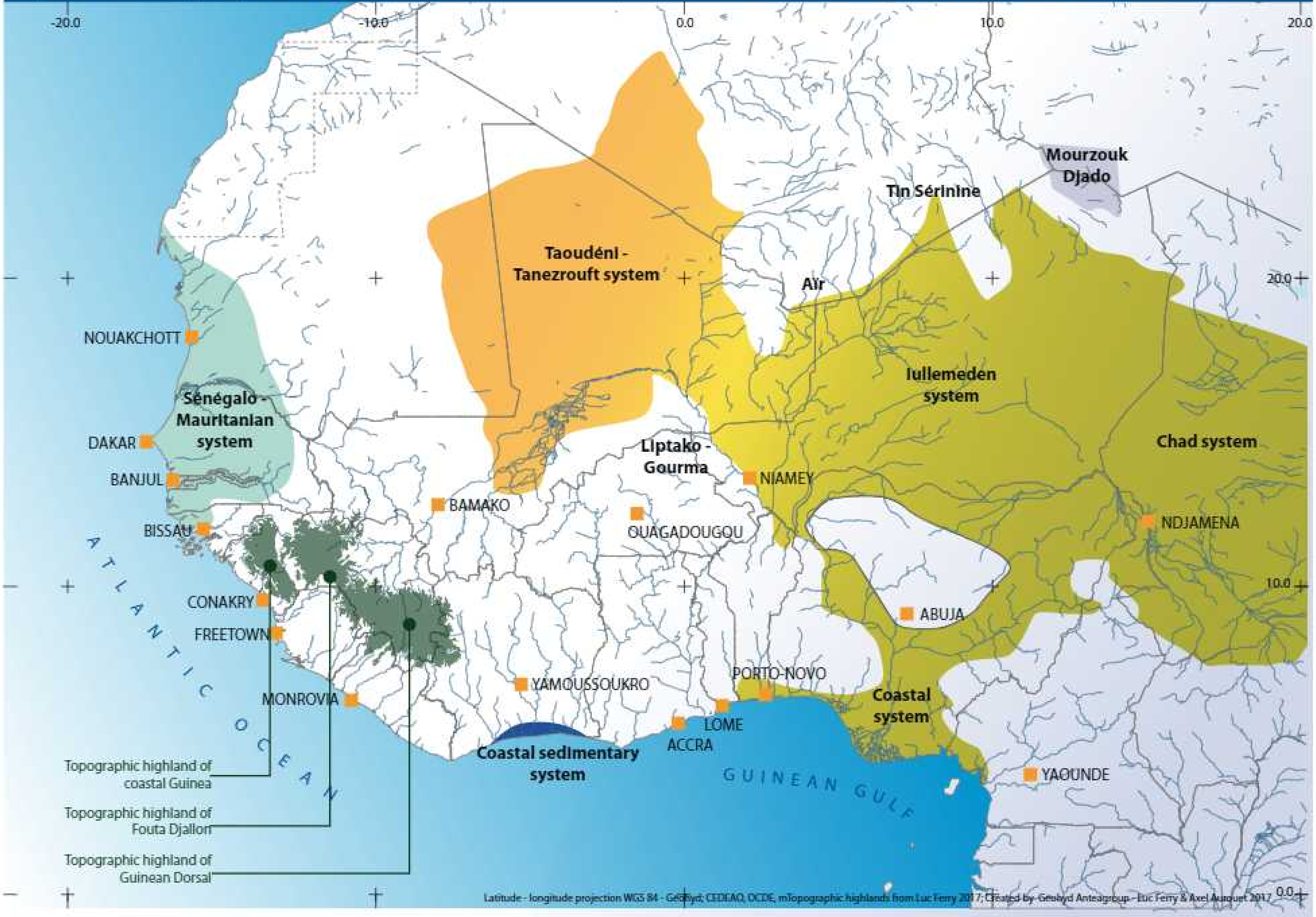
GEOCHEMISTRY OF THE FOUTA DJALLON GROUNDWATERS AND ITS EXTENDED AREA

The Birimian area waters, to the North-east of Fouta Djallon and in the upper Niger basin, are characterised by low concentration of dissolved salts (conductivity < 350 µS/cm) with a slight acidity due to the geological substratum. The major ions are represented by bicarbonates, calcium and magnesium. In the greenstone facies, the waters are much more mineralised (conductivity of 2000 to 3000 µS/cm). In the Pre-Cambrian sandstone facies, (Madina-Kouta to the north of Fouta) the waters are generally bicarbonated, calciferous and with magnesium or sodium. Mineralisation is low (Conductivity < 300µS/cm) and the waters are acidic (pH of 5 to 6). Far from Fouta Djallon, the terminal proterozoic waters in north Mali have a wide range of quality and mineralisation depending on the surrounding rock (sandstone, quartz, dolerites...). Conductivity varies between 100 and over 2000µS/cm with an average conductivity around 600 µS/cm. With calcium or sodium carbonate, these waters can develop towards sodium sulphate facies depending on calcite saturations. Significantly briny waters (Orange, 1990) hypersulphated sodium typical of hydrothermal sources have been noted. The left bank water tables of the Falémé correspond to surrounding Birimian schist where Wackermann and Blot note strong mineralisation. The sandstone area groundwater (Fouta Djallon) is very diluted and has low mineralisation. The bedrock waters have an intermediary between schists and sandstone with dominant bicarbonate-calcium or sodium. Overall, silica readings are high in groundwaters, except the sandstone groundwaters. The granite groundwaters are more acidic, richer in potassium and chlorine than the basic aquifer waters which have dominant bicarbonate rich in calcium and magnesium.

Well in a RPID-FDH pilote site

Map 23 > West African aquifer systems

from M. Niasse & C. Mbow © Club du Sahel et de l'Afrique de l'Ouest / OECD (2006)



SUMMARY ON WATER RESOURCES

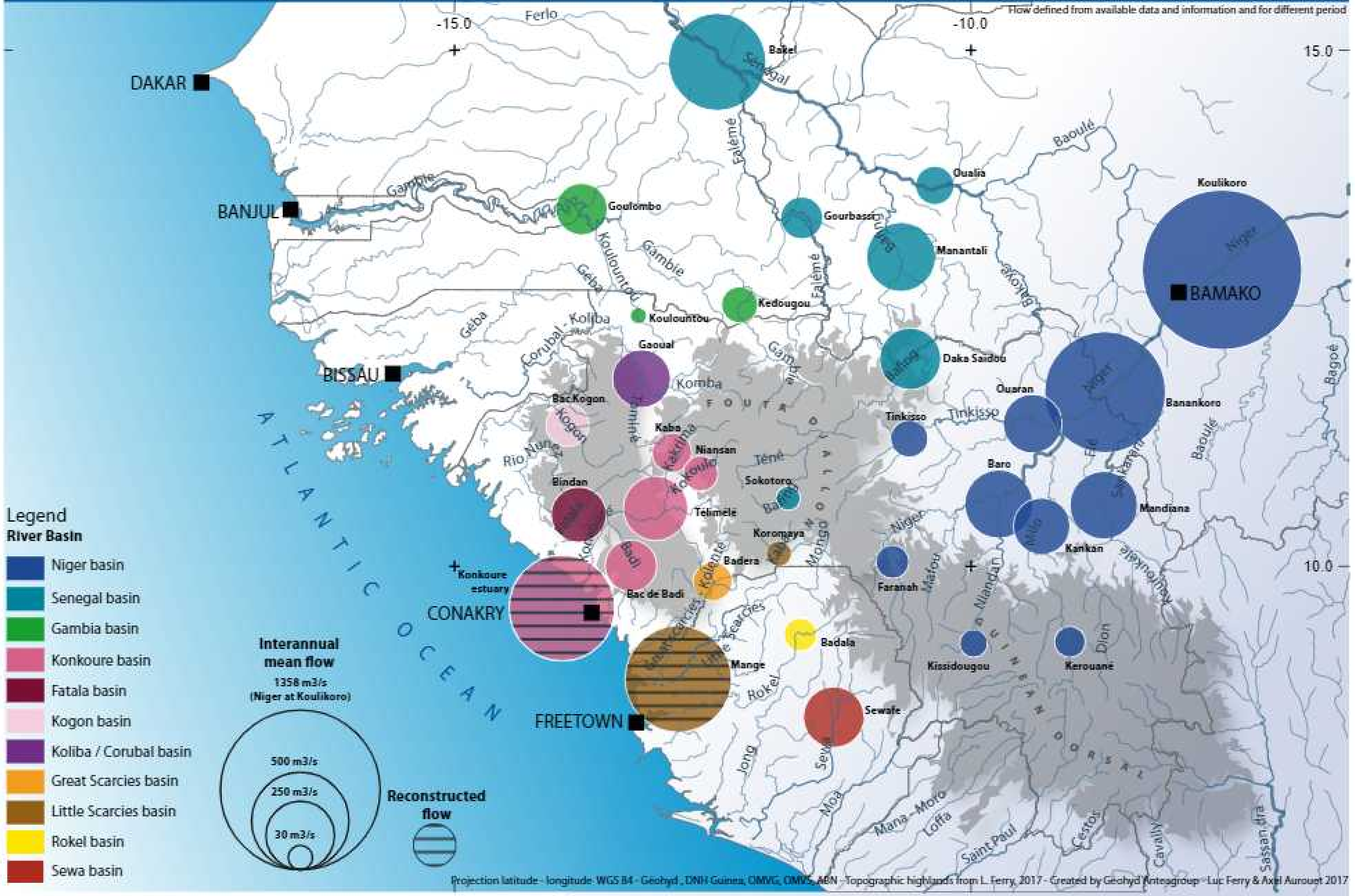
The water resources of the Fouta Djallon highland are characterized by the absence of a generalized aquifer in the heart of the highland. There is little groundwater present and it is very reactive to rainfall, even if scattered hilltop water tables can be found. Significant groundwater resources can be found in water tables associated with waterways amid circulation in the valley floors. This fundamental component of the Fouta Djallon's hydrosystem exerts considerable influence over the hydrological regimes of surface water which all work more or less in the same way: in the highland, flow rates during low water periods (December to June) are very low, sometimes close to zero, because they are not supported - or very little - by groundwater. With the monsoon's first rains (June-July), flow rates increase abruptly to culminate in September, in parallel with the rainfall. Average flow rates are often multiplied more than fifty-fold between April-May and August-September. The steep slopes over the first kilometers of the waterways then cause spectacular waterfalls (Kionkon, Salaa, etc.). When the rains stop, in the absence of an associated water table, groundwater recession sets in quickly to regain low water levels. The way this hydrosystem works has been characterized by Orange (1990) as being a tropical transition regime. In the downstream areas of the Niger and Senegal Rivers, the hydrological regime changes to become a pure tropical regime, then a Sahelian regime characterized by a shortening of the periods of high water.

In the Sahelian parts of the Niger and Senegal Rivers, in particular, productive aquifers of the Taoudéni basin and the Senegal-Mauritania basin provide relative support for the flow rates of both rivers. Hydrological regimes are different and the gentle slopes create a very different morphology to the waterways at the heads of the river basins, with much slower flow velocity.

These hydrological regimes are sometimes disrupted with the influence of large hydraulic structures which were primarily built for power generation. This is particularly true for the Senegal River with the modification of low water regimes downstream from the Manantali dam on the Bafing in Mali. It is also the case for the Konkouré River, which is entirely Guinean and widely developed (Garafiri, Kaléta Souapiti, etc.).

The way the highland's hydrosystems function is only partially monitored. There is currently no monitoring network for groundwater levels in Guinea, even if an inventory of wells and boreholes is kept up-to-date by the National Department for the Development of Boreholes. The National Directorate of Water currently monitors a network measuring flow rates of waterways for all of Guinea, and therefore for the Fouta Djallon highland. However, material and accessibility issues disrupt the correct functioning of this monitoring network. The Fouta Djallon highland being located at the intersection of three transboundary basin organizations (NBA, OMVS, OMVG) and being the origin of many transboundary rivers, monitoring water resources in a sustainable and reliable way is a major issue beyond the borders of Guinea. National and international institutions have already considered the creation of an observatory for the Fouta Djallon. In partnership or in synergy with the observatories which exist at the level of basin organizations, this observatory should become an important cornerstone for the sustainability of monitoring networks and for shared knowledge related to water resources in the Fouta Djallon highland.

Map 24 > Mean internannual river flow on main rivers form Fouta Djallon and surrounding highlands



Projection latitude - longitude WGS 84 - Geohyd , DNH Guinea, OMVG, OMVS, ABN - Topographic highlands from L. Ferry, 2017 - Created by Geohyd Antea group - Luc Ferry & Axel Aurouet 2017

WATER USES IN THE FOUTA DJALLON HIGHLAND

A GROWING RURAL POPULATION, HIGHLY SIGNIFICANT HYDROELECTRIC POWER AND MINING POTENTIAL

This chapter contains the demographic and agricultural elements of the Fouta Djallon highland area, mainly in its Guinean part. It also draws up an inventory of other uses of water such as fishing, hydroelectricity or mining. All of this inventory is compared with the links that these different uses may have with water, whether from a qualitative or quantitative point of view.

DEMOGRAPHY AND WATER REQUIREMENTS

MAINLY LOCATED IN THE NATURAL REGION OF CENTRAL GUINEA, THE GUINEAN PREFECTURES LINKED TO THE FOUTA DJALLON AMOUNTED TO MORE THAN 3.2 MILLION INHABITANTS IN 2014, AND THEY HAVE SEEN THEIR POPULATION DOUBLE SINCE 1983. THE HEART OF THE HIGHLAND CONTAINS ONE OF THE POOREST POPULATIONS IN GUINEA, AND THE RATE OF ACCESS TO SAFE DRINKING WATER AVERAGES TO CLOSE TO 47% WITHIN THE RPID-FDH PROJECT AREA, WHICH INCLUDES PARTS OF MALI, SENEGAL, GUINEA BISSAU AND SIERRA LEONE. THIS POPULATION IS ESTIMATED TO REPRESENT BETWEEN 15 AND 20 MILLION PEOPLE.

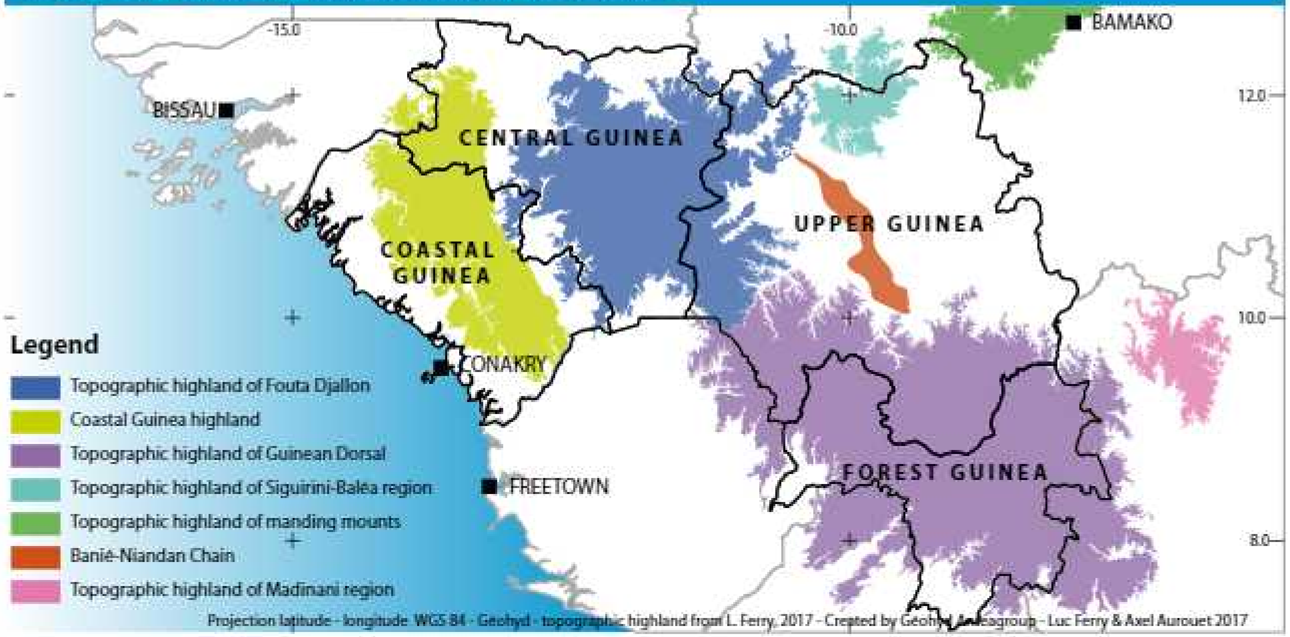
ADMINISTRATIVE BOUNDARIES

The centre of the Fouta Djallon topographical highland is mainly focused on Guinea in the natural region of Central Guinea (map 25). Fouta Djallon has 3 administrative regions, which are Labé, Mamou and Faranah, and 10 principal prefectures (Dabola, Dalaba, Dinguiraye, Kouiba, Labé, Lélouma, Mali, Mamou, Pita and Tougué) (map 26). In its RPID definition, the central zone of the Fouta Djallon highland (or the restricted extended area) directly covers 15 prefectures, with an extra 7 which are partially covered (map 26). These 15 prefectures cover the Labé, Mamou, Faranah, Boké and Kindia regions. The 7 other prefectures contain part of the Kankan administrative region. Finally, in this definition established as part of RPID, it would be possible to also add the prefecture of Kouroussa which itself could have a link with the borders of the Fouta Djallon topographical highland. It should be noted that the FAO definition of the Fouta Djallon highland includes 6 additional prefectures in Guinea, covering nearly all of Guinea.

In total, 65% of Guinea's prefectures are linked to the RPID restricted extended area of the Fouta Djallon highland (22 prefectures out of 34). The RPID wider extended area of the Fouta Djallon highland (map 2) directly covers 5 countries (Guinea, Sierra Leone, Guinea Bissau, Mali and Senegal) and the area of influence covers 8 countries (adding Sierra Leone, Mauritania, Niger and The Gambia). By including the 22 Gambia prefectures already mentioned above, there are nearly 61 prefectures (or districts in Sierra Leone) which are covered by the RPID wider extended zone of the Fouta Djallon highland, i.e. 17 administrative regions. In total, the Fouta Djallon highland RPID area of influence covers 71 administrative regions (or districts for Sierra Leone) in 8 countries.

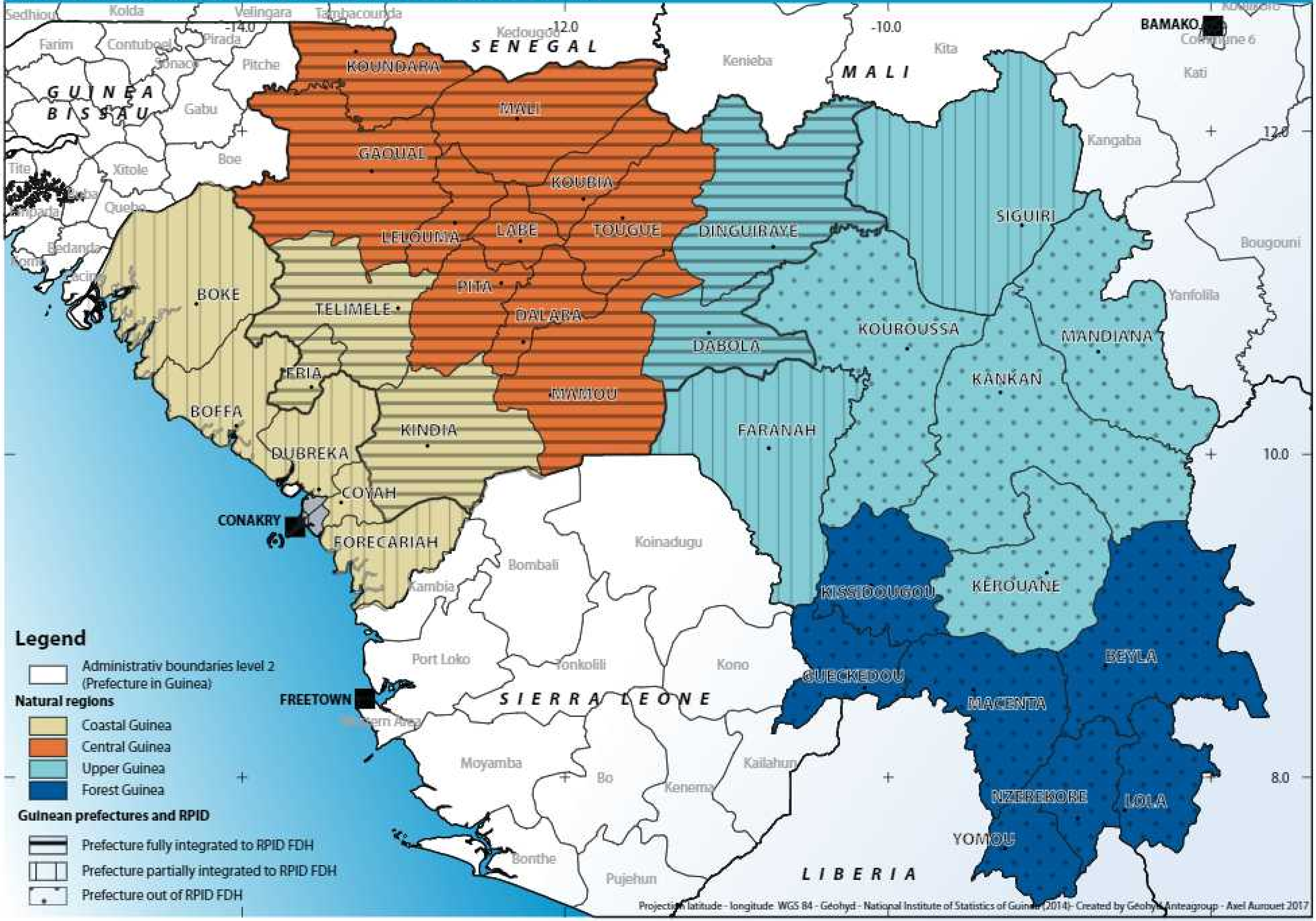
Finally we note that the Fouta Djallon highland is linked to 3 transboundary basin organisations (the Niger basin authority, the Senegal river development authority and the Gambia river development authority) which, whilst they do not have administrative status, are the management and planning bodies for the water resources where the projects directly benefit from the administrative bodies focused on the Fouta Djallon highland.

Map 25 > Topographic highlands and natural region of Guinea



Panel referring to the Fouta Djallon near Dalaba

Map 26 > Natural region of Guinea and associated RPID-FDH prefectures of Guinea



POPULATION IN THE HEART OF THE FOUTA DJALLON HIGHLAND AND ITS EXTENDED AREAS

POPULATION IN THE HEART OF THE HIGHLANDS

The population living in the RPID zone at the heart of the Fouta Djallon highland is nearly 3,250,000 people (15 prefectures fully included in the Fouta Djallon highland - 2014 census). This figure reaches nearly 5,715,000 people for 2014 by including 7 additional prefectures which are partially within Guinea. In total, nearly 53% of Guinea's total population (nearly 10 million inhabitants in 2014) is more or less linked to the Fouta Djallon highland (figure 33). The population density at the heart of the highland is also one of the highest in Guinea (between 50 and 100 inhab./km²) with maximum density in the prefecture of Labé, where the density approaches 150 inhab./km²(map 27). As throughout Guinea, except Conakry and some surrounding areas, the population is mainly rural (nearly 70%). Lélouma, Pita and Télimélé are the prefectures in Fouta Djallon with the most rural populations. Fria and Kindia have the most "urban" population. Based on an average current ratio of 30 litres per inhabitant and per day, the annual water demand of populations in the heart of the highland is a volume of 62.5 Mm³, i.e. nearly 2 m³/s flow equivalent. The objectives to satisfy water needs in the sub-region tend towards 100 litres per inhabitant and per day. If this rate was reached, the necessary volume of water for the population would nearly reach 209 Mm³, including 118 Mm³ for the 15 prefectures for the RPID zone at the heart of the Fouta Djallon highland. In the last 30 years, the population of the Fouta Djallon highland has more than doubled, increasing from 1,800,000 inhabitants in 1983 approximately to around 3,250,000 inhabitants currently (figure 34). This demographic growth in the heart of the Fouta Djallon highland has notably caused increased pressure on water resources, wood and land resources.

NEARLY 15 MILLION INHABITANTS IN THE EXTENDED AREAS OF FOUTA DJALLON

The population of the different extended areas of the Fouta Djallon highland has not been assessed accurately. By including populations at an administrative region level, it can be estimated at 15,000,000 inhabitants maximum. This population rises a little to over 22,000,000 inhabitants by including the adjacent regions very partially linked to the Fouta Djallon RPID extended area (map 29). The entire population of the 8 countries which are part of the Fouta Djallon highland' RPID is currently estimated at nearly 69,500,000 inhabitants with populations mainly located on the oceanic front in Dakar, Conakry and Sierra Leone, but also around Bamako, Niamey, Tilabéry and Dosso. As a comparison, we note that the population of the Niger basin is estimated at over 135 million inhabitants, the Senegal basin at 10.6 million inhabitants and the Gambia basin at a little over 5 million. Most of the population in these extended areas cover Guinea itself, where over 5,715,000 inhabitants are covered. Mali has the maximum 6,225,000 inhabitants affected. This population is slightly overestimated as it includes regions partially included in the extended areas (Kayes and Koulikoro). Finally Senegal has around 830,000 inhabitants. Guinea and Mali therefore have nearly 68% of the population in the extended areas, 12% for Mali, a little over 7% for Sierra Leone and less than 3% for Guinea-Bissau. Still based on a ratio of 30 litres per inhabitant per day, the annual water demand for the populations in these zones represents a volume between 165 and 240 Mm³, i.e. between 5.2 and 7.6m³/s flow equivalent. If the objective of 100 litres per inhabitant per day is reached, between 550 and 800 Mm³ of water will be required to supply the populations in these zones.

Figure 33 > Population of Guinea that is concerned by Fouta Djallon in 2014

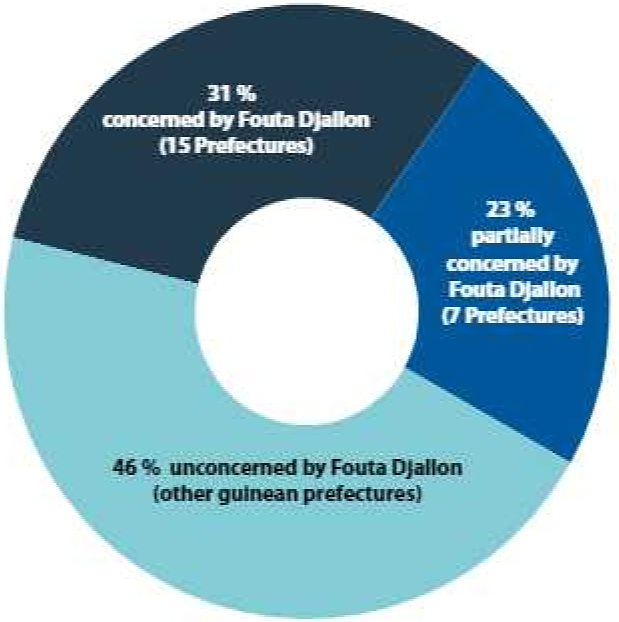
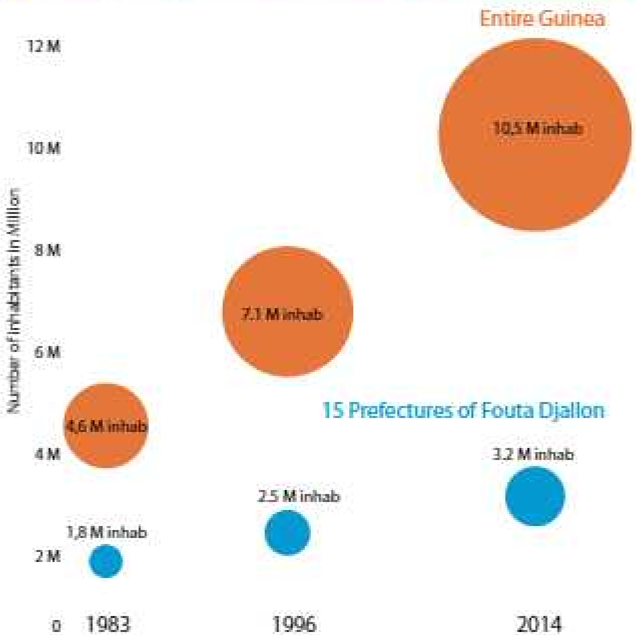
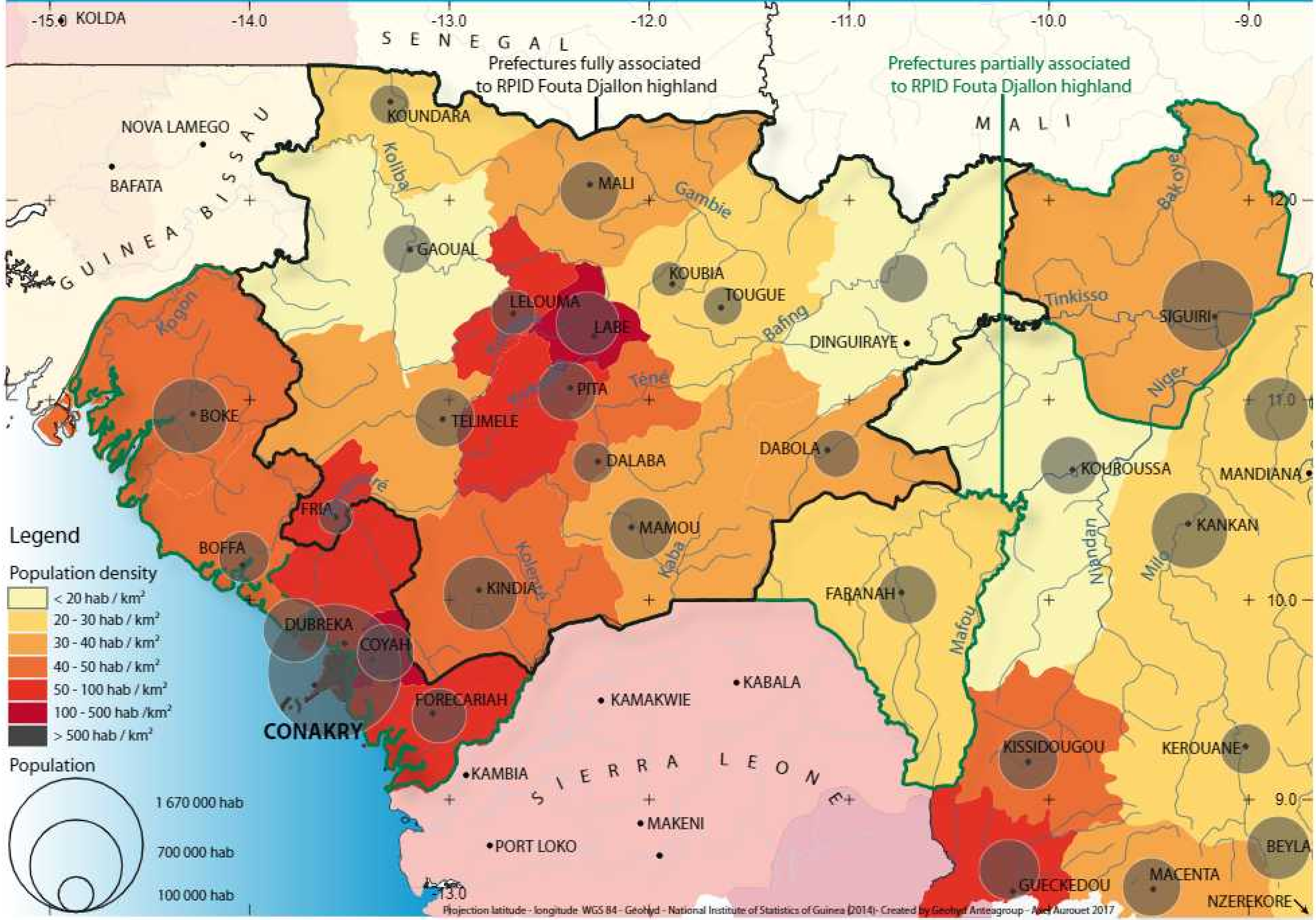


Figure 34 > Population trend between 1983 and 2014 in Guinea and in prefecture of Fouta Djallon



House in the Fouta Djallon highland

Carte 27 > Population and population density inside guinean prefectures of Fouta Djallon highland (2014)



DEMOGRAPHY

ACCESS TO DRINKING WATER

The drinking water access rate is defined by access to water from a tap (public, personal or neighbouring) via a borehole, an equipped source or an "improved" well. The drinking water access rate in the Fouta Djallon Highland was established at around 47% in 2002 (figure 35). This rate is slightly below the average in Guinea (77% in 2015 – map 28) but has increased in relation to the 1994 figures. The region of Labé has an access rate (51.6%) slightly above the Mamou region (43.2%) which is also the region which had the lowest access rate in the country in 2002. The main method of drinking water supply is a borehole and a standard well in the Labé region. In Mamou, a supply from rivers/lakes/seas and river were most common in 2002, followed by a borehole. Urban populations have a higher access rate than rural populations (74.7% vs. 52.8% in Guinea). For the Fouta Djallon RPID extended area, it should be noted that the drinking water access rate seems lower in Guinea in relation to the Mali zone of the Senegal basin, particularly with regards to an increased percentage of water supply through hydrants in the Mali zone. In its socio-economical study of the Senegal river basin, the OMVS also mentions that most of villages in Guinea (90% of Guinea villages in the Senegal river basin) have seasonal difficulties in accessing drinking water, explaining the higher rate of using rivers and backwaters to collect drinking water. Paradoxically, only 25% of villages surveyed in the Mali zone have seasonal difficulties. This fragility in accessing drinking water in the Fouta Djallon highland reflects the low availability of underground waters and their drying up, which goes hand in hand with the rainy season.

SANITATION

In 2002, the toilet access rate was under 48% in the Labé region and nearly 60% in the Mamou region (figure 36). Various types of latrines (covered or uncovered, ventilated or improved) are the main method of accessing toilet facilities. The most recent studies completed by the OMVS (2009) mention that nearly 70% of households surveyed in the Guinea zone of the Senegal basin had a latrine, which is higher than the 2002 survey. These percentages are lower than those identified in the Mali zone of the Senegal river basin where a latrine rate of over 98% was observed in OMVS studies. Finally, the washing facilities rate in the regions of Mamou and Labé seems to be around 83% and on average the villages in these regions have 2.6 community or shared latrines. Still according to the survey carried out by the OMVS, the average number of rainwater collection networks is 0 in the Mamou and Labé regions, with an average rate in the Senegal basin which is not much higher. In 2002, the administrative region with the highest levels of poverty in Guinea was Labé (65% of individuals below the poverty line). In Mamou, this rate was below 45%. In addition to being one of the poorest regions in Guinea, Labé was also the region with the broadest level of poverty in Guinea.

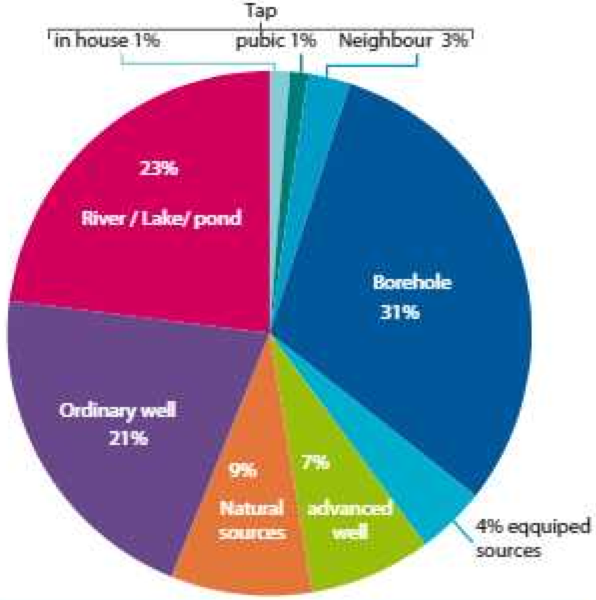
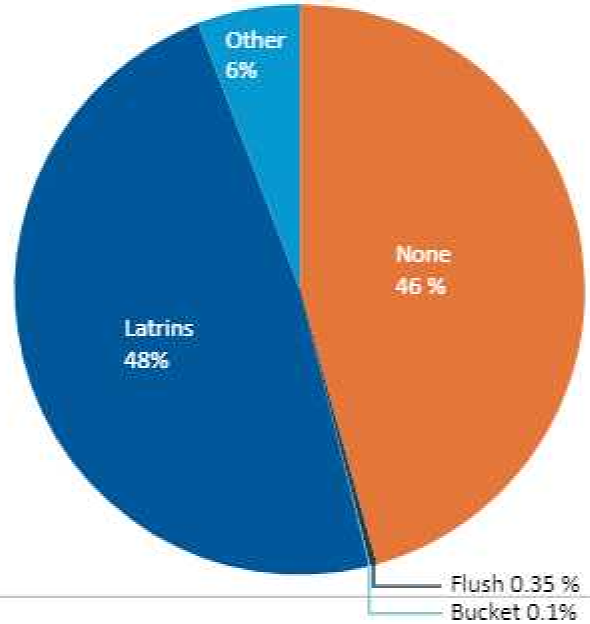


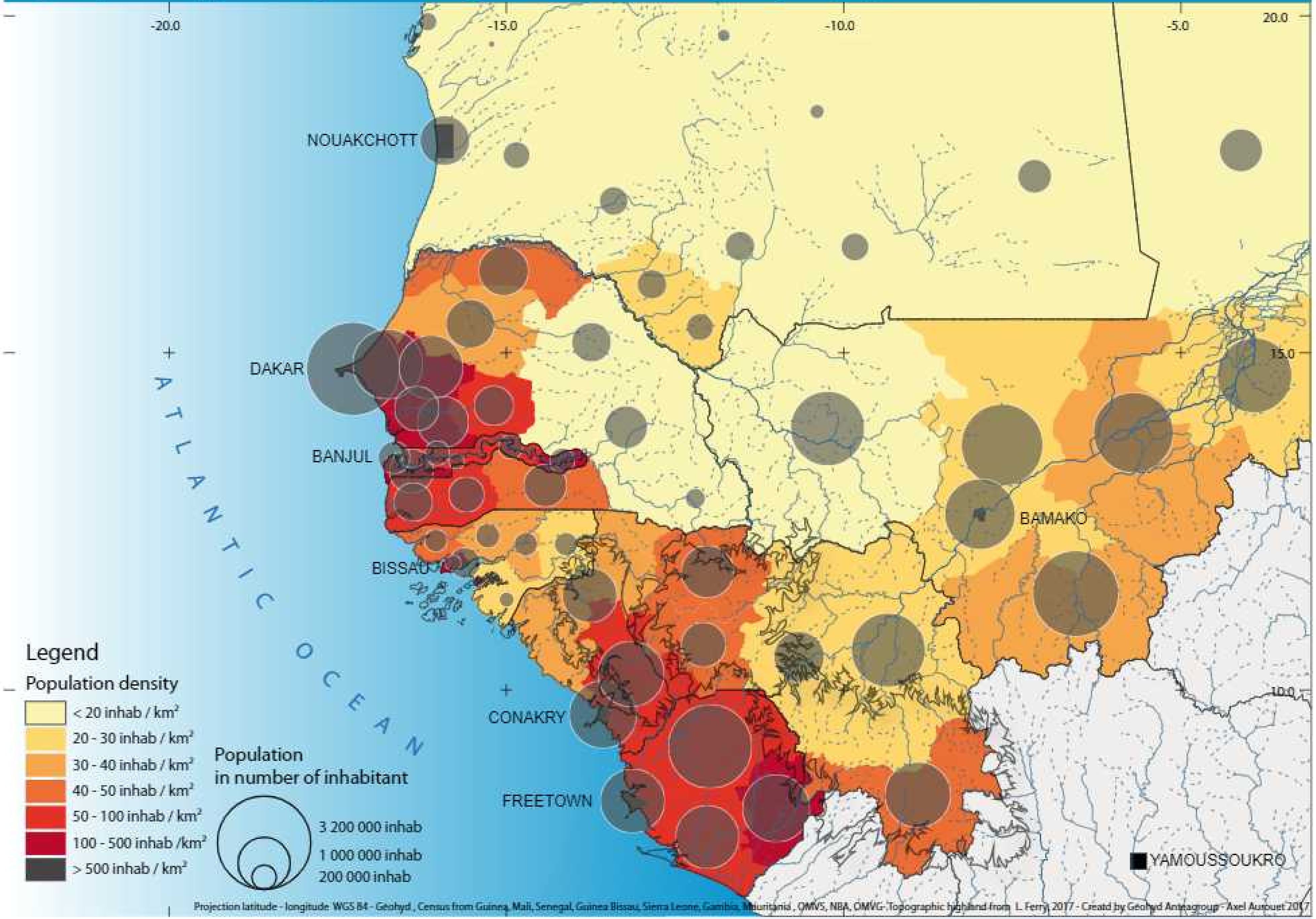
Figure 35 > Modality and rate of access to drinking water in the administrative regions of Mamou and Labé (2002)

Figure 36 > Access to the toilet in the administrative regions of Mamou and Labé (2002)



Map 28 > Percentage of the population with access to improved water source at national scale (2015)

Map 29 > Population and population density in administrative regions of extension zones of Fouta Djallon highland (2014)



AGRICULTURE

FONIO IS THE EMBLEMATIC CROP OF THE FOUTA DJALLON HIGHLAND. CASSAVA AND MAIZE REMAIN PREDOMINANT. THE FOUTA DJALLON IS ALSO A SIGNIFICANT CATTLE FARMING AREA TO THE SOUTH, AND CONTINENTAL FISHING PLAYS AN IMPORTANT ROLE. TAPADE, WHICH IS THE FOUTA DJALLON'S TYPICAL AGRARIAN SYSTEM, IS AN INGENIOUS SYSTEM RECOGNIZED BY THE FAO.

THE TAPADES, AN ORIGINAL CULTIVATION SYSTEM IN THE HEART OF FOUTA DJALLON HIGHLAND

Guinea has good agro-climatic conditions, a large hydrographic network and a polder which encourages the practice of agricultural activities during a good part of the year. Agriculture is the main production activity in Guinea, involving around 85% of the population. In the Fouta Djallon highland zone, the cultivation system is traditional and based on slash-and-burn deforestation with a specific feature in Fouta Djallon which is the tapades (an agricultural method unique to Fouta Djallon). These are enclosures forming patches of greenery and habitats on the Fouta Djallon plateaus. These are enclosed residence, domestic livestock farming and gardening areas. They allow livestock farming as well as cereal crops (fonio) on open field spaces around the tapades, as well as having protected gardens. These gardens produce all year round, thanks to continued support of organic, grass and ash material. The Guinea tapades were often presented as the solution to the problem of coexistence between agriculture and livestock farming. This traditional farming method was listed in the "Globally Important Ingenious Agricultural Heritage Systems" (GIHAS) by the FAO.

CULTIVATION IN THE HEART OF FOUTA DJALLON HIGHLAND

At the centre of the Fouta Djallon, the cultivated surface area was estimated at nearly 260,000 ha in 2001 for the regions of Labé and Mamou. This surface area reaches 420,000 ha by including the Boké region. The cultivated surface areas in the regions of Labé and Mamou represent 19% of the cultivated surface areas in Guinea. In the region of Labé, fonio is the main crop (28% of cultivated surface areas), followed by maize (20%), potatoes (13.5%) and cassava (11%). Next is peanut and taro (6 to 7% each). The region of Mamou also has significant surface areas of fonio crops (21%) but rice crops are the most common (25%) in terms of surface area. Unlike the Labé region, there are few potato crops and more millet. In the Boké region, the most common crop is rice (map 31), which covers nearly 48% of the cultivated surface area in the region. Rain-fed cultivation is largely dominant in the Labé region (80% of crops) and Mamou region (98%). In the region of Labé, there are also low-land cultivation (12% of crops) and, to a lesser extent, irrigated and bank cultivation (4% of crops for each type in the Mamou region and less than 1% in the Labé region). The irrigation water requirements are estimated at nearly 21Mm³/year for the Mamou and Labé regions (2007-2008 SDAGE Senegal).

AGRICULTURAL PRODUCTION IN THE HEART OF THE HIGHLAND

In all prefectures associated to RPID -FDH like region in the heart of Fouta Djallon highland (Labé – Mamou), the most significant production is cassava (770,000 tonnes/year) (figure 37 – map 30). It is important to note that this geographic sector is the principal producer of fonio (361,000 tonnes i.e. 74% of production in Guinea – map 39), maize (440,000 tonnes; i.e. 59% of production in Guinea- map 32) and potatoes (53,000 tonnes i.e. 100% of the production in Guinea). By including the 7 partially covered prefectures, we can also include cassava (960,000 tonnes i.e 59% of production in Guinea) and peanut (409,000 tonnes i.e 76% of production in Guinea). In total between 55 and 66% of the Guinea cereal production is linked to 22 prefectures in the Fouta Djallon highland RPID area, which makes the region a "granary" for Guinea.

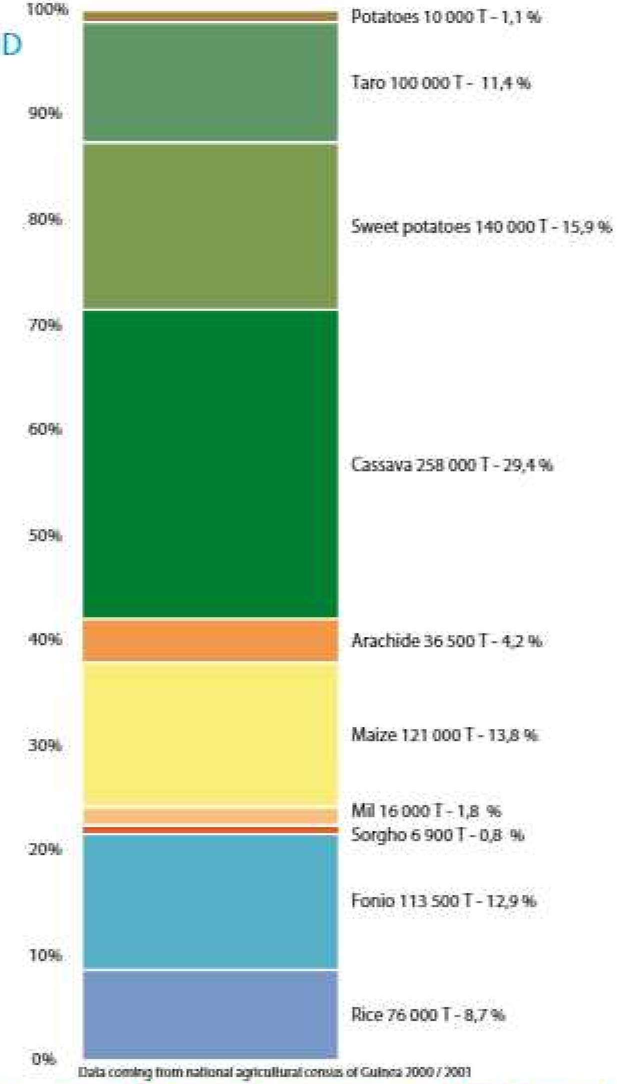
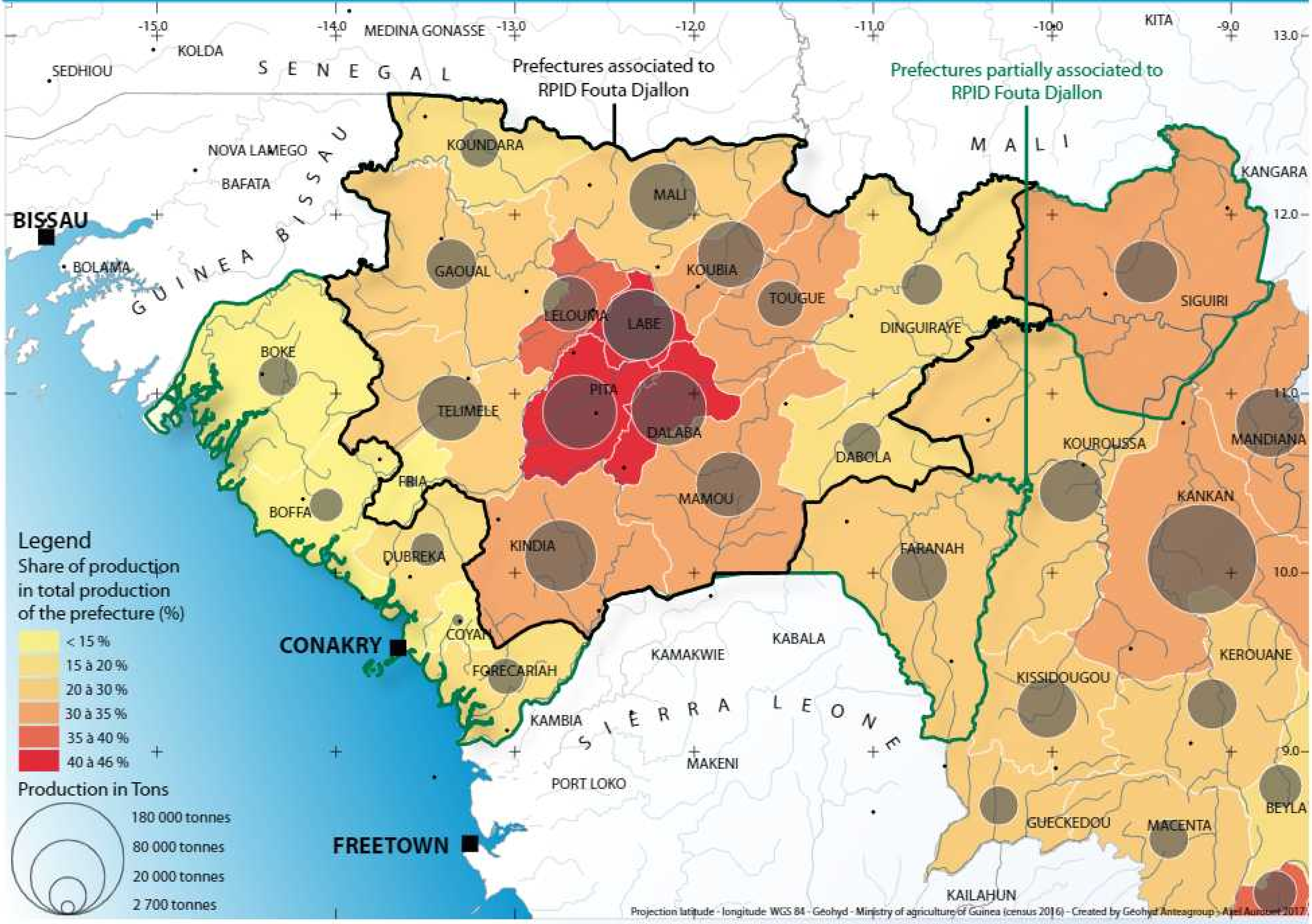
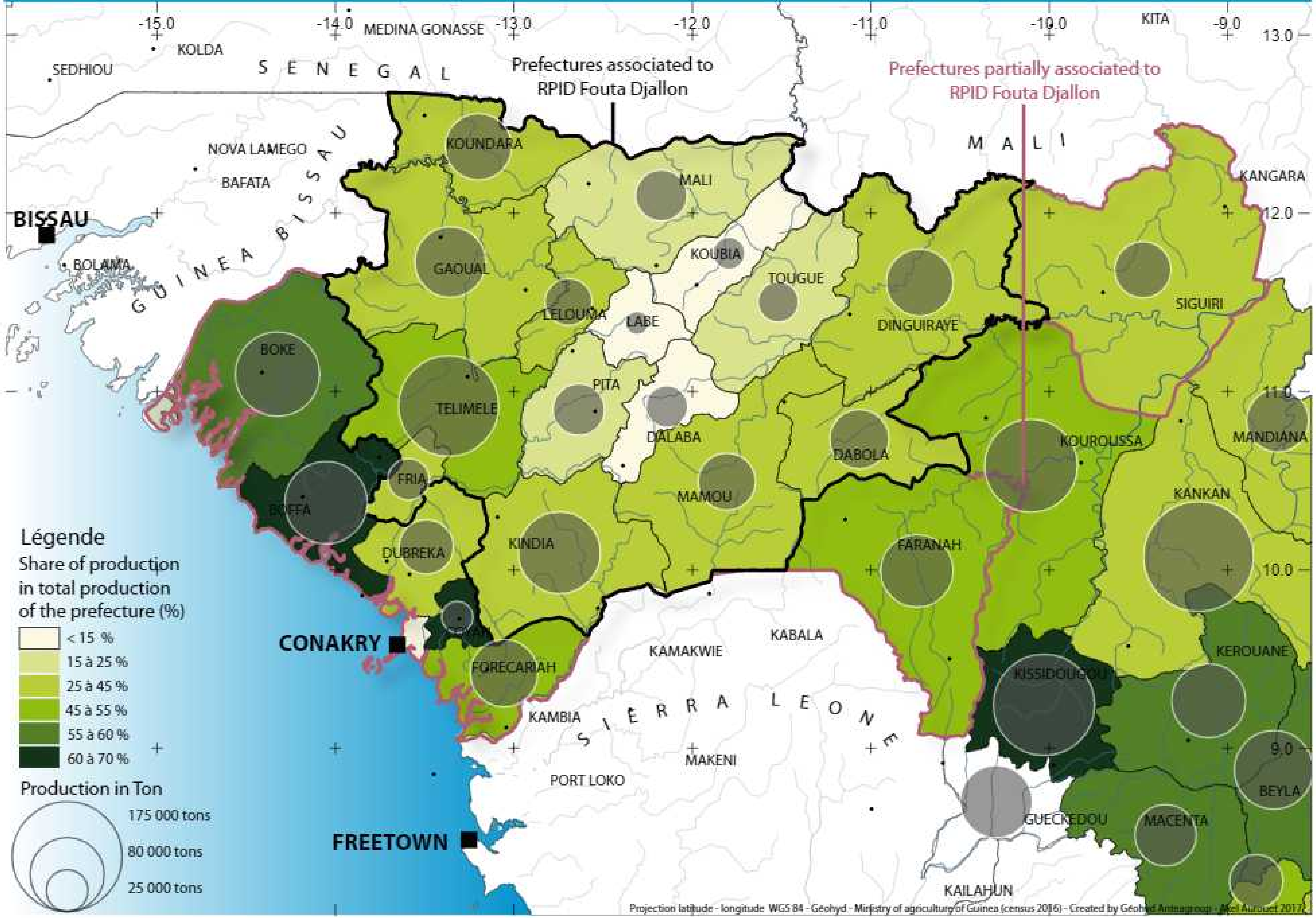


Figure 37 > Distribution of agricultural production in tons and by type of crop in administrative region of Labe and Mamou in 2000 - 2001

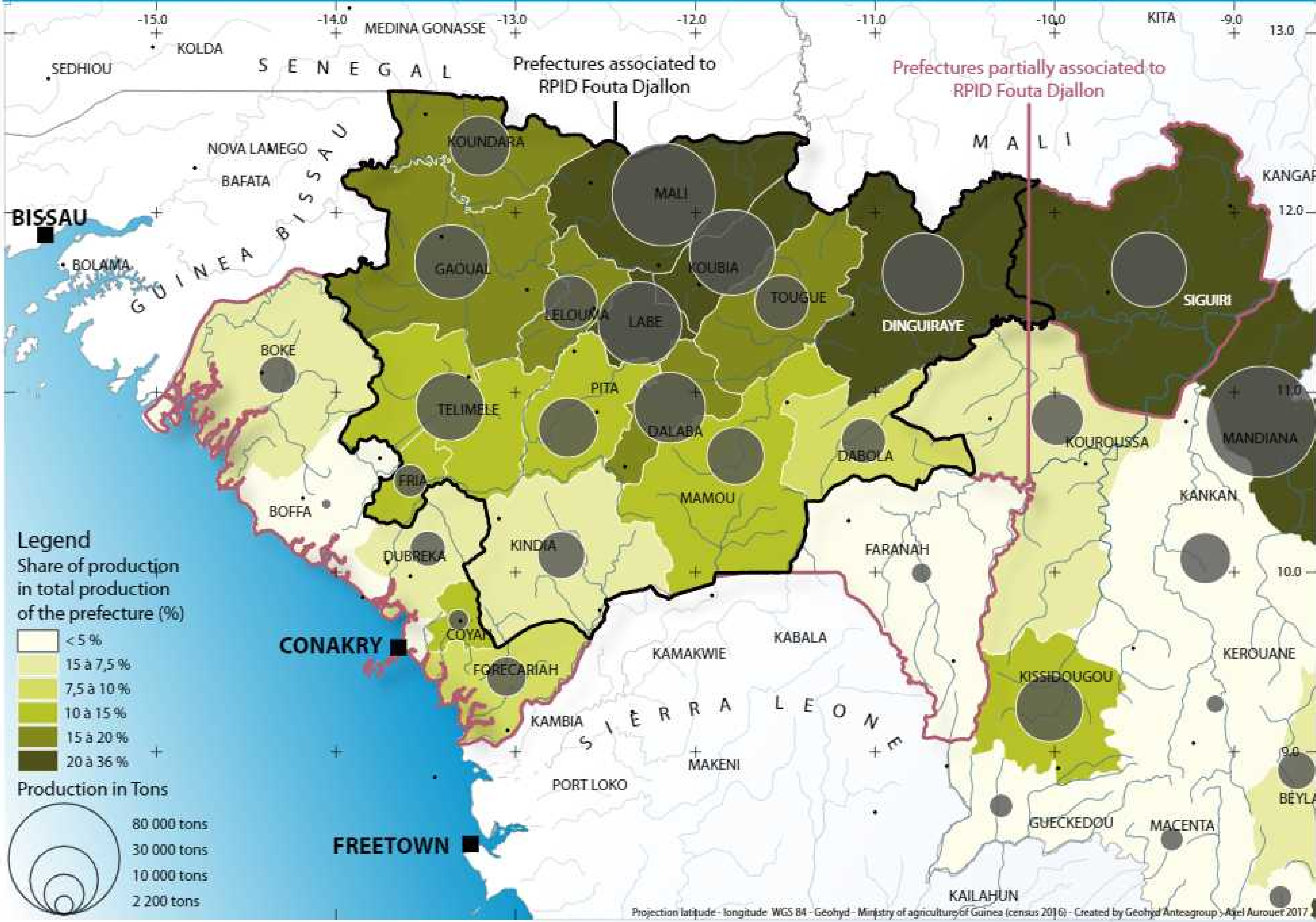
Map 30 > Production and share of production of cassava inside Guinean prefectures of Fouta Djallon Highland



Map 31 > Production and share of production of rice inside Guinean prefectures of Fouta Djallon Highland



Map 32 > Production and share of production of maize inside Guinean prefectures of Fouta Djallon Highland



LIVESTOCK FARMING IN THE HEART OF FOUTA DJALLON HIGHLAND

Whilst the Fouta Djallon Highland central area can be considered as the granary of Guinea, it is also the main area for livestock farming in Guinea (map 33). Livestock farming is extensive and traditional. Between 55 and 60% of Cows, Sheep and Goats in Guinea are found in the 15 prefectures associated with the Fouta Djallon (figure 38). This figure rises to over 80% when including the seven partially covered prefectures. The number of Cows is nearly 4,200,000 (2016) with around 1,430,000 Sheep and 1,900,000 goats. Based on a water requirement of 30l/TLU and per day (TLU – Tropical Livestock Units), nearly 31 Mm³/year is required for watering in the 15 prefectures. This volume rises to nearly 45Mm³/year when including the 7 additional prefectures. Finally, we note that there is also poultry farming with approximately 1 in 3 households having them. The cow and goat population continues to grow in the highland but is less sustained than in other Guinea regions.

Ministry of agriculture of Guinea (census 2016)

Figure 38 > Number of cattle, sheep, goats and pigs in the Guinean prefectures of the Fouta Djallon highland (2016)

AGRICULTURE IN THE EXTENDED AREA OF FOUTA DJALLON HIGHLAND

CULTIVATION

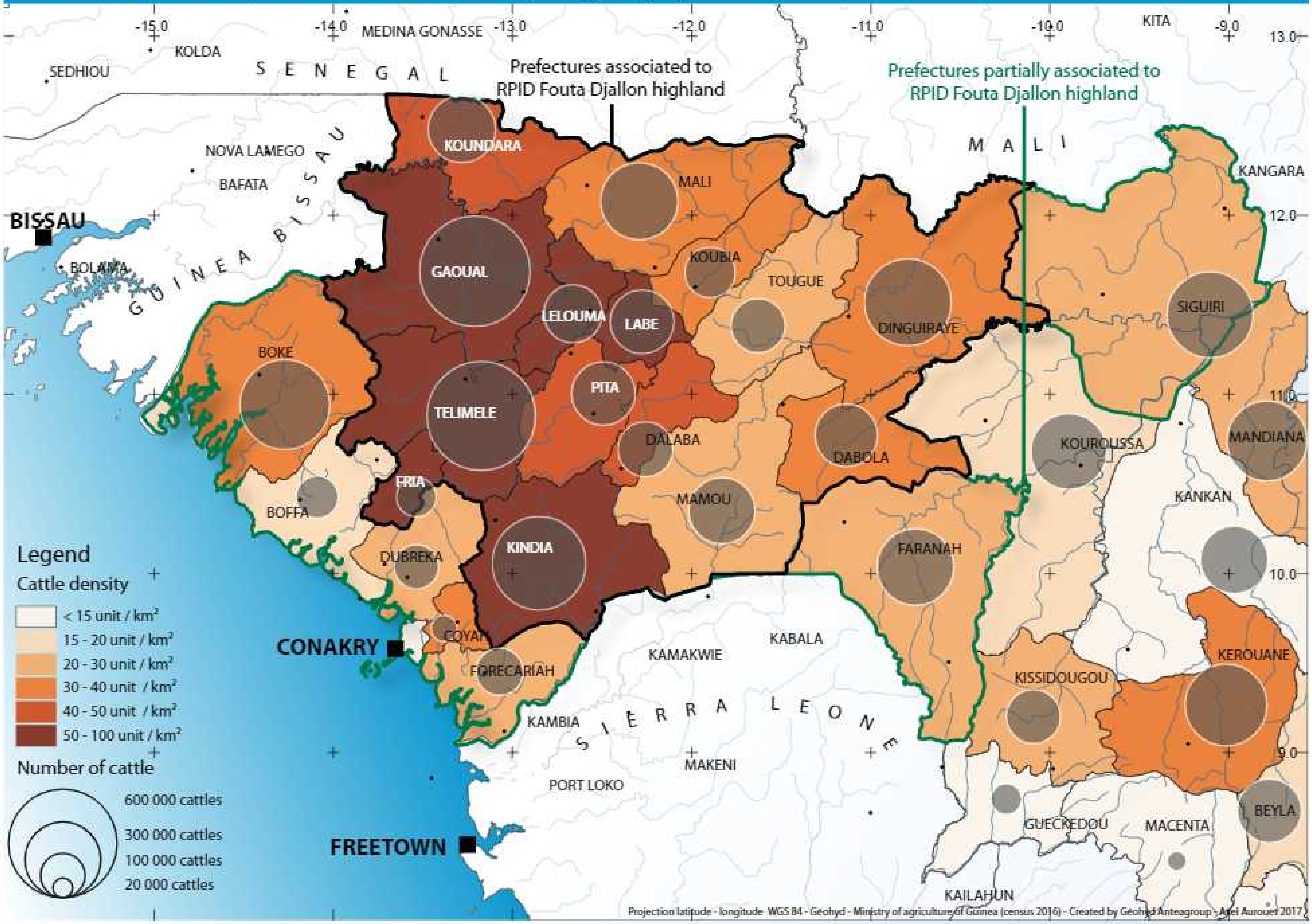
In the extended area of the Fouta Djallon Highland's RPID, West Guinea and the Northern fringe of Mali and Senegal mainly contain Maize, Rice, Millet and Sorghum crops. Finally, there is some cotton production, particularly in South-East Mali. The Mali sector also has the largest surface area of Sorghum and Millet. The main cultivation type remains rain-fed (over 90% of surface areas) notably in Mali and Guinea. To a lesser extent there is low-land cultivation, bank cultivation, flood recession cultivation and irrigated cultivation. In Senegal, flood recession cultivation is more common, as well as in the Malian part corresponding to the Niger river inner delta. Irrigated cultivation is also more common in Senegal, but continues to grow across the zone. Finally, there is also market gardening production, mainly with peanuts, then onion, okra, pepper, bananas, potatoes, and locally tomatoes.

LIVESTOCK FARMING AND PASTORALISM

The Malian herd is one of the largest in the region with extensive livestock farming. Cows are the most common (zebus) followed by sheep and goats. In the fringes of Senegal, the region of Kanel and Matam, outside of the Fouta Djallon highland extended area RPID, is the ultimate livestock farming region. In the extended area, there are 5 major pastoral systems like those in Mali: the nomad or transhumant pastoral system (Sahelian zone) the transhumant agro-pastoral system linked to flooded land (inner delta), the transhumant or sedentary agro-pastoral systems linked to exposed land (systems mainly in the RPID extended area, agro-pastoral systems in cotton areas (South-East Mali) and suburban livestock farming systems (often with modern equipment).

Plowing in Fouta Djallon highland

Map 33 > Cattle and Cattle density inside Guinean prefectures of Fouta Djallon Highland (2016)



CONTINENTAL FISHING ACTIVITY

Whilst deemed to be a relatively marginal activity due to the Fouta Djallon's isolation and river blindness epidemics, a study by the national fisheries department looking at continental fishing found that fishing in rivers and adjoining seas plays an important role in food security and the creation of jobs for rural communities in the sector. According to this study, the average landing figures per fisher would be comparable to those in the Senegal upper valley (around 2.6 tonnes/fisher and per year on average). Constraints in terms of fishing in Fouta Djallon are mainly linked to the rarity of the resource on the one hand and a lack of equipment on the other. In the Fouta Djallon highland' extended area RPID, the sectors of Kéniéba, Baoulé (in the Baoulé biosphere reserve) and Bakoye are also deemed to be significant fishing sectors. The Kayes lowland region is deemed to have strong natural fishing potential which is now even higher in this sector due to the presence of the Manantali dam which attracts many fishers, particularly from the Niger basin. The average annual landing per fisher in Manantali is estimated at 10 tonnes/fisher and per year, i.e. around 1000 tonnes/year (map 34). At the RPID extended area covering the Niger basin, fishing activity remains significant although most of the activity in Mali is located in the Niger inner delta (80% of Mali total i.e. 40,000 to 120,000 tonnes/year depending on the year). Production linked to the Sélingué dam on the Sankarani is estimated at around 3,000 tonnes/year. The remainder of fishing activity is scattered along the Niger for both the Guinea and Mali portions and is mainly focused on navigable portions. Finally, very far away from the Fouta Djallon, there is also estuary and sea fishing in progress in Guinea, The Gambia and Sierra Leone, which is a much more significant activity than continental fishing in these countries.

FUTURE THREATS TO WATER QUALITY?

Agriculture in a broad sense is a fundamental component with regards to food security issues. The development of agriculture is accompanied with the use of fertilisers and phytosanitary products, where frequent long-term use can damage water quality. An overly high concentration of fertiliser can lead to plant overgrowth in rivers and dams, and phytosanitary products are toxic for human health and the fish population. In the Guinea portion at the heart of Fouta Djallon, the use of pesticides and fertilisers remains quite low compared with the situation in Guinea. Pesticides are "rarely" used in the Fouta Djallon highland. In 2016, around 95,000 tonnes of pesticides were received in the 15 prefectures of the Fouta Djallon. This is 18% of the total tonnage received in Guinea (figure 39). The highest consumer is the region of Nzérékoré followed by Kankan, suggesting that the Niger basin is more exposed to these products. The quantities of fertiliser received at 15 prefectures in the Fouta Djallon highland amounts to nearly 4,100 tonnes/year. By adding partially covered prefectures, this tonnage rises to 7,600t, i.e. nearly 66% of the "fertiliser" input in Guinea. In its specific survey on the use of inputs in the Senegal basin, it tends to show applied doses of around 2 to 5 kg/ha for pesticides (Mali zone) and doses of Nitrogen-Phosphorous-Potassium (NPK) between 4kg/ha (Rice, maize) and 22kg/ha (millet).

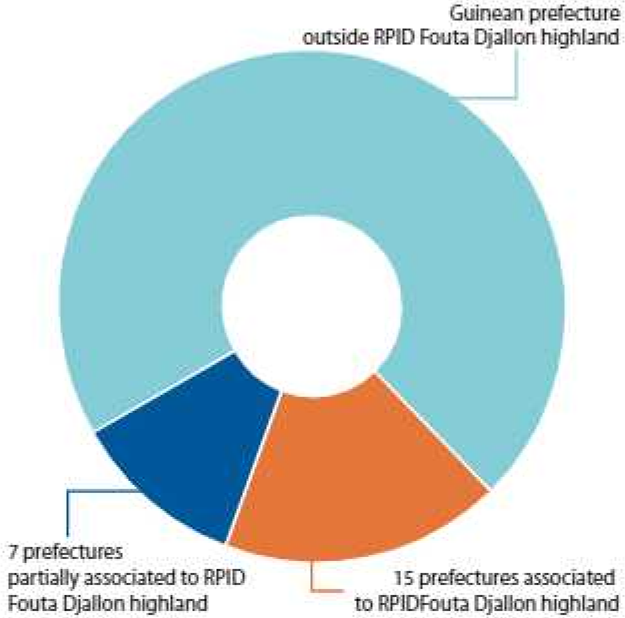
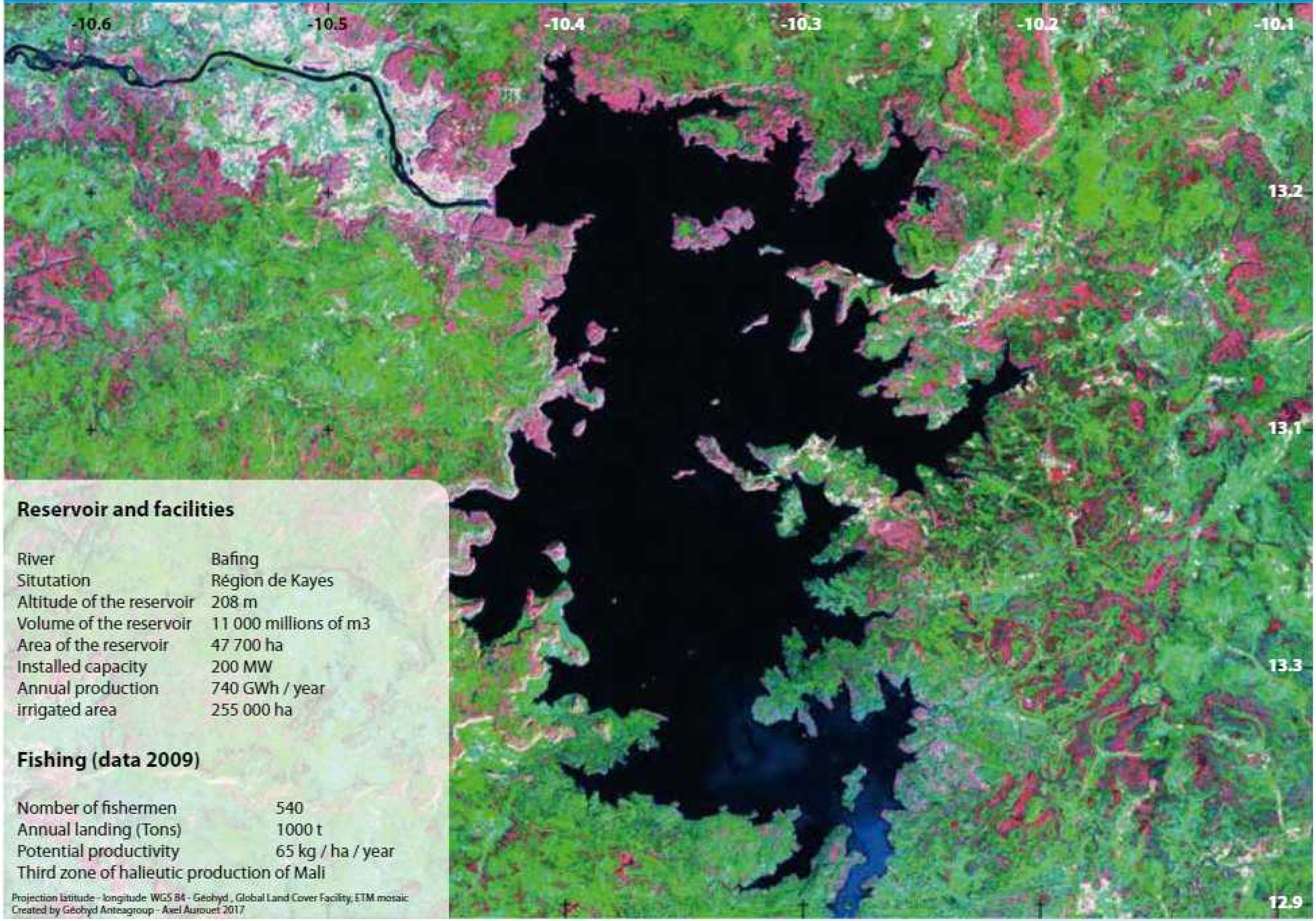


Figure 39 > Contribution of the prefectures of Guinea in the total use of pesticides in Guinea

Fisherman on Niger river banks at Bamako

Map 34 > Artificial lake of Manantali dam on Bafing river (Kayes region)



Reservoir and facilities

River	Bafing
Situtation	Région de Kayes
Altitude of the reservoir	208 m
Volume of the reservoir	11 000 millions of m3
Area of the reservoir	47 700 ha
Installed capacity	200 MW
Annual production	740 GWh / year
irrigated area	255 000 ha

Fishing (data 2009)

Nomber of fishermen	540
Annual landing (Tons)	1000 t
Potential productivity	65 kg / ha / year

Third zone of halieutic production of Mali

Projection latitude - longitude WGS 84 - Géohyd , Global Land Cover Facility, ETM mosaic
Created by Géohyd Anteagroup - Axel Aurouet 2017

HYDROELECTRIC POWER POTENTIAL OF FOUTA DJALLON

LE THE FOUTA DJALLON'S HYDROELECTRIC POTENTIAL, LINKED TO THE POWERFUL WATERFALLS LOCATED IN IT, HAS BEEN IDENTIFIED FOR A LONG TIME. ITS POTENTIAL CAPACITY IS THUS ESTIMATED TO BE APPROXIMATELY 2,600 MW, WHICH IS 47% OF GUINEA'S POTENTIAL. THERE IS AN ESTIMATED POTENTIAL CAPACITY OF 2,800 MW FOR THE TERRITORY OF MARITIME GUINEA. HYDROELECTRIC DEVELOPMENT PROJECTS IN THE HIGHLANDS OR ON THEIR BORDERS HAVE INTENSIFIED IN RECENT YEARS, IN KEEPING WITH NATIONAL AND TRANSBOUNDARY ISSUES.

A LONG-TERM AND MULTI-LAYERED POTENTIAL

Hydroelectric power is a major issue for Guinea but also more generally for all countries bordering the rivers coming from Guinea. The Gambia has indicated an ambition to meet its entire electricity demand by 2020 and Guinea wants to increase electricity access by 50%. Mali and Senegal continue to actively develop their hydroelectric power and Sierra Leone wants to triple its installed capacity by 2020. The numerous and powerful waterfalls in the Fouta Djallon, like in other regions in Guinea, have attracted attention for this potential, which is estimated at around 26,000 GWh/year for the entirety of Guinea. The "technically feasible" potential would be around 19,300 GWh/year and the "economically feasible" potential at around 18,200 GWh/year. This "economically feasible" potential represents 5,500 MW of raw power, of which 50% are estimated in Maritime Guinea and 47% in Central Guinea in the Fouta Djallon highland (figure 41). Within this overall potential, the part estimated for "small-scale" hydroelectric power still amounts to nearly 12,000 GWh/year, so 46% of the total potential. This small-scale hydroelectric power, with an average capacity between 3 and 10 MW, could produce nearly 2,845MW at around 111 sites across Guinea, whereas current production is around 5.1MW for this type of facility. Currently the installed power in Guinea is estimated at around 368 MW including the recent commissioning of the Kaléta works, which itself contributes 240 MW. Despite this, the Guinea potential remains very underused: less than 7% (figure 40).

HYDROELECTRIC POWER STILL UNDERUSED IN GUINEA BUT USED OUTSIDE OF GUINEA

THE KOUKOURÉ BASIN, THE TOP HYDROELECTRIC POWER PRODUCER IN GUINEA

The Konkouré river is by far the most used river basin with a concentration of over 99% of Guinea's hydroelectric power generation (table 6). The complex of Samou, a Badi tributary, itself a tributary of the Konkouré, has three facilities commissioned between 1953 and 1969 located to the north of Conakry. This complex has a dual purpose of power distribution and the supply of drinking water on the Conakry-Kindia axis. It has 47 MW distributed between, from upstream to downstream, the Baneya or Banéah dam (264 Mm³ with a 5 MW production capacity plant), the Kalé dam associated with the Donkéa production plant (9Mm³ for a 15 MW production capacity plant) and the Grandes Chutes dam (1 Mm³ with a 27 MW production capacity plant). The Banéah facility remains a regulated facility but overflows are still possible considering the average annual inlets estimated at 353 Mm³. The Kinkon facility, located in the centre of Fouta Djallon on the Kokoulo and near to Pita, dates from 1966. With an installed power of 3.4 MW, it is a concrete facility overlooking a near 110 m waterfall, but the retained volume is quite low (<3 Mm³) and does not allow regulation of the Kokoulo. This facility supplies the towns of Pita, Labé, Dalaba and Mamou, and its maximum productivity seems to have never been reached. The Garafiri dam is positioned on the Konkouré, with 75 MW and a useful volume around 1200 Mm³ for a fall height of nearly 56 m. Set up in 1999 for use in the 2000s, it supplements power supply for Conakry, without ever managing to cover the entire demand. The dam has led to the creation of an artificial lake measuring nearly 79 km² but has also caused a strong modification in the hydrological regimes of Konkouré and, as a result, has led to softening of estuary waters. Finally, the recent Kaléta dam is also positioned on the Konkouré, the largest hydroelectric power generator with 240 MW of installed power. Its artificial lake covers a surface area of nearly 2.82 km² for a stored volume of nearly 23 Mm³. Other facilities in Guinea are smaller. On the Niger river basin, on the Tinkisso course to Dabola, there is also a concrete facility with a fall height of 60 m and an installed capacity of 1.5 MW which aims to serve Dabola, Dinguirate and Faranah. This facility does not regulate the Tinkisso and offers a minimum guarantee on its electrical production during low water. Finally, micro-plants, such as Sérédou (0.64 MW) and Loffa in Macenta (0.14 MW) seem functional, even if they do not cover the local needs.

REGION	POWER STATION NAME	INSTALLED CAPACITY (MW)	RIVER	BASIN	HEIGHT (M)	COMMISSIONING	GROUPS
Kindia	Banéah	5,00	Samou	KONKOURÉ	19,5	1969	2x2,5 MW
Kindia	Donkéa	15,00	Samou	KONKOURÉ	74	1965	2x7,5 MW
Kindia	Garafiri	75,00	Konkouré	KONKOURÉ	56	1999	3x25 MW
Kindia	Grande chutes	27,00	Samou	KONKOURÉ	115	1953	2x5 MW + 2x8,5 MW
Kindia	Kaléta	240,00	Konkouré	KONKOURÉ	49,2	2015	3x80 MW
Mamou	Kinkon	3,40	Kokoulo	KONKOURÉ	110	1966	4x0,85 MW
Nzérékoré	Loffa	0,16	Ouin-ouin	LIBERIA	24	1958	1x0,16 MW
Kindia	Samankou	0,16	Samankou	FATALA	70	1995	1x0,16 MW
Faranah	Tinkisso	1,65	Tinkisso	NIGER	60	1970	3x0,55 MW
Sérédou	Sérédou	0,64	Loffa	Loffa		?	

Table 6 > Main hydroelectricity facilities in Guinea (2016)

MANANTALI AND SÉLINGUÉ, HYDROELECTRIC POWER FROM GUINEA

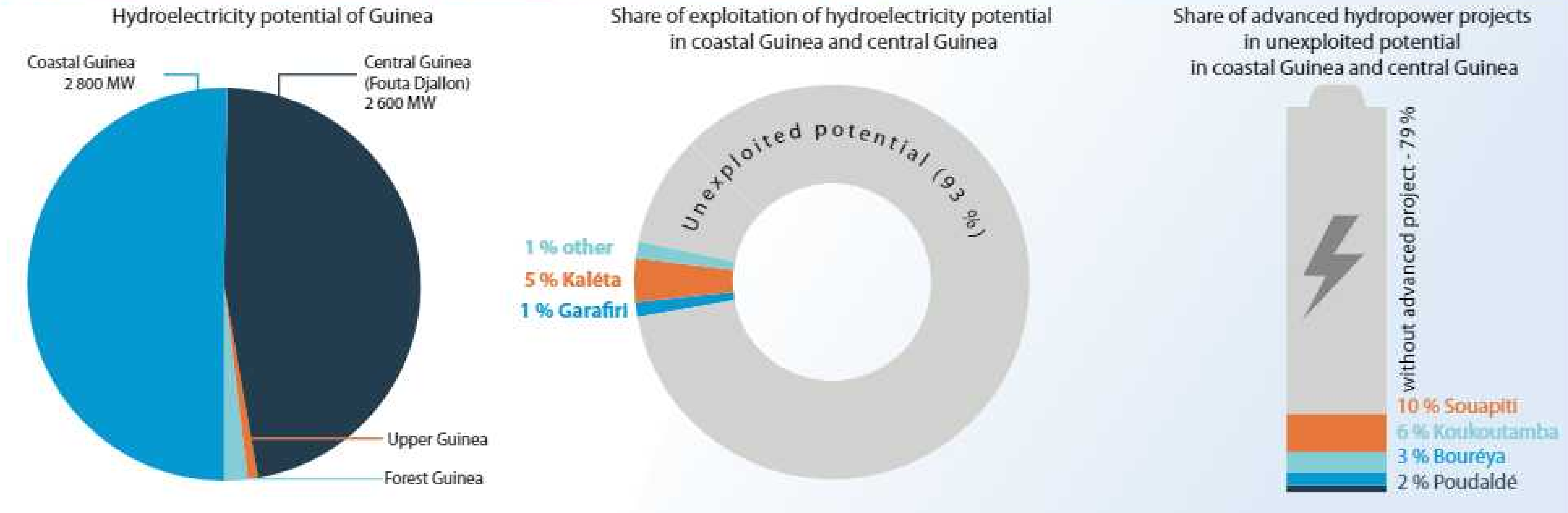
The Manantali dam in Mali has a direct link with the Fouta Djallon highland as it is positioned on the lower course of the Bafing in Mali. It controls nearly 50% of the Senegal upstream basin's inlets and started operating in 1987. It helps control floods, stabilise downstream activities during low water periods (drinking water, irrigation, rain-fed cultivation, sailing), and produce energy (800 GWh/year) shared between Mauritania, Senegal and Mali. Its storage volume is considerable (11,000 mm³) and helps store the equivalent to an average flow year in Bafing. Its completion was carried out by the OMVS (Senegal River Development Authority) by country delegation. Currently, the Manantali's actual production seems to be around 740 GWh. Electricity produced at Manantali is distributed towards Bamako, Nouakchott and Dakar by over 1,500 km of high voltage lines. The Sélingué dam, whilst dependent in part of the Guinea waters by the Sankarani, is not directly linked to Fouta Djallon. With a surface area of 460 km², its artificial lake has a capacity of nearly 2,700 mm³ for an installed power at the dam of around 44 MW (247 GWh/year). Built in 1980 and renovated between 1996 and 2001, this dam produces nearly 30% of Malian production and is an energy supply for the south of Mali.

WORKING TOWARDS DEVELOPMENT OF HYDROELECTRIC POWER IN THE FOUTA DJALLON HIGHLAND' WATERS WITH TRANSBOUNDARY CHALLENGES

GUINEA HYDROELECTRIC POWER ON THE RISE...

Hydropower development projects in Guinea quickly rise (map 34). After the recent commissioning of the Kaléta plant, the Souapiti project, 6 km upstream from Kaléta on the Konkouré, is currently being built with a planned power of nearly 515 MW, i.e. double that of Kaléta. At the same time, no less than 441 MW installation at the centre of the Fouta Djallon highland were part of a feasibility study carried out at the Koukoutamba (294 MW) and Bouréya (161 MW) sites for the Fouta Djallon part of the Bafing (Senegal DB). The Fomi dam (90 mW installed power) on the Niandan (Niger DB) is currently undergoing a feasibility study, as well as the Poudaldé facility (90 MW) on the Kogon slope in the Boké region. Excluding Fomi, all of these projects are linked in some way to the Fouta Djallon highland and their potential. Other projects are currently in the pre-feasibility stage, which is the case for Morisanako, on the Sankarani (Niger DB) with a 100 MW power and Gozoguezia (48 MW) in the Macenta region on the Lofia basin (towards Liberia). Finally, no less than 11 hydroelectric power projects are currently undergoing discussions. This includes the projects of Amaria (285 MW on the downstream course of the Konkouré), Tiopo (90 MW), the Grand Kinkon (280 MW on the Kokoulo, Konkouré slope), Balassa (181 MW on the Guinean Bafing before entering Mali), Digan (128 MW), Kora Findi (100 MW), Djolol Yillabhé (72 MW), Diaraguéla (72 MW on the upstream course of the Niger), Fello Soungan (53 MW) and the N'Zébela (20 MW on the Diani-Vano slope towards Liberia). In addition, smaller capacity projects are also being considered, such as Sérédou (2.25 MW on the Véré), Lokoua (6MW on the Lofia slope), Nongoa (8 MW on the Makona slope), and Fouguia (3.2 MW on the Tinkisso). Whilst not all of these projects will be carried forward, this project dynamic underlines Guinea's position with nearly 1,150 MW in a very advanced construction phase (over 3 times its current capacity), 148 MW during the pre-feasibility stage and 1,218 MW in the prior study phase.

Figure 40 > Hydroelectric potential, exploitation and exploitation project linked with Fouta Djallon highland



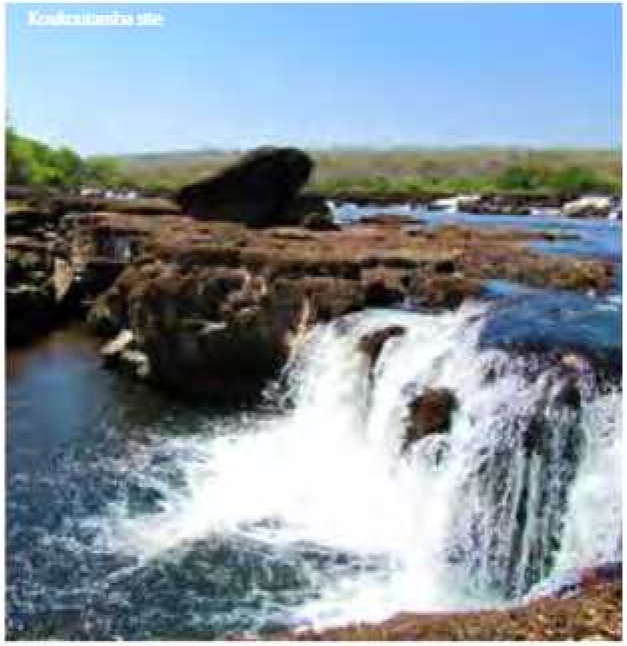
... INTERCONNECTED WITH THE SUB-REGION

Whilst these projects are effectively located in Guinea, some of them involve much larger transboundary cooperation challenges. The most emblematic project is that of Kaléta where the construction project is part of a transboundary interconnection framework with the Sambangalou hydroelectric power dam project in Senegal, with 128 MW power, on the Gambia river on its exit into Guinea. This project, funded through the Gambia river development authority (OMVG), estimated at nearly 654 M USD, is part of the Kaléta and Sambangalou construction project and their interconnection to supply OMVG member states. No less than 1660 km of interconnections are planned as part of this project. Whilst Kaléta's construction is complete, Sambangalou's construction has not yet started. The Koukoutamba and Bouréta hydroelectric power dams are also a transboundary interest and are both part of the Senegal river development authority (OMVS) for a cost of around 1,094 M USD. They also have an interconnection phase with OMVS member states. Finally the Fomi dam on the Niandan is carried out by the Niger Basin Authority (ABN) for the total estimated sum of 503 M USD.

MULTIPLE CHALLENGES FOR SURFACE WATER RESOURCES, SUCH AS GARAFIRI

During a study of the impacts of the Garafiri dam (Ferry et al., 2003), other than the modification of flows through flood reduction and increased low level flows, it is underlined that this facility has a significant impact on the salt front of the Konkouré during low water periods. In comparison, it seems that this fall has led to a progressive disappearance of certain oyster populations on estuary sectors on the Konkouré. It should be noted that for this dam the sediment transport assessments are in the lower fork, upstream from the dam rather than in the dam. The highest concentrations in depth are also more linked to iron oxide precipitation than accumulation of suspended particles from upstream zones. Nevertheless, it is underlined that the daily flow variations should play a significant role on downstream sediment, notably by remobilising sediments and by causing bank collapse. These daily fluctuations also affect dissolved oxygen downstream and therefore the immediate aquatic environment. Before entering the Konkouré estuary, the quantity of suspended materials has been estimated between 91,000 and 127,000 tonnes per year. These measurements were taken before the commissioning of the Kaléta facility. The main effects of these facilities can therefore be, potentially:

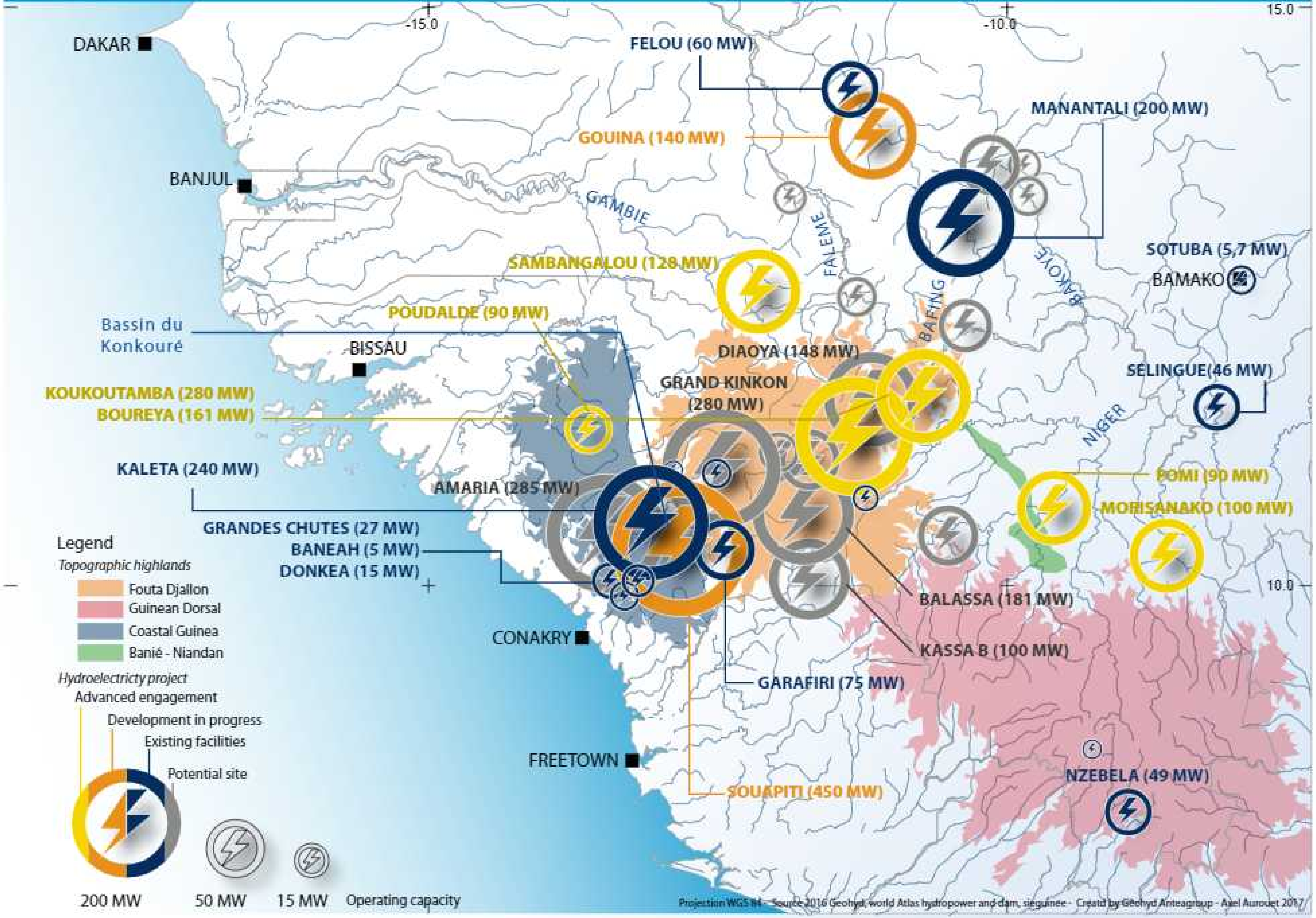
- The general modification of flow regimes,
- Interception of solid flows and destabilisation of the sediment regime,
- The flash suspension of sediments
- Collapse of downstream banks under the effect of daily flow variations,
- Immediate downstream damage to the aquatic environment (flora & fauna),
- When the facilities are not too distant from estuary zones, modification of the estuary salt front and people associated with these conditions.
- Finally it is also necessary to underline that artificial dams caused by these major hydraulic facilities cause a net loss of resources by evaporation of the stagnant flow depth. With its 79 km² lake and average evaporation of 1500 mm/year, potentially over 118 Mm³ of water is lost over the year on a Garafiri-type facility, i.e. the equivalent of 3.8m³/s or even 7% of the total stored volume.



Koukoutamba site

Kokoulo river, nearby Kinkon hydropower plant

Map 35 > Hydroelectricity facilities and hydroelectricity projects linked with Fouta Djallon highland



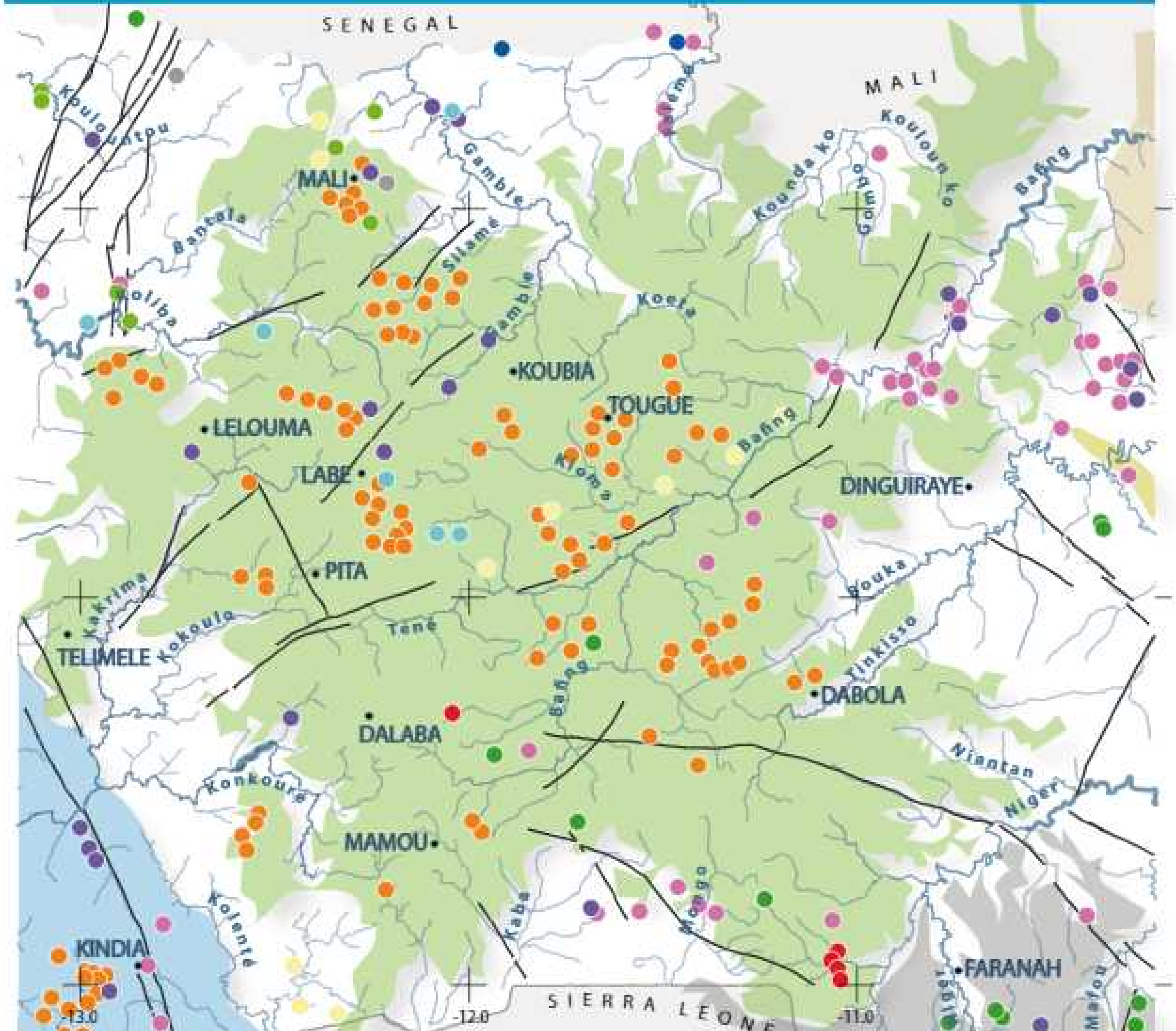
MINING

BAUXITE DEPOSITS CONSTITUTE THE MAIN MINERAL WEALTH OF THE HEART OF FOUTA DJALLON HIGHLAND. SOME SIGNS OF DIAMOND SHOW UP IN THE FOUTA DJALLON PART OF THE GAMBIA RIVER, AND THE GUINEAN PART OF THE BAFING VALLEY SHOWS TRACES OF GOLD. ITS EXTENSIONS, ESPECIALLY THOSE LOCATED IN THE GUINEAN HIGHLANDS, MAINLY CONTAIN GOLD, DIAMONDS AND IRON.

BAUXITE, THE MAIN MINERAL RESOURCE IN THE FOUTA DJALLON HIGHLAND

Bauxite is a major mining resource in Guinea and it is also the main mining resource in the Fouta Djallon highland (map 36). We note here that Guinea's bauxite resources are recognised as the largest and richest in the world. They are assessed at nearly 40 billion tonnes including 20 billion reserve tonnes currently proven. The breadth of these estimated reserves would supply the world aluminium industry for approximately 3 centuries. Bauxite deposits are mainly focused on the south-west part of Guinea, in the Boké region (>12,000 million tonnes), in the Kindia-Fria sector (>1,700 million tonnes) and in the Fouta Djallon highland (>1,500 million tonnes). In the Fouta Djallon highland, there are also some scattered diamond deposits or areas in the Labé - Koubia sectors and in the Mali zone, nickel deposits or areas to the south-east of Labé and some gold deposits or areas in the south part between Mamou and Faranah and in the north zone of Dinguiraye which extends to the east in the Siguiri zone. In the South-east zone of the Fouta Djallon highland, in the Faranah sector, on the border with Sierra Leone, there are also corundum deposits or areas (mineral made of aluminium). Finally, we note that the extraction of carbonated rocks (limestones - dolomites) take place in the highland at the enclosed valleys of the Bafing and the Gambia.

Map 36 > Gitology or evidence of ore in heart of Fouta Djallon highland



Source : Ministry of Mines, Geology and Environnement - map « des Minéraux utiles de la république de Guinée » (2006)

MINERAL RESOURCES IN THE FOUTA DJALLON HIGHLAND' EXTENDED AREAS

The Fouta Djallon highland' extended area has significant mineral diversity and richness, directly linked with the resources in Guinea (map 38). The upper Niger zone, in the Guinea regions of Kankan and the extension towards the south-east of Mali, has a significant gold wealth, notably in the Banié-Niandan chain sector, bordering the Siguiri basin and extending towards the west to the Fouta Djallon highland' foothills. Further south, in the Kérouané sector, there are many gold and diamond deposits extending to the Forest Guinea border. Diamond zones are found in the Bamako sector. In the Kérouané sector, there are also mined iron deposits in the Simandou mountains. Directly to the north of the Fouta Djallon highland, on the Mali-Guinea border, there are several uranium areas. The Falémé valley, in its upstream course leaving Guinea, has iron and gold mineral wealth. Further afield, in its downstream part and in the extension to Senegal, there are zones with copper and chrome. Copper and chrome deposits are also identified in Guinea downstream from the Rio Corubal (Koliba) and Koulountou. Finally, in the downstream part of the Bafing, at its confluence with the Bakoye, iron mineral zones with marble mining are indicated.

MACRO-ECONOMIC ASPECTS OF THE MINING SECTOR IN THE AREA

Following the colonial period, at the beginning of the 1990s, most African States, the World Bank and the European Union all recognized that the mining sector was the only realistic option for short term development in a region with very little skilled labor, provided it was entrusted to the private sector (OECD, 2002). The World Bank then implemented a development strategy based on two principles:
- Exploration and operations are high-risk investments that should be done by the private sector (foreign direct investment and local investment) - Member States must minimize geological, political and economic risks by managing the allocation of mining claims and by setting up environmental management policies. Funding set up to build geological and mining infrastructure (mapping, databases, mining cadastral systems have really ensured an important development of the sector since the 1990s, with many mine openings. Today, the countries of the Fouta Djallon highland area all more or less strongly depend economically upon this sector (map 37). In many countries such as Guinea, Mali, Burkina Faso or Côte d'Ivoire, placer mining remains the largest mining «employer» (more than one million people estimated for Guinea). Industrial operations generate a few thousand salaried jobs on the national level, which is far from negligible. Although they are far behind public service employment, these jobs, which are usually paid correctly and mostly located outside of main urban areas, have a major social impact: a salary in the bush provides a livelihood for 10 to 15 people. Thus, there are indirect benefits for neighboring villages, especially in terms of trade development.

Map 37 > Importance of mining income in countries linekd to Fouta Djallon highland

MULTIPLE POTENTIAL IMPACTS OF MINING ACTIVITY ON WATER RESOURCES

FROM A QUANTITATIVE POINT OF VIEW

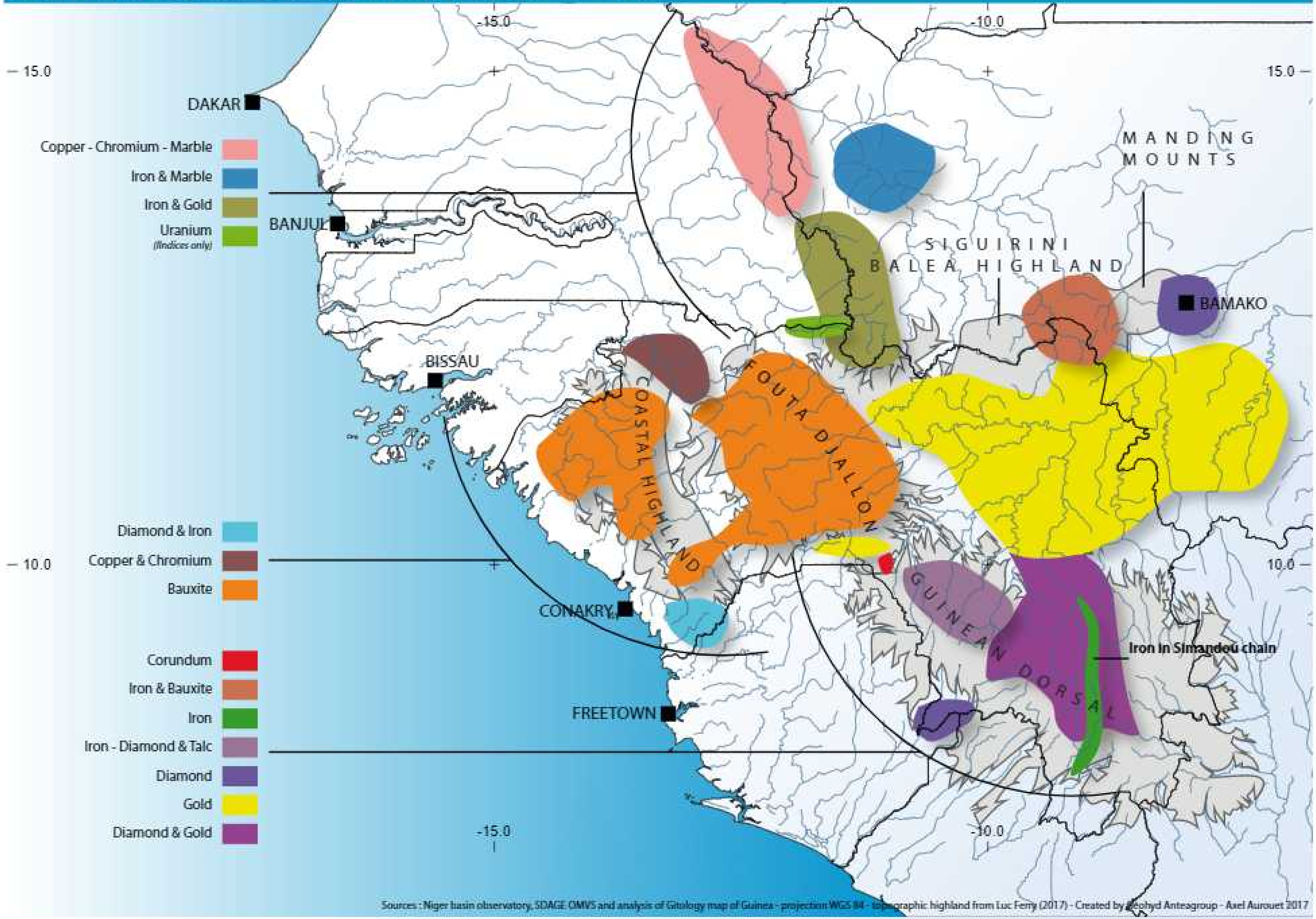
The industrial mining sites consume water in large quantities for domestic living purposes, but also for mining activity (watering tracks, rinsing equipment, etc.) and even more for industrial processes. For example, in Kamsar (Boké region), the wet drying dust recovery process uses 2,400 m^3 of water per day and in Sangaredi (on the Kogon), a daily pumping of nearly 4,500 m^3 is carried out with 30% industrial water and 70% drinking water. Finally, the main water resource used is the surface water by direct pumping from the river. Whilst these water uses do not pose a specific problem during high and middle water periods, drying-up periods are sometimes quite critical on rivers where the flows tend towards 0. The impacts on underground waters can be present in surrounding pits and boreholes, notably in the pumping range where they exist. Finally, one of the major impacts of the mining industry in Guinea is certainly the increase in sediment load. By exposing the large land surface areas, mining industries increase erosion process.

ON WATER QUALITY

Hydro-metallurgic treatments are considered the main source of water pollution by the mining industry. In Guinea, two processes are a major environmental and health concern: gold cyanidation and alumina production. Processing processes for bauxite, a major resource in the Fouta Djallon highland, generate sediment waste called "red mud" which is very acidic and toxic. In service between 1960 and 2012, the Fria plant was the only alumina production unit in Guinea with a red mud volume up to 1 Mm^3/year which was carelessly spilled into the Konkouré for many years (picture below). The situation has improved from 1993 with the creation of dams and reservoirs to store the mud. But the break in the upstream dyke due to strong rains in 2007 and 2009 demonstrated that the river is not free from major pollution. Acid mining drainage is another possible consequence of mining activity on water and aquatic environment quality. As a result, significant volumes of sulphur-rich rocks are exposed to water and atmospheric oxygen, and this leads to metal acid pollution in groundwaters.

Spillway of sludge's dam downstream of Fria complex (January 2002)

Map 38 > Gitology area or evidence of ore in Fouta Djallon highland and its extension zones



Sources : Niger basin observatory, SDAGE OMVS and analysis of Gitology map of Guinea - projection WGS 84 - topographic highland from Luc Ferry (2017) - Created by Géohyd Anteagroup - Axel Aurouet 2017

SUMMARY ON WATER USES

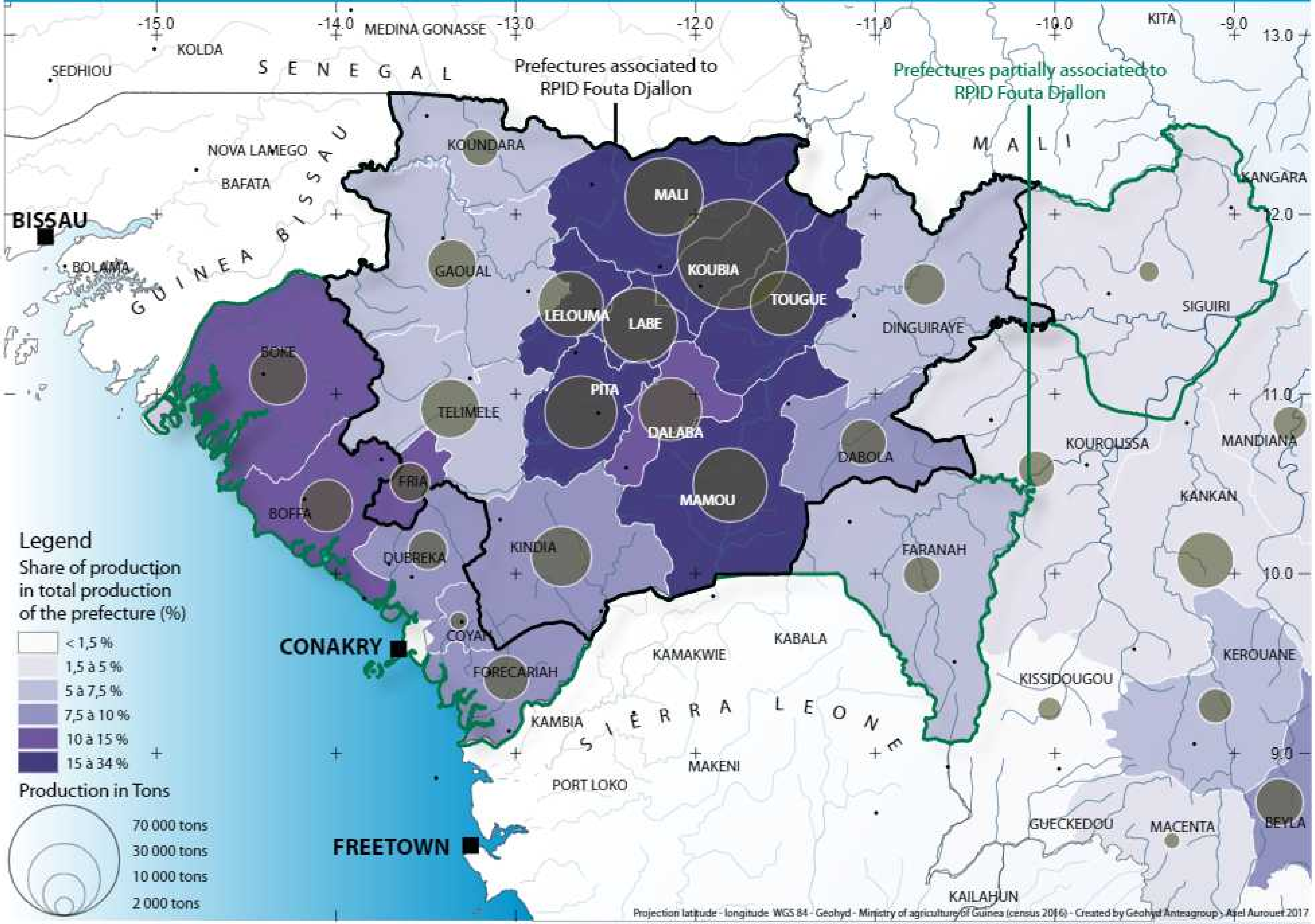
By and large, eight countries are concerned by the Fouta Djallon highland, through the RPID project for the Fouta Djallon. The inventory of populations really influenced by the Fouta Djallon highland in all eight countries (based on the segmentation of the RPIP-FDH project) has never been undertaken. However, we can estimate the population to be approximately 15 million inhabitants, including 5.7 million for Guinea. This population inventory further emphasizes the important place that the Fouta Djallon highland occupies for the riparian populations of the rivers. However, the population most «dependent» upon the Fouta Djallon highland remains Guinea. With close to 3.75 million inhabitants in the prefectures located at the heart of the Fouta Djallon highland, and 5.7 million with the aggregation of neighboring prefectures, more than half of Guinea depends upon the Fouta Djallon and its resources. The region remains remote, with moderate access to roads. The rate of access to safe drinking water was 47% at the beginning of the 2000s, and the poverty ratio was among the highest in Guinea.

Agriculture in the Fouta Djallon highland employs approximately 85% of the population, using traditional practices based on clearing and slash-and-burn techniques. «Tapades», which are an agrarian system originating in the Fouta Djallon, are a specific marker of this area. These are the mixed areas of residence, domestic husbandry and enclosed gardens, listed under the «Globally Important Agricultural Heritage Systems» (GIAHS) by the FAO. Although cassava remains the main agricultural production with maize and potatoes, fonio is a crop that can be found in much of the Fouta Djallon plateaus, which are the leading producing areas for it in Guinea. The Fouta Djallon is also one of the main livestock farming areas in Guinea with approximately 4.2 million head of cattle. Agriculture in the Fouta Djallon is sometimes held responsible for soil erosion. There is little consensus in the literature regarding this causal relationship even if, from a quality perspective, clearing practices, overgrazing and slash-and-burn techniques remain susceptible to degrade soils broadly.

The hydroelectric potential of the Fouta Djallon highland, currently estimated to be 26,000 GW for Guinea, has been identified for quite some time. The highland represent close to half of Guinea's potential. The other half is concentrated in the southern part of Guinea, in the coastal Guinea mountains, but it mainly concerns waterways originating in the Fouta Djallon. Nowadays, this potential is starting to be harnessed to a significant degree with the construction of the Kaléta and Souapiti dams, in addition to the Garafiri dam which is older.

The Fouta Djallon is a significant mining reserve. Bauxite (rock with a high alumina and iron oxides content) constitutes the main deposit at the heart of the Fouta Djallon highland, and gold deposits are present in the northeast extension of the Fouta Djallon highland, in the Bafing valley. Gold, diamond and iron deposits are found throughout the Guinean Highlands. This mineral wealth represents an important resource for economy of the Fouta Djallon, and more widely, for Guinea. Gold and copper deposits are also found in the extensions of the Fouta Djallon highland, in Senegal and Mali.

Map 39> Production and share of production of fonio inside Guinean prefectures of Fouta Djallon Highland



WATER CHALLENGES IN THE FOUTA DJALLON HIGHLAND

AND RESPONSES GIVEN

This chapter identifies the issues of biodiversity protection, water-related conflict and water governance in relation to the major driving forces of predictable impacts related to climate change. It gives an overview of the situation and issues in the Fouta Djallon highland and its extension areas.

REMARKABLE NATURAL SPACES AND SPECIES

THE FOUTA DJALLON HIGHLAND CONTAIN OUTSTANDING NATURAL AREAS WITH CLOSE TO 56 FOREST RESERVES AND THE RECENT CREATION OF THE BAFING NATIONAL PARK. THE FOUTA DJALLON HIGHLAND PROVIDE A HOME FOR LARGE POPULATIONS OF CHIMPANZEES ACROSS WEST AFRICA, AS WELL AS OTHER IMPORTANT SPECIES. THEIR BIODIVERSITY IS VERY RICH BUT REMAINS FRAGILE.

PROTECTED AREAS

There are nearly 64 classified forests in the natural region of Central Guinea (map 40) which cover most of the Fouta Djallon highland. In the contours of the Fouta Djallon highland, there are 56 classified forests in the Guinea portion, 1 forest reserve in Sierra Leone (Kuru Hills) and a scientific interest zone for flora in the Mali extension of the topographical highland. In addition to these spaces, a national park was created in Middle Bafing on the Bafing slope between the sources of the Bafing until it exits into Guinea. The number of protected forests in Guinea is very limited and are found in Lower Guinea, Upper Guinea and Forest Guinea outside of the topographical Fouta Djallon. Their inventory has not been completed in full. In the Guinea extended areas, all ecosystems in the Guinea coastal river outlets and Guinea Bissau (mangroves) are recognised as "internationally important wetlands" and there is the Badiar national park to the north-west of Guinea on the border with Senegal and on the Gambia basin. We also note the presence of the Niokolo Koba National park in the south-east of Senegal, considered as a biosphere reserve and part of the UNESCO world heritage list, and a chimpanzee reserve in Mali, near Kéniéba, known as the Bafing chimpanzee sanctuary. Finally, in the eastern foothills of Fouta Djallon, there is the Upper Niger National Park made up of 2 sectors: Mafou for a surface area of 6470 km² and Kouya (6000 km²) with a rich and diverse biology known for birds (323 different species), insects and large mammals (monkeys, leopards, buffalo, cobs, etc...).

Bubal

FOUTA DJALLON FAUNA

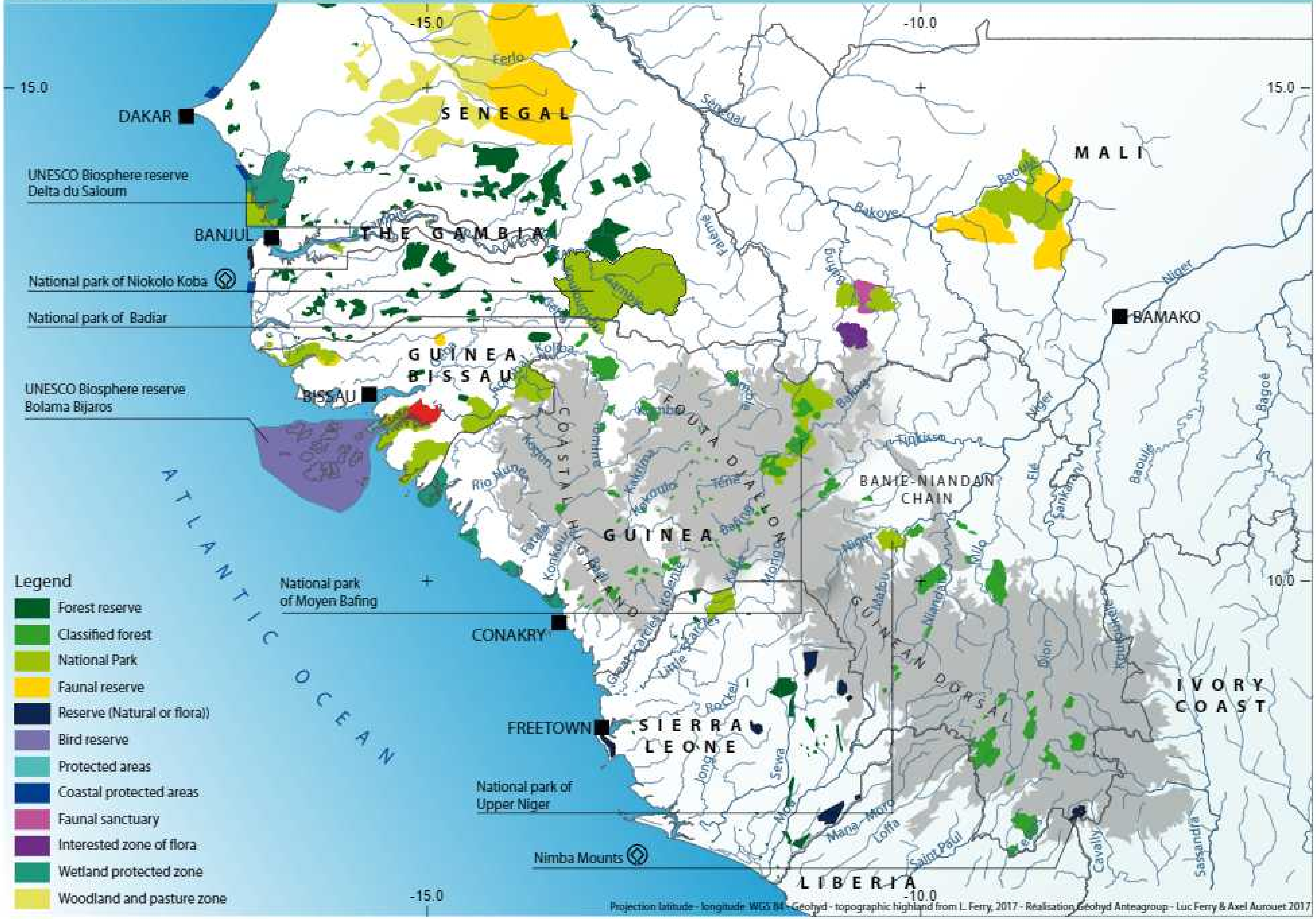
Inventories completed in the Fouta Djallon highland area and more generally in Central Guinea show the diverse fauna in this area. There are jackals, leopards, cows, hippopotamuses, monkeys, red colobus, baboons and chimpanzees. The Fouta Djallon chimpanzee populations are the largest in the sector of West Africa (nearly 17,700 individuals) with an increased number in the Middle Bafing national park (4,700 to over 5,500 individuals noted). The specific zone of the Middle Bafing national park is also a zone which is subject to various dam and mining projects (inactive for the moment) which require vigilance regarding preservation of these chimpanzee populations in this region.

THE MAIN THREATS TO ENVIRONMENTAL DAMAGE

Other than climate changes which can modify ecosystems and the habits of the animal populations which live there, the main threats to this natural heritage are agro-pastoral activities through soil damage, the introduction of improved varieties, destructive insects, cultural nomadism, brush fires which destroy the plant populations and fauna habitats, carbonation, hunting, fishing, forest exploitation, mining and industrial activities, major hydroelectric power facilities and urbanisation through reduced natural spaces in favour of artificial spaces. All those factors need to be controlled or anticipated to reduce damage to the natural areas of the Fouta Djallon.

Chimpanzee

Map 40 > Protected areas linked with Fouta Djallon highland and its extension zones



Projection latitude - longitude WGS 84 - Géohyd - topographic highland from L. Ferry, 2017 - Réalisation Géohyd Anteagroup - Luc Ferry & Axel Aurouet 2017

CLIMATE CHANGE AND ADAPTATION

IPCC MODELS WITH REGARD TO THE EVOLUTION OF PRECIPITATION AND TEMPERATURE IN THIS REGION VARY. HOWEVER, CLIMATE CHANGE SHOULD EXACERBATE RAINFALL AND WATER VARIABILITY IN THE FOUTA DJALLON HIGHLAND. ADAPTATION PROJECT INITIATIVES HAVE ALREADY BEEN SUGGESTED THROUGH THE NATIONAL ACTION PLAN ON CLIMATE CHANGE ADAPTATION IN GUINEA.

Whilst the issue of climate change is already well established in the concerns of managing and planning water resources, items allowing a structured and precise discussion are still partial, patchy and sometimes even contradictory. To date, in line with the very general GIEC guidelines, it seems to be noted that river hydraulicity is moving towards a decrease in the sub-region.

IPCC ANALYSIS ON THE SUB-REGION

Climate change has been studied by various scientific teams, whose work has been regularly discussed and published as part of the GIEC. Over the last century, the West Africa Sahel region has been dealing with decreased rainfall (map 41), linked to changes in atmospheric circulation and changes linked to the configuration of surface sea temperatures in the tropical regions of the Pacific, Indian and Atlantic basins. Significant periods of drought were experienced from the 1970s to the 1990s, after a rainy period during the 1950s and 1960s. The fall in rain was mostly linked to a reduction in the number of significant rainy periods during the monsoon peak period (July to September) and during the first rainy season to the south at around 9°N. The reduction in rainfall and devastating drought in the Sahel region during the last three decades of the 20th century were part of the most pronounced climate change, all regions included. In the Sahel, rain reached a minimum after the 1982/3 El Niño episode. Modelling studies suggest that Sahel rainfall was more influenced by climate change on a large scale (probably linked to changes in anthropogenic aerosols) than local land allocation changes. For the African continent, simulations carried out on climate change indicate (figure 41) a considerable variation from one model to the other. The strongest simulations highlight global warming and a fall in rainfall in North Africa and an increase in rainfall in East Africa. There is a wide range of projections for rainfall in Sub-Saharan Africa, with some models predicting falls and others increases. The planned trends must be considered in the context of this significant uncertainty even if all experts agreed on a decrease in rainfall depth.

Map 41 > moving of isohyets between 1951 - 1969 and 1970 - 1981 period From l'Hôte & Mahé (1995)

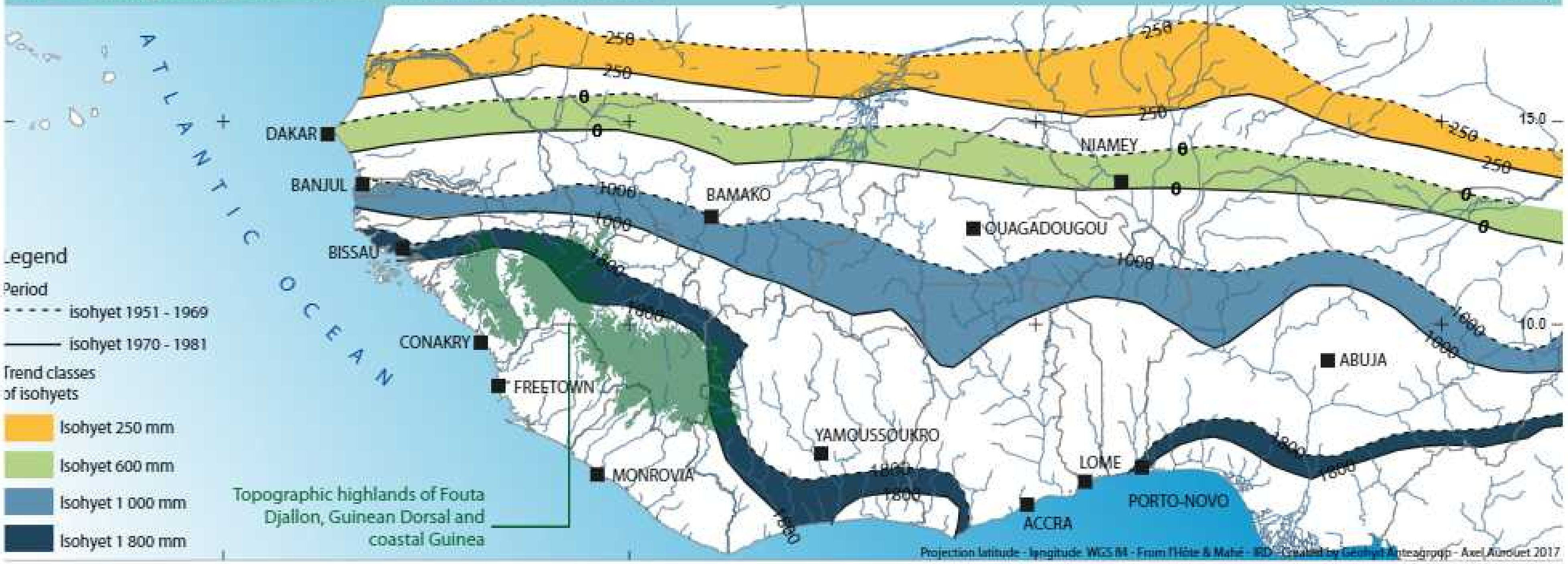
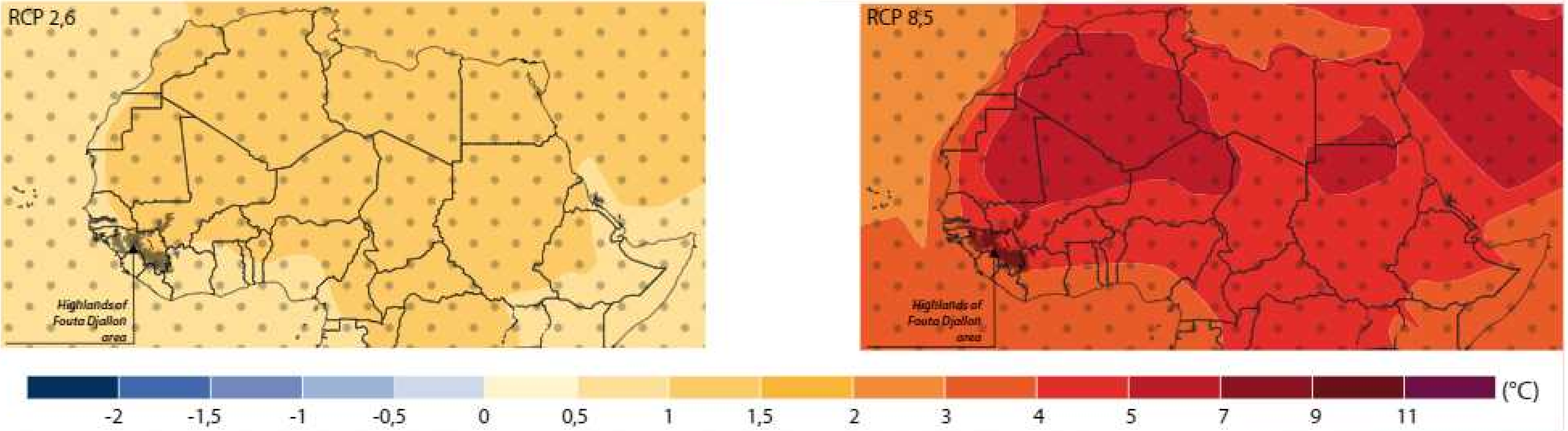
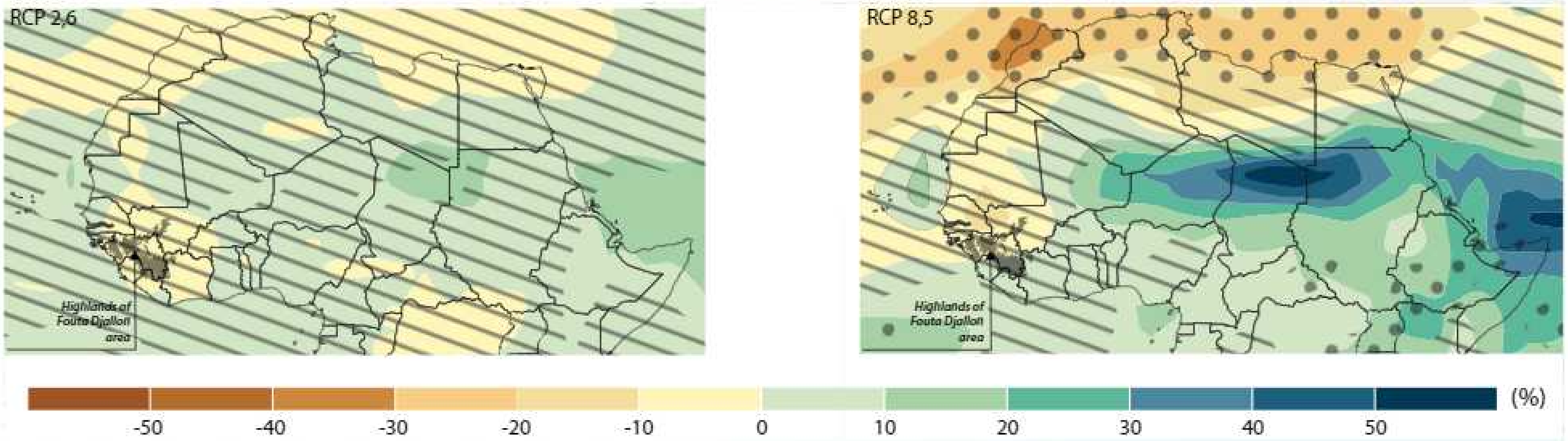


Figure 41 > Predicting Climate Change in Sub-Saharan Africa and North Africa by 2100 - IPCC 2013

EVOLUTION OF THE AVERAGE SURFACE TEMPERATURE (DIFFERENTIAL BETWEEN THE PERIOD 1986-2005 AND 2081-2100)



EVOLUTION OF THE RAINFALL (DIFFERENTIAL BETWEEN THE PERIOD 1986-2005 AND 2081-2100)



The maps represent the results of the CMIP5 multi-model averages for RCP2.6 (CO_2 emission – 421 ppm) and RCP8.5 (CO_2 emission – 936 ppm) over the period 2081-2100. For all maps, the dashed lines indicate the regions in which the multi-model average is large relative to the internal natural variability (meaning greater than two standard deviations over 20 years averages) and in which 90 % at least of models agree on the sign of change. In the rainfall trend maps, the lines represent the sectors for which averages were modeled for the period 1986-2005.

ANALYSIS PERFORMED IN THE FRAWORK OF NATIONAL ADAPTATION PLAN FOR CLIMATE CHANGE IN GUINEA

IDENTIFIED CLIMATE TREND FOR 2100

The flow of all transboundary rivers with a source in Fouta Djallon or Guinea are and will always be particularly sensitive to climate change in Guinea. The NAPA (National Adaptation Action Plan), developed in 2005, summarises the understanding and predicted consequences of climate change. The presented projections for 2100 in this document indicate (figure 41), a temperature increase between 0.5 °C and 4.8 °C in the part of Guinea north of the 10th parallel (Central Guinea - Fouta Djallon- and Upper Guinea). South of the 10th parallel (Maritime Guinea and Guinea Forest Region), projected temperature increases are set between 0.4 °C and 3.9 °C by 2100. With regard to rainfall, changes in the distribution and volume of precipitation are expected. In the natural region of Central Guinea, which is the region of the Fouta Djallon highland, the reduction in rainfall would be between -2.8% and -26% by 2100. This reduction in rainfall would be between -4.3% and -40% in Upper Guinea, between -1.5% and -15% in Maritime Guinea, and between -1.8% and -17.3% in the Guinea Forest Region. From a global perspective, the regions located to the northwest and to the northeast of Guinea (above the 10th parallel) will experience a 31% decrease in rainfall compared to the current average, starting in 2050. This decrease could continue, to eventually reach a maximum of 40% by 2100. The regions located south of the 10th parallel north should show a deficit of 7.4% in 2050, to reach a maximum of 15% in 2100.

RISKS AND CONSEQUENCES RELATED TO CLIMATE CHANGE

The main risks associated with the Fouta Djallon highland and identified as part of the project are drought, strong sun exposure (particularly in the regions of Koundara and Gaoual and in the plains of Upper Guinea towards Dinguiraye and Siguiri), the risk of flooding in the prefecture of Gaoual, the effect on rainfall and increased intensity of stormy rainfall encouraging poor infiltration and rapid discharge of water. These effects are expected to be felt over all Guinea with, in addition, a risk of surface temperature increase at sea level for Maritime Guinea. These risks are expected to have multiple consequences, which touch upon all aspects related to water and all socio-economic aspects. Among the most emblematic consequences, we will specifically note rivers and ponds drying up (major resources in the Fouta Djallon), prolonged low-water periods for large rivers, social conflicts related to water shortages, declining soil yield and reduced crop yield, surge of bush fires, silting up of river beds, losses of crops and livestock, infrastructure destruction related to floods or even landslides due to sudden and violent rain.

VULNERABILITY OF THE RESOURCE AND OF SOCIO-ECONOMIC GROUPS

From the perspective of water resources related to the Fouta Djallon highland, existing projections place the flow rate loss in the Konkouré river at the Télimélé station at 30% and, in the most worst case scenario, at 54% by 2100. These trends in river flows are generally expected for Guinea with flow reduction percentages that could reach 72% north of the 10th parallel (case of the Milo River in Kankan). Farmers are the most vulnerable socio-economic group in Central Guinea and the Fouta Djallon. Then come the gardeners and planters, whereas the quarry operators, merchants/transporters, small ruminant pastoralists and poultry farmers rank among the least vulnerable. The drought remains the phenomenon which will most impact socio-economic groups in Central Guinea and in the Fouta Djallon. Next come high insolation, rainfall disruption, thunderstorm activity and floods.

ADAPTATION OPTIONS FOR CLIMATE CHANGE SUGGESTED BY THE NAPA

According to the Poverty Reduction Strategy Paper in Guinea, poverty is more pronounced in rural areas where most of the populations live and carry out activities that provide them with most of their means of subsistence. Several adaptation options are suggested by the NAPA according to natural region, resource, and socio-economic group. Similarities with some regional options and greater relevance for some of these options (ability to ensure adaptation, coherence with strategic plans, or even local conditions for execution) have helped to select ten main options (Table 7). Based on these options, twenty-five project profiles organized according to climate vulnerability and areas of poverty have been suggested within the framework of the NAPA (Table 7). If part of the project profiles more specifically concerns the coastal area (initiation of populations to oyster farming techniques, the protection of seaside crop areas or even the production of spawning grounds in estuaries), other project profiles more specifically concern the Fouta Djallon highland. This is true in particular for project profiles based on anti-erosion practices, the promotion of wire fences and living hedges, the popularization of impluvia (rainwater collection technique for domestic use) or even the support for the development of community plantation.

women carrying water

Table 7 > Climate change mitigation options et project profiles in Guinea and Fouta Djallon highland (NAPA)

OPTION	PROJECT PROFILES IDENTIFIED BY THE NAPA IN GUINEA	BUSINESS SECTOR CONCERNED	CONCERNS THE FOUTA DJALLON
Promotion of agroforestry	1. Support for the development of community and private cashew plantations	Forestry	YES
	2. Support to the implementation of management plans for community forests	Forestry	NO
Use of positive endogenous knowledge and practices	1. Use of positive endogenous knowledge and practices	Cross-sectoral	YES
Promotion of appropriate technologies in terms of adaptation	1. Initiation of coastal populations to mangrove oyster farming techniques	Coastal area	NO
	2. Promotion of solar energy use to extract sea salt	Coastal area	NO
	3. Popularization of anti-erosion structures for soil protection	Agriculture/Livestock farming	YES
	4. Intensification of bulrush millet cultivation in the northern part of Guinea	Agriculture/Livestock farming	YES
	5. Development of an early warning system for securing agricultural productivity	Agriculture/Livestock farming	YES
	6. Promotion of solar-powered fish dryers to reduce pressure on the mangrove	Forestry	NO
	7. Promotion of compressed earth blocks (CEB) to reduce the environmental impacts of fired bricks	Forestry	YES
	8. Promotion of wire fences and living hedges in Central Guinea	Forestry	YES
Promotion of fire management and deferred grazing	1. Promotion of fire management and deferred grazing	Forestry	YES
Protection and restoration of fragile ecosystems	1. Protection of seaside crop areas	Coastal area	NO
Information, education and communication	1. Dissemination of MEAs and national legal texts pertaining to the protection and sustainable use of natural resources	Cross-sectoral	NO
	2. Promotion of environmental education for coastal communities	Cross-sectoral	NO
Promotion of the development and integrated management of small hydraulic structures	1. Creation of micro-dams with multiple purposes	Water resources	YES
	2. Creation of hillside impoundments	Water resources	YES
	3. Creation of improved wells	Water resources	YES
	4. Surface water purification using Hydropur	Water resources	NO
	5. Popularization of impluvia	Water resources	YES
Protection of spawning grounds	1. Protection of spawning grounds in the Fatala, Konkouré and Méllacoré estuaries	Coastal area	NO
Hydro-agricultural development of plains and lowlands	1. Development of irrigated rice-growing in Central and Upper Guinea	Agriculture/Livestock farming	YES
Promotion of income-generating activities	1. Promotion of small ruminant pastoralism	Agriculture/Livestock farming	YES
	2. Promotion of vegetable crops	Agriculture/Livestock farming	YES
	3. Creation of grasscutter ranches to reduce bush fires and improve the living conditions of rural populations	Agriculture/Livestock farming	NO

CONFLICTS LINKED TO WATER (From NIASSE & BARRY)

WATER-RELATED CONFLICTS ARE ESSENTIALLY LOCAL IN THE FOUTA DJALLON HIGHLAND, AND THEY ARE LINKED TO DIFFICULT ACCESS TO SAFE WATER AS WELL AS TO DISPLACEMENT DURING THE CONSTRUCTION OF HYDRAULIC STRUCTURES. THERE ARE NO INTERNATIONAL CONFLICTS STEMMING FROM WATER COMING OUT OF THE FOUTA DJALLON HIGHLAND.

When dealing with water-related conflicts and the transboundary aspect, there is no real summary of water-related conflicts in Guinea and even less for the Fouta Djallon highland. In addition, a conflict only arises when a claim leads to a dispute. Before this moment, there is only the risk of conflict. A university study by the establishment 2iE (Barry, 2011) attempts to create a map of water-related conflicts or rather types of conflicts which exist, have existed or which could exist in Guinea. Whilst these conflicts could be major and lead to negotiations at a national level, most of conflicts arise at a much more local level, without being any less damaging for the affected populations.

OVERVIEW OF LOCAL AND INTERNAL CONFLICTS TO GUINEA

At the first level of local conflicts, hydroelectric power facilities have a significant position, notably when moving and then rehousing local communities where the sites can have significant cultural importance. It seems that the populations displaced during the construction of the Garafiri facility did not benefit from a satisfactory relocation. There are also conflicts between urban and rural populations when it involves waiting for a minimum quantity of water from a well. Generally these populations are women and vulnerable children and poor organisation or frustration can sometimes cause violent altercations. Conflicts between farmers and livestock breeders are also noted in Guinea, especially those sharing the same resource (rivers and shorelines) used for market gardening in the low levels and watering. Destruction of crops on the one hand and a lack of clear marking-out of the grazing area on the other cause tension which can end in violence. Barry mentions that for this type of conflict, and in certain Fouta Djallon regions, a prior discussion is held between those involved in order to jointly define the crop and grazing areas. There are sometimes conflicts linked to water billing between users and water management companies. Faced with the scarcity, distance travelled to get the water or fluctuations in the water supply, tensions can arise regarding the amount to be paid and disputes which can sometimes turn violent. Finally, water pollution linked to industrial activities, notably mining-related, are also sources of tension between the public and operators, with the former criticising the latter for not putting into place resources to limit pollution which affects other activities and the health of local populations. This overview of local conflicts in Guinea reflects local conflicts observed in West Africa in general. These conflicts arise when the resource is difficult for the population to access, when facilities damage cultural or historic practices or when arbitration is not clearly established for sharing access to water resources.


Watering livestock in river


Cultures with fence in the Fouta Djallon highland

COMMON FEATURES OF WATER TRANSBOUNDARY CONFLICTS IN WEST AFRICA

In addition to local conflicts, there are also transboundary conflicts. In its work to prevent conflicts and on cooperation in managing West African transboundary river water, Niassa lists the risks of transboundary conflicts which have existed (Senegal and Mauritania in 1988 - next chapter; Ghana and Burkina Faso in 1998, Benin and Niger since the 1960s; Nigeria and Niger in 2002, Cameroon and Nigeria between 1980 and 2002) and makes general observations on the risks of conflict. Therefore, many are linked to the modification of flow regimes caused by hydroelectric power facilities. On the one hand, Niassa notes that the construction of water control facilities pushes local governments to "mark their territory" by trying to control the largest possible portion of the land in question. Therefore it notes that the lack of control by populations of new challenges caused by major hydro-agricultural facilities leads the latter to maintain their traditional practices (migration or agriculture) when there is a deep upset in progress (reducing the flows of certain periods and increase of others, scarcity on one side and opulence on the other...). Finally, the impacts experienced or expected from dams are also sources of tension between local communities (notably downstream from the facilities) which can be alarmed very early on due to a fall in flow or a change in water quality when the facility is not yet constructed. Nevertheless, in West Africa there is no major transboundary conflict directly linked to water (Niassa 2014). For the Fouta Djallon, despite Guinea's distancing from transboundary institutions, and even though tensions have been felt, no conflict has arisen between Guinea and its neighbours. Since 2006, Guinea joined the OMVS and OMVG and large-scale development projects (Kokoutamba, Fomi, Kaléta dams, etc.) which are beneficial for Guinea and the sub-region which are starting to operate in a collaborative environment where water leads to cooperation rather than conflict.

TRANSBOUNDARY BASIN ORGANISATIONS AS MODERATORS OF REGIONAL WATER CONFLICTS?

Cooperation within a transboundary basin organisation (CBO) does not exclude conflicts between countries. In the Senegal basin, between 1987 and 1989, the construction of the Manantali facility deepened social inequalities by not totally responding to commitments made. The priority given to hydroelectric power production over flood recession cultivation and irrigated cultivation has notably created a land open to tension by making households unable to cultivate their land, causing a wave of emigration and proletarianization in the valley. The gap is therefore deepened between disadvantaged farmers and those who, with resources, were able to benefit from the facility. In this vein, tensions and quarrels between opposing Senegalese farmers and Mauritanian shepherds rose and caused a diplomatic freeze between Senegal and Mauritania for three years. During this period when Senegal and Mauritania would only speak through intermediaries, the OMVS continued to operate, acting as a communication agent between both countries, and it played the same role in progressively easing tensions between the country (Alam et al., 2009: 94 ; Green Cross, 2000 : 57 ; Niasse, 2004 : 7). Other tensions have arisen between Senegal and Mauritania, especially on the project to revitalise fossil valleys and each time the OMVS has acted as an "arbitrator". It should be noted that this area of conflict prevention is a key part of CBO concerns which, like the ABN and OMVS, have procedures in place regarding the settlement of international water-related disputes. Niasse notably suggests reinforcing this function of "regulation, prevention and management of conflicts by transboundary basin organisations" by implementing information sharing systems, implementing a code of conduct between member states (foundation in water charters) or even the development of a ECOWAS regional directive on shared water management.


Laundry in river

ABN - "Any dispute arising between member states in the interpretation or application of this agreement is governed amicably through direct negotiations. Failing that, the dispute is taken by one of the parties to the Summit (of Heads of State and Government) who rule as a last resort. " Source: Reviewed convention creating the Niger Basin Authority (Faranah, October 1987), article 20.

OMVS - "If there is no deal between the countries, any dispute which arises between them regarding the interpretation or application of this convention will be resolved through conciliation or mediation. If there is no agreement, the contractor countries must submit to the Organisation of African Unity's arbitration and conciliation committee. As a last resort, they will submit it to the International Court of Justice in the Hague". Source: Convention relating to the Senegal river status (11 March 1972), article 18.

THE FOUTA DJALLON HIGHLAND'S GOUVERNANCE

THE RPID-FDH ORIGINATED IN THE 1980S TO FIGHT AGAINST DROUGHT AND DESERTIFICATION. FOLLOWING LOCAL ACTIONS ON PILOT SITES, IT HAS EXPANDED ITS EFFORTS THROUGH THE CREATION OF NATIONAL PARKS AND FOREST RESERVES IN GUINEA AND ITS BORDER AREAS. THE FOUTA DJALLON HIGHLAND LIE AT THE CROSSROADS BETWEEN THREE TRANSBOUNDARY BASIN ORGANIZATIONS AND ECOWAS-WRCC PROMOTES COORDINATION FOR A REAL INTEGRATED MANAGEMENT OF WATER RESOURCES WITHIN THE FOUTA DJALLON HIGHLAND AND THE ONES ORIGINATING IN THEM.

THE FOUTA DJALLON HIGHLAND REGIONAL INTEGRATED DEVELOPMENT PROGRAMM

HISTORY AND OPERATING ENVIRONMENT

The international community recognized the need for a regional approach to the integrated development of the FDH during the International Conference on Soil, held in Dalaba (Guinea) in 1959. However, it is only in the beginning of the 1970s, in the aftermath of the Sahel drought, that, during the thirty-third sessions of the Council of Ministers of the Organization of African Unity (OAU), held in Monrovia (Liberia), the decision was made to carry out a concerted action under the aegis of the OAU. The OAU, in partnership with UNEP, FAO, UNESCO and UNSO, has therefore implemented the Regional Program for the Integrated Development of the Fouta Djallon highland (RPID-FDH) at the beginning of the 1990s. The RPID-FDH concerns eight countries dependent upon the waters of the Highlands: The Gambia, Guinea, Guinea Bissau, Mali, Mauritania, Niger, Senegal and Sierra Leone. Longtime observers, Benin and Nigeria, riparian countries of the Niger River, are about to become full members of the bodies of the RPID-FDH. The objective of the RPID-FDH is «to ensure the protection and rational use of natural resources in the FDH in order to contribute to the improvement of living standards for the population of the highland». It is implemented by the AU Commission, through the Office for International Coordination of the African Union (OIC-AU). The influences of the RPID-FDH project have been divided into two sectors. A project sector focused on Guinea and a wider sector which integrates the 7 other countries (Map 47).

The fundamental components of the RPID-FDH are:

- Sub-regional cooperation
- Sustainable management of natural resources and improvement of living conditions
- Adaptation and mitigation of risks related to climate change
- Coordination of regional and national efforts and capacity building

The institutional framework of the RPID-FDH consists of decision- and policy-making bodies, advisory and monitoring-evaluation bodies, and implementing bodies.

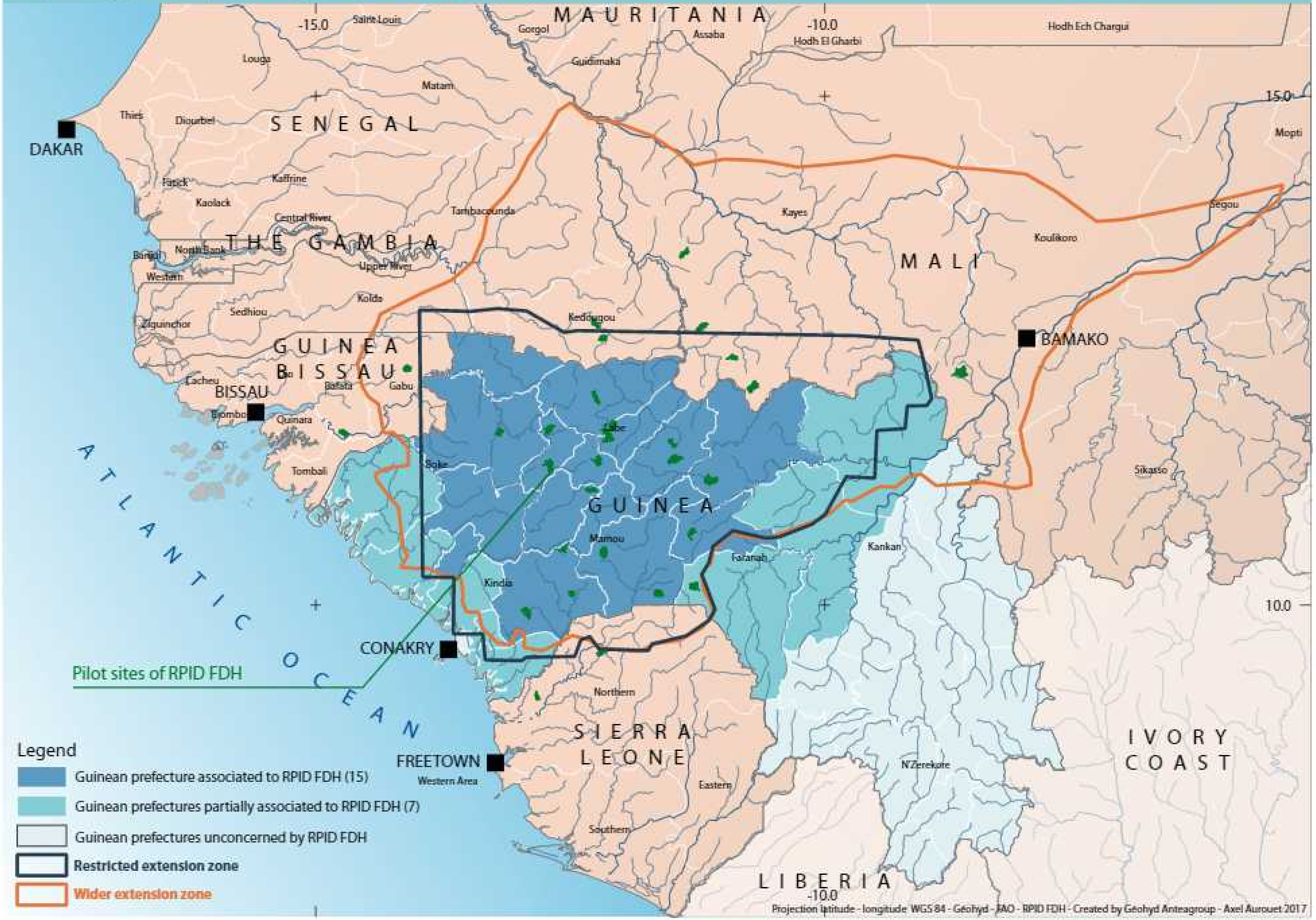
- The decision- and policy-making bodies are: (I) the Summit of Heads of State and Government; (II) the Ministerial Conference.
- The advisory and monitoring-evaluation bodies are: (I) the Regional Advisory Committee; (II) the Scientific and Technical Committee.
- The implementing bodies are: (I) the Office for International Coordination; (II) the National Coordination and Monitoring Bodies.

It must be emphasized that Summit of Heads of State and Government of the RPID-FDH has never met to date, and that the Scientific and Technical Committee is not operational as yet. Among the achievements of the RPID-FDH, the following can be specifically noted:

- The production of numerous studies on the FDH;
- A variety of activities on pilot sites;
- The development and signature of the Framework Convention of cooperation between the riparian States of the rivers originating in the Fouta Djallon highland by the 5thMinisterial Conference of the RPID-FDH, held in Freetown (Sierra Leone) in November 2011;
- The ratification by several Member States of said Framework Convention;
- The initiation of documents available for the Observatory, along with an action plan for the Observatory;
- Monitoring and management indicators;
- A data collection network;
- The construction of premises for the Observatory at the OIC-AU;
- The development of the draft document for the Cooperation Convention with Basin Organizations;
- The INRM (integrated natural resources management) project of the FDH

Panel of RPID FDH in a pilot site

Map 42 > Geographical shape of Fouta Djallon highland RPID project and location of pilot sites



VARIABLES ACTIONS DURING TIME

The first step (1981-1987) involved implementing infrastructures and working structures including the Fouta Djallon highland Integrated Development and Restoration Service (FDH/IDRS) and, on the other hand, establishing a diagnosis on the causes of the deterioration of natural resources, identification of 12 river basins followed by the development of an intervention strategy to regularise the shared river regime and improve living conditions for local communities. The second step (1988-1998) involved implementing experimental projects through the so-called "Pilot Representative Basin (BRP)" basin development approach (Map 4). The main activities carried out on these pilot sites are :


View on a RPID FDH pilot site

- The technical supervision of groups for gardening and compost techniques, and support for equipment and seeds in Guelin;
- Introduction of a rice huller;
- Training of group leaders in sound governance and community life;
- Planting of forest trees and fruit trees in 2012, 2013 and 2014 over an 8 ha surface area in Guelin;
- Equipment support for the private nurseryman of the pilot site;
- Allocation of firefighting equipment for the firefighting committee;
- Development of 6.52 ha of lowlands with a submersion irrigation system and a 26.94 ha barbed wire fence and slopes landscaped with vetiver plants and deferred grazing;
- Planting of a living hedge in Guelin;
- Delivery of oxen, harrows and plows to the Tolo center and to Guelin, and training in animal traction;
- An experience sharing trip with farmers who are leaders in livestock farming, gardening and forestry;
- Awareness-raising for the stakeholders and partners with regard to fighting bush fires;
- Planting of 170 fruit trees in 2014;
- Installing 2 information panels for the pilot site.

Success in these activities has taken the form, inter alia, of reduced conflicts between farmers and livestock breeders with the use of fences, the progressive phasing-out of mountain slopes to start work in developed lowlands - thus limiting logging - agricultural production not limited to the rainy season, reduced numbers of bush fires due to awareness-raising and firefighting equipment provided, improvement of revenue, or even areas opening up due to the development of lowlands. Nonetheless, the activities carried out do not yet affect all pilot sites, and these activities should be continued and expanded in the future.

The regional programme was extended to create and manage two national parks (the Badiar Park in Central Guinea and Mafou park in Upper Guinea -map 40) and two transboundary protected areas (Guinea - Guinea Bissau and Guinea - Mali). An assessment of these projects, carried out in 1998, highlighted a good number of positive results but also noted weaknesses, the lack of relevant indicators for monitoring, assessment and analysis of the impact and lack of an appropriate framework between the different parties involved.

INITIATIVE TO TRANSFER THE RESPONSIBILITY OF THE RPID-FDH FROM THE AFRICAN UNION TO ECOWAS

The principle of ultimately transferring the responsibility for the program to ECOWAS was enshrined from the onset in the conceptual logic of the RPID-FDH. It is based on the principle of subsidiarity, which is one of the action principles of both the AU and ECOWAS. Thus, based on the fact that the Fouta Djallon highland, which is entirely located in West Africa, is first and foremost a heritage landmark of this region, the 73rd Ordinary Session of the OAU Council of Ministers approved «the principle of a transfer of responsibility» for the RPID-FDH to ECOWAS and therefore committed the OAU's General Secretariat to carry out consultations with the Executive Secretariat of ECOWAS in order to set its modalities (Decision CM/DEC LXXXIII).

And it is by referring to this decision, later confirmed by the 3rd Ordinary Session of the Council of Ministers of the African Union (AU) held in July 2003 in Maputo (Mozambique), that the AU's Commissioner for Rural Economy and Agriculture requested the ECOWAS Commission's Chairman to implement the decision above, in an official letter dated April 16, 2013. A process to transfer responsibility for the RPID-FDH from the AU to ECOWAS, started in 2014, is currently at an advanced stage. The adopted roadmap revolves around key activities:

- To formalize transfer of the program's responsibility from the AU to ECOWAS;
- To develop a Five-Year Investment Plan (FYIP) for the Fouta Djallon highland;
- To organize an information and advocacy campaign to preserve and sustainably manage the Fouta Djallon highland.

In parallel with the responsibility transfer process for the RPID-FDH, ECOWAS, through its Water Resources Coordination Center (WRCC), is currently conducting operational activities in the field. These activities essentially focus on the development of this water atlas, thus aiming to widely share knowledge on the Fouta Djallon, and on the implementation of a partnership platform between Basin Organizations and ECOWAS to preserve and sustainably manage the Fouta Djallon highland.

Map43 > Countries and transboundary basin organization of ECOWAS region

WATER GOVERNANCE IN THE FOUTA DJALLON AND ITS EXTENDED AREAS

INTEGRATED WATER RESOURCES MANAGEMENT FRAMEWORK

By adopting the "Ouagadougou Declaration" in March 1998, the West African countries are firmly committed to a national process to transition towards integrated water resources management (IWRM). Working on the transition towards the IWRM involves moving from sector-based water management - with the inherent faults linked to this type of management - to integrated management based on the principles adopted during the water and development conference in Dublin, January 1992 (figure 42).

bodies for the participation of users, each according to their own legislation. The following are also involved in the FDH:

- For the NBA, the «National Coordination» for Guinea and the local bodies of the GIRENS program (Integrated Water Resources Management for Upper Niger);
- For the OMVG, the «National Monitoring Committee» and the «Local Coordination and Monitoring Committees»; and
- For the OMVS, the «Local Coordination Committees» of Mamou, Tougué, Mali and Siguiri.

The TBOs of the Highlands have been particularly active in the protection/restoration of the heads of the sources of their respective basins, involving local populations in the process.

ECOWAS-WRCC regularly presents the IWRM situation and progress in member countries. This exercise took place in 2003, 2005, 2007 and 2012. The tables below present the latest known situation in December 2012. The table 9 deals with the three key fields: politics, legal and institutional. The table 8 presents the progress of planning instruments: IWRM road maps and IWRM action plans.

«TRADITIONAL» WATER RESOURCES MANAGEMENT

- Sectoral
- Not taking the environment into account
- Technocratic
- Male-dominated
- Centralized
- Opaque
- Source of conflict
- Supply-based
- By administrative entities

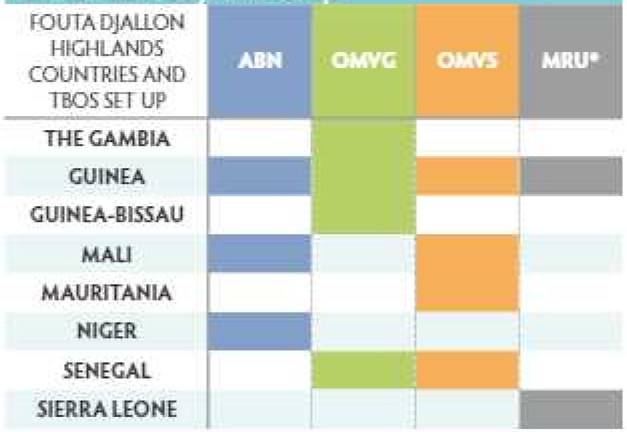
IWRM TRANSITION PROCESS →

«INTEGRATED» WATER RESOURCES MANAGEMENT

- Trans-sectoral
- Taking environmental imperatives into account
- Participatory
- Mindful of «gender» aspects
- Decentralized
- Obligation to provide information
- Consensual
- Demand-driven
- By bodies of water (basins, aquifers, lakes)

Figure 42 > Transition process to IWRM according to Dublin Conference on Water and Development 1992

Figure 43 > The countries of the Fouta Djallon highland and the TBO they have set up



* The Mano River Union is a political organisation for development that develop the setting up of an integrated water resources management framework along the international river, Mano-morro.

In the Fouta Djallon highland, water resource management is the responsibility of the eight tributary countries affected by national issues, and the CBO transboundary basin organisations regarding international issues (map 43 and figure 43). Local communities in the Republic of Guinea (urban communities and developing rural communities), located in all or a part of the FDH, are governed by the Local Government Code of 2006. According to this Code (still in force until the promulgation of the Revised Code adopted by the National Assembly in February 2017), municipalities are competent in terms of the «management of water and water points». They can set up and manage any public service within their areas of competence on their territory. Local public services include, in particular, «the distribution of drinking water». In addition to this system, through its water resource coordination centre (WRCC), the ECOWAS promotes and coordinates the transition to the IWRM. Mauritania left ECOWAS in 2000 but plans to rejoin.

The OMVS adopted its Water Charter in 2002 and the NBA adopted its Water Charter in 2008. The three TBOs of the Fouta Djallon highland (NBA, OMVG, OMVS) have implemented national

Table 8 > Planning tools situation and their state of implementation at end of 2012

COUNTRY	PHASE 1	PHASE 2 PLANNING		PHASE 3 IMPLEMENTATION IMPLEMENTATION OF THE ACTION PLAN
		ROADMAP	IWRM ACTION PLAN	
THE GAMBIA	Completed	Completed 2009	To be initiated	n.a.
GUINEA	Completed	Completed 2011	To be initiated	n.a.
GUINEA-BISSAU	Completed	Completed 2009	To be initiated	n.a.
MAURITANIA	Was not part of the 2012 survey			
MALI	Completed	n.a.	Completed 2008	In progress
NIGER	Completed	n.a.	Startup planned for 2013	n.a.
SENEGAL	Completed	Completed	Completed 2007	In progress
SIERRA LEONE	Completed	Completed	To be initiated	n.a.
ECOWAS REGION	Completed	n.a.	Completed 2000	In progress

Countries having benefited from support: From the ACP-EU / UNEP project to support IWRM; From the ACDI-GWP project to support IWRM

Table 9 > State of the water management framework at end of 2012

COUNTRY	POLITICAL		LEGAL											INSTITUTIONAL				
	Is there a national water policy document?	Is this document based on IWRM principles?	What is the legal status of water?	Is there a Code, or specific laws, related to water?	If so, does implementation regulation exist?	Participation of stakeholders in management?	Management by river basin?	Application of the subsidiarity principle?	Application of the "User Pays" principle (UPP)?	Application of the "Polluter Pays" principle (PPP)?	Is there a particular role for women planned?	Is the private sector involved with water management?	Is the national legal framework harmonized with international agreements?	Is there a cross-sectorial executive body responsible for IWRM?	Is there an inter-ministerial coordination body?	Is there a national advisory authority?	Are there basin management bodies?	Is there a National or a Regional Water Partnership?
THE GAMBIA	2007	◆	C	1979	o	◆	◆	◆	◆	◆	◆	◆	o	◆	◆	◆	n.a.	2011
GUINEA	➔	◆	S	1994	o	◆	◆	➔	➔	➔	X	X	o	◆	X	◆	◆3	2006
GUINEA-BISSAU	1992	o	S	➔	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	X	◆	◆	➔	2011
MALI	2006	◆	S	2002	o	◆	◆	◆	◆	o	◆	◆	o	◆	◆	◆	◆2	2003
NIGER	2000	◆	V	2010	o	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	7*	2006
SENEGAL	2005	o	S	1981	o	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆1	2002
SIERRA LEONE	2010	◆	V	1961 2004	o	◆	o	X	X	X	o	X	o	◆	◆	➔	F	2012
CEDEAO (régional)	2008	◆	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	◆	◆	◆	◆5	2002

Table legend:
◆ Yes / exists (2000: exists since the date indicated)
o Partly exists
➔ Currently being drafted or created
F Expected in the future
X No or does not exist
n.a. = not applicable

Status of water
C: common property
S: property of the State
P: private property
V: variable status as the case may be

Note
* In Niger, geographically delineated water management units (WMU) have been set up, but they are not strictly speaking basin organizations.

SUMMARY OF THE ISSUES

Climate change and its consequences are a major issue for the Fouta Djallon highland. The water resources' marked dependence upon rainfall exacerbates the variable character of the waterways' flow rates. The effects of the worsening of climatic conditions (prolonged drought) of the 1970s are still very present in the minds, and rainfall levels of the past 20 years have not caught up with those observed from the beginning to the middle of the 20th century. The IPCC's rainfall forecasts vary according to the predictive models selected and do not allow for the identification of converging trends for West Africa: some predict more rains, others less. However, as indicated in the National Action Plan on climate change adaptation in Guinea, warming is likely certain, and it will be between 0.3 and 2.2 °C. This holds true also for the modification in rainfall distribution and its unpredictability. For this reason, several adaptation projects are identified in the area of the Fouta Djallon highland, the most emblematic of which for water resources and agriculture concerns are the drilling of improved wells, the popularization of impluvia, the popularization of anti-erosion practices, the development of early warning systems for securing agricultural production or even the promotion of positive endogenous practices.

Water can be a source of conflict on a local or an international scale. With regard to the Fouta Djallon, which is the origin of many transboundary rivers, the conflicts identified are more local in nature. These are most often the result of population displacement caused by large hydraulic structures or even by poor access to safe drinking water. There are no identified conflicts on an international scale related to the water resources of the Fouta Djallon. By promoting cooperation and the exchange of information, the various basin organizations concerned by the Highlands play an important role in their prevention. It is also important to note that Guinea is part of the ECOWAS Directive on the development of hydraulic infrastructure in West Africa, adopted in June 2017 in Monrovia, Sierra Leone. This directive contains recommendations which tend to maximize the advantages of the structures, and to anticipate in order to minimize the negative impacts of large dams.

In general, the Fouta Djallon highland is a strategic space, the significance of which has long been identified. The Regional Program for the Integrated Development of the Fouta Djallon highland (RPID-FDH) was a 1981 initiative from the Organization of African Unity related to desertification and drought issues. Currently, actions to fight against bush fires, to limit land clearing or to develop land are carried out on pilot sites and the Program has been extended to create 2 national parks in Guinea and 2 protected areas.

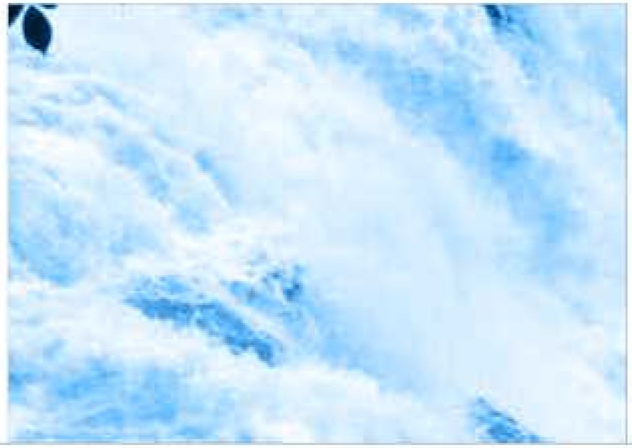
Lastly, the Fouta Djallon is a space that is rich in biodiversity, and fauna includes leopards, monkeys, hippos, baboons and chimpanzees. Chimpanzee populations are among the largest in West Africa (17,700 individuals). The Fouta Djallon harbors almost 64 forest reserves and it has recently seen the creation of the Bafing National Park between its source and its outlet from Guinea. However, this great resource remains fragile in the face of human activities and climate challenges. This is why a rich biodiversity is a factor taken into account for all development reflections and projects.

Fonio field in Guinea

CONCLUSIONS OF THE ATLAS

The water atlas for the Fouta Djallon highland highlights the plurality of the Highlands' definitions in the literature dedicated to them. The definition of the Fouta Djallon highland provided in this atlas must be understood in the light of the definition of other neighboring highlands, especially the Guinean Highlands and the coastal Guinea mountains which also play a significant role in the dynamics of water resources in this area and in the West African sub-region. One of the added singular values of the atlas is that it makes it possible to grasp the segmentation of watersheds and the highlands to which they belong.

This atlas highlights the abundance of surface water resources in the Fouta Djallon highland to the detriment of groundwater resources. The latter, very localized and not generalized throughout the Highlands, are dwindling fast and cannot provide a lasting resource during the entire year. Thus, waterways constitute a considerable resource, but one that remains fragile in the face of climate-related drought or rainfall deficit. It seems essential to continue the effort to acquire hydro-morphological knowledge in order to better plan and manage water resources, in addition to the actions led on a wider scale in the main West African watersheds concerned by the Highlands: Gambia, Senegal and Niger. Improving knowledge is a challenge, especially due to the difficulty to acquire basic information related to waterways and to sustain the process using the appropriate digital tools. This challenge must be met while fully aware of the situation in the countries concerned.



This document also features the main socio-economic activities in the Fouta Djallon and its extensions. Despite a diversified agricultural sector and significant mining resources, the area of the Fouta Djallon highland is dominated by hydroelectric development. The multiplicity of recent or planned projects (Kaléta structure with an interconnection with Sambangalou, Souapiti structure, Félou structure, Gouina, etc.) confirms the significant hydroelectric potential offered by the highland. The positive socio-economic consequences expected of these projects are real. Nevertheless, vigilance is called for to limit and mitigate the sometimes negative consequences of these works on hydrological regimes, habitats, biodiversity or the quality of water.

Although quite an exhaustive overview of the situation of the Fouta Djallon has been provided throughout these pages, there remains themes and topics which, because of the lack of literature or sufficient knowledge, have not been addressed thoroughly. This is particularly true for erosion issues in the Fouta Djallon highland, water quality, floods or even the evolution of forest cover in the highland. There is currently no institution in charge of compiling and centralizing all information pertaining to the Fouta Djallon highland and the information acquisition networks (hydro-climatic, water quality, piezometry, etc.) are scattered among several institutions. These deficiencies and the fragmentation of information demonstrate the benefit provided by an «observatory» type of information system based on strengthening all information production lines, training the people concerned who are the links in this chain, and translating the whole into indicators that shed light on the issues.

The water atlas represents an initial knowledge base concerning these Highlands which are important for the sub-region. The many upcoming issues and challenges, whether they arise from climate, agriculture or demographics, are an invitation to continue this work with the objective to reach a balanced and sustainable management of water resources and natural spaces.

ICONOGRAPHY

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GLOSSARY

AU	African Union
ECOWAS	Economic Community of West African States
FAO	Food and Agriculture Organization
FDH	Fouta Djallon Highland
GLC	Global Land Cover
IPCC	Intergovernmental Panel on Climate Change
IRD	French Research Institute for Development
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resource Management
LCBC	Lake Chad Basin committee
MBA	Mono Basin Authority
MRU	Mano River Union
NBA	Niger Basin Authority
NAPA	National Action Plan for Adaptation
OAU	Organization of African Unity
OECD	Organization for Economic Co-operation and Development
OMVG	Organization for the Development of Gambia River
OMVS	Organization for the Development of Senegal River
PET	Potential evapotranspiration
RET	Real evapotranspiration
RPID-FDG	Regional Program for the integrated Development of the Fouta Djallon Highlands
TBO	Transboundary Basin Organization
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
VBA	Volta Basin Authority
WHO	World Health Organization
WRCC	Water Resource Coordination Center of ECOWAS
WWF	World Wide Fund for nature

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