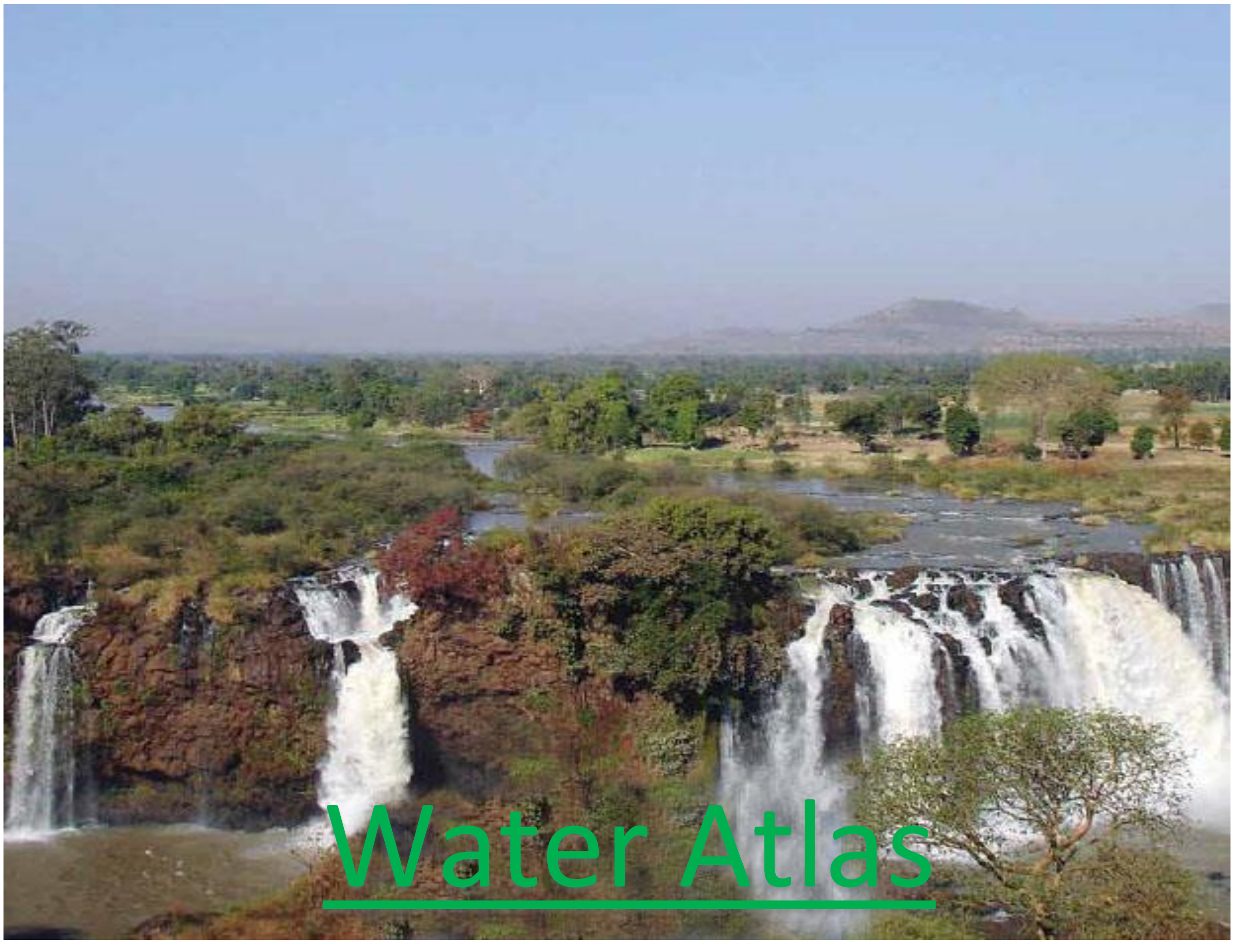


Water Atlas
of
Abbay Basin

Abay basin development office

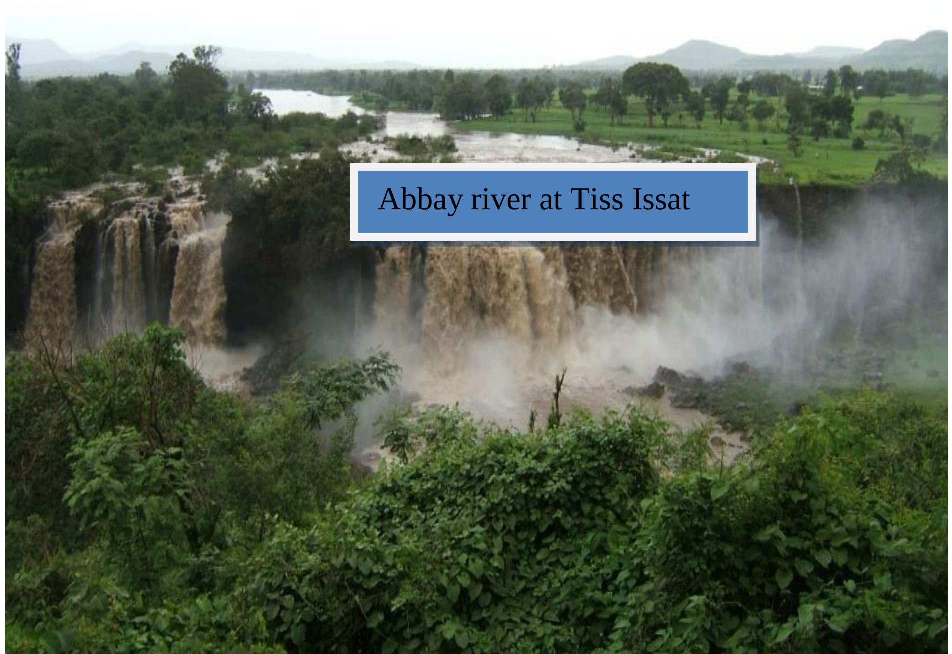
April 2020

Chapter One

Introduction

Introduction

Abbay basin development office has been established with overall objective to make better use of the potentials of the basin for the socio-economic and sustainable development of its population in accordance with Integrated Water Resource Management/ IWRM/ principles. The establishment of the Authority has significant contributions in creating efficient and stable mechanisms for the implementation of the Ethiopian Water Resource



Management Policy through river basin plans and effective and sustainable joint management by relevant stakeholders of the water resource of the basin. Water is a scarce and vital socio-economic resource that needs to be managed on a strategic planning basis with long term visions and objectives. In order to guide and support the basin water resources strategic planning and water management functions properly organized basin information plays decisive role.

Therefore, collecting, compiling, analyzing, and disseminating information for proper planning, administration and steering of water resources in the Basin is one of the powers and duties of the Authority. Since Atlas is among the information disseminating mechanisms, the Authority has prepared this Atlas. It provides stakeholders and researchers with the general overview of the river basin. Moreover; such kind of data organization will ensure data availability and consistency of information about the basin. Our objective is to provide scientific data and analysis that help both policy makers and local citizens make better decisions about land, water and other related natural resource utilization in the basin.

This Atlas is a visual account of the over all aspects of Abbay river basin, revealed through maps and images as well as graphics and photos. In general, the atlas describes Biophysical Environments, Administrative Boundaries, Access to Services, Demographic Characteristics, Administrative units and Land use/cover features, Climate, Hydrology,

Infrastructure, Tourism, and monitoring stations for meteorological, hydrological and water quality data collection and analysis.

Basins in Ethiopia

Quick Summary

12 total basins in Ethiopia 8 river basins 1 lake basin 3 dry basins Except Awash basin, all river basins are transboundary	Total runoff (122 bln m^3) The three largest river basins in runoff: Abbay (54.5 bln m^3) Baro Akobo (23.23 bln m^3) Omo-Gibe (16.6 bln m^3)	The three largest river basins in size: Wabishebele (202,220 sq.km) Abbay (199,812 sq.km) Awash (112,700 sq.km)

Ethiopia has 12 Basins. Among these, 8 are river basins (Abbay, Baro-Akobo , Omo-Gibe , Tekeze , Genale-Dawa, Awash, Wabi Shebele and Mereb), 1 is lake basin (Rift Valley) and the remaining 3 are dry basins (Denakle, Ogaden and Aysha). In generally, a river basin within a country is treated as a hydro-geographical boundary of an area of land that feeds the water it receives to a common river or lake or swamp before it crosses the international boundary.

The Ethiopian basin master-plan studies and related river-basin surveys show that the aggregate annual runoff from the basins amounts about 122 billion m³. The 3 largest river basins **(Abbay, Baro-Akobo, and Omo-Gibe**) contribute about 77 percent of the total runoff from a catchment area comprising about 31 percent of the total area of the country.

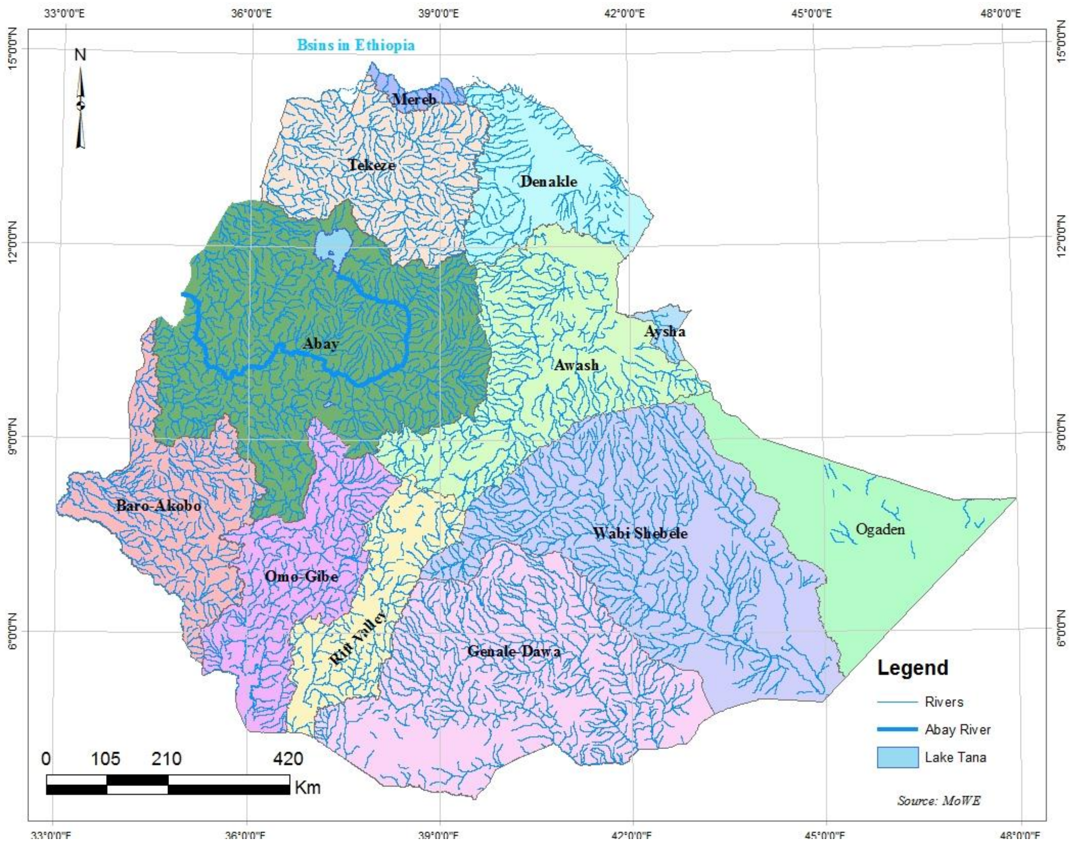


Figure 1.1 Basin in Ethiopia (source : MoWE)

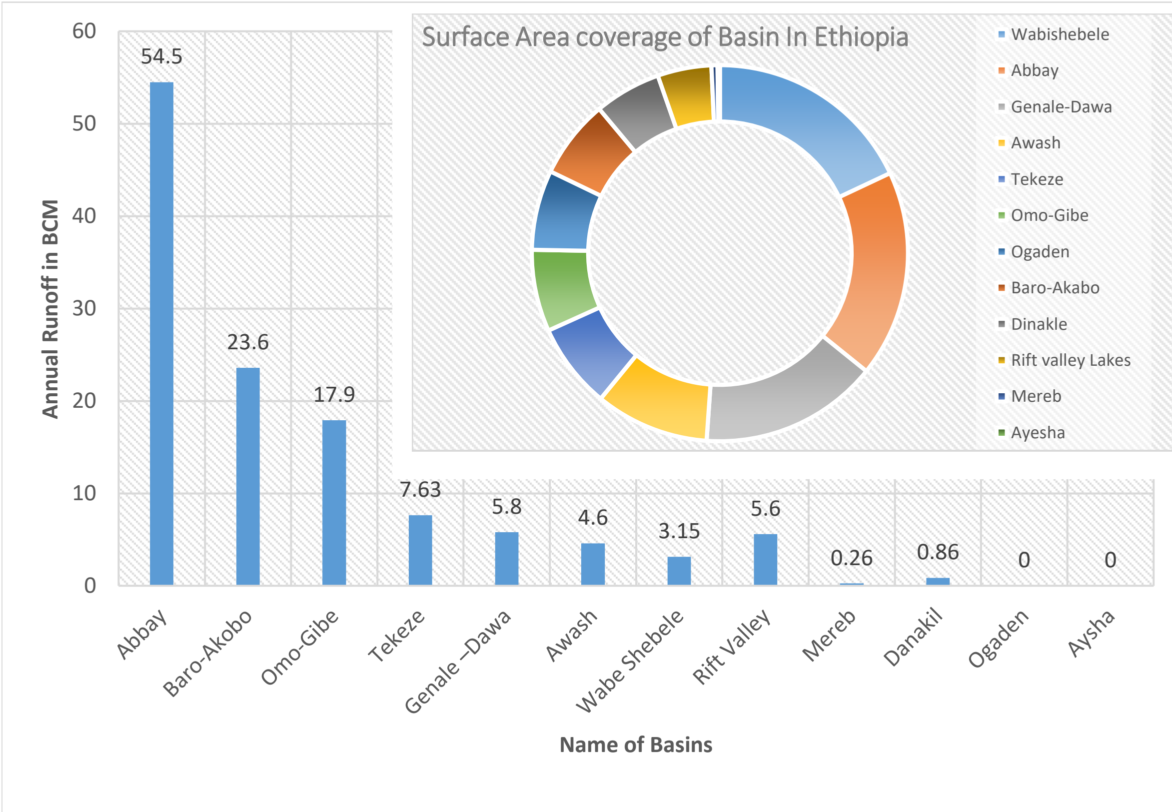


Figure 1. 2 Annual runoff from each basin *source: MoWE, Watere sector development program, Main report*

No.	Basin Name	Source	Altitude at source	Terminal	Altitude At terminal	Area (Km^2)
1	Abbay	Sekela, West Gojjam	2000	Sudan Border	500	199812
2	Awash	Ginichi	3000	Terminal lakes	250	112700
3	Ayesha	-	-	Djibouti Border	400	2223
4	Baro-Akabo	Illubabor	3000	Sudan Border	395	75912
5	Dinakle	-	-	Kobar Sink	160	64380
6	Genale-Dawa	Bale	4300	Somali Border	180	172259
7	Mereb	Zalambesa	2500	Eritrean Border	900	77120
8	Ogaden	-	-	Somali Border	400	79000
9	Omo-Gibe	Ambo	2800	Rudolph lake	350	52000
10	Rift valley Lakes	Arsi Mountain	4193	Sudanese Border	550	5900
11	Tekeze	Lasta/Gidan	3500	Chew Bahir	300	82350
12	Wabishebele	Bale Mountain	4000	Somali Border	200	202220

Table 1.1: Physical characteristics and mean annual flow of surface water at the outlet of the river basin

The Abbay Basin

Quick summary

Location: NW part of ET b/n $7^{0}40^{'}-12^{0}51^{'}$N and $34^{0}25^{'}-39^{0}49^{'}$E Population: 32,899,221 It is main part of Eastern Nile Basin	Total Area: 199812 sq.km 89644 (46%) sq.km in Amhara 62831 (31%) sq.km in Oromia 44297 (23%) sq.km in Benishangul-Gumuz	Annual runoff: 54.5 BCM Main river(Blue Nile) source: Lake tana Farthest source: Sekela Main tributaries: (rivers feeding lake tana, Bales, Jemma, Didddesa, Beshilo, Dabus)

The Abbay basin finds itself in Ethiopia that is marked by high and rugged mountains, flat topped plateaus, deep gorges, river valleys and plains. The remarkable geographical diversity has implications for the uniqueness of the basin and in how its watershed needs to be managed in order to ensure sustainable economic development that is resistant to the reality of climate change and global warming on one hand and to enable environmental restoration that can support development aspirations on the other hand.

Abbay basin is the most important river basin in Ethiopia and in the rest of sub-Sahara Africa. It accounts 50% of Ethiopia total average annual rainfall runoff. It holds the largest fresh water lake in the country known as Tana and is the home of diverse flora and fauna (The Abbay Basin Master Plan 1999).

The source of Abbay river is Gilgel Abbay, which starts near Sekela and flows northwards into the wide and shallow Lake Tana. Lake Tana receives other tributaries including the Megech, Ribb and Gumara rivers. Abbay exits from the lake and flows south, then westwards cutting a deep gorge toward the western part of Ethiopia. A number of tributaries join in Ethiopia. In Sudan it flows across a relatively flat desert to Khartoum (Yilema and Awulachew 2009)

Abbay River basin is fabled as the source of the Nile, a land of dramatic gorges and mountains, an isolated land of history and mystery which has been largely hidden from the outside world. It is also a land of about 33 million people who scratch a minimum existence from the land, and whose general condition is one of poverty and insecurity. Originally a land of magnificent forests, it is now a land of fields and pastures. The Ethiopian highlands in general, including much of the basin, is also a land dramatized in textbooks for the magnitude of the soil erosion. However, within Ethiopia, it is very much seen as a land of potential, reflecting its status as the source of the country's main food surpluses, and the extensive water resources which are seen to leave the country to nourish downstream countries without profiting their land of origin.

Water Atlas of Abbay Basin

Without synthesized information, identifying and devising mitigation measures for the critical threats to the sustainability of the water and related natural resources of the basin becomes a challenge.

As much as certain aspects of our environment such as topography do not change, most aspects of our physical environment change. As populations grow, effective planning for sustainable development requires dependable information about the trends in our changing environment.

As part of expanding the knowledge base, the ABA has developed a water atlas for the Abbay basin to provide synthesized, interpreted information to the stakeholders and thereby promote evidence based decision making. The Abbay basin water atlas provides a visual account of the status of the resources, present observed trends, vital statistics and the biophysical status of the basin.

The Atlas will provide a platform for viewing the spatial and temporal distribution of resources within the basin especially hot and hope spots and their environmental, economic and social significance. By guiding and informing basin-wide planning, the Abbay basin water atlas together with the state of river basin plan will significantly contribute to achievement of the ABA goals.

Geographic Location of Abbay Basin

Abay Basin, located in the north western part of Ethiopia, is the largest contributor about 55MCM/year of the Nile basin accounting 62% of the inflow at Aswan. The Gelgel Abbay, one of the major tributaries of Lake Tana, is believed to be the head of the Blue Nile. Gelgel Abbay starts in the highland plateaus of Gojjam flowing in a general north direction to Lake Tana.

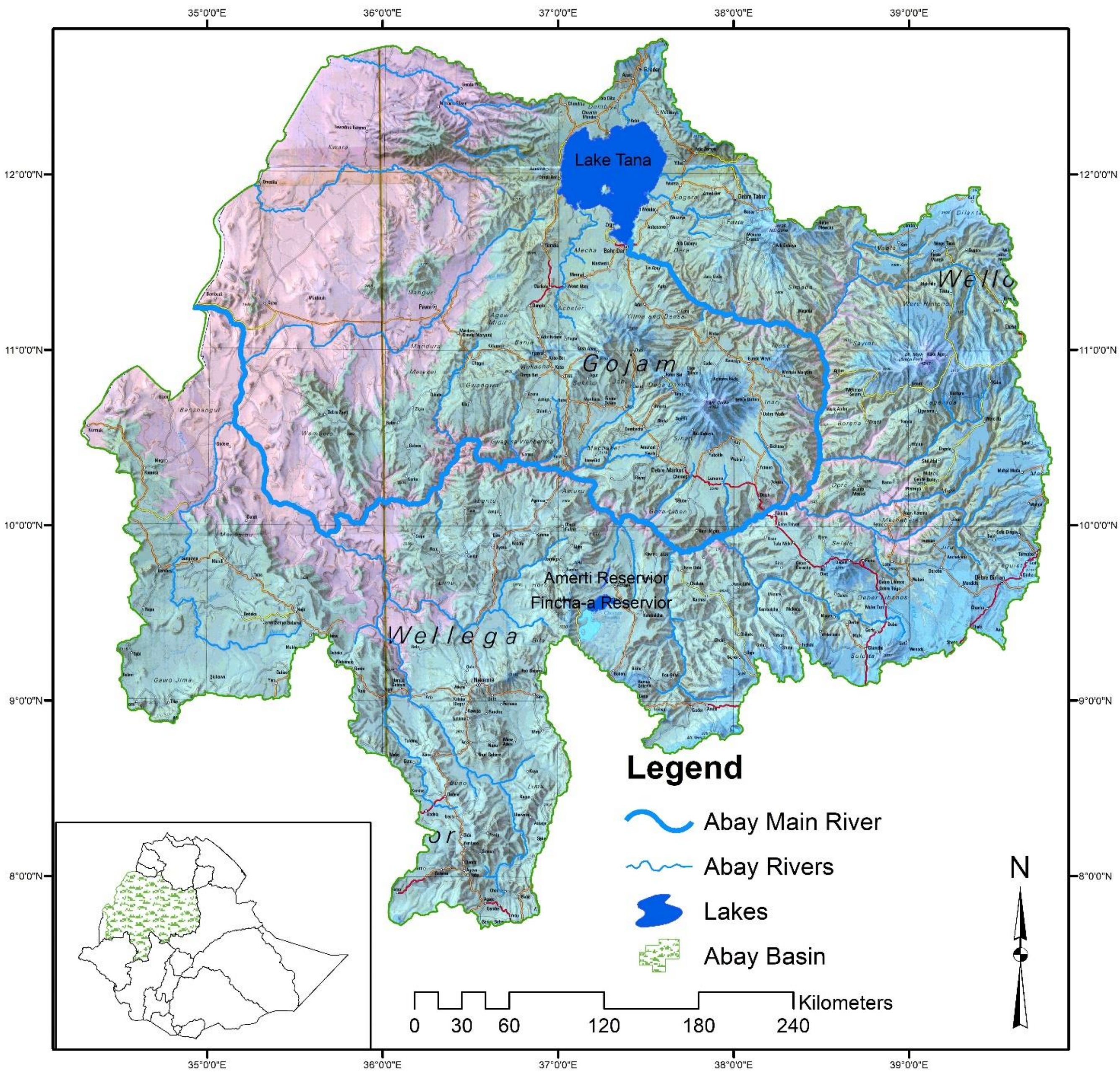
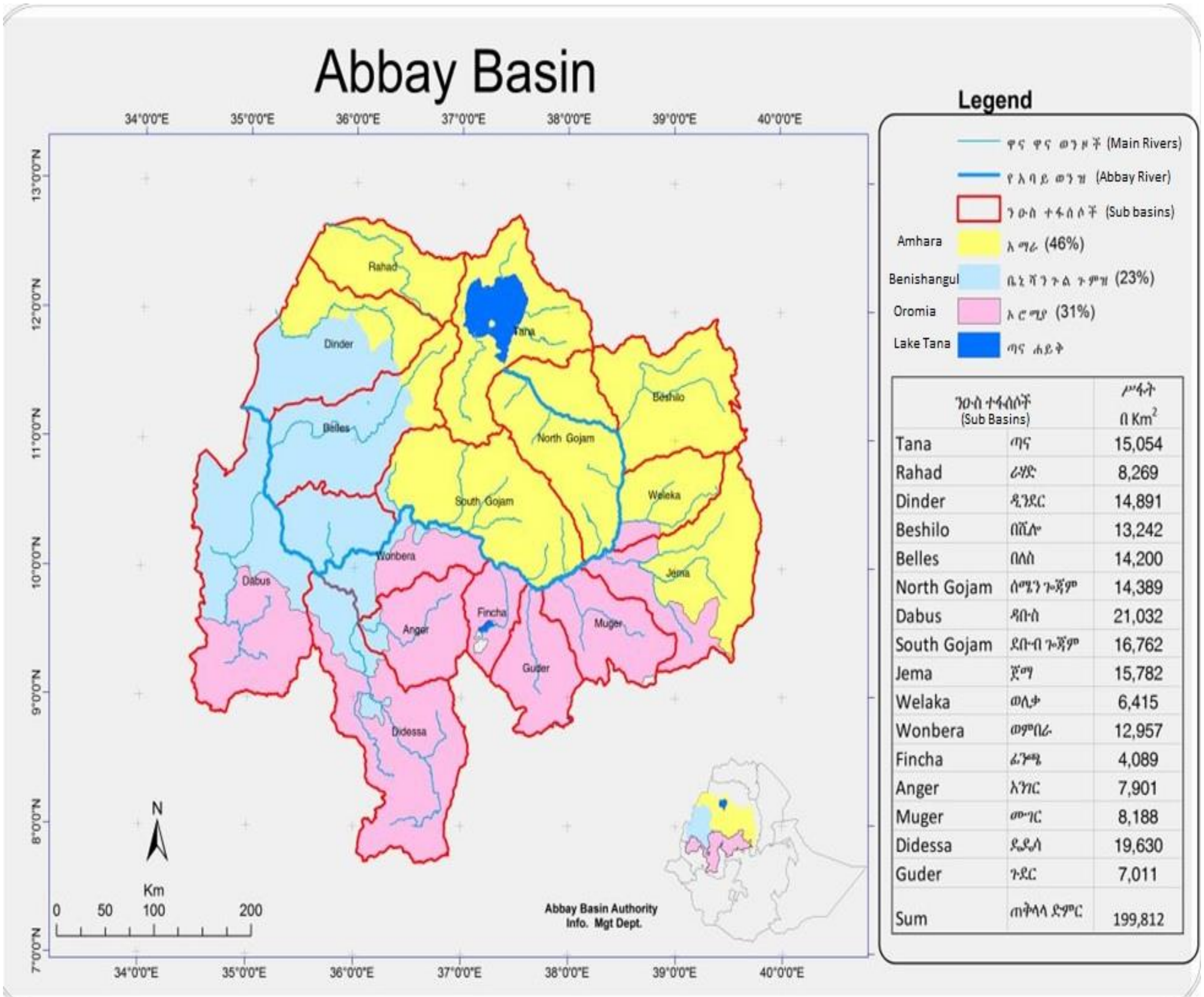


Figure 1.3. Abbay river basin boundary



ንዑስ ተፋሰሶች (Sub Basins)		ሥፋት በ Km²
Tana	ጣና	15,054
Rahad	ራሃድ	8,269
Dinder	ዲንደር	14,891
Beshilo	በሺሎ	13,242
Belles	በለስ	14,200
North Gojam	ሰሜን ጎጃም	14,389
Dabus	ዳቡስ	21,032
South Gojam	ደቡብ ጎጃም	16,762
Jema	ጀማ	15,782
Welaka	ወሊቃ	6,415
Wonbera	ወምበራ	12,957
Fincha	ፊንጫ	4,089
Anger	አንገር	7,901
Muger	ሙገር	8,188
Didessa	ዲዴሳ	19,630
Guder	ጉደር	7,011
Sum	ጠቅላላ ድምር	199,812

The Abbay river basin is located in the north western part of Ethiopia between 7^0 40' N and 12^0 51' N latitude, and 34^0 25' E and 39^0 49' E longitude. The basin is the second in area coverage (199,812 km^2 and the largest in annual runoff (54.5 **BM³**). It shares a boundary with the Tekeze basin to the north, the Awash basin to the east and south east, the Omo-Gibe basin to the south, and the Baro-Akobo basin to the south west. The

country's largest freshwater lake, Lake Tana, the source of the Blue Nile (Abbay) river is located to the north of the basin. The basin occupying 20% of the country's territory and it covers an area of 60% of Amhara, 40% of Oromia 95% of Benishangul-Gumuz regional states. The basin is subdivided into 16 sub basins based on the major rivers in the basin.

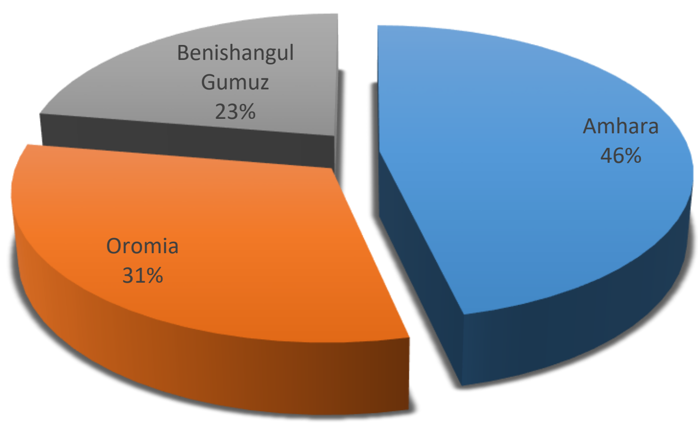
Administrative Units (Regions and Woredas)

The administrative structure of the country is hierarchical, from regional states, to zones, Weredas and Peasant Associations (PA) or Kebeles. According to the current regional structure, the basin covers three regional states namely Amhara regional state (93,565km2), Oromia regional state (62478km2), and Benishangul-Gumuz regional state (44,676km2), and some portion of Addis Abeba city administration.

Region	Zones	No of woredas	No of Kebeles
Amhara	North Gondar	11	166
	West Gondar		
	Central Gonder		
	East Gonder		
	South Gondar	10	264
	North Wello	7	114
	South Wello	18	391
	North Shewa	21	251
	East Gojam	17	415
	West Gojam	16	389
	Agew Awi	7	185
	Bahir Dar Sp.	1	
Oromia	West Wellega	16	338
	East Wellega	16	283
	Horo Gudru Wellega	10	188
	Qelem Wellega	7	99
	Illubabor	10	229
	Jimma	11	201
	West Shewa	17	389
	North Shewa	17	312
	South West Shewa	3	12
Benishangul Gumuz	Metekel	6	115
	Asosa	7	189
	Kamashi	5	72
	Maokomo Special	1	
	Pawi Special	1	25

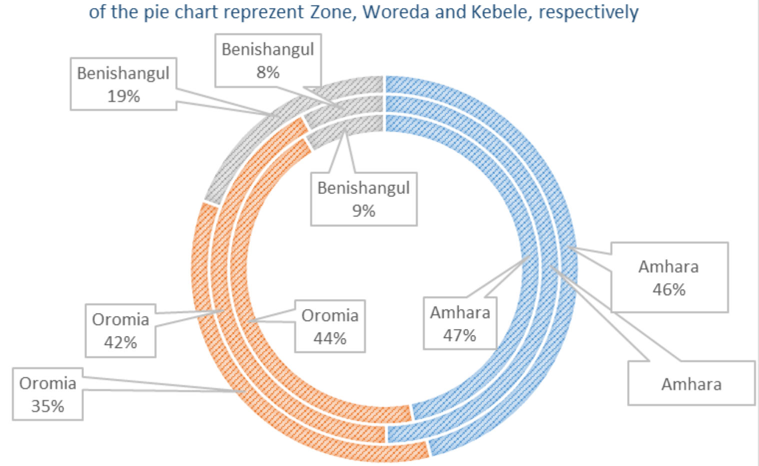
Table: Distribution of Administration Units in basin.

Area Coverage in the Basin



Zone, Woreda and Kebel distribution

As a hierarchical administration of the regional system, from outer to iner, each ring of the pie chart reprezent Zone, Woreda and Kebele, respectively



despite the areal coverage and due proportion of the region's in the basin; it has been shown that in this chart, zone to woreda, and woreda to kebele level of administration shows almost proportional distribution in all regions.

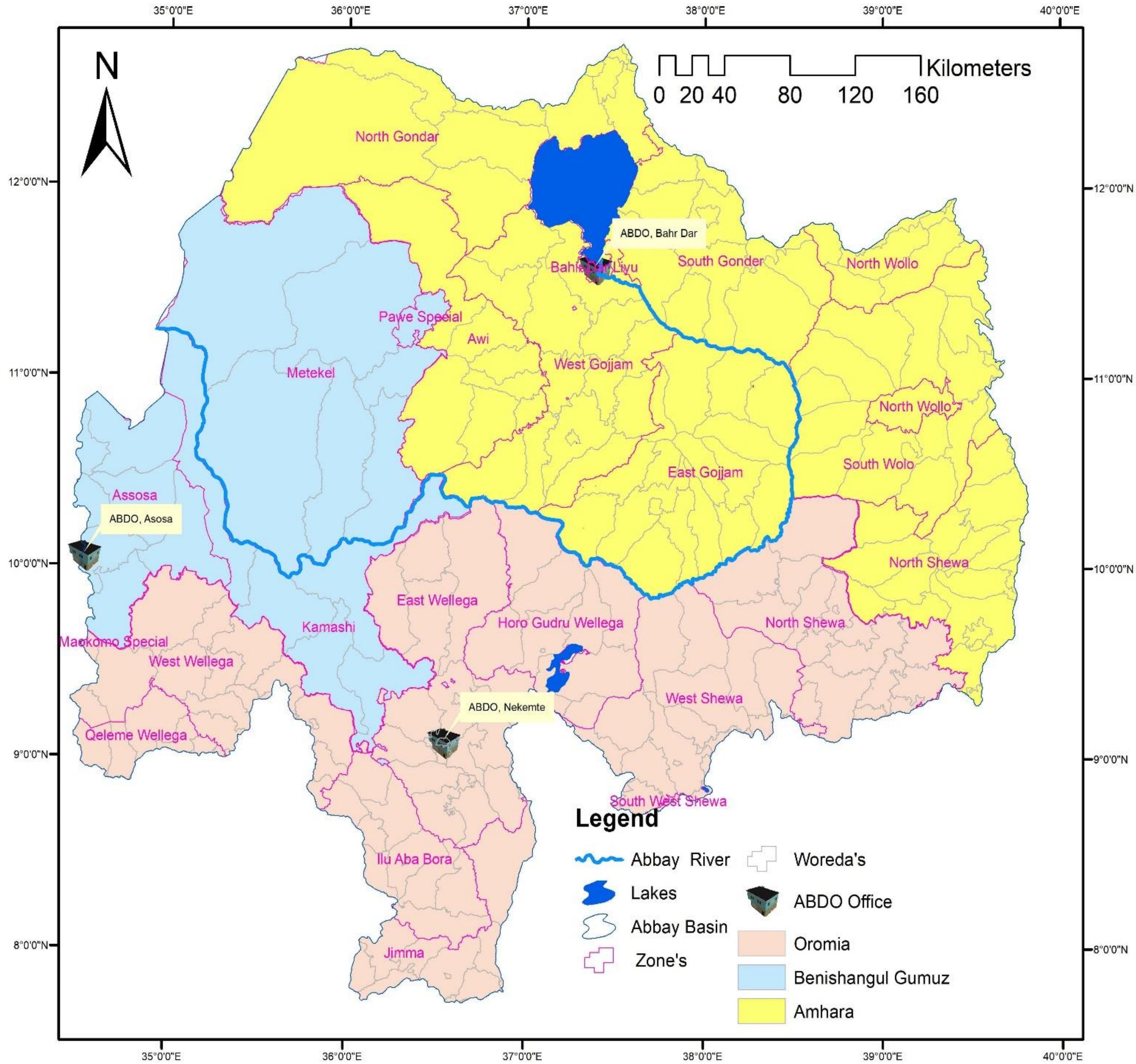


Figure 1.4: Administrative Divisions (Region's and woreda's) in the basin

Chapter Two

Pysiographic Characteristics

Topography

Quick Summary

Elevation range:	Main river course profile:	Slopes:
498m asl – 4261 m asl 1295m asl @ lake Tana and 490m asl @ Guba	Length = 922 km It is a river with deep gorges through its course flows in a general south direction from its main start lake tana to Abay main bridge and then to a general westward direction to ethio-sudan border.	> 30% in the highlands < 7% in the lowland It has 1.4m/km average slope along the main river course

The topography of the Abbay basin signifies two distinct features; the highlands, ragged mountainous areas in the center and eastern part of the basin and the lowlands in the western part of the basin. The altitude in the basin ranges from 498 masl in the lowlands up to 4261 masl in the highlands. The maps below in Figure 31 and Figure 32 show the elevation and the slope of the basin.

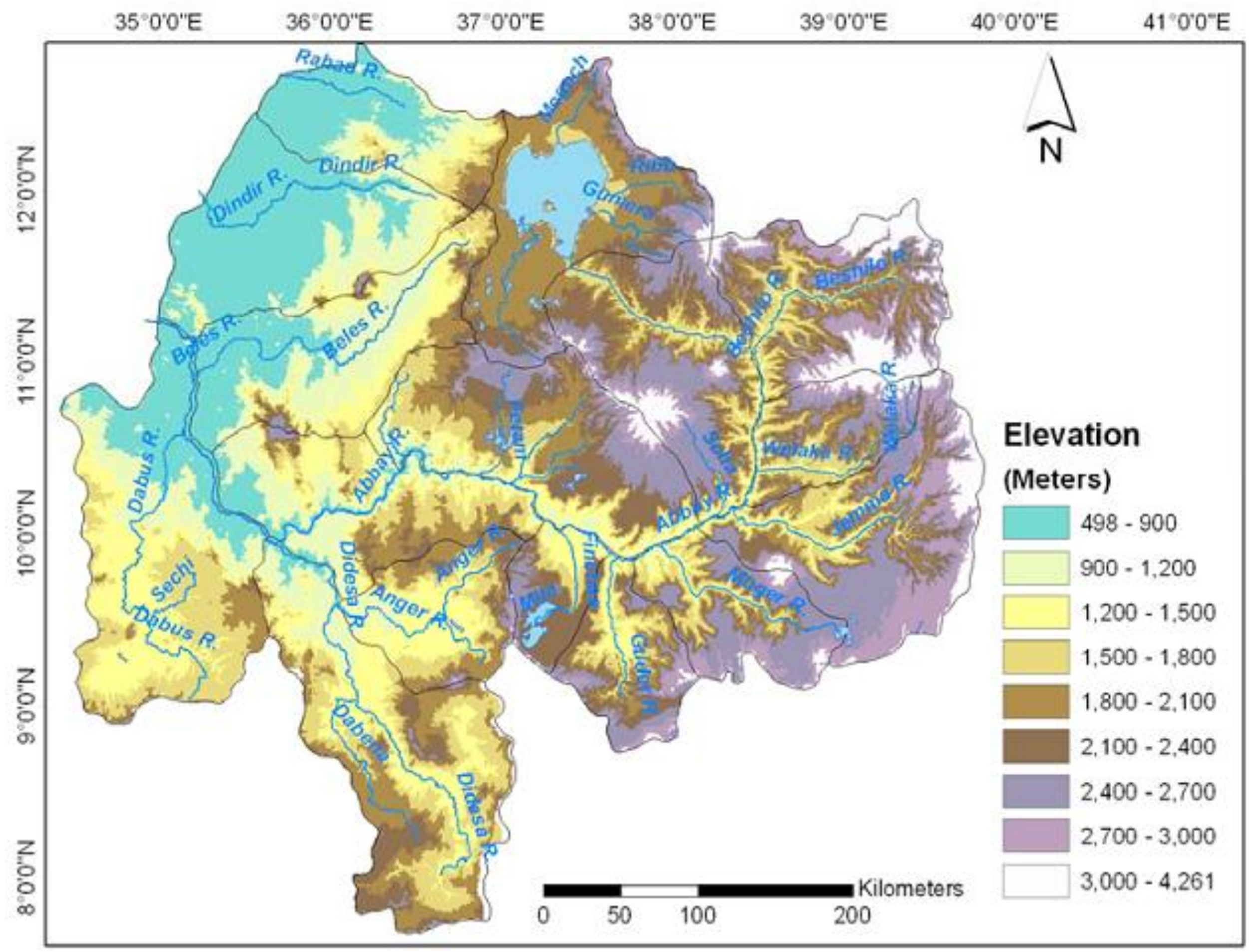


Figure 2.1: Topography of the Abbay Basin

Topographic profile along the main river:

The Abbay river has a channel length of 922 km and falls 1,295 m from Lake Tana (1,785 m asl) to the Ethiopian border (490 m asl) at Guba. Shortly after leaving Lake Tana the river plunges over the spectacular Tis Issat falls and thereafter the river enters the deep abbay river gorge. This is a spectacular structure that may be between 10 - 20 km wide and up to 1.3 km deep. The gorge is bounded by sheer escarpments and during the USBR study (1964), the gorge was considered to be as scenically spectacular as the Grand Canyon of the Rio Grande in North America. Within Ethiopia, the Abbay river has an average slope of 1.4 m/km and is swift and turbid.

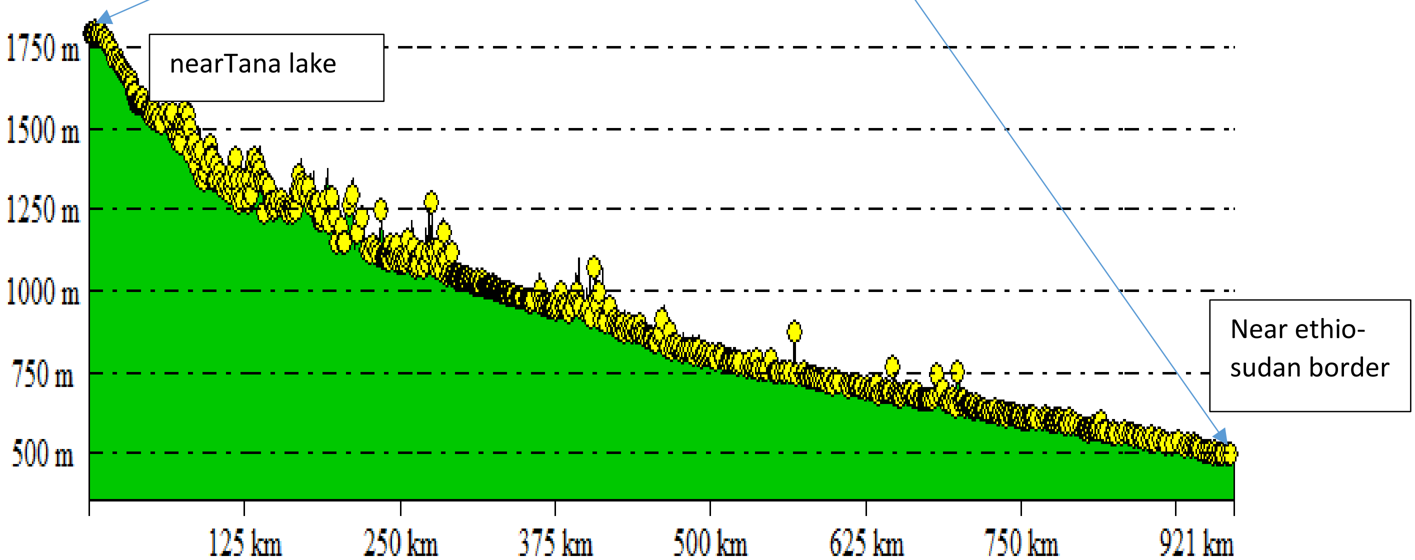
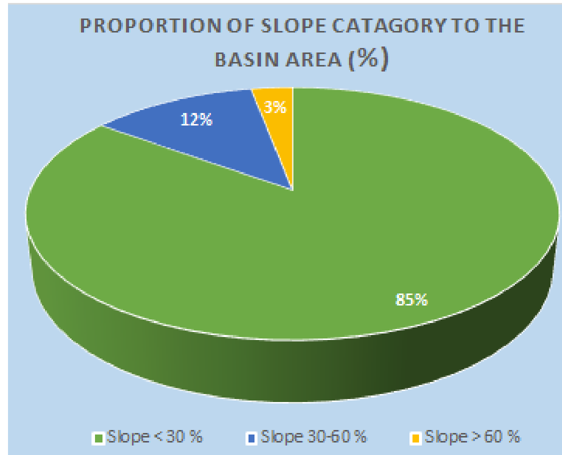


Figure 2.2. River path profile (elevation along the main Abay River from Lake Tana to Ethio-Sudan border.

Slope in the basin

Slope is a measure of terrain steepness that is, the degree to which land is not horizontal. Slope affects the agricultural suitability of different areas. Steep slopes are more difficult to cultivate and more likely to lose soil and nutrients through erosion.

The highlands extend from 1500 masl up to as high as 4260 masl, with a slope of greater than 30 percent in the eastern part. Whereas the lowlands flatten 1000 masl to 500 masl with a slope of less than 7 percent, in Dinder and Rahad sub basins.



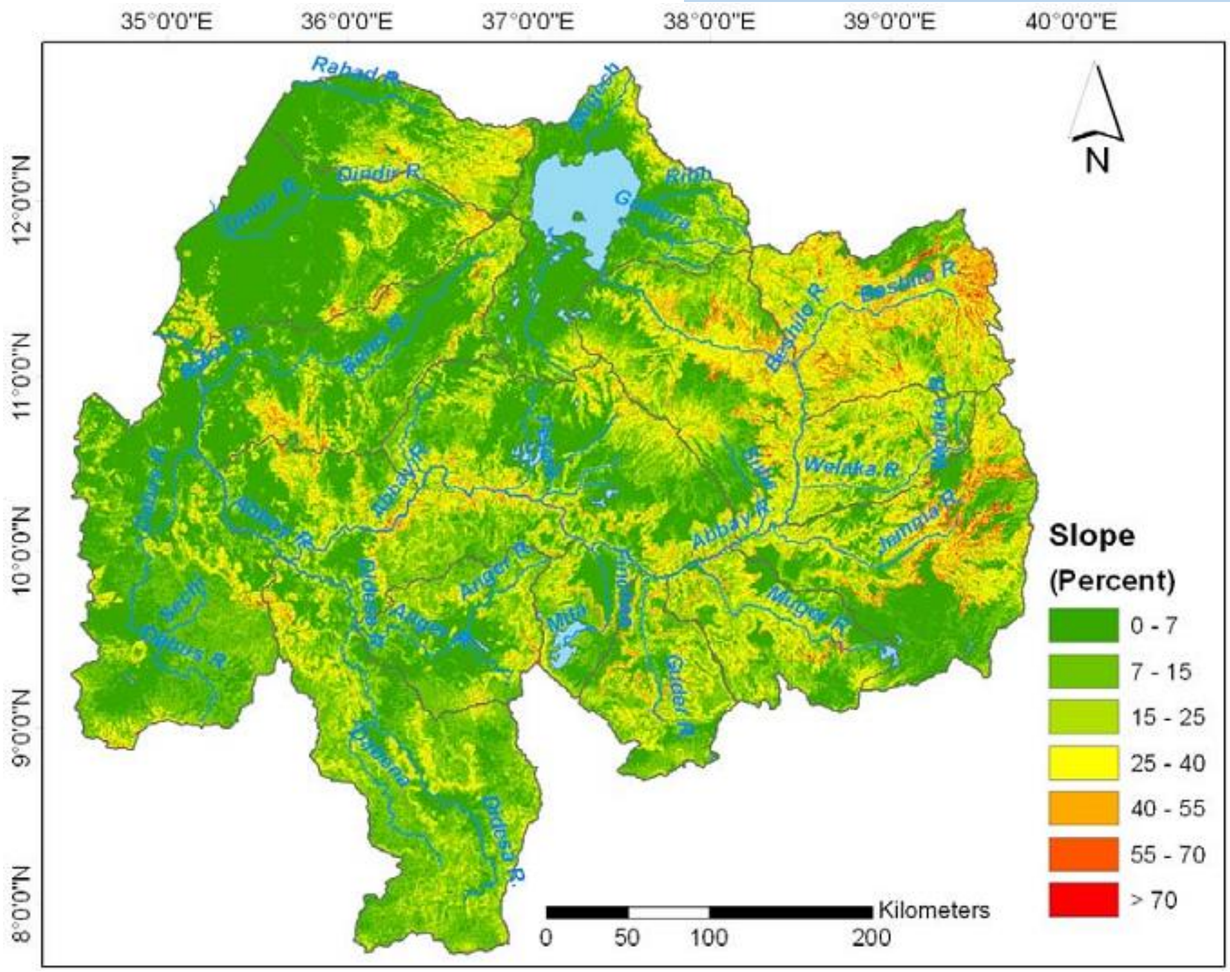


Figure 2.3: Slope of the Abbay Basin

Agro ecology

Traditional Agro-Ecology Zone and Elevation

The agro-climatic zones of the basin are considered based on the topographic nature that ranging from about 470 amsl to the highest elevation about 4260 amsl. There are four Tradational Agro ecological zones as described in the table (left).

Elvation (m)	Traditional Agro_Ecology Zones	Proportion in %
< 1500	Kolla	37.3
1500 - 2300	Weyna-Dega	40.1
2300-3200	Dega	17.3
3200- 3700	Wurch	5.1
>3700	Alpine Wurch	0.2

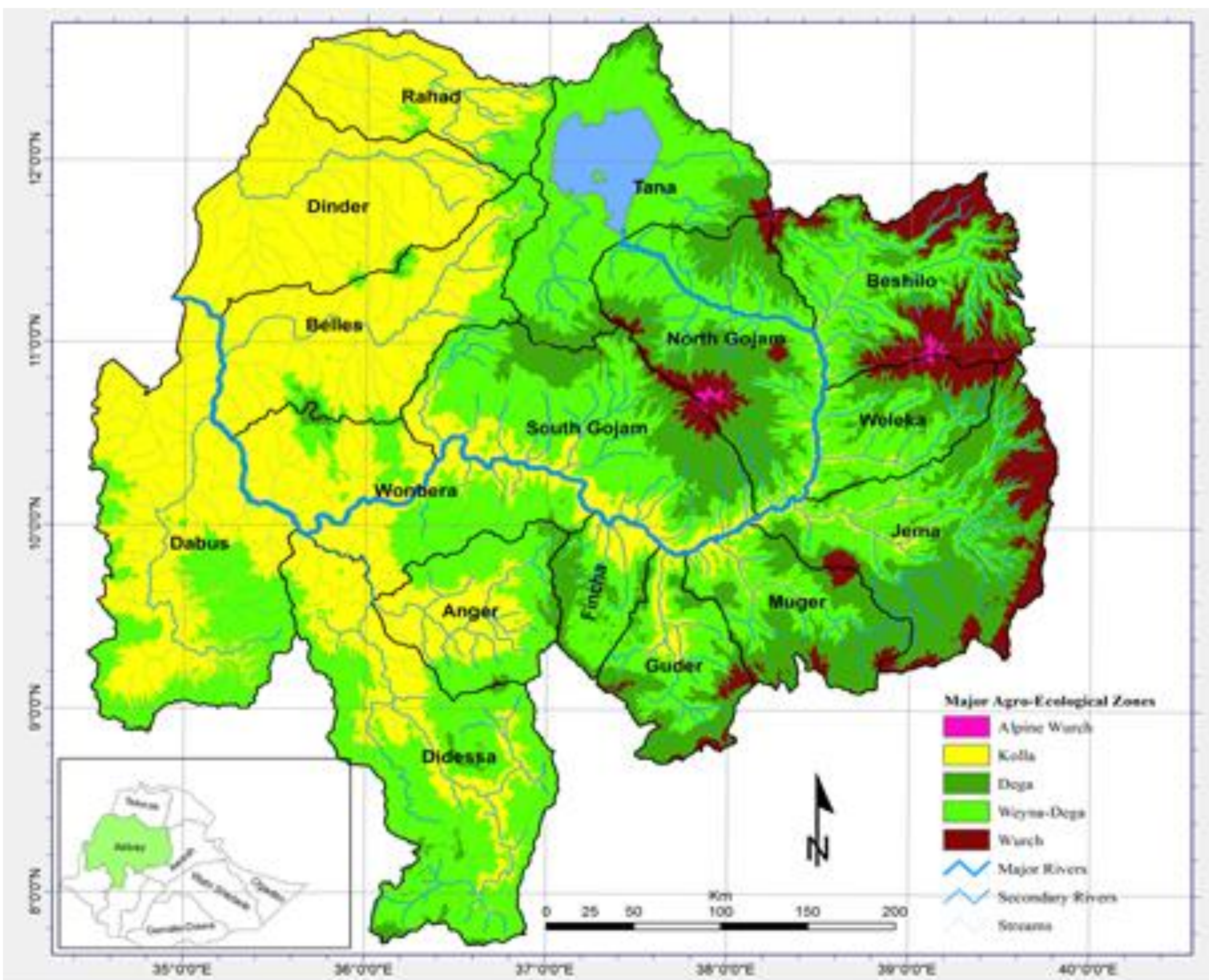


Figure 2. 4 Traditional agro-ecological zones within the basin

Major Agro-Ecological Zones

Agro-Ecological zones have been defined in different ways for different parts of the world, reflecting the most important local conditions in determining agricultural options. Elevation is the primary determinant of agricultural land use options in Ethiopia due to its influence on temperature. Other important factors vary across the country. As indicated in the map below; the agro-ecology of the basin is divided into three major climatic zones, cold to very cold, tepid to cold, and hot to warm, and further divided into moist, sub moist, humid and sub humid.

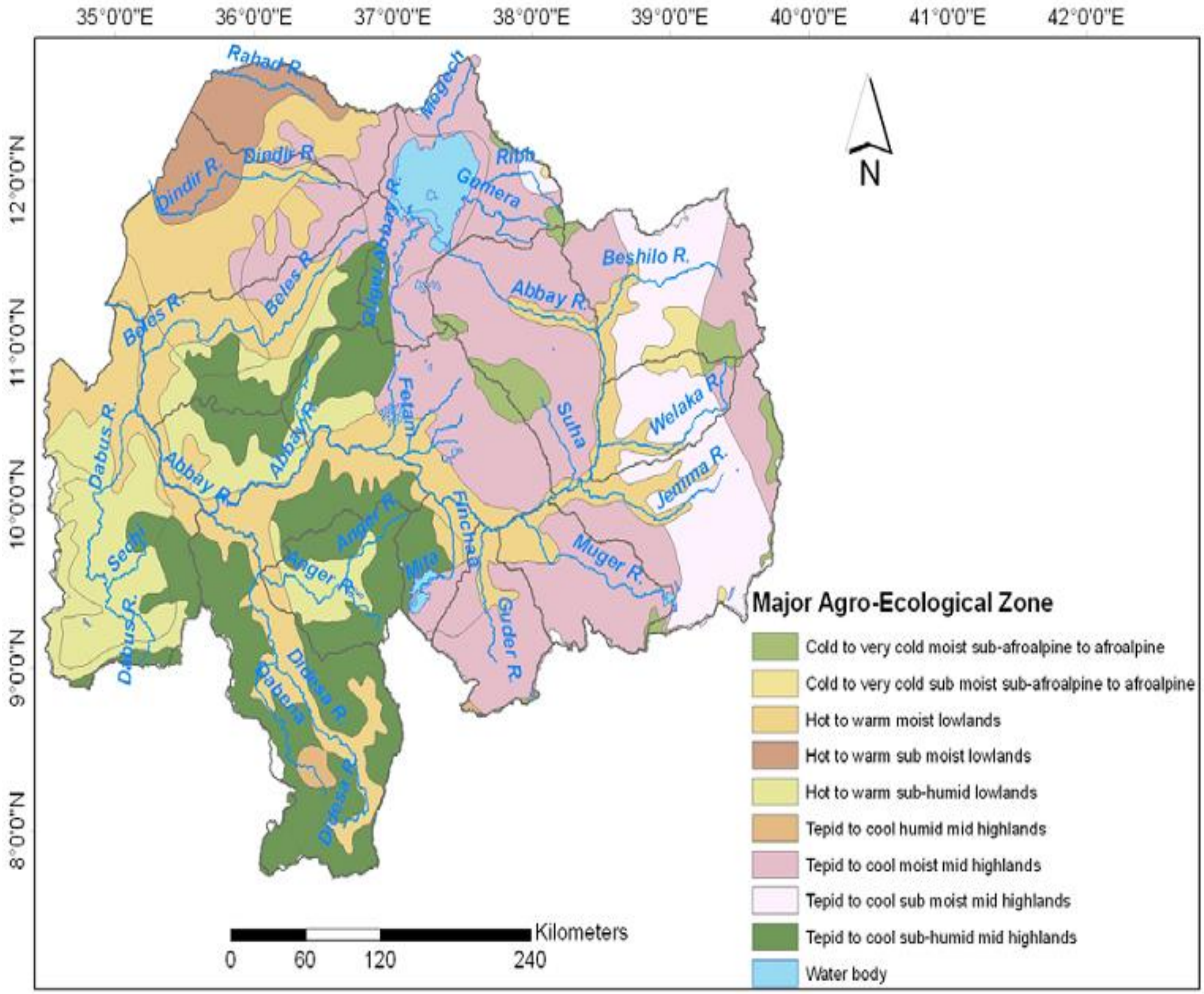


Figure 2.5: Major Agro-Ecological Zones in the Abbay Basin

Land use / Land Cover

The land cover for the basin is mainly characterized by dominantly cultivated, in the eastern part, and grass land, wood lands, and forest to the western part according to the Ministry of Water Resources (Ethiopia) land cover classification.

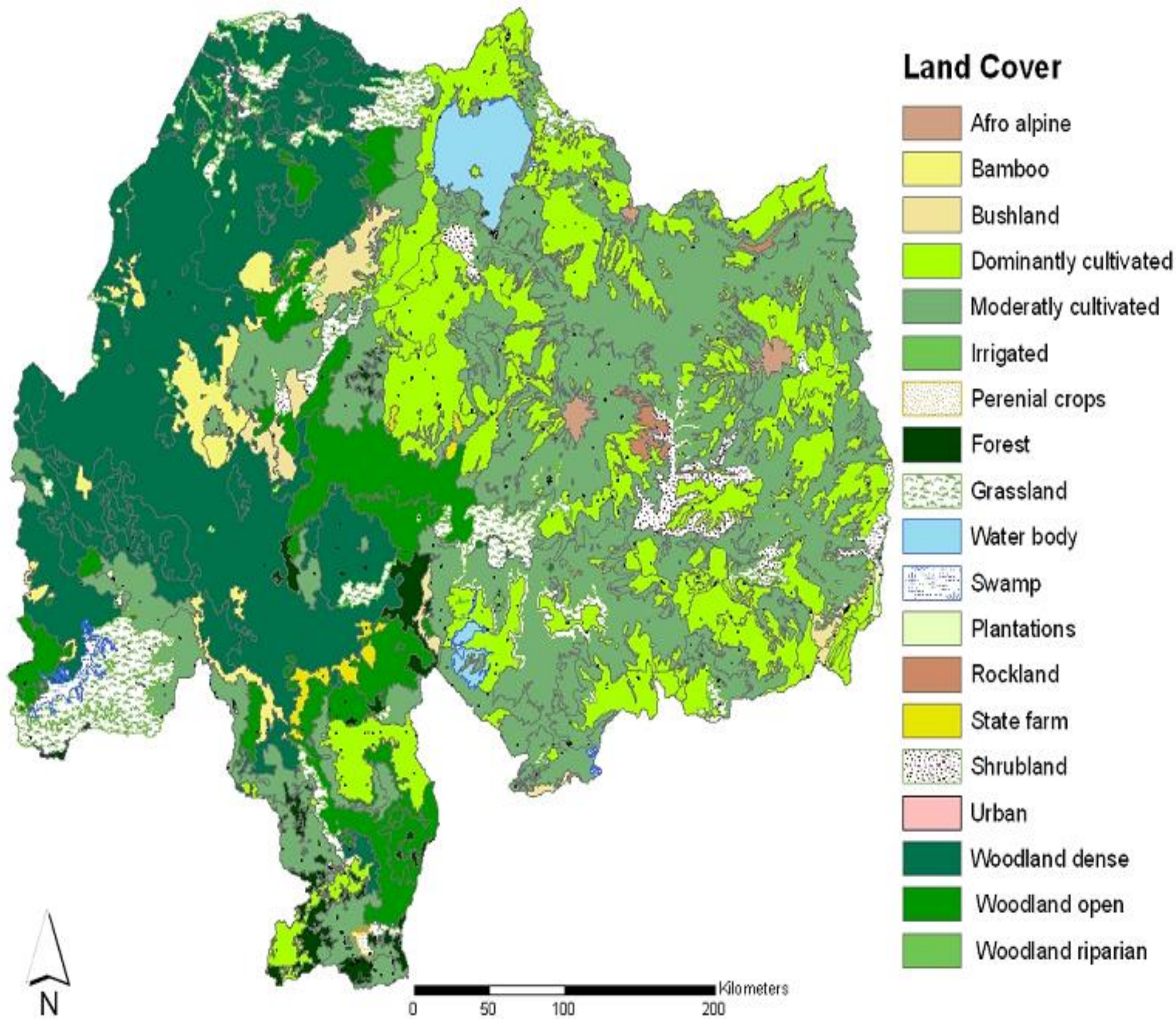
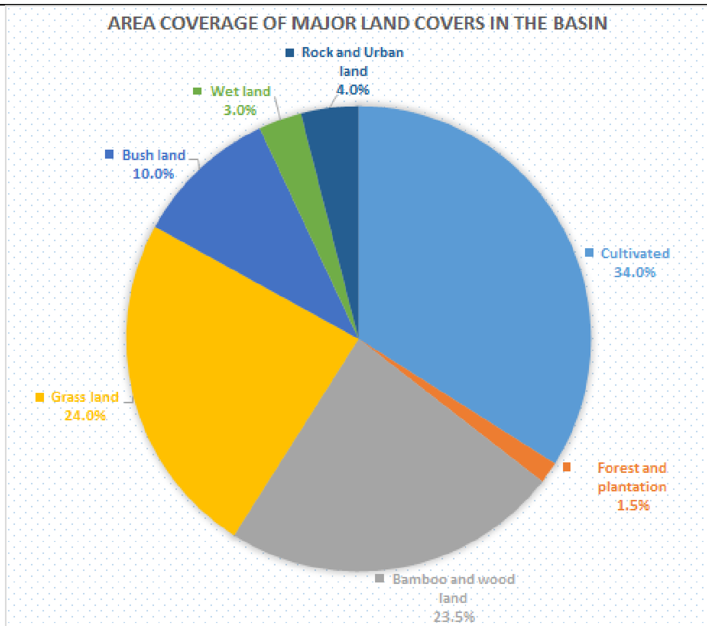


Figure 2.6: Land Cover in the Abbay Basin (Source: Ministry of Water Resources, Ethiopia.)

The land cover of the basin essentially follows the highland and lowland pattern. Once dominantly covered with forest, almost the entire highland area is now under farmland.

The lowlands, by contrast, are still largely untouched by development. This is not to say, however, that they are uninfluenced by man. Indeed, most of the lowland vegetation probably represents a fire climax vegetation, with resistance to the frequent burning that occurs.



Land Cover	Area	% basin
Afro-alpine	113 841	0.57
Cultivated	6 799 341	33.93
Forest + plant	281 233	1.41
Bamboo	689 685	3.45
Woodland	4 080 461	20.29
Bush & shrub	2 016 032	10.22
Grassland	4 614 311	23.09
Wetland	579 876	2.9
Rock	795 879	3.98
Urban	10 411	0.05

Table: Land cover distribution in basin

North Shewa, around menz

Woodland field; Berta, Benishangul gumuz

how forests are shifting to cultivation land

Agricultural land, semen mountain park

Soil Type in the Basin

The major dominant soil types in the basin are Alisols and Leptisols, followed by Nitosols, Vertisols, Cambrisols, Fluvisols and Luvisols.

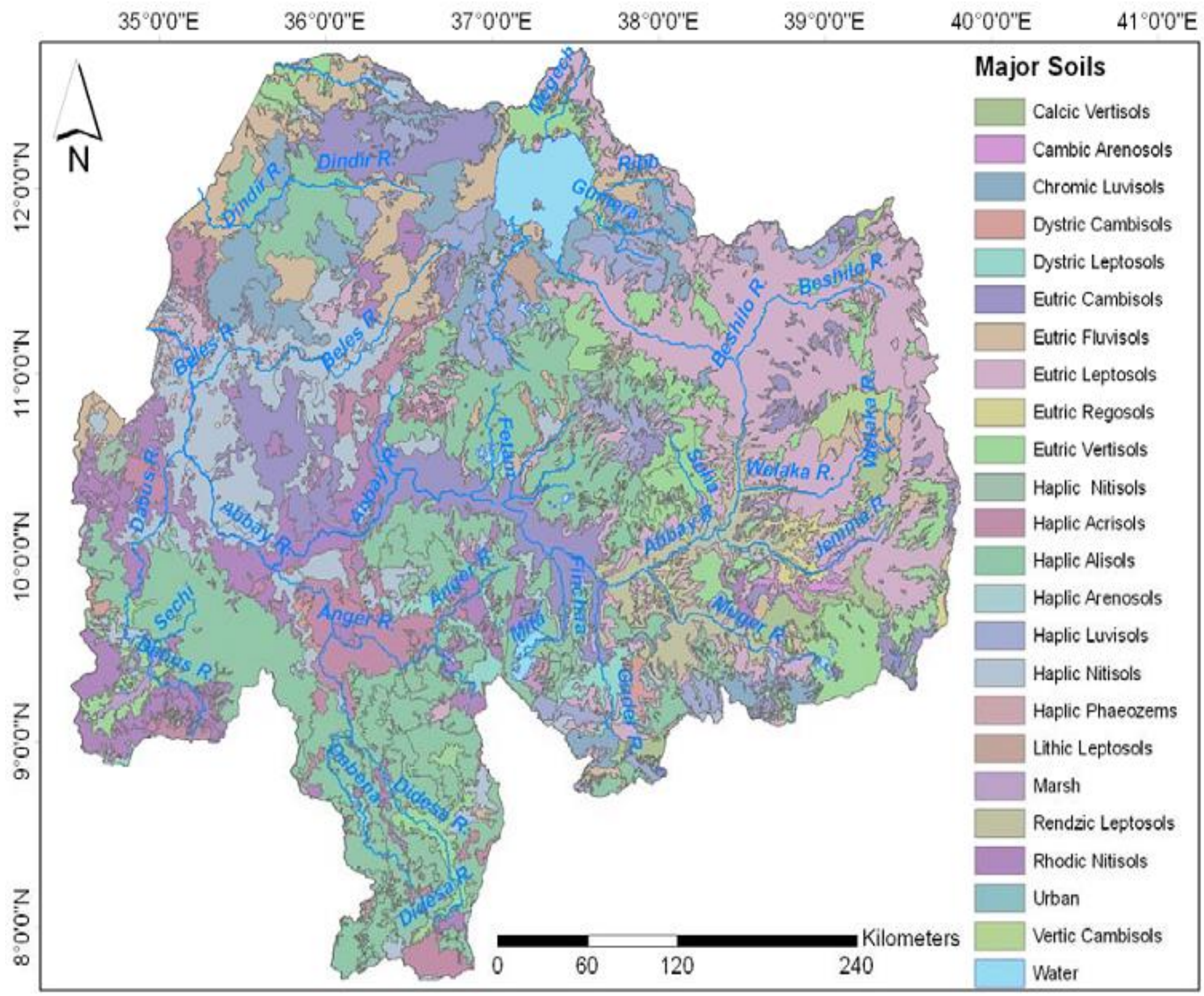
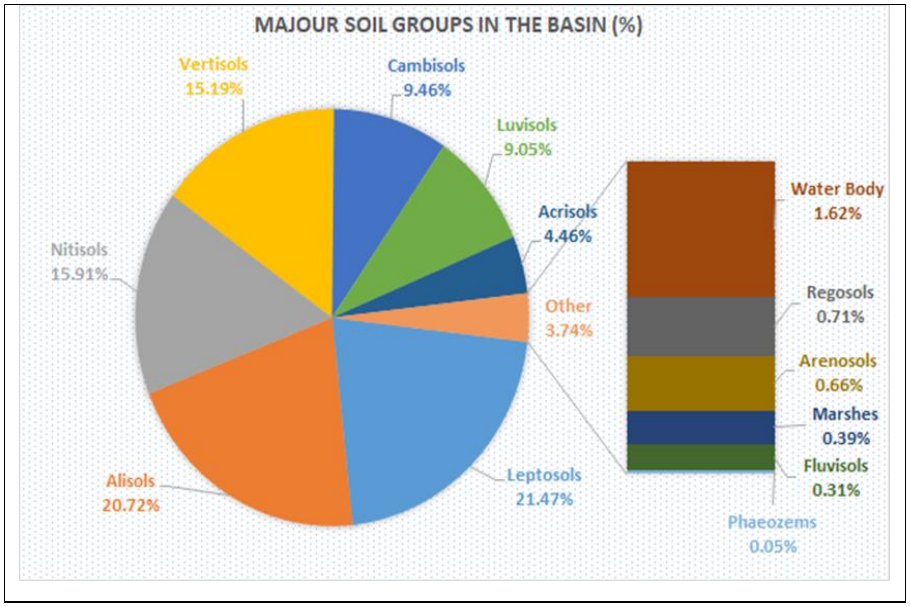


Figure 2.7: Major Soil Types in Abbay Basin (Source: Ministry of Water Resources)

The Fluvisols consist of moderately deep to deep and moderately well drained soils. They are found adjacent to main streams and are subject to annual flooding, consequently receiving fresh sediments from each flood. The Fluvisols mainly occur north of Asosa, along Abbay river course and along the valleys of Rahad and Dinder rivers.

Vertisols are one of the most dominant soils of the basin, making up 15% of the total area. They are mostly imperfectly to poorly drained, dark grey soils, formed on flat to almost flat plains. Vertisols are very to extremely hard when dry and very sticky and plastic when wet which is reflected in their poor workability - the soil is typically too heavy for traditional cultivation.



Alisols are the second most important soils in terms of area coverage. These soils are reddish brown in colour and have deep profiles, usually exceeding 100 cm. Alisols are mainly derived from basalts, granites and granodiorites and possess favourable drainage, structure and workability.

Nitisols is the third most important soil group within the basin in terms of area. They are mostly found in Wellega and Metekel areas and represent the largest area of soils found in both Oromiya and Benishangul-Gumuz regions respectively.
Nitisols are derived from basalts/tuffs and granites/associated felsic materials. The soils are reddish brown in colour, clay to clay loam in texture, well drained and very deep. They also have good permeability, a favourable structure, and high water holding capacity.

The Luvisols are derived form various volcanics and undifferentiated lower complex rocks. They are common on flat and gently sloping topography in cooler climates of west Gojam and North Gondar. Luvisols are well drained/deep soils and are characterised by a cation exchange capacity greater or equal to 24 cmol(+)kg^{-1} clay and a base saturation greater than 50 percent.

Leptosols represent the most important soils in terms of area coverage (30,330 km^2) within the basin, mostly occurring in North and South Wello. They are shallow soils with limited profile development and are usually prone to drought. Apart from offering limited grazing resources they have little sustainable agricultural potential, although most are currently cultivated. The susceptibility of these soils to erosion is one of the reasons which precludes their sustained use for agriculture. The soils are cultivated out of sheer necessity exacerbating the existing serious erosion problem.
The Leptosols are developed on relatively young surfaces and were probably only moderately deep to deep by origin. Moreover, since they occur on steep slopes, they are exposed to a high degree of erosion which is responsible for the further decrease in depth.

Cambisols are derived from a wide range of parent materials (basalts, rhyolytes, trachytes, granites, granodiorites, etc.). They have favourable physical characteristics and depending on topography and climate, they are intensively used for peasant subsistence agriculture. The Cambisols are moderately deep to deep and well drained.

Acrisols are mature soils that have developed on old land surfaces characterised by seasonally wet and dry humid tropical climates. They exhibit strongly weathered profiles and may be affected by aluminum toxicity and high phosphorus fixation. Acrisols are characterised by a cation exchange capacity of less than 24 cmol(+)kg^{-1} clay and a base saturation of less than 50 percent.

The Phaeozems identified within the basin occur in Abbay Chomen swamp. They are clay loam to clay soils developed on alluvium. Their coverage within the basin is small (90 km^2) and thus represent an almost negligible proportion (0.05%).

Geological Formation of the Basin

The geology of the basin signifies different formations such as Basalt, Alluvium, Lacustrine deposit, sand stone, granite and marbles. The dominant rock is Basalt (Tarmaber basalt, followed by Ashange basalt, and Amba Aiba basalt)

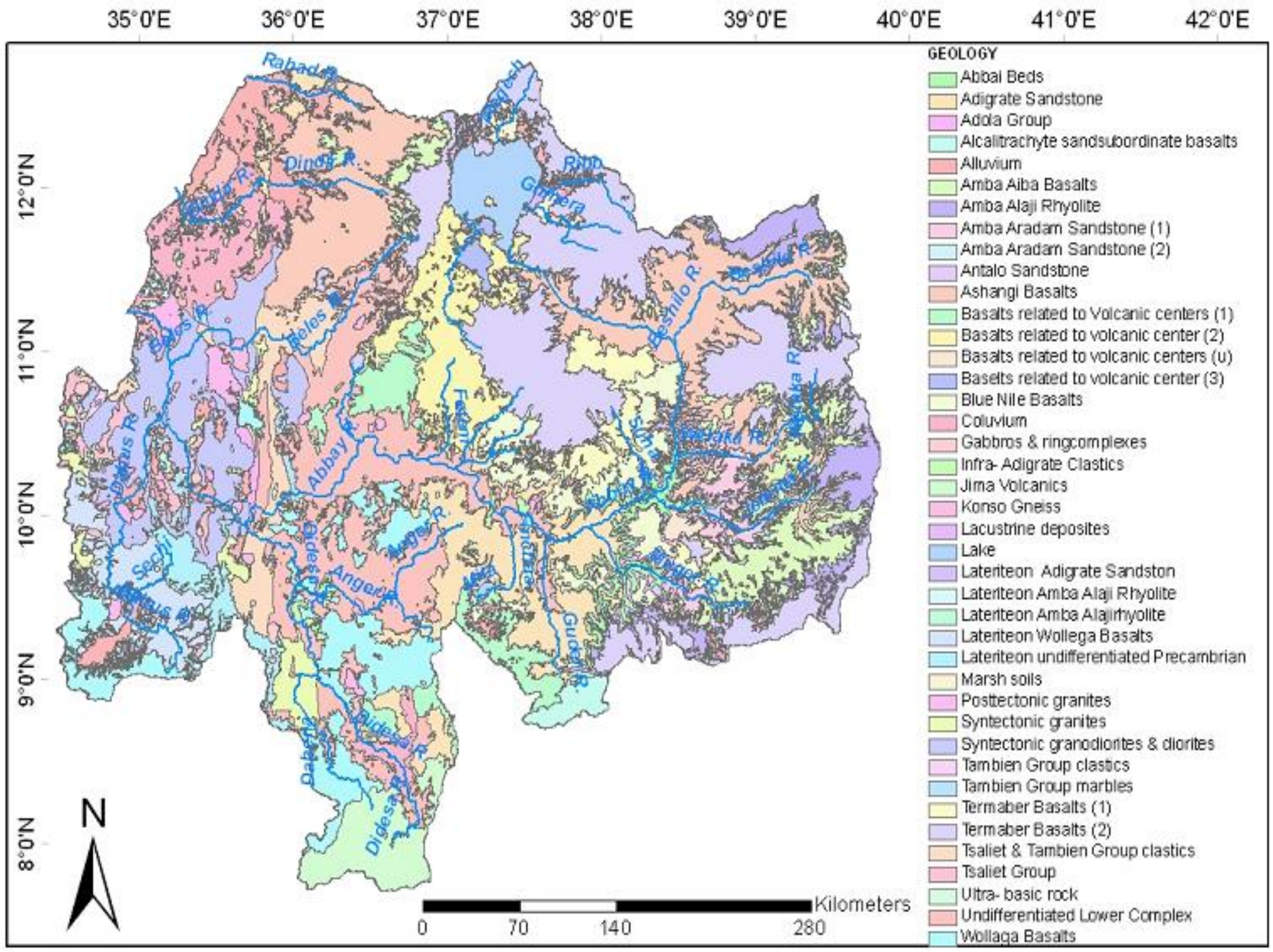


Figure 2.8: Geology of the Abbay Basin (Source: The data source is Ministryof Water Resources of Ethiopia.)

The Highlands of the basin are composed of basic rocks, mainly basalts, while the Ethiopian lowlands are mainly composed of Basement Complex rocks as well as metamorphic rocks, such as gneisses and marble. Where the Abbay has cut through the basalts, there are restricted areas of lime stones and then sandstones before the Basement Complex is reached.

Hydro-geology in the Basin

Table 2. 1 Aquifer types and productivity in the basin

		Extensive aquifers			Localized aquifers
		Intergranular permeability	Fracture permeability		Fracture and intergranular permeability
			Consolidated sediments	Volcanics rocks	
Q a	Alluvial deposits, sometime teraced	Moderate/high			
Q c	Eluvial and colluvial deposits	Moderate			
Q l	Lacustrine deposits	Moderate			
Q t	Basaltic lava flows			Moderate	
T n	Tarmaber basalts			Moderate	
T v	Welega basalts			Moderate	
M a	Amba Alaji rhyolites			Moderate	
T s	Amba Aiba basalts			Moderate	
T b	Ashangi basalts			Moderate	
T x	Undifferenciated volcanites of the eastern border of the Ethiopian plateau			High	
T e	Blue Nile basalts			Moderate	
K s	Amba Aradam sandstones		High		
J a	Antalo limestone		High		
Jk s	Tekeze sandstone				
J g	Abbay beds		Low		
J s	Adigrat sandstone		Moderate		
d	Infra Adigrat clastics		Moderate		
Y	Granite and quartzo-diorite				Low
b	Undifferenciated and metamorphic basement				Low
l m	Low grade metamorphic				Low
h m	High grade metamorphic				Low

Types of aquifers

The hydrodynamic characterisation of the various geoglogical series leads to the following remarks for the Abbay basin:

(i) The inter granular permeability is only present in the Quaternary deposits, that is only 1% of the surface of the basin; the productivity is generally moderate; the high productivity only concerns the Kombolcha area in the eastern vicinity of the eastern border of the basin, South of Dessie;

(ii) Most of the surface of the basin, 67% of the surface of the basin are covered by aquifer characterised by fracture permeability; the productivity of the aquifer formed by consolidated sediments is considered as moderate to high, Abbay Beds excepted; they cover about 11% of the basin; the volcanics productivity is considered as moderate; they cover 56 % of the basin;

(iii) The metamorphic basement of the western part of the basin has a low productivity.

Recharge

Aquifer recharge is mostly linked to rainfall infiltration. In the bottom of the valleys, recharge can occur under the water course bed during the periods and in the locations where surface water level is higher than groundwater table.

obtained through the Abbay river flow at the Sudan border at the end of the dry season i.e. 100 m^3/s.

Discharge

In the Abbay basin, springs and water table emergence, including river drainage, certainly form one of the most important output of the aquifer system. Borehole abstraction presently does not form a significant output when compared with spring flow and river drainage. An order of magnitude of this latter discharge can be obtained through the Abbay river flow at the Sudan border at the end of the dry season i.e. 100 m^3/s.

Wet land in the Basin

Abbay basin has abundant wetland ecosystems that are distributed across the sub basins. *Of the total skin area of the basin, its* wetlands area accounts 2.9% (FDRE MoWR, 1998). Out of the 2.9% the basin water bodies areas accounts about 1.7% of the basin area coverage i.e. 3,415 km^2 are and about 1.2% i.e. 2,384 km^2 are marshy and swampy wetlands.

Wetlands are much more common in the Amhara region (2.74% of area of which 90% of the wetlands are found within Abbay drainage system (Woody Biomass 2002) than in Oromia (1.11%) or Benishangul-Gumuz (0.45%).

The wetlands of Amhara Region are distributed all over the region, but the largest portion of the wetlands are found in the Abay River drainage system associated with Lake Tana such as Fogera, Dembi, Kunzela flood plains, marshes and swamps are dominant within Awi and Western and Eastern Gojjam zones. Benshaungul Gumez Regions of the basin are dominated by riverine types of wetlands associated with Dubus Rivers.

Furthermore the Oromia Region, especially with a varied landscape and considerable rainfall up to 2200mm in Illubabor highlands, has varied wetlands from small wetlands scattered all over to larger and bigger wetlands located deep in forested areas. The dominant types found in the region include valley bottom swamps, marshes, floodplains, human made reservoirs mainly Fincha, peat swamps and forested and riverine wetlands.

Accordingly, the total coverage areas of wetlands in the Tana, Debub Gojjam, Fincha and Beles sub basins are estimated to be above 70,000 hectares of marshy or swampy areas. Tana sub basin is the largest center of wetland areas in the basin as well as in Ethiopia. Wetlands of the sub basins are rich in bird, plant and large mammals' diversity including reptiles.

Photos of wetlands:

Wetlands around Tana (upper right), around Foggera (bottom two)

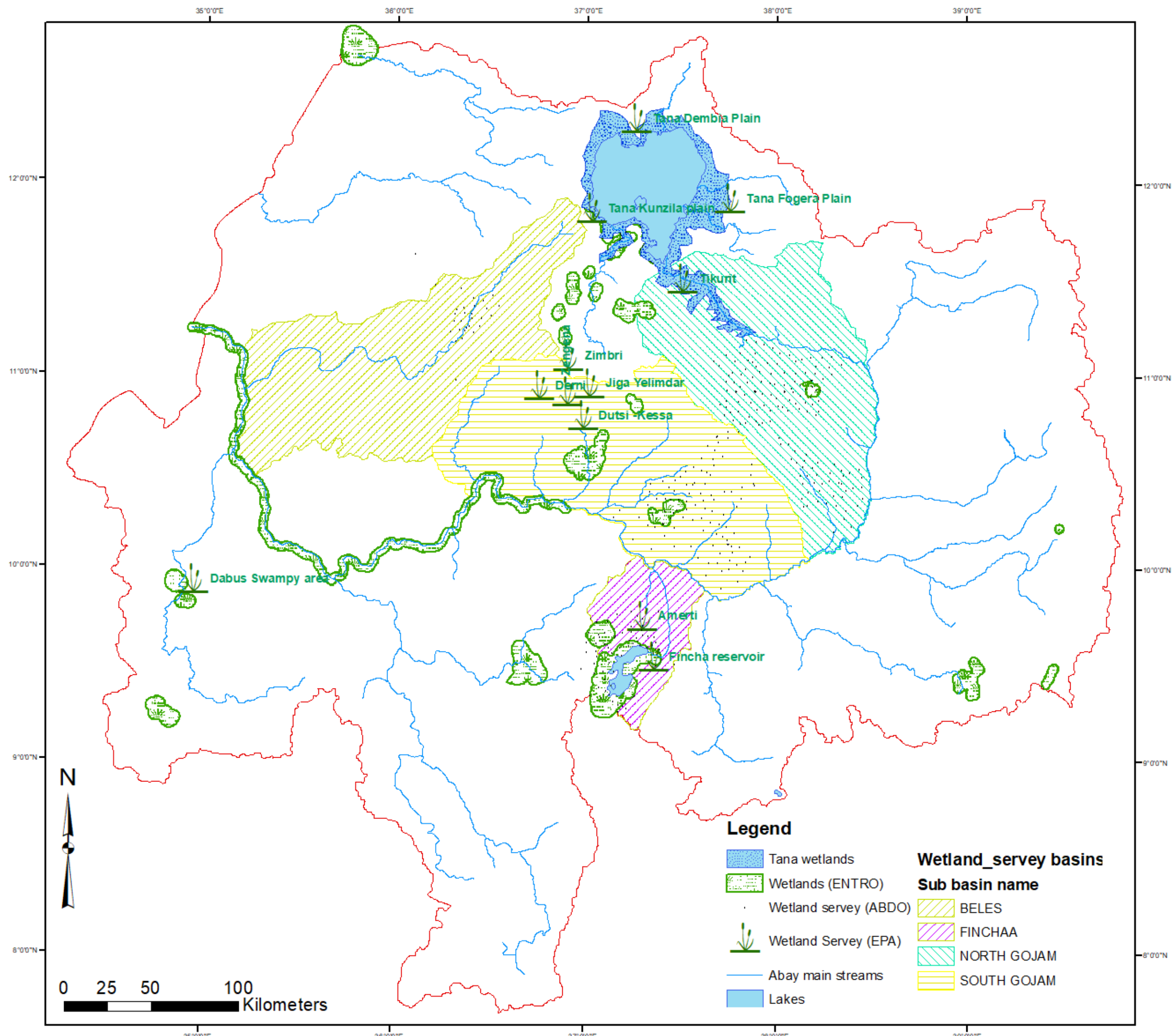


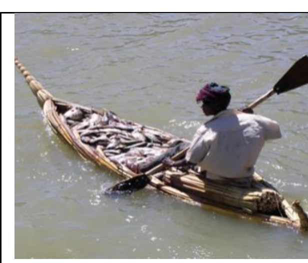
Figure 2.9 Wetland distribution in Abbay Basin

Source: developed by the ABDO office (this map was developed by combining a data set from ENTRO, wetland survey done by EPA, ABA, and other research studies for the purpose of this work only. So, it is unauthorized for a third party to use and even to cite this map for any applicable study)

Geba Flood Plain from Illubabor Oromiya

Chebere Wetland Hurumu Woreda Illubabor

Wetland agriculture – Gimbi Area



Fishing by Tenque in Lake Tana

Wet land survey in selected watersheds

Accordingly to the survey done by ABA professionals substantiated respective woreda's agricultural office data sets, the total coverage areas of wetlands in the Tana, Debub Gojjam, Fincha and Beles sub basins are estimated to be above 70,000 hectares of marshy or swampy areas. Tana sub basin is the largest center of wetlands areas in the basin as well as in Ethiopia. Wetlands of the sub basins are rich in bird, plant and large mammals' diversity including reptiles.

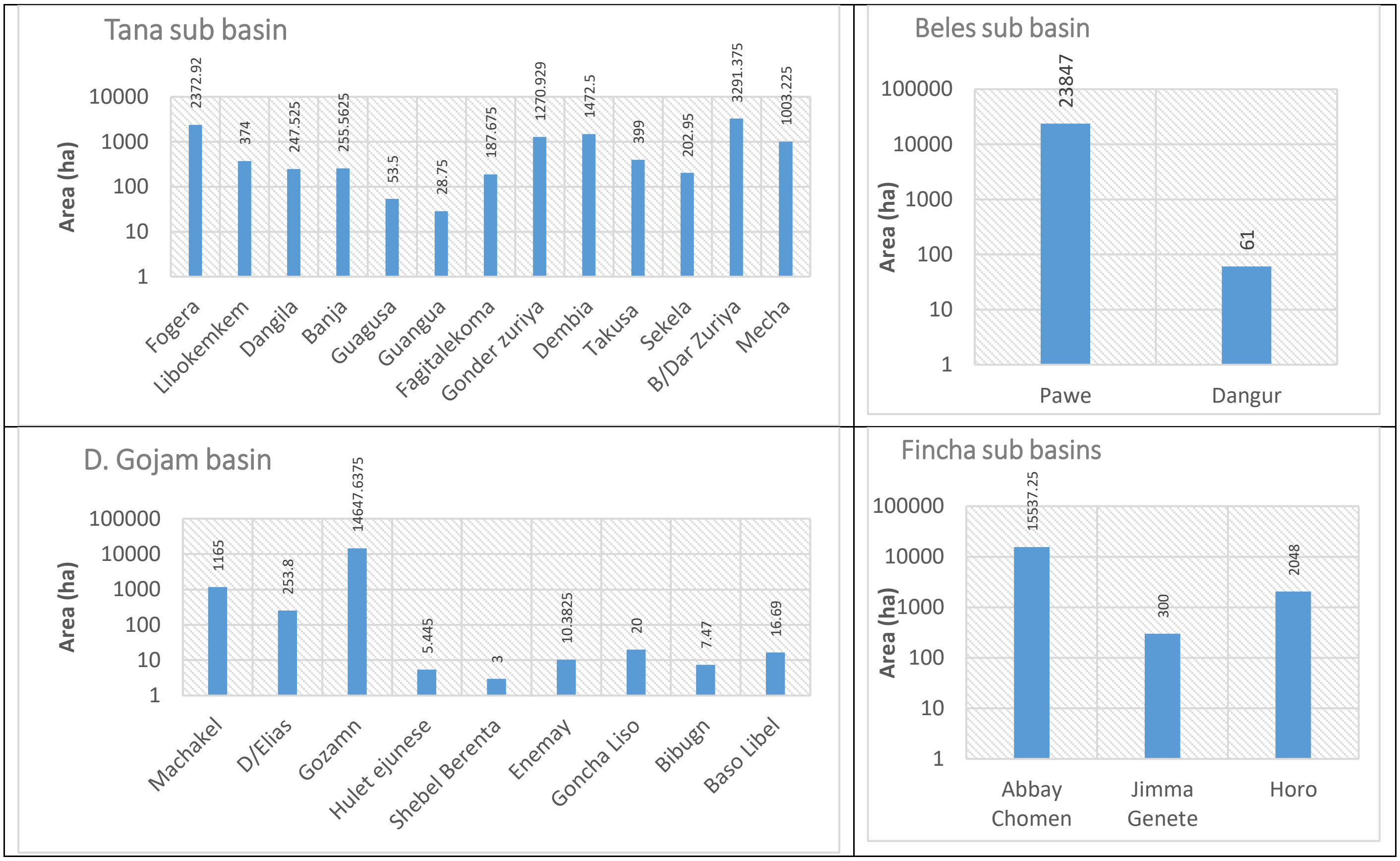
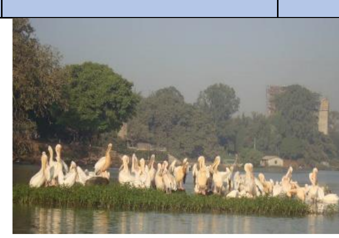


Figure 2.10 wetland distribution in the main wetland area sub basins

Wet land use in the basin	Bird species	Plant species in wetlands
Animal grazing (*special for dry season grazing*) Agriculture and fishing (*e.g. flood rice cultivation in Fogera and fishing in Tana)* Craft material (*e.g. Tanqua, Gessa, agelgel made from Papyrus, palm products and sedges)* Social/Ceremonial use (*green-grass cuts like cheffe, Qetema)*	Koki, Gigra, Groose, Amora, Kura, Dimbit, Sorene, Eagle, Pigeon, Segon	Fila, Gicha, Papyrus, Tucha, Muja, Guasa, Qetema, Kega, Koso, Woyira, Acacia, Bamboo, Sugar cane, Euclyptus Comaldulesis, Olea Africana

Papyrus at lake Tana

canariensis



Birds

Papyrus made Tanqua in Lake Tana

Chapter Three

Hydro-climate of the basin

Climate characteristics of the basin

Quick Summary

Climate class	Rainfall	Temperature	Evapotranspiration
Tropical climate in Weastern part Temperate climate in Eastern part	Range: 787 - 2200 mm Average pricipitaion (representation to basin) is mainly experienced in central, low rain fall in the eastern and north western; and high rain fall in the south and south western part of basin.	Max Tem: Min Tem: Warm area: Cold area:	PET:1,056 - 2,232mm In water balance definition, NE part of the basin is main Water sink area while the East and Southern counter parts are Water source areas of the basin.

Climate Classes of the Basin

The climate of Abbay varies from cool highland to tropical type climates. The climate in the basin is dominated by two main factors: the near-equatorial location, and the altitude, from about 470m to more than 4,260m above sea level. The influence of these factors determine a rich variety of local climates, ranging from hot and nearly desert along the Sudan border to temperate on the high plateau or even cold on the mountain peaks.

According to *the modified Köppen system* there are Five types of climate in the basin as indicated in the map below.

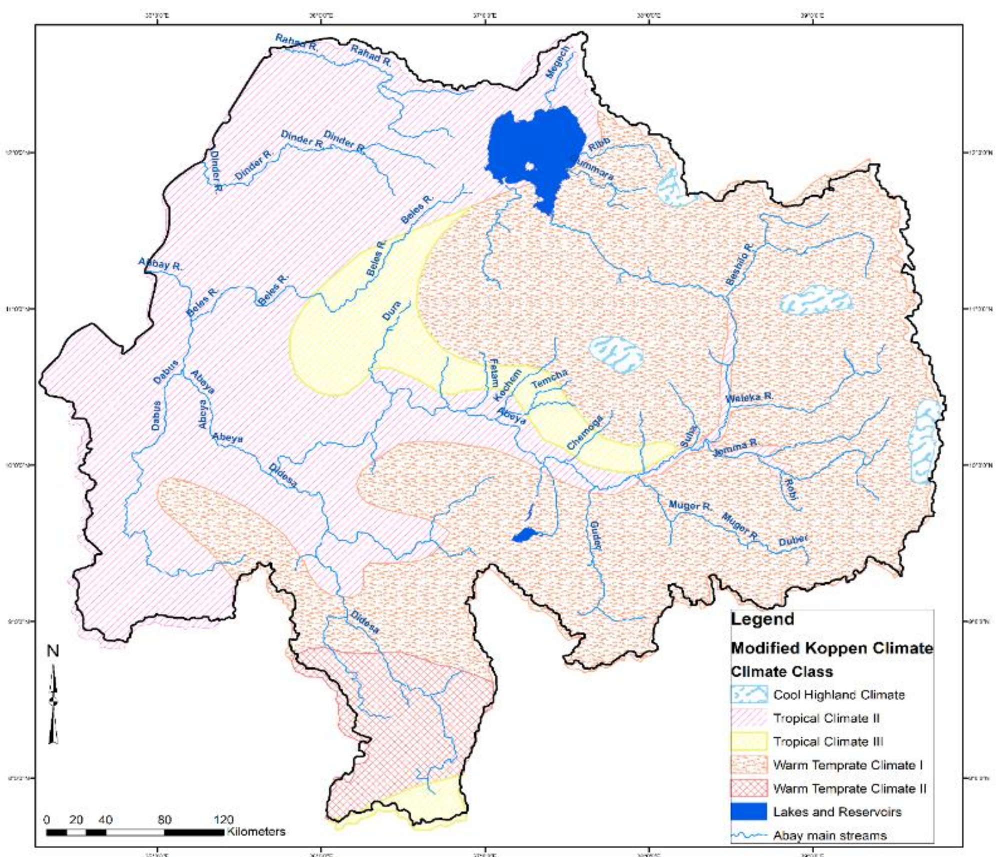


Figure 3.1 Modifiedd Koppen climate classification of the basin

Rain Fall

The rainy season (Kiremt) in the basin contributes from about 50% up to nearly 90% of the annual rainfall to the north and north east part and 40% to the south part of the basin. The small rainy season (Belg) is only significant in the extreme east of the basin. The south and southwest parts of the basin receives high precipitation while the east and northeast parts of the highlands receive low precipitation. The rainiest sub basins are in the southern part of the basin in the Oromia region. Generally rainfall ranges between about 787 mm and 2200 mm per year; The lowest rainfall recorded less than 1000 mm per annum in the Beshelo, Welaka, Jemma, Muger, Guder, and parts of Dinder and Rahad.

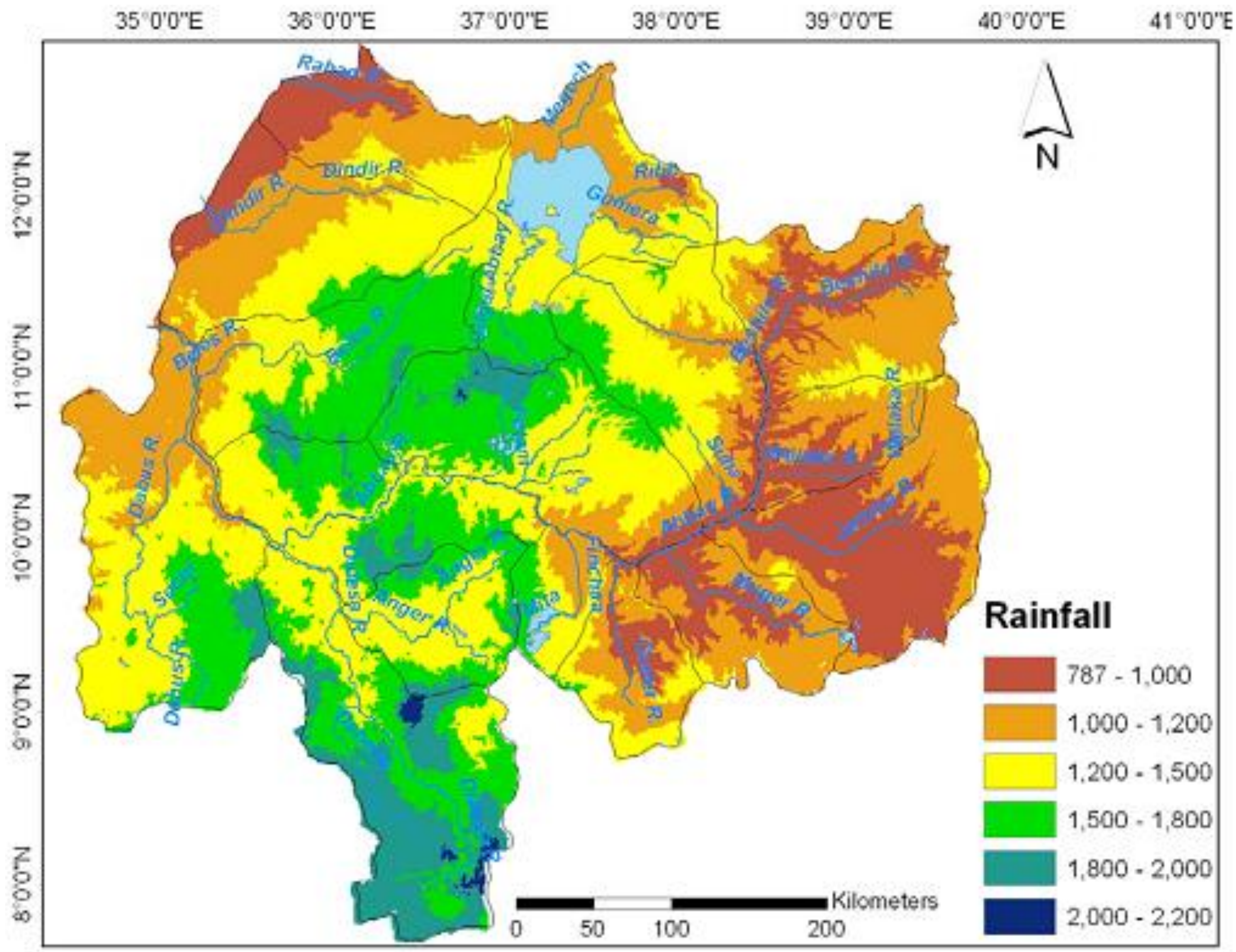


Figure 3.2: Rainfall Distribution in the Abbay Basin

Temperature

The highest temperature is observed in the north western part of the basin, in parts of Rihad, Dinder, Beles and Dabus, the maximum temperature being 28^0C - 38^0C and minimum temperature 15^0C - 20^0C. Lower temperature observed in the highlands of Ethiopia in the central and eastern part of the basin. The maximum and minimum temperature in the highland regions of the basin ranges from 12^0C - 20^0C and -1^oC to 8^oC respectively.

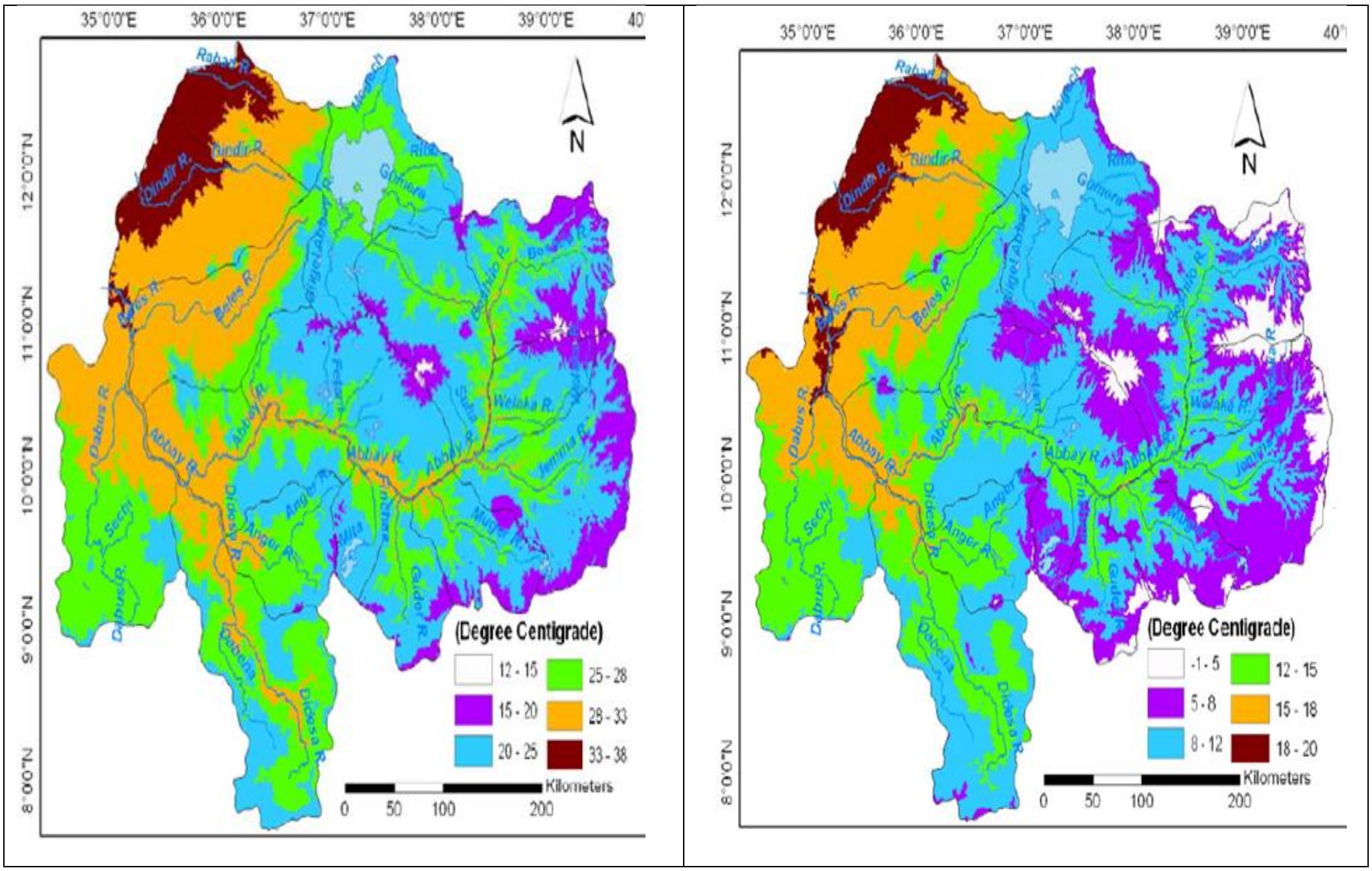


Figure 3.3: Maximum (left) and Minimum (right) temperature distribution in the basin

Evaporation

Potential Evapotranspiration (PET) in the basin ranges between 1,056mm and 2,232mm per year. High PET is observed between 1800mm and 2,232mm per year in North Eastern parts of the basin, in Dinder, Rahad, and parts of Beles and Didessa sub basins. The Eastern and Southern parts having lower PET ranging between 1,200 and 1,800mm per year and the lowest PET below 1,200mm per year observed in the parts of the highlands. This is highly correlated with the temperature.

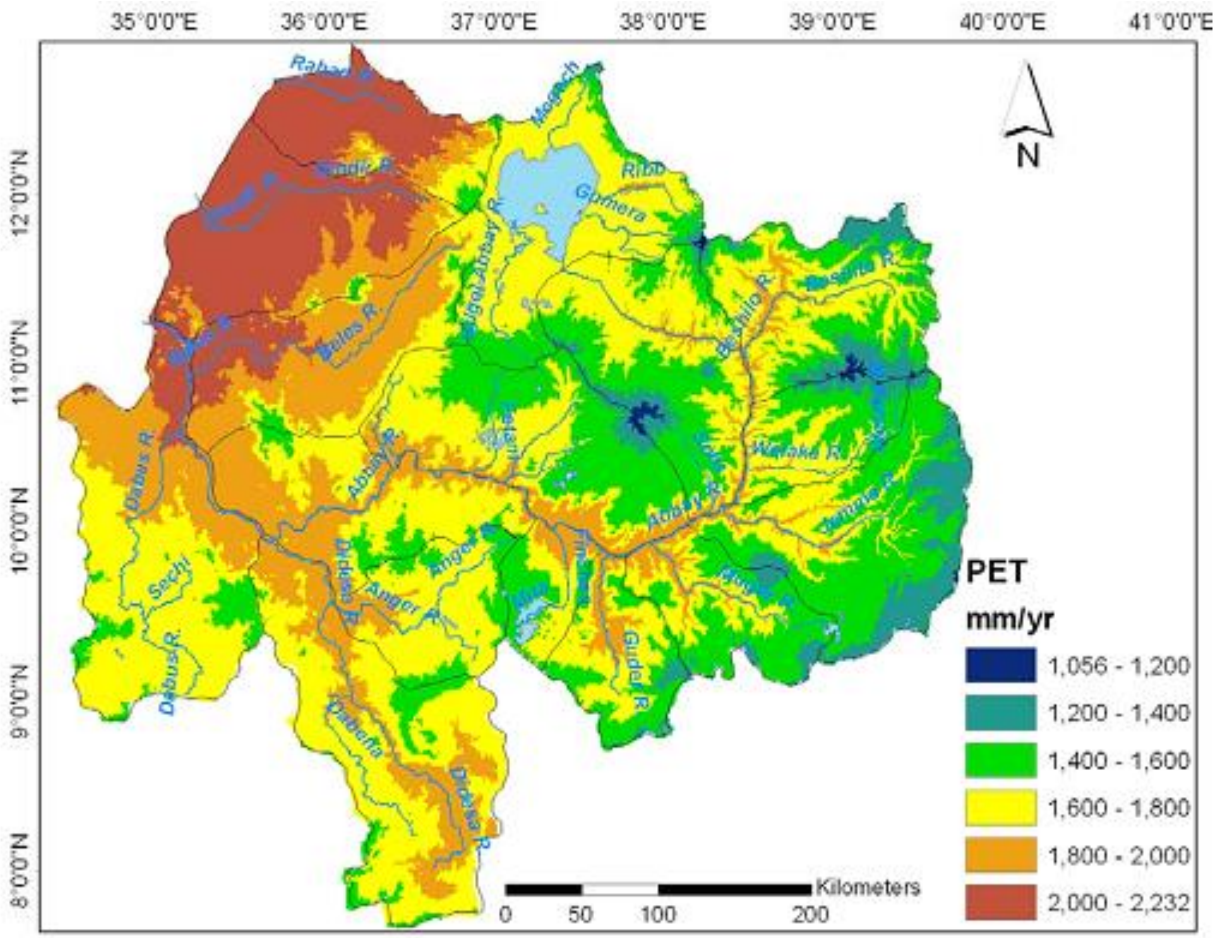


Figure 3. 4 Average annual Potential evapotranspiration in the basin.

Relative Humidity and Wind Speed

Seasonal pattern determines the annual variation of all climatic parameters. From December to February which is dependent on location, relative humidity is at its minimum and sunshine duration is at its maximum; from March to May which is dependent on location wind speed is maximum; about August, the daily variation of temperature is low, relative humidity is high, sunshine duration is short and wind speed is low. Wind speed depends of the exposition of the measuring station: valley, hill, plateau, etc.

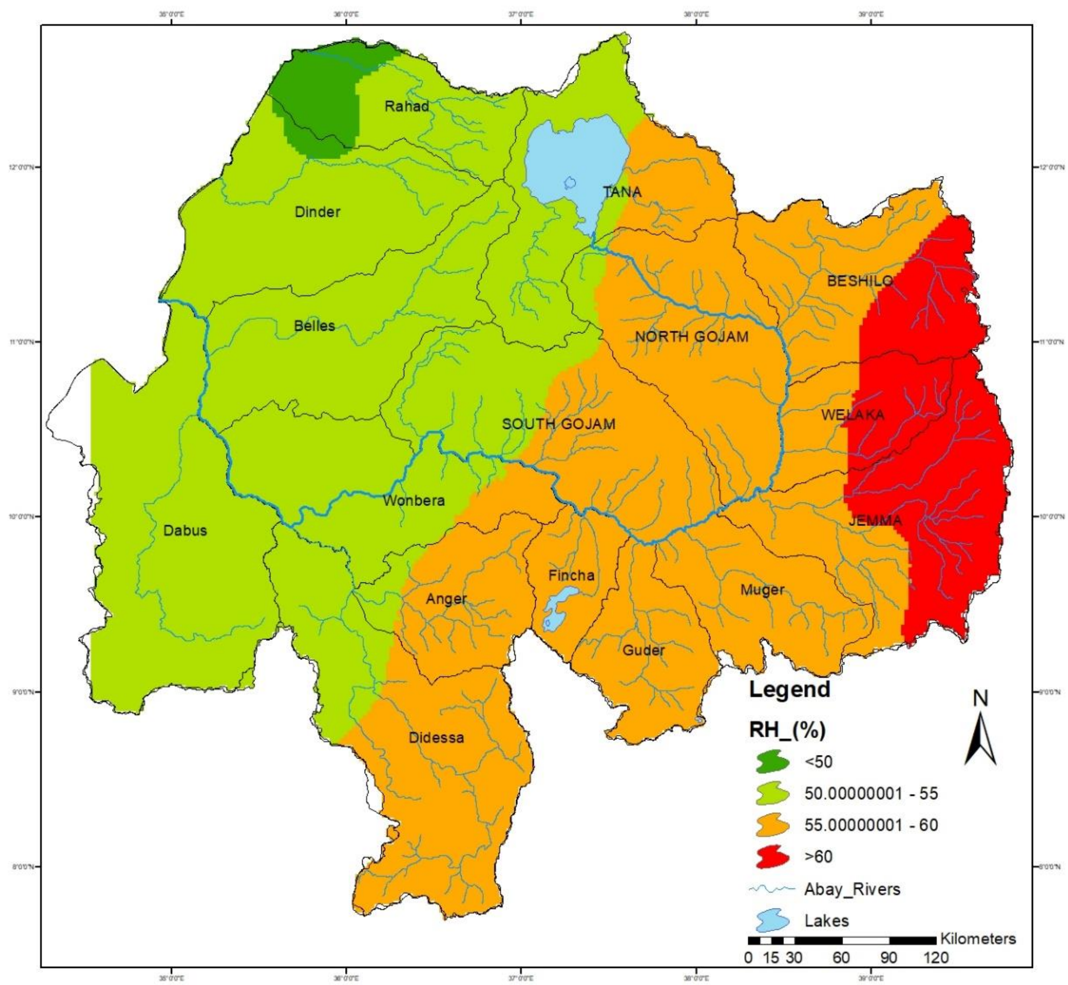


Figure 3. 6 Average annual Relative humidity in the basin (Source: developed by office, ABDO)

(Method: the information is first extracted from FAO climate information tool for some locations of sellected sites (*reprezentative sites of different altitude and climate zones*), and then plot and interpolated with IDW methods using Arc GIS environment.)

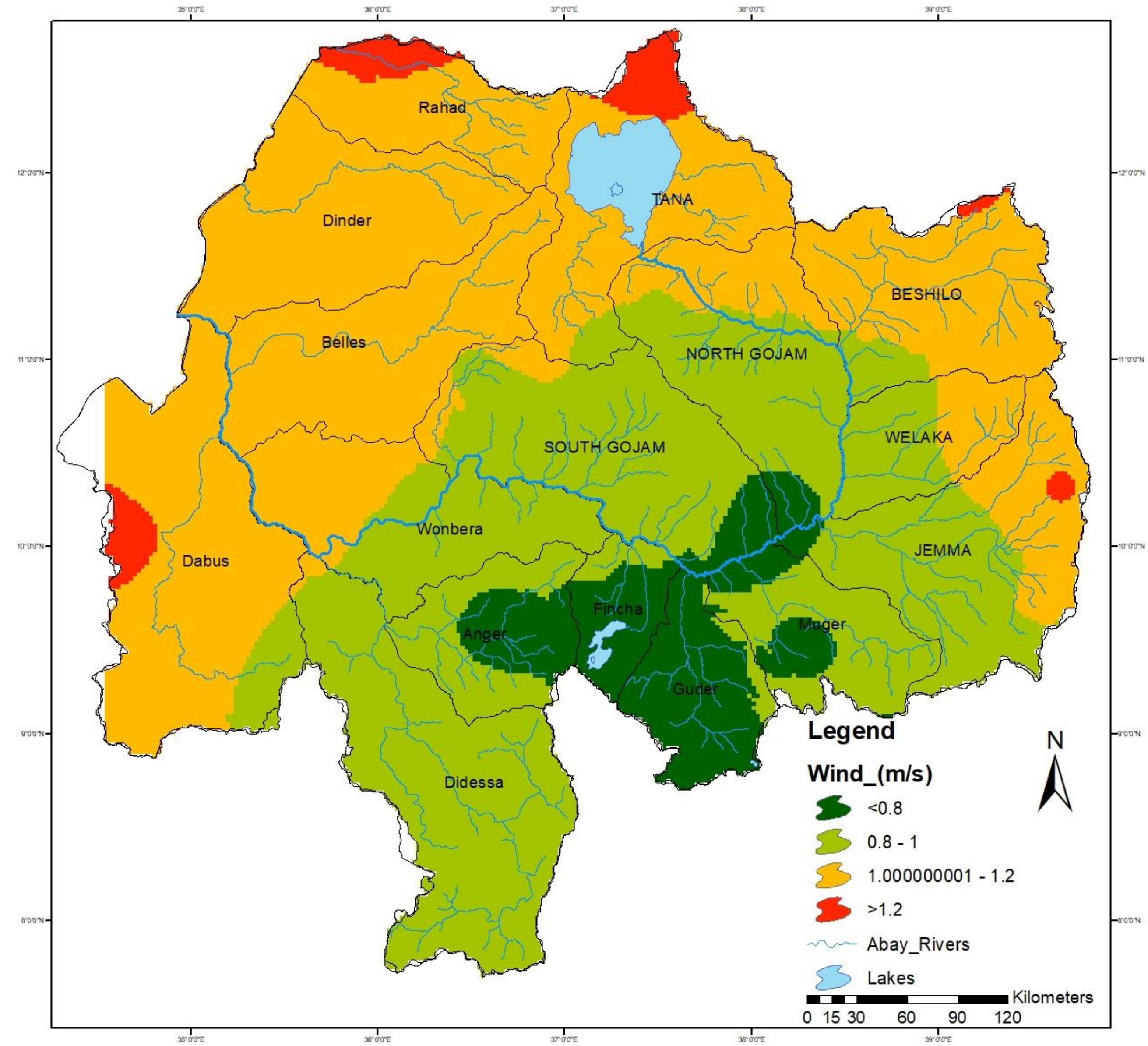


Figure 3. 6 Average annual Wind speed at 2 m height in the basin.
(Source: Developed by office, ABDO)

(Method: the information is first extracted from FAO climate information tool for some locations of sellected sites (*reprezentative sites of different altitude and climate zones*), and then plot and interpolated with IDW methods using Arc GIS environment.)

Climate Monitoring Stations

Generally, there are more than 349 identified meteorological stations which contain 30 1st class or principal, 28 class two, 112 3rd class and 176 4th class rain gauge stations in the basin monitored by NMA. There are also 33 new and upgraded meteorological stations which are established through HIS/BIS within and around the basin specifically in Tana and Beles sub basins. Out of 33 upgraded stations seven of them are automatic recording and transferring data to ABA data center starting from about January 2015 G.C. The climatic data network shows there is uneven scattering of the stations over the basin and insufficient coverage of low and high areas.

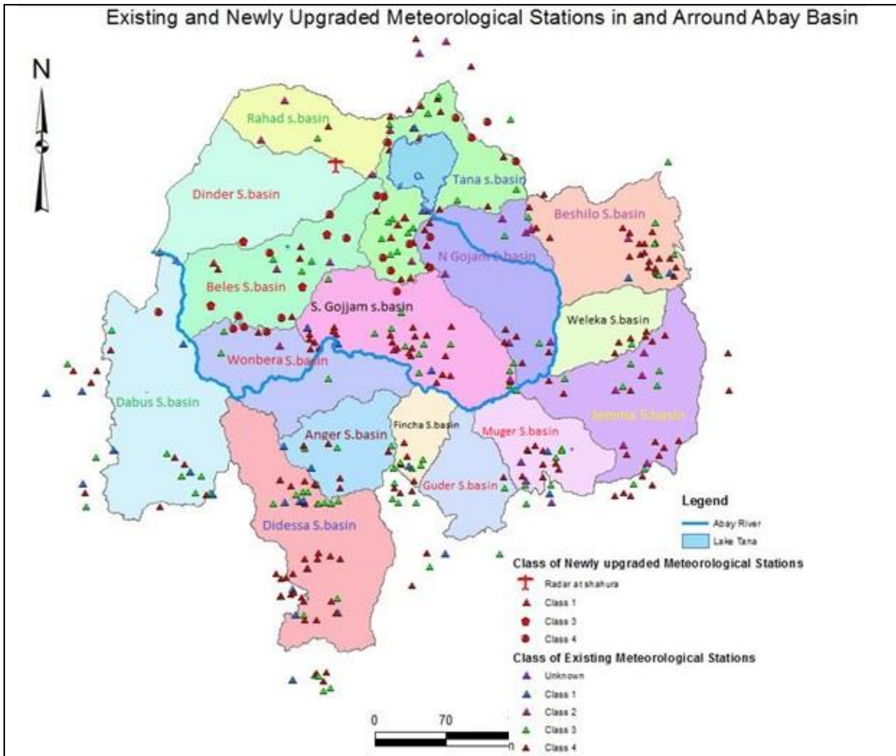


Figure 3.7 Meteorological monitoring station in the basin

The Tana, Dedissa and Jemma sub basins have intense stations and data coverage; both the eastern and the western parts of the basin have a very low station density. The catchments of Beshilo and Welaka, Rahad, Dinder and Beles, have a very poor coverage of meteorological stations. A radar is also found the basin specifically Shahura area.

Hydrology of the Basin

Drainage and Catchment of the Abbay River-Basin:

The Abbay river basin is sub divided in to 16 major watersheds and more than 20 main tributary rivers. In all major rivers of the basin 80% of the flow occurs in a period of four months from July to October. The main tributaries of the Abbay are the Dabus and Didessa rivers with respectively 10% and 8.5% of the total flow at the border.

Though Abbay starting from its source Gish Abbay (Sekela) to flows south ward and to join Lake Tana at its South Wester tip, the main Abbay river starts at the outflow of lake Tana location in its south eastern tip at Bahir Dar. Abbay flows in a relatively shallow river banks, in a general south direction on medium altitude (1800masl) plateau for some 30 km and at Tiss - Esat (water that smokes) it is plunged with a 50m deep fall, usually knowen as Tiss Esat Fall, which then after it enters in to the Abbay/Nile gorge. Abbay, then drains the Gojjam highlands (part of the central highlandplateaus of Ethiopia with an altitude reaching to more than 4000 masl) in its right bank and the North Gonder, South Wollo and North Showa highland plateaus (also part of the central plateaus of Ethiopia) in its left bank.

The river after entering the gorge, flows in a clockwise spiral and initially in a general south direction, collecting runoff from its major tributaries such as Beshilo, Welaka and Jemma in the left bank and Abeya, Suha and Muga (as part of South Gojjam Watershed) in its right bank. From the Addis-Bahir Dar highway bridge and downstream, Abbay river flows in a general West direction following the same clockwise pattern and collects runoff from the West Showa and Wellega highland plateaus (part of the western highland plateaus of Ethiopia) in its left bank through its major tributaries Muger, Fincha, Angar, Deddesa and Dabus and in it right bank collecting runoff from the Gojjam highland plateaus (part of the Central and western highland plateaus Ethiopia) through its major tributaries such as Yeda, Chemoga, Birr, Fettam, Dura and Beles, all together identified as the South Gojjam watershed. The Dabus in the left and the Beles in the right are the two major contributors joining the Abbay close to the border.

Figure 3. 8 Drainage Network and Sub Catchments in Abbay basin

No.	River name	Length(m)	No.	River name	Length(m)
1	Didessa	444,619	12	Anger	182,561
2	Dinder	351,764	13	Welka	172,864
3	Beles	341,538	14	Guder	147,465
4	Dabus	330,610	15	Dura	135,647
5	Rahad	329,840	16	Gumara Shet	130,844
6	Jemma	227,038	17	Jedeb	125,350
7	Beshilo	211,249	18	Fincha'a	125,271
8	Wench'i	199,603	19	Birr	117,166
9	Dabena	193,020	20	Chacha	99,168
10	Gilgel Abbay	185,917	21	Suha	90,596.1
11	Muger	183,086	22	Megech	88,914.1

Table 3. 1 Descriptions of major rivers in the basin

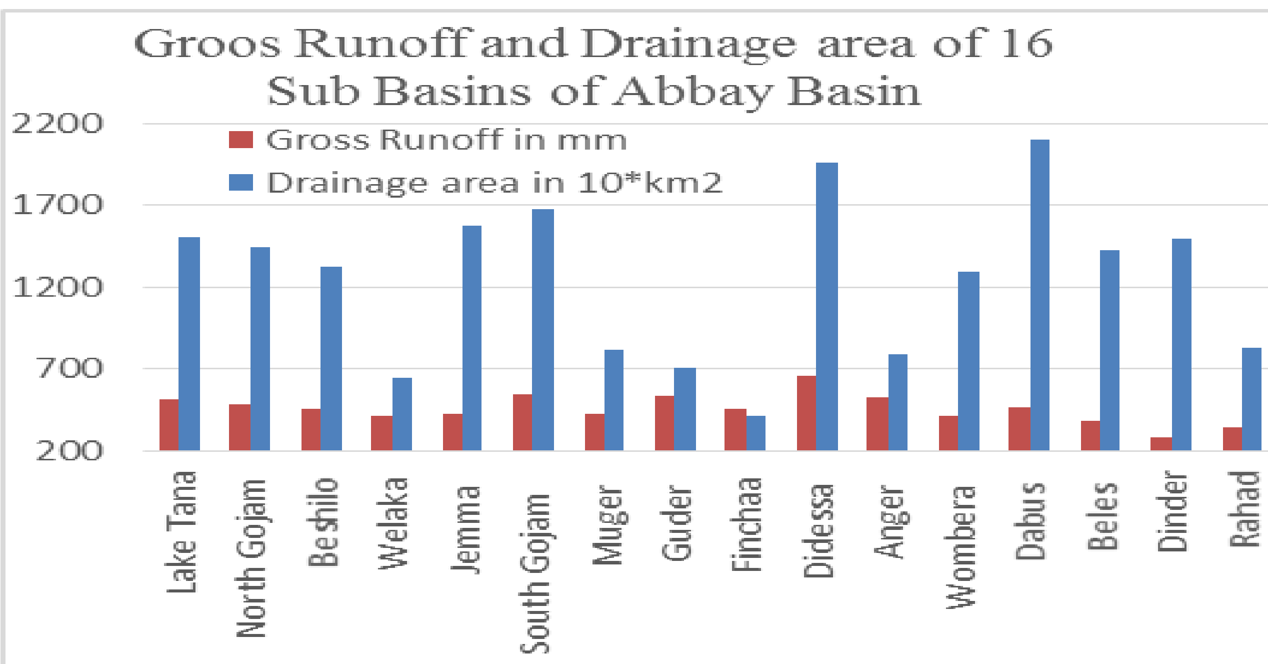


Figure 3.9 drainage area and runoff potential in Abbay sub basins

Annual River flow patterns for hydrological stations

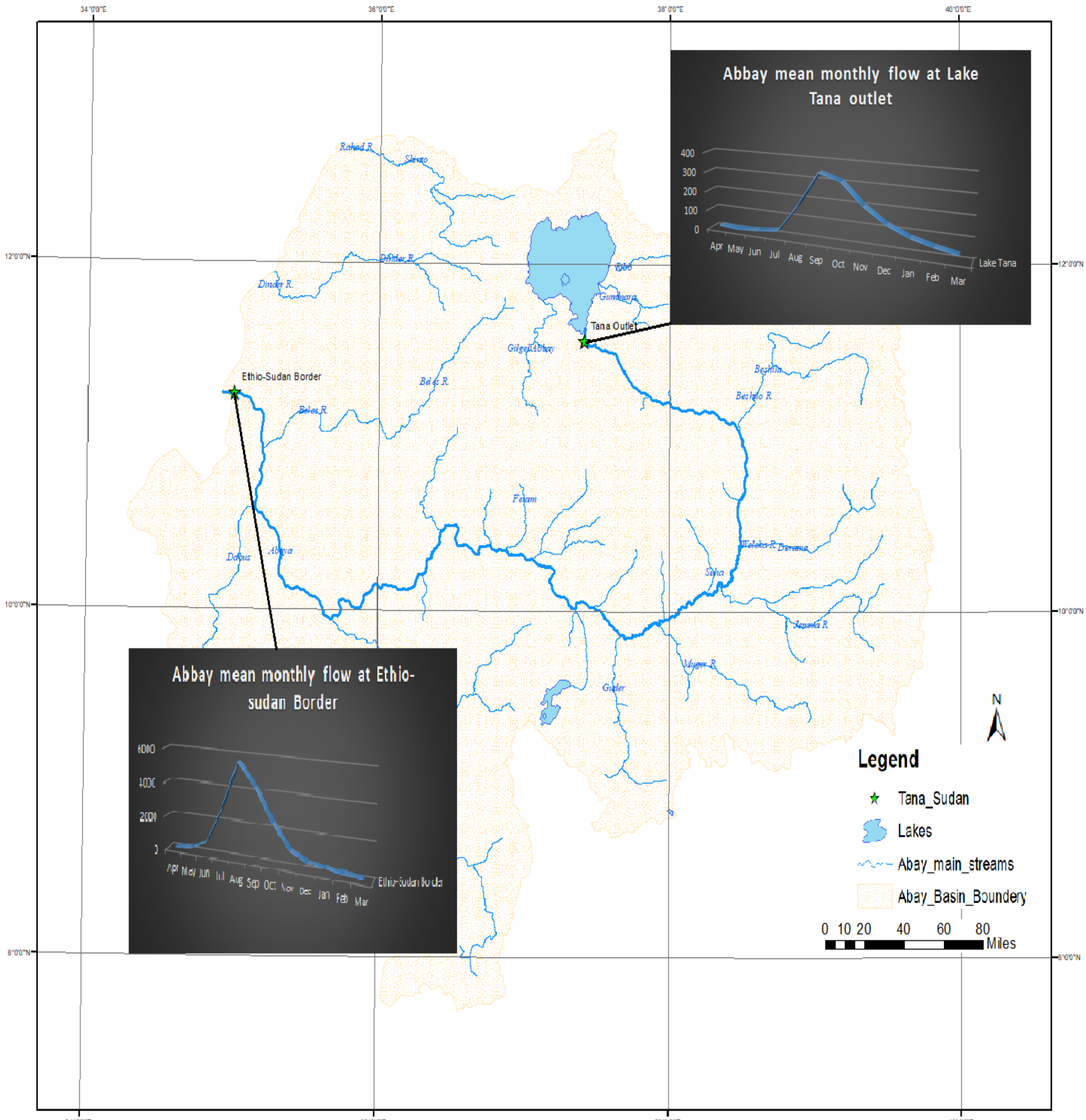


Figure 3.10. Abbay River runoff at the source and border of Ethiopian teritory

Mean monthly discharges for the Abbay at the outlet to Lake Tana and at the Ethiopian/Sudan border are shown in Tables 3.2 and 3.3.

Table 3. 2 Mean monthly discharge of the Abbay river at the outlet to Lake Tana (m^3/s)

Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Av. Yr.
Mean	83	55	34	19	11	9	31	174	345*	312	205	130	117
Max	151	108	66	29	19	19	71	341	645*	556	351	229	645
Min	29	19	12	5	2	1**	10	35	71	82	58	41	1

* = max ; ** = minimum value.

Table 3. 3 Mean monthly discharge of the Abbay river at the Ethiopian/Sudan Border (m^3/s)

Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Av. Yr.
Mean	345	229	162	141	240	722	2841	5634*	4340	2468	1019	526	1556
Max	527	434	306	194	470	1453	6018	6988*	5919	3708	1551	755	6988
Min	212	137	93	81**	99	472	1930	3693	2813	1305	681	324	81

* = max ; ** = minimum value.

At the Ethiopian border the catchment area has increased by about ten times (in comparison to the outlet at Lake Tana) as does discharge. However the maximum and minimum discharges at both sites are different with the Abbay at the Sudan border peaking in August whereas the maximum discharge from the Abbay at Lake Tana is one month later in September.

The minimum discharges also show a similar pattern with the Abbay at the Sudan border experiencing its lowest flow in April, while the Abbay at Lake Tana records its lowest flow, two months later in June. The difference is due to the storage effect of Lake Tana in delaying the release of flows from the lake. The discharge for the Gilgel Abbay, one of the tributaries that flow into Lake Tana, also demonstrates the storage lag that occurs in the lake with the Gilgel Abbay recording maximum discharge in August and minimum in April which is the same as the Abbay at the Sudan border. Flows at both places are also strongly influenced by dry and wet years and despite the natural storage ability of Lake Tana the lowest daily flow ever recorded in the Abbay at the exit from Lake Tana is 0.26 m^3/s recorded in June 1970 and the highest 683 m^3/s recorded in September 1975. At the Sudan border the respective extreme value flows are 67 m^3/s in May 1965 and 9,308 m^3/s in August 1969.

There is a 10 times increase in discharge between the Abbay at Lake Tana and the Abbay at the Sudan border which demonstrates the importance of the inflow yielded by the additional 156,933 km^2 catchment area from the Abbay tributaries.

Sub basins and main tributaries hydro climatic characteristics

Table 3. 4 ***Sub basin hydro-climatic characteristics in Abbay basin***

Sub-basin name	Area (km^2)	Annual Rainfall (mm)	Annual evapo-transpiration (mm)	Annual runoff (mm)	Annual flow (Mm^3)	coefficient of runoff
Guder	7,011	910	1,307	312	2,187	0.34
Dabus	21,030	2276	1,112	297	6,246	0.13
Finchaa	4,089	1766	1,290	438	1,719	0.25
South Gojam	16,762	1633	1,183	299	5,012	0.18
Anger	7,901	1813	1,318	298	2,355	0.16
Beles	14,200	1655	1,274	306	4,345	0.18
Didessa	19,630	1816	1,308	289	5,673	0.16
Muger	8,188	1347	1,210	298	2,440	0.22
North Gojam	14,389	1336	1,242	305	4,389	0.23
Jemma	15,782	1105	1,059	304	4,798	0.28
Tana	15,054	1313	1,136	253	3,809	0.19
Welaka	6,415	1072	1,263	323	2,072	0.3
Beshilo	13,242	982	1,140	296	3,920	0.3
Wombera	12,957	1660	N/A	299	3,874	0.18
Dinder	14,891	N/A	N/A	188	2,797	N/A
Rihad	8,269	N/A	N/A	133	1,102	N/A

Table 3. 5 Hydro-meteorological characteristics of selected catchments (1995-2004)

Catchment number	Catchment name	Area (km^2)	Long term mean annual values (mm a^{-1})			
			P	**E_P**	**Q**	**E**
1	Megech	511	1138	1683	421	717
2	Rib	1289	1288	1583	349	939
3	Gumera	1269	1330	1671	841	488
4	Beles	3114	1402	1826	643	759
5	Koga	295	1286	1751	606	679
6	Gilgel Abay	1659	1724	1719	1043	681
7	Gilgel Beles	483	1703	1741	897	806
8	Dura	592	2061	1788	1004	1056
9	Fetam	200	2357	1619	1400	956
10	Birr	978	1644	1677	553	1091
11	Temcha	425	1409	1512	623	785
12	Jedeb	296	1449	1454	861	587
13	Chemoga	358	1441	1454	461	980
14	Robigumero	938	1052	1362	289	762
15	Robijida	743	1002	1379	222	780
16	Muger	486	1215	1654	480	735
17	Guder	512	1734	1744	713	1020
18	Neshi	327	1654	1416	686	967
19	Uke	247	1957	1488	1355	602
20	Didessa	9672	1538	1639	334	1204

Note: P, EP, Q and E stand for basin precipitation, potential evaporation, discharge and actual evaporation, respectively.

Hydrological Monitoring Network

Currently there are about more than 159 hydrologic stations in the basin monitored by ABA according to the basin information. Out of all stations 43 are modern HIS/BIS hydrological data collection platforms stations that are installed in Tana and Beles sub basins. The hydrometric network is not evenly distributed over the basin; on the contrary, it is mainly concentrated along the main roads while large areas lack of gauging stations. The worst case is that of the Beshilo, Welaka and Jemma basins, where only very small upper catchments are gauged. Extrapolation of rainfall-runoff relationships that might be established in other basins would be fairly imprudent, since the area covering the Beshilo, Welaka and north of Jemma has particular characteristics when considering physiography, slopes, vegetation and land use, etc.

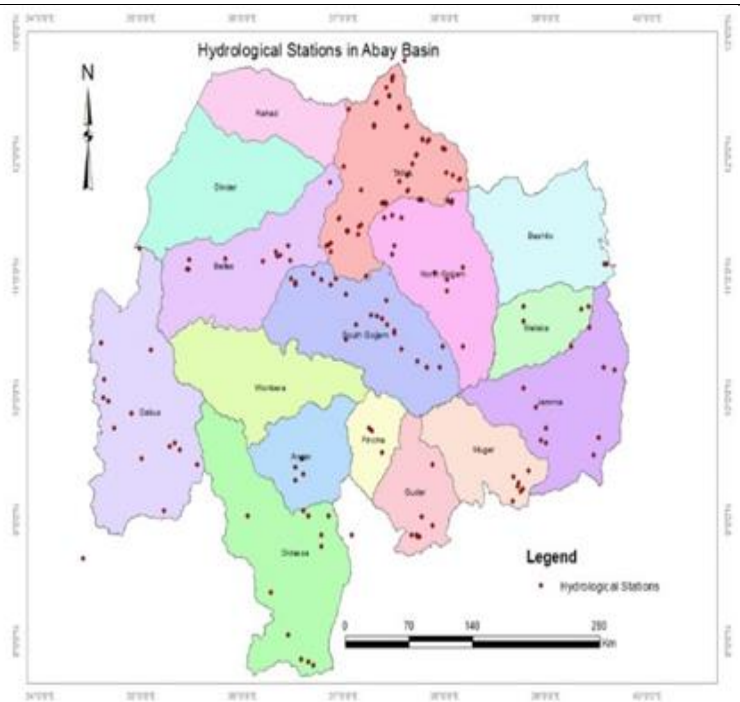


Figure 3. 2 Hydrological stations network of the basin

Figure 3. 1 Manual hydrological stations in the basin

Figure 3. 3 Automatic hydrological telemetric stations in the basin

Climate effect in the basin

In the coming 20-100 years there will be an increase in temperature, a decline in rainfall, an increase in potential evapo-transpiration and a decrease in flow at the border. Muger, Beles, and Welaka are expected to be the three warmest sub-basins with the mean annual temperature of 22.9, 22.4, and 22.4°C respectively. The highest seasonal mean temperature was 25°C and it was from the Muger sub basin during *Belg* season while the lowest temperature of 15.9°C was for the Fincha sub basin during *Bega* season.

For the period of 2021-2051, Muger continues to be warm with a seasonal mean temperature of 26.5 °C during the *Belg* season. The lowest temperature for the same time period reported totals 16.8 °C during *Bega* in the Jemma sub basin. During the period, 2071-2100, Muger is expected to be warmer with an increase in temperature by 19% as compared to the temperature for the 1983-2011 period. North Gojam is expected to have the lowest temperature in the period 2071-2100 even with an increase of 21% of during 1983-2011

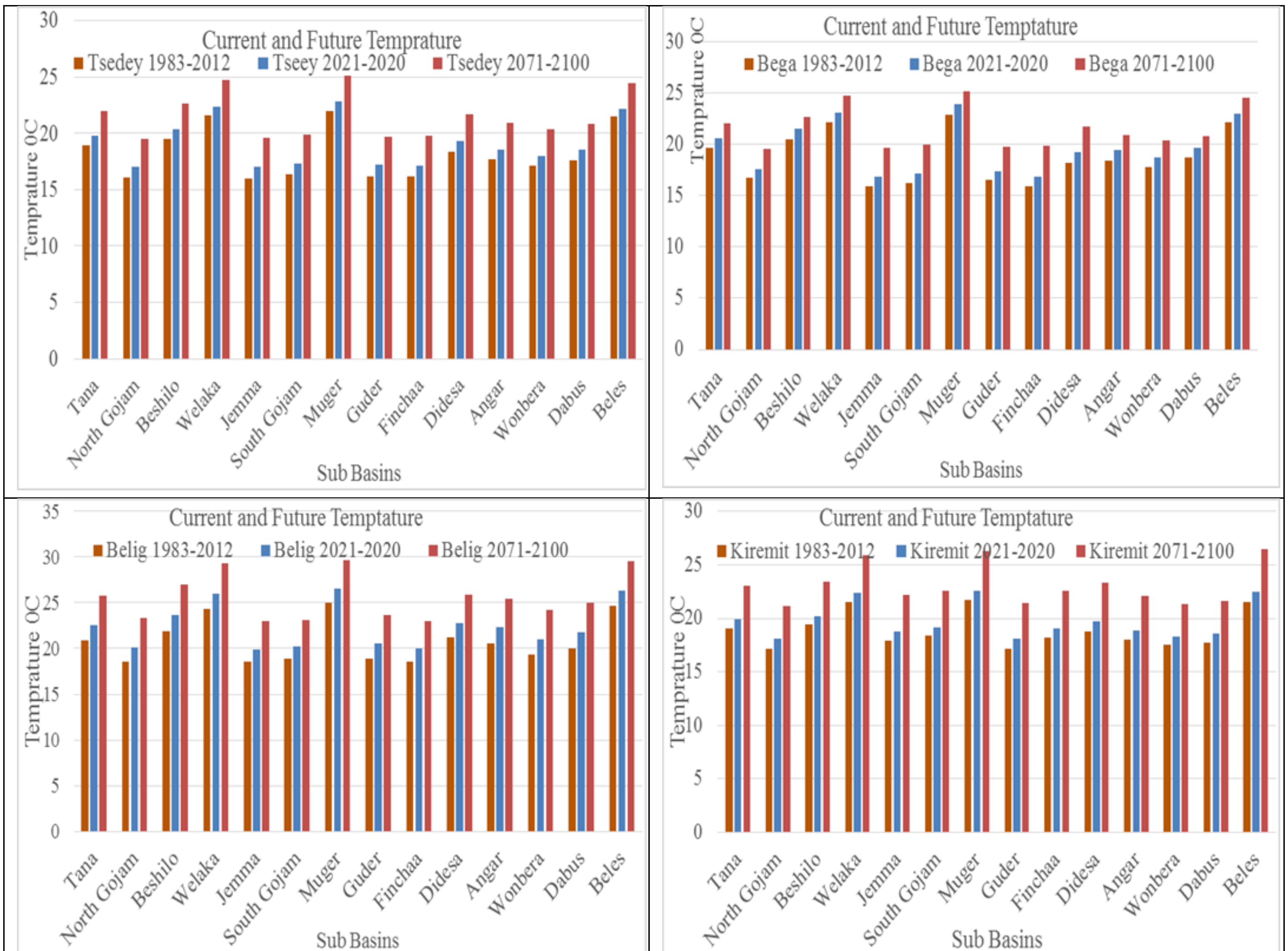


Figure 3. 4 Mean seasonal CCLM current and future temperature scenarios of sub-basins based on ECHAM5 A1B IPCC scenario (1983-2100)

Chapter Four

Socio-economic profile of the basin

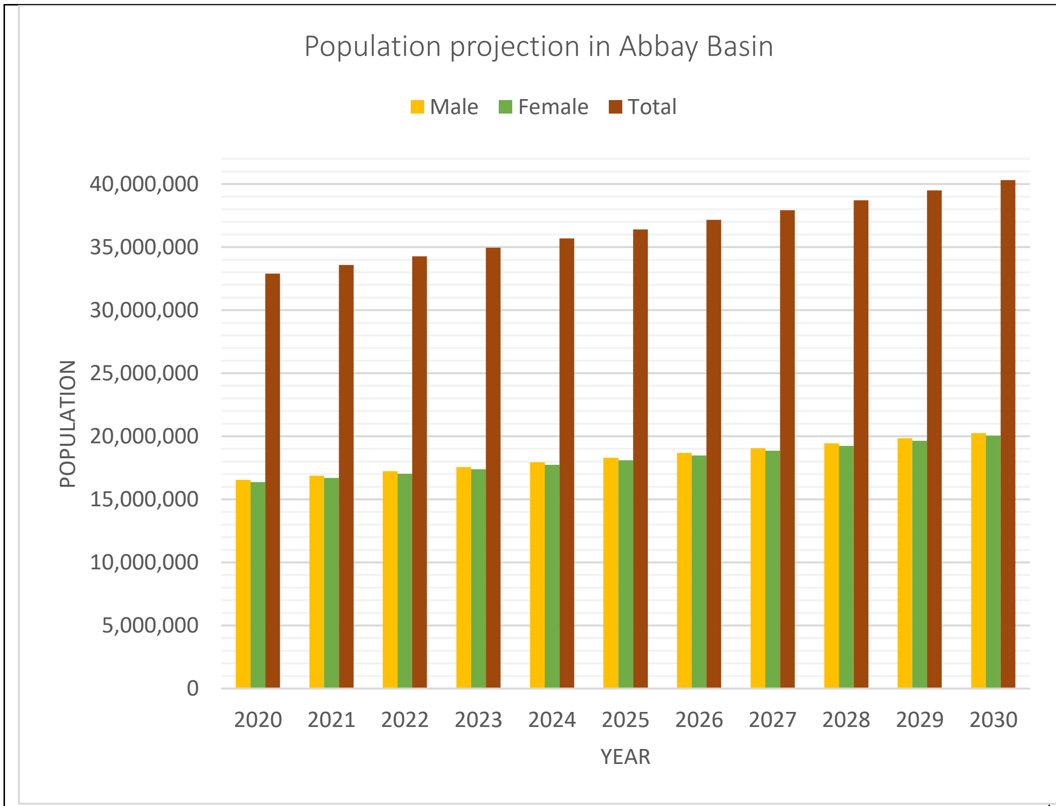
Population Distribution

Quick Summery

Expected Population of the Basin in year 2020	
In Amhara	**19,739,532**
In Oromia	11,843,719
In Benishangul Gumuz	1,315,970
Total	32,899,221

Population Density in the Basin	
Wester Part of the Basin	**< 150 person/sq.km**
Easter and Southern part of the Basin	> 150 person/sq.km

According to CSA and ANRS BoFED, in 2020 the total population of the basin was expected to be about 33 million and it is expected to increase more than 40 million as of year 2030. This number is expected to share about 32 percent of the total population of the country. This figure includes the major cities and towns of the basin population i.e Bahir Dar, Gondar, Deber Markose, Fiche, Assosa, Nekemete, Ambo, etc. From the total population of the basin Amhara region has the population of 60% , Oromia region 36% and Benishangul-Gumuz has the population share of 4 % in the basin.From the total basin population on average 80% of inhabitants live in rural areas of the basin while the rest 20 % population dwell in urban areas.



Year	*Male*	*Female*	*Total*
2015	14,729,945	14,573,398	29,303,343
2016	15,095,247	14,934,818	30,030,066
2017	15,465,081	15,300,721	30,765,802
2018	15,814,592	15,646,518	31,461,109
2019	16,172,002	16,000,129	32,172,130
2020	16,537,489	16,361,732	32,899,221
2021	16,876,507	16,697,147	33,573,655
2022	17,222,476	17,039,439	34,261,915
2022	17,575,537	17,388,747	34,964,284
2024	17,935,835	17,745,217	35,681,052
2025	18,303,520	18,108,994	36,412,513
2026	18,678,742	18,480,228	37,158,970
2027	19,061,656	18,859,073	37,920,729
2028	19,452,420	19,245,684	38,698,104
2029	19,851,195	19,640,220	39,491,415
2030	20,258,144	20,042,845	40,300,989

Figure 4. 1 Graphical and Tabular representation of population growth and trend

As can be seen the table above, the basin population have swelled considerably from 29.3 million to 40.3 million from 2015 -2030. This shows that, fertility manifests itself for the increment of the basin's population. Apparently to the general growth trend, one can see several discernable changes in the proportion of people in urban and rural areas.

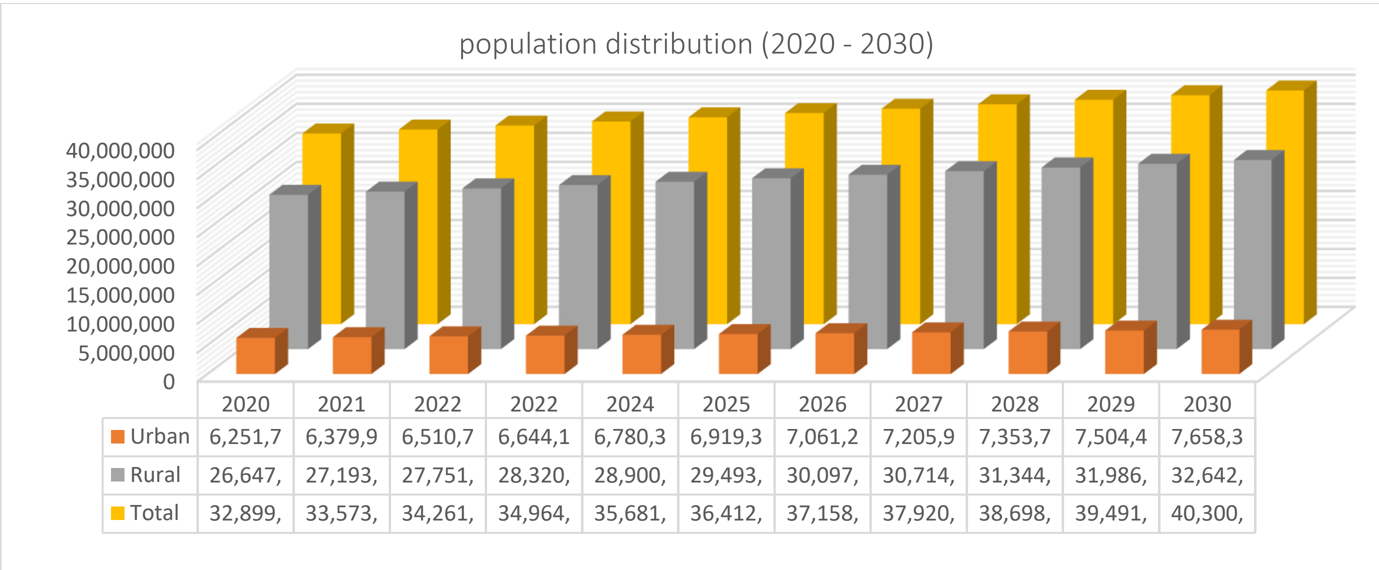


Figure 4.2: urban and rural population distribution in the basin

Population Density

According to UN global population, highly populated areas of the basin include, the northern part of Lake Tana ,the central part of the basin and the southern ends of Didessa sub-basin but there may be variation among the rural and urban areas. The distribution of basin population as shown in the figure below depicts that, the northern, central and some southern end of the area (Tana, South & North gojjam and Didessa sub-basins) are densely populated areas.

Moderately populated area of the basin, covers majority of the central parts and Eastern parts of the basin, (Jemma, Woleka, Beshilo, Anger, Muger, Guder,and Fincha), on the other hand, most of the Western parts of the basin (Belese, Dinder, Rahad, Dabus and Wonbera) are characterized by sparsely populated area.

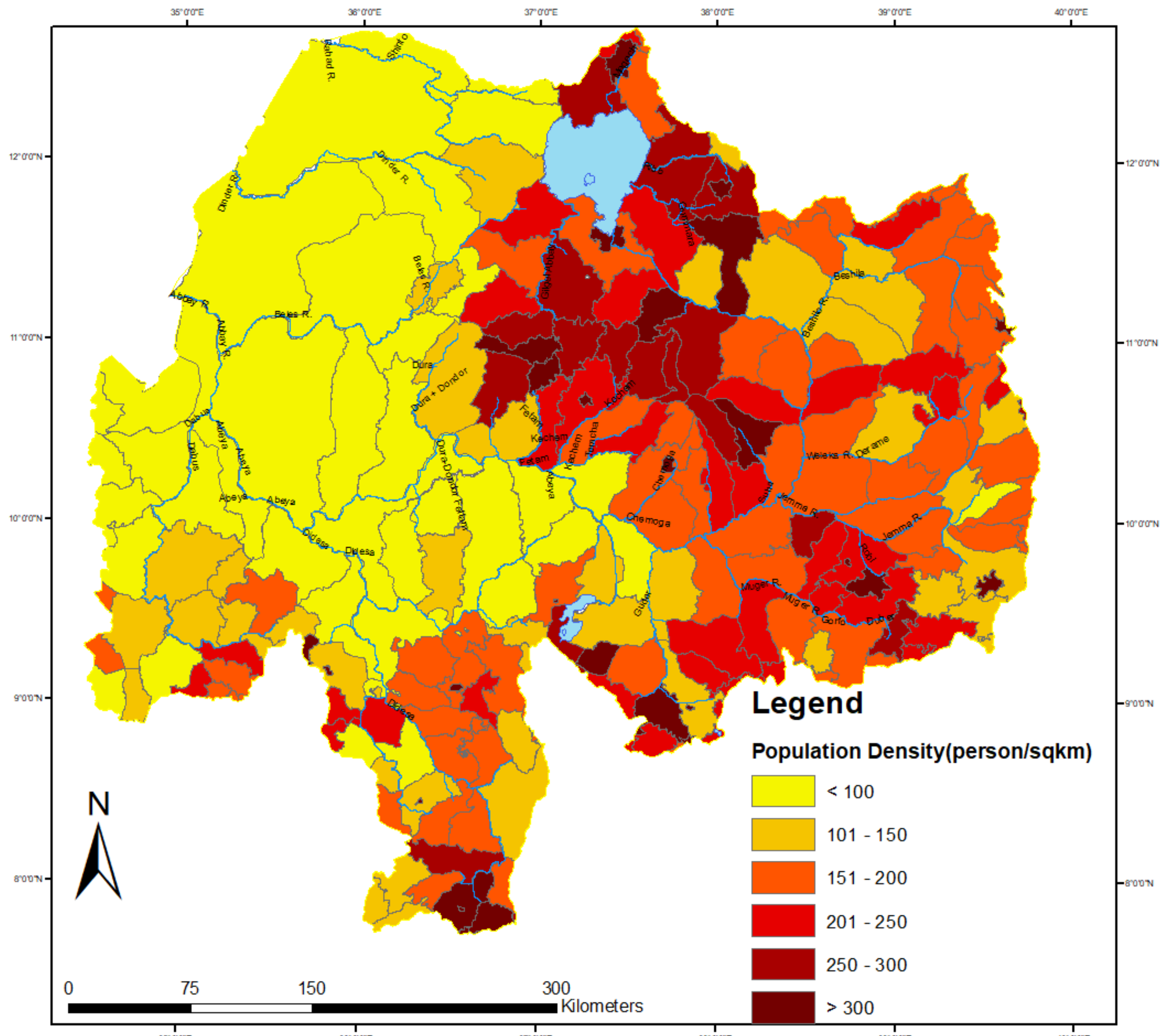


Figure 4. 3 Population density distribution in the basin (*Source : source data is extracted from UN global population grid,V4 and mapped to the study area*)

Demographic Characteristics of the basin

Quick Summery

Age distribution	Sex distribution	Ethnicity and linguistic
younger 44 % Working age 53 % Older age 3 %	Male 50 % Female 50 % sex proportionality is major socio economic factor in the basin	Amhara and Amharic is majority in Amhara region, Oromo and Afan-Oromo is majority in Oromia regions, and Diversified ethnicity and language in Benishangul Gumuz region of the basin.

Demographic factors provide insights to the causes of change in basin communities. It is expressed changes in the sex profile of the population, age structure, cultural and ethnic composition, and religion composition and dependence ratio. The basin has characteristics of almost proportional distribution of population in sex, and it is an important social factor for different governmental, non-governmental and community based organizational intervention to bring equity between males and females in the basin.

In terms of age category of the basin, it is characterized as population of younger ages with high dependability ration (more than 40 % of population below age of 15) and low life expectancy ration (only about 5% of the population who lives long above age of 65).

The population of Abay basin consists of Amhara, Oromo, Gumuz, Agew, Berta, Shinasha, Mao,Koma and other ethnic groups. The major spoken language in the basin also includes Amharic, Afanoromo, Agew, Gumuz, etc.

Gender and Age distribution

Abay Basins feature population pyramids flatter at the bottom, which is characteristic of populations with younger age structure. The broad base and narrow top of the pyramids also indicate low life expectancy. All regions of the basin exhibit similar population pyramid structures, with the exception of some of the major cities.

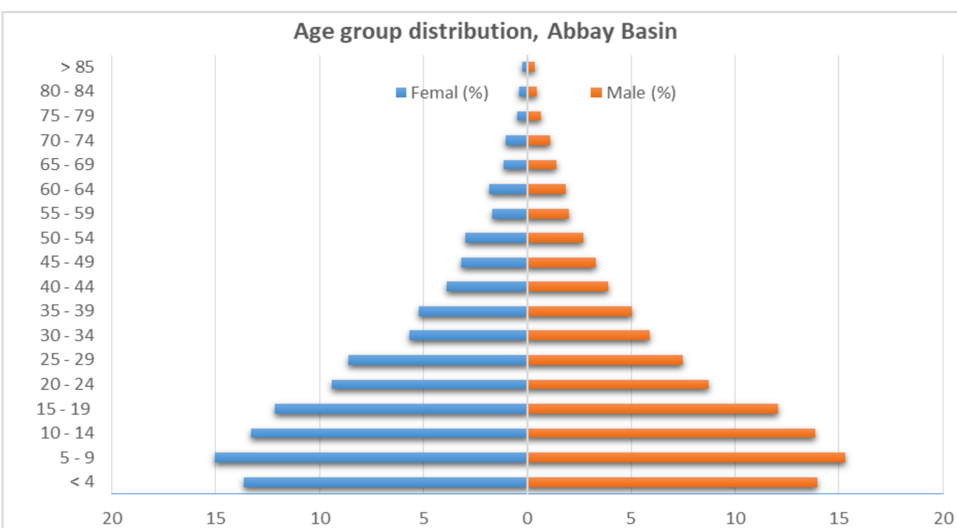


Figure 4.4 Gender and Age distribution in the Basin.

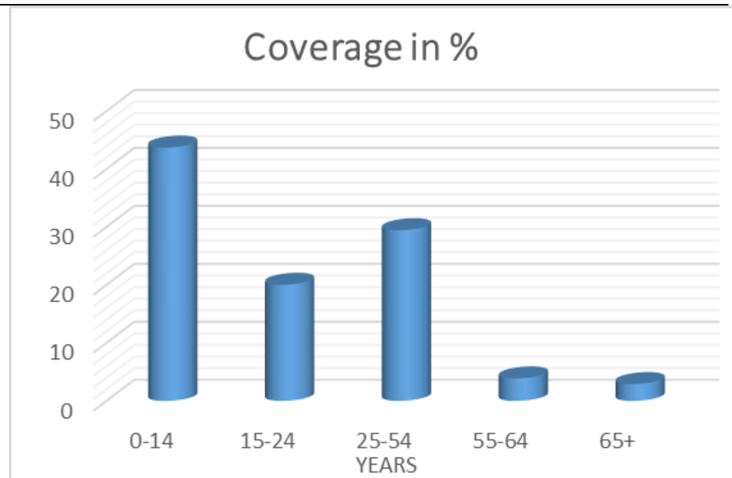
Age Structure and Socio-economic implication

Age Structure is one of the most basic characteristics of population of a basin as numbers and percentage of a population is each category is very important to determine the social and economic structure of the population through identifying demand for schooling, health care as well as other basic needs including food for those who are not able bodied to support themselves due to their ages. It also helps to know potential labor, identify priority issues and the focus of interventions in the allocation and management of resources, man power and materials in the basin.

Major Age Structure (table, left) and coverage (graph, right) in the basin's population:

Age Structure	Number of population	Coverage in %
0-14	13,447,732	43.71
15-24	6,165,467	20.04
25-54	9,060,529	29.45
55-64	1,196,790	3.89
65+	895,285	2.91

Source; CSA, 2017 projection & CIA world fact book,2016



Child age Population (0-14) of the basin

This population of the basin projected to be 13,449,567 which accounted for 43.71 percent in 2017 that requires huge investment of socio-economic issues like education and health. The size of the population in this age category in comparison with the rest of the age groups is an indirect indication of the existing fertility level of the basin in which higher size relative to other ages implying high fertility.

Working age Population (15-64) of the basin

This is the productive age group and highly helpful for the basin's socio-economic development. The basin's total population size of this working age population projected to be 16,425,026 (accounting for 53.38 percent of the total basin population) in 2017.

Old Age Population (65+) of the basin

Old Age Population of the basin shares smaller proportion relative to the child and working age categories. In terms of size, this age group is projected to be 895,407 in 2017 (2.91 percent).

Dependence ratio:

It is the ratio of persons in the ages defined as dependent (under 15 and over 64 years) to persons in the ages defined as economically productive (15-64 years) in a population which is 0.873 : 1

Distribution of facilities in the basin

Education facilities

The prevalence of different education institutions/schools indicates the level of interaction for productive economic and active social integration of members of the basin population.

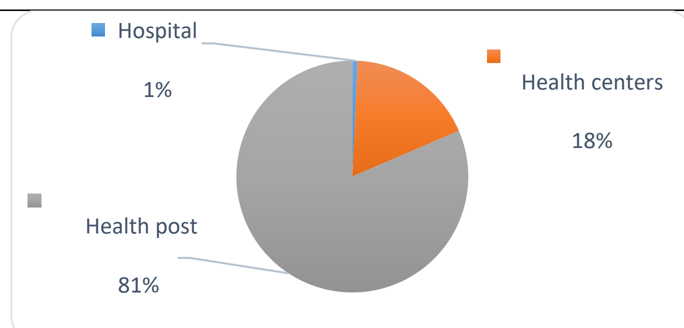
Table 5. 1 Number of schools (Governmental and Non-Governmental) and respective number of students inrolled.

No	Types of educational institution	Number of institutions	Enrolment
1	Primary school (1-8)	11,981	6,324,102
2	Secondary school (9-12)	935	722,408
3	Universities	15	NA

Health facilities

There are about 47 (1%) hospitals, 1125 (18%) health centers and 5145(81%) health posts with in the basin, with reference to the national standard of the number of hospitals in the basin is not achieved. These numbers may not include those health institution under construction of both during and after data collection period. These health institutions provide necessary health services to the people of the basin

Health institution	Number	Ration
Hospital	47	1 : 495610
Health centers	1,125	1 : 20705
Health post	5,145	1 : 4527



Health facility coverages in the basin
(*Source; different Abbay basin woredas health office*)

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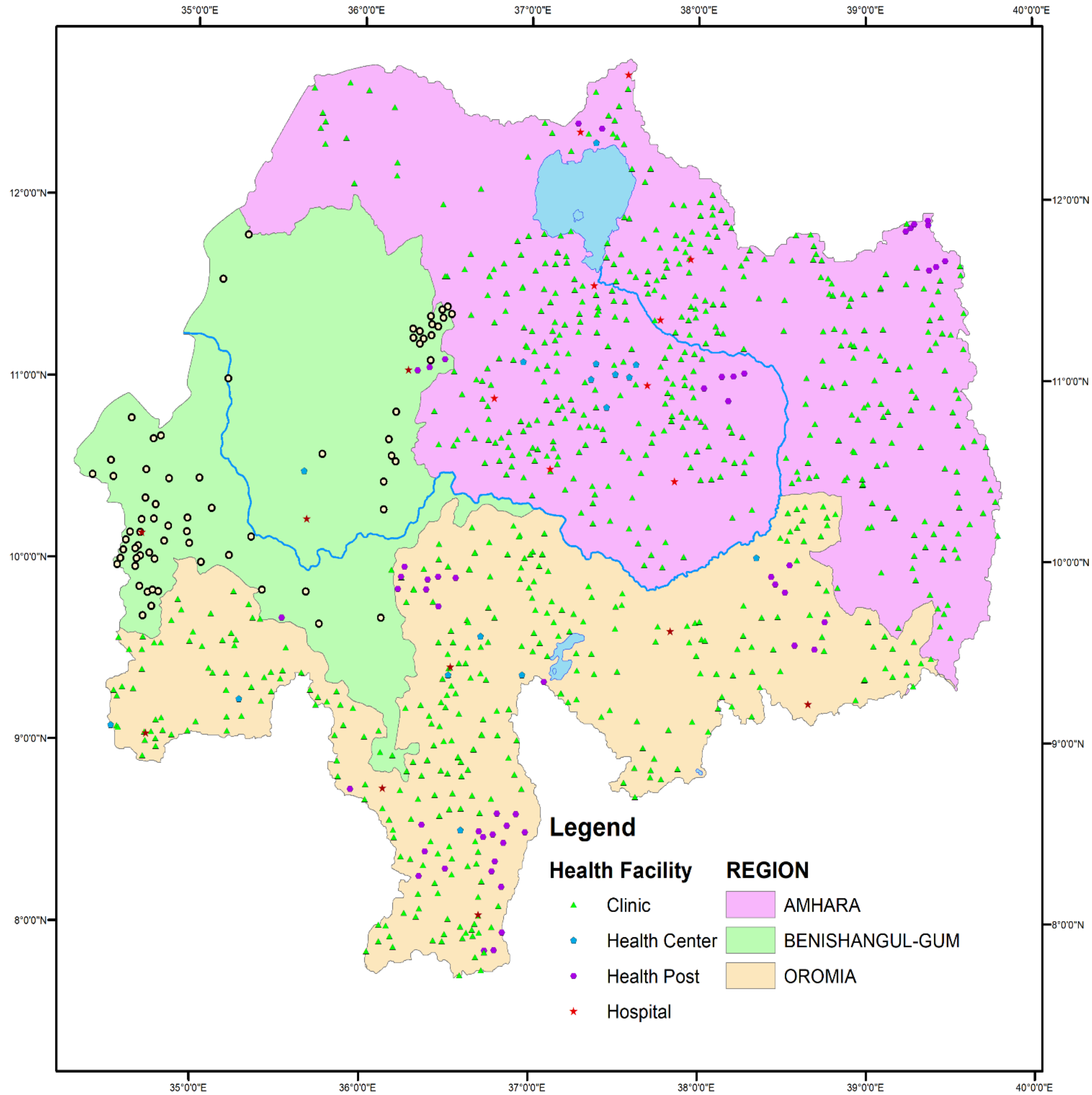


Figure 4.8 Distribution of health facilities in the basin.

Road network in the basin

Quick summary:

Road class	Length (km)
All weather Road	6893
Dry Weather Road	6034
Total	12927

	Amhara	Oromia	Benishangul Gumuz
All Weather Road	3556 km	2748 km	728 km
Dry Weather Road	3760 km	3268 km	893 km
Trail	23769 km	19270 km	2451 km

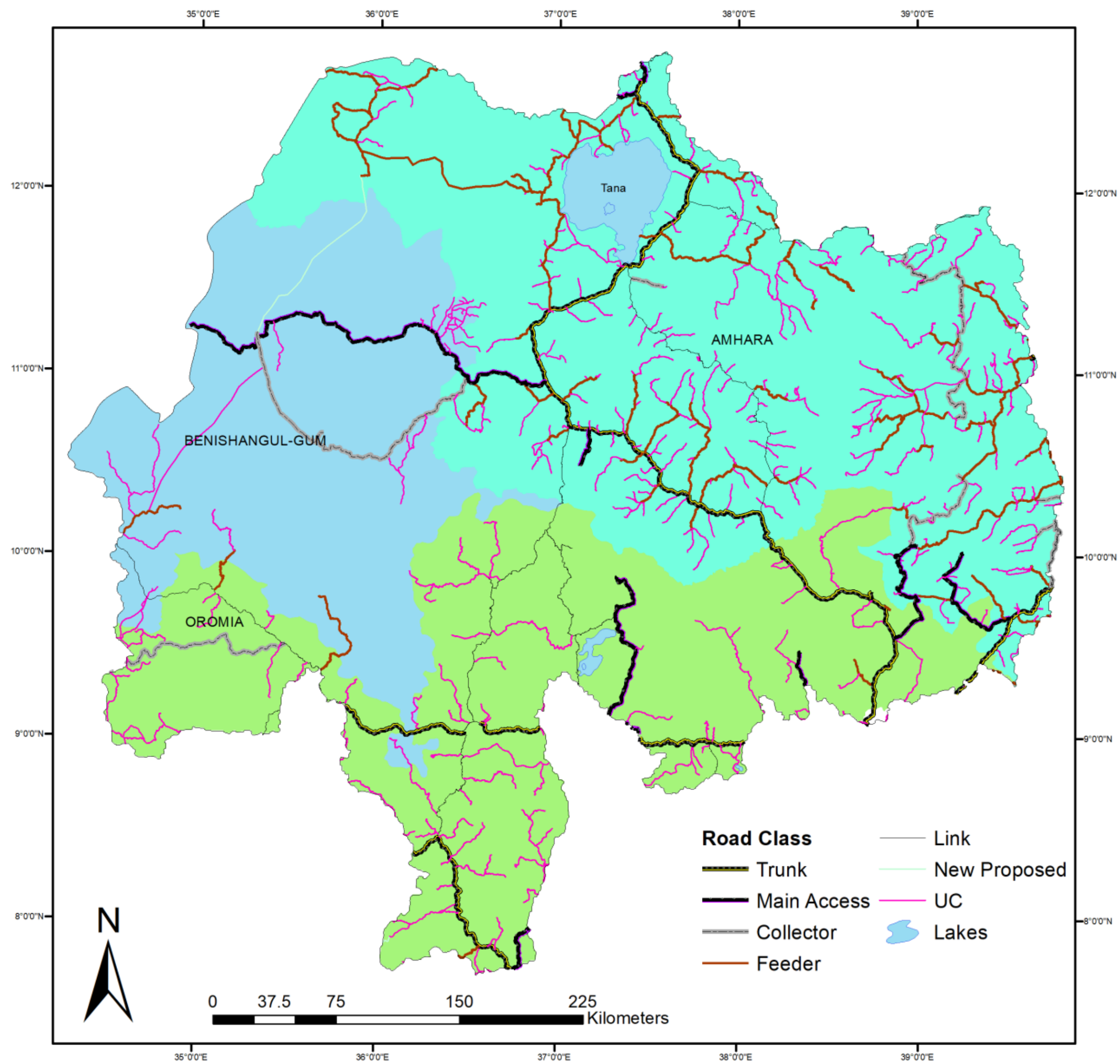


Figure 4.9: road networks in the basin

Considering the ERA's survey of road networks, it can be analyzed and abstracted that only 25 percent of the basin area is found within 10 km from the major road networks, which is described as Trunk, Main access and Link Road.

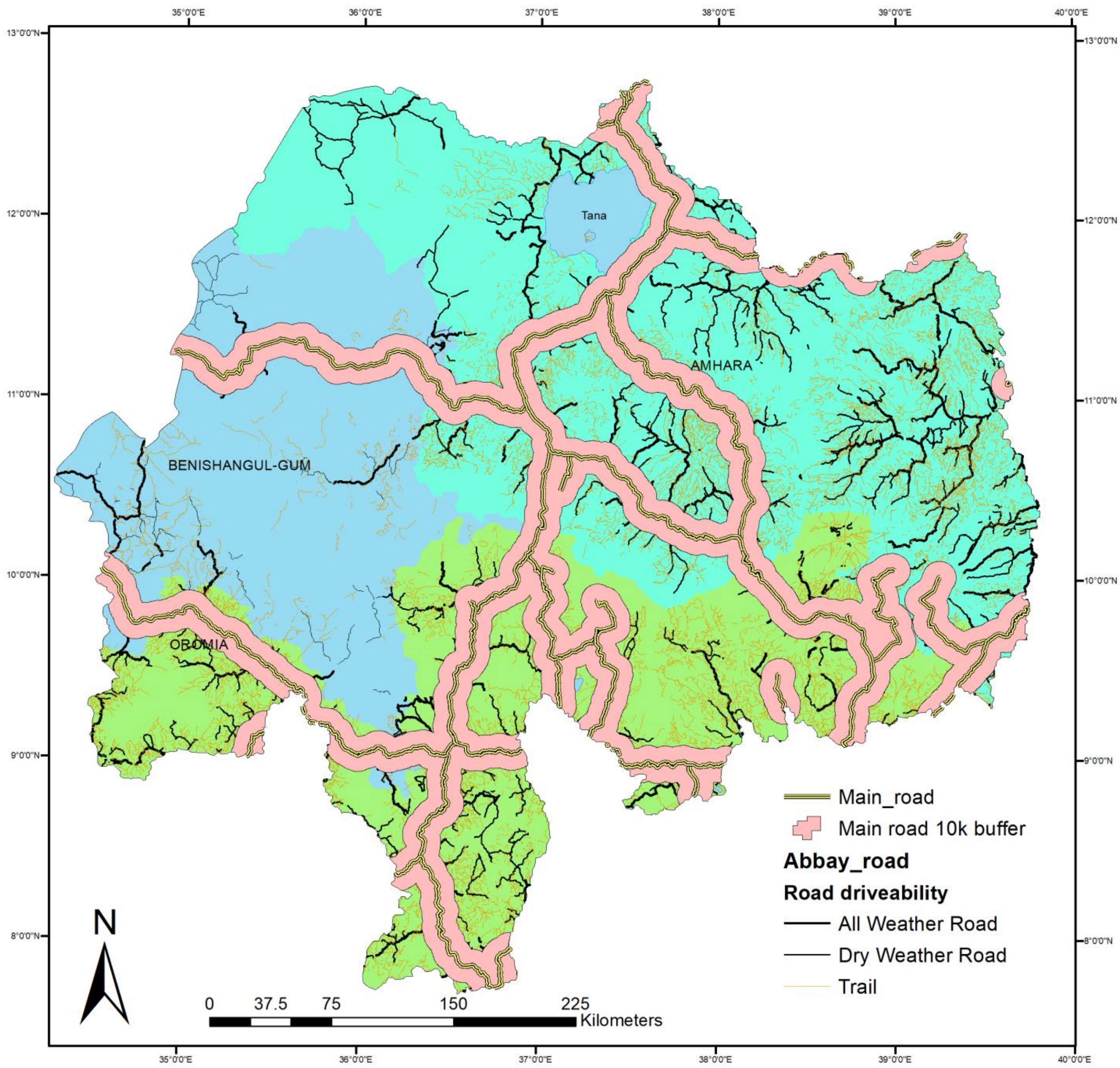
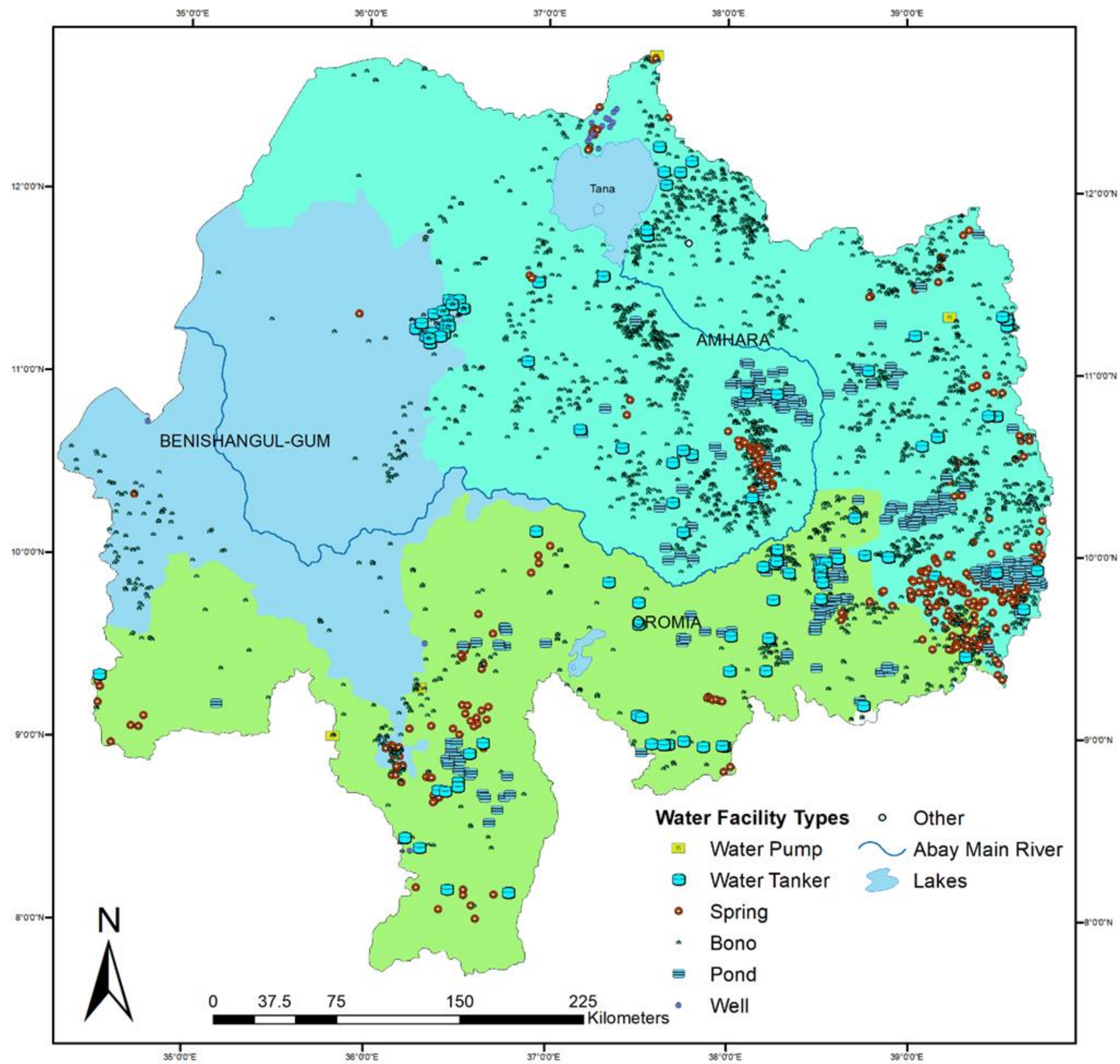


Figure 4.10. Major road network distribution

Water Facilities



Bono	Pond	Spring	Water Tanker	Water Pump	Deep Wells
2595	260	345	101	4	20

Figure 4.11. Water facility distributions in the basin

Tourism

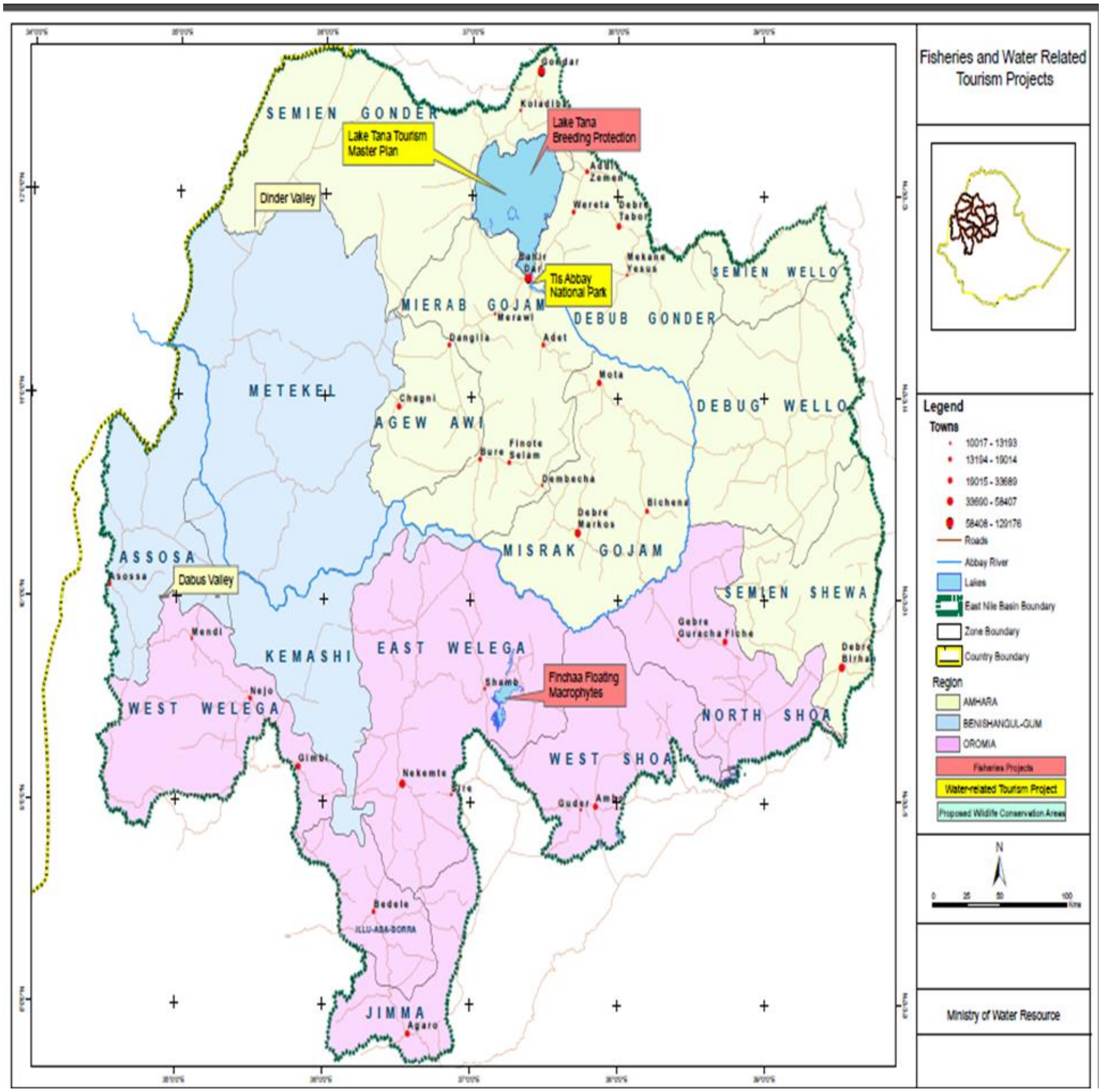


Figure 4.6 Tourist and park sites of the basin

The basin offers various tourism attractions, including: Lake Tana, Blue Nile falls; historical sites in Bahir Dar, Gondar and Lalibella; Blue Nile gorge (Debre Markos); Nekemte and Ambo; Didesa river valley (wildlife) and the coffee area and its capital Jimma have potentially high appearance for tourists. The number of international visitors to the basin was estimated 25,000 in 1999, and is expected to increase with 8.8 % per year.

Especially, Lake Tana and its island, terrestrial vicinities comprise impressive attractions of natural and cultural settings in 19 monasteries, and 39 islands with associated wet and dry lands. Tana is not only endowed with natural heritages but also rich in cultural and historical attractions. Old aged religious attractions of monasteries and churches with impressive ceremonies and sacred places are abundant. Historical value of Blue Nile river sources expedition and church heritage studies on religious icon of ancient paintings, ceremonies and architectural designs and fossil remains of emperors are few to mention.

Photos showing some of the tourist attraction sites

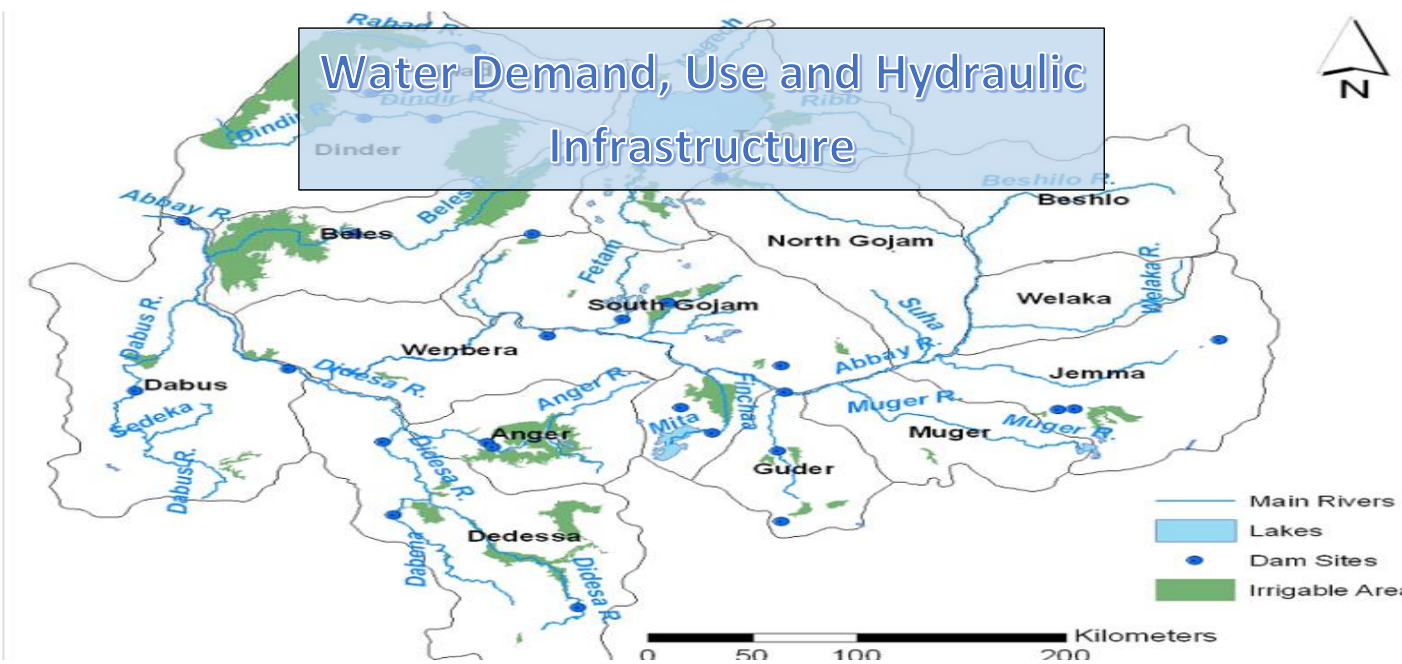
Water Transport

One of the importances of Lake Tana is its suitability for navigation. It is ideal for water transport. Many of the lake boundary people economic activities rely on these waterways for transport of principally industrial products, agricultural products, people and domestics via the eight ports as shown in the figure. These waterways are crucial for transport and communication.

Figure 2 Lake Tana transport arteries and ports

Chapter Five

Water Demand, Use and Hydraulic Infrastructure



Hydraulic Infrastructure in the basin

Storage dams in the Basin

Ethiopia is now actively exploiting its water resources by building dams, reservoirs, irrigation and diversion canals and hydropower stations. The benefits of the dams are not only limited to hydropower. Many dams are multi-purpose dams that are also designed to provide water for irrigation, drinking water and flood control. However, hydropower and irrigation is expected to be the main benefit of the dams.

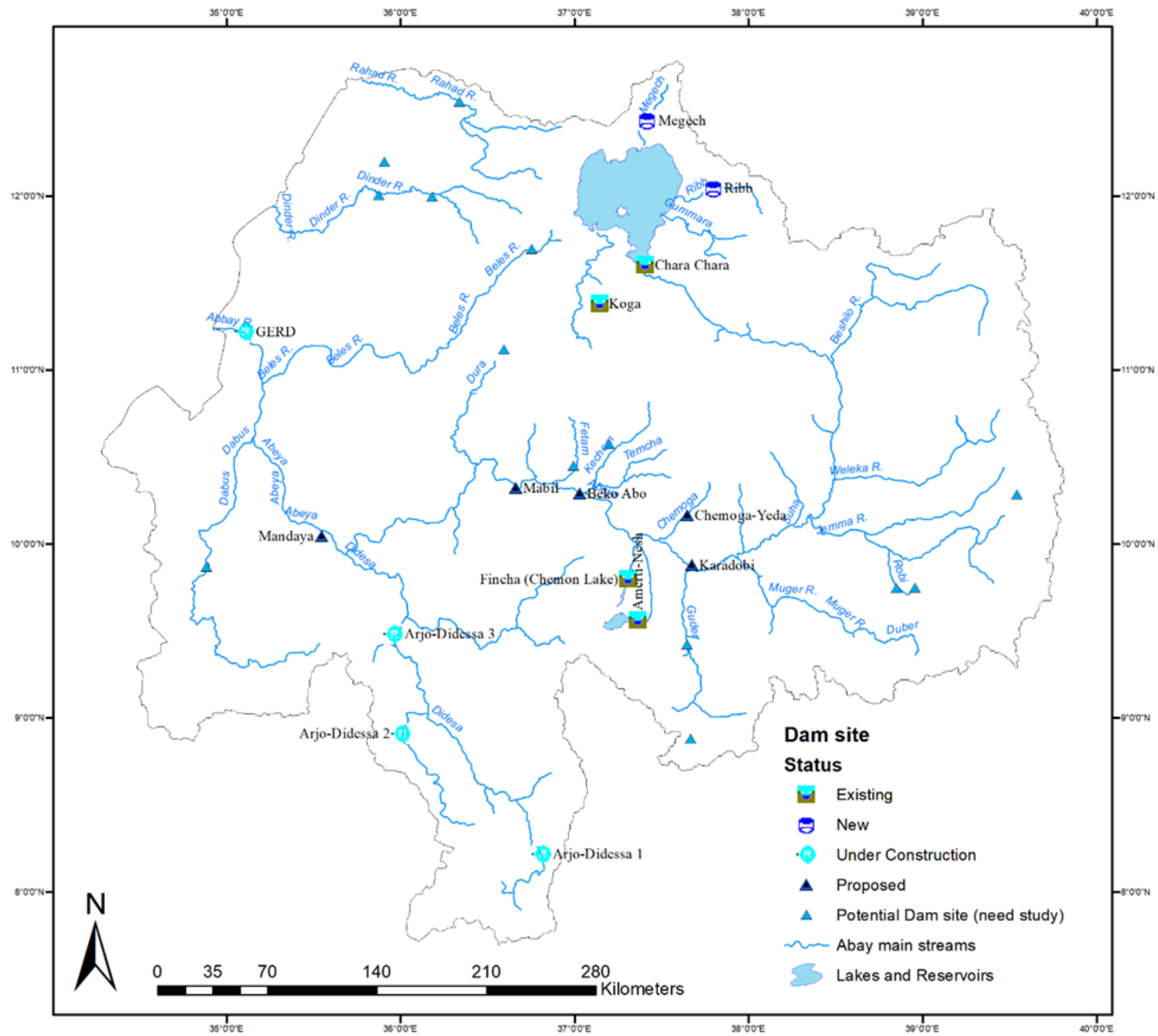


Figure: map of dam site in the basin

Table 5. 1 List of dams and reservoirs

Dame/Reservoir	Status	Use
Koga	Existing	Irrigation
Fincha (Chemon Lake)	Existing	Irrigation, Water Supply
Amerti-Nesh	Existing	Hydropower, Irrigation
Megech	Newly Commenced	Irrigation, Water Supply
Ribb	Newly Commenced	Irrigation, Flood control, drinking water
GERD	Under Construction	Hydropower
Arjo-Didessa 1	Under Construction	Irrigation, Flood control
Mandaya	Proposed	Hydro power,
Chemoga-Yeda	Proposed	Hydropower,
Karadobi	Proposed	Hydropower
Mabil	Proposed	Hydropwer
Beko Abo	Proposed	Hydropower

Irrigation development and schemes

Abbay river basin has abundant irrigation potential in terms of available water resources and suitable irrigable land. Large scale irrigation projects around Lake Tana-Beles and Didessa Sub basins are underway. In addition to large irrigation projects there are also traditional and modern medium scale irrigation practices which is very large in aggregate.

In the Abbay basin, the Master Plan identified a potential of about 2.5 million ha of large and medium-scale irrigation schemes, of which 526,000 ha were deemed to be economically feasible. That potential comprises 93 different irrigation schemes identified in more than 10 sub-basins. The mode of water supply for these projects varies from pumping from lakes (Lake Tana), run of river diversions and storage dams. According study it is identified that the Abbay river basin has a potential of 211 irrigation projects, of which 90 are small-scale, 69 are medium-scale and 52 are large-scale. A total of 815,581 hectares of potential irrigable land is estimated, out of which 45,856 ha are for small scale, 130,395 hectares for medium-scale and 639,330 hectares for large-scale development this are with the exclusion of traditional schemes.

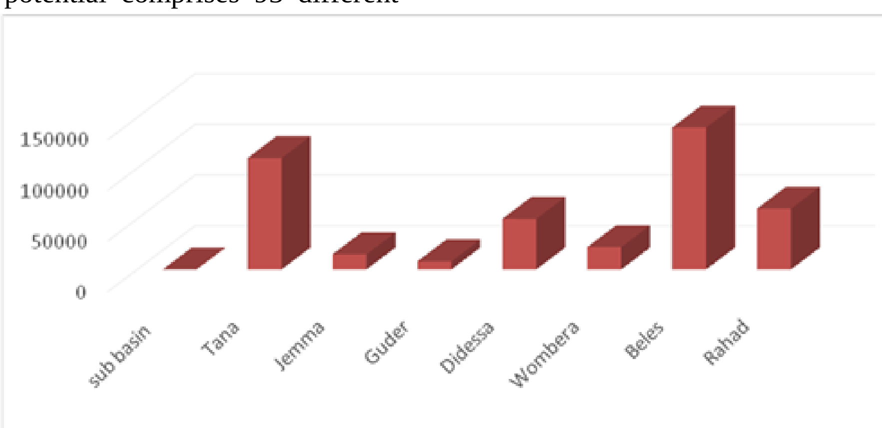


Figure 4. 1 Distribution of 526,000 ha feasible irrigation potential in the basin

There are currently three large reservoirs in the Abay Basin, built for hydropower and irrigation. Around 20,145 ha of sugarcane are irrigated from the Finchaa Reservoir, approximately 7,000 ha of mixed crops irrigated from the Koga Reservoir from which became operational in 2008 and Tana Beles transfer multipurpose project irrigates more than 75,000 after generating 460 MW of power.

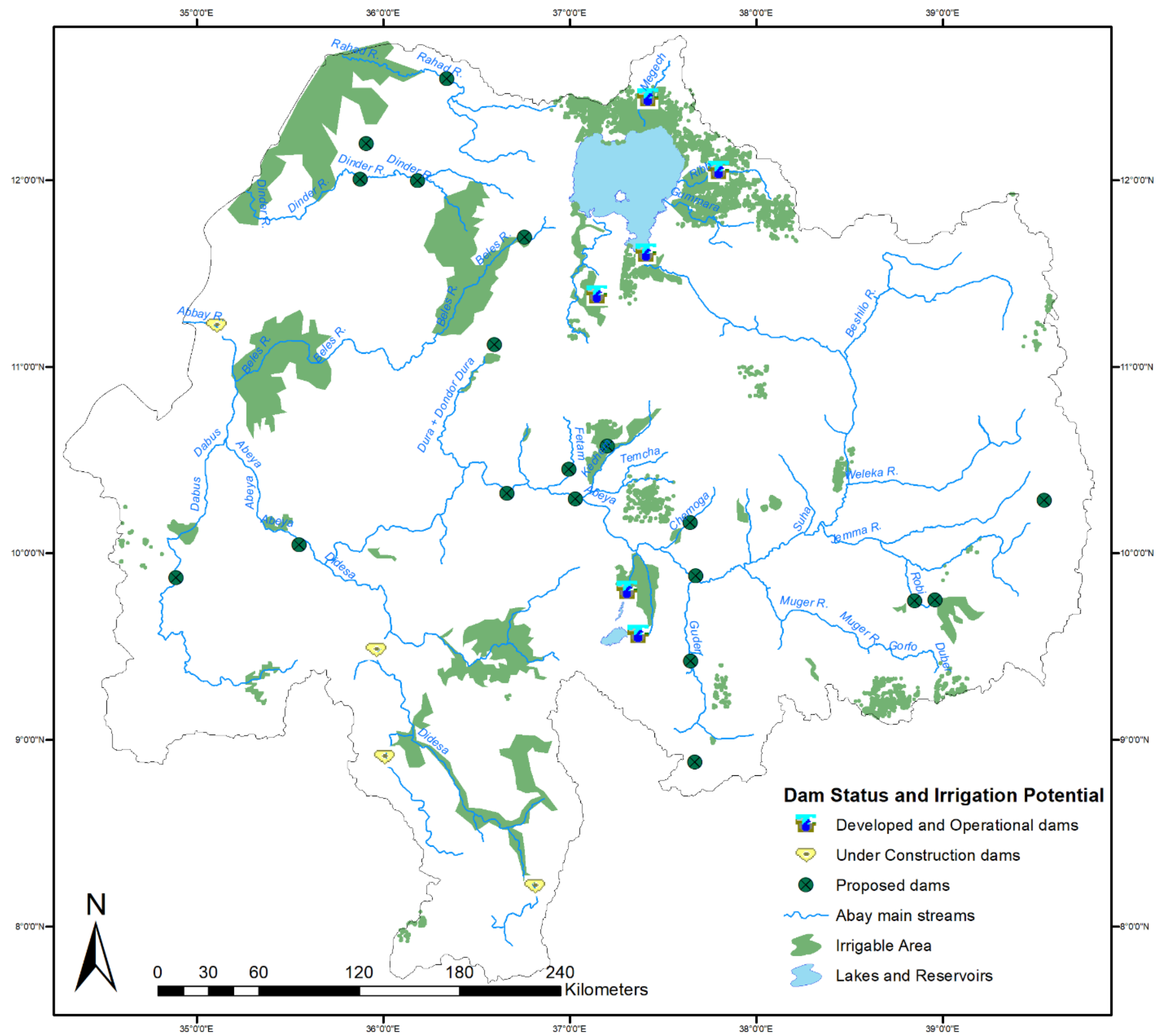


Figure 5. 2 Large and medium irrigation potential and dam sites in the basin

Table 4. 2 Large scale operational irrigation projects in the basin

Project Name	Catchment	Command area(ha)	Description	Status	Storage (MCM)	Annual demand(MCM)
Fincha irrigation	Fincha	20,145	8,145 previously and expansion from east bank to west bank to irrigate additional >12,000ha	Operational		456.6
Koga irrigation	Koga	7,004	Community irrigation project with storage dam constructed at koga river	Operational	83.1	72.179*
Tana-Beles	Tana and Beles	75,000**	Transfer from Tana generating 460MW of power and irrigatingdownstream	Semi operational		277.5
Didessa	Didessa	15,000	Multi purpose	Semi operational	22	
Raji	Arjo Didessa	3492.6	Irrigation agro industy	operational	10	
	Total	120,642				

* Data is from many years average value of koga irrigation project office.

** Data is from Tana Beles project office desk communications.

Table 4. 3 Planned and under construction irrigation schemes in the basin

Name	Sub Basin	Command area(ha)	Description	Status	Annual water demand(MCM)
Tana Irrigation	Tana	61,853	Megech**,Ribb**,Gumera Gilgel Abay	Under construction except Gumera, Jemma	516
Arijo- Didessa Irrigation and HP*	Didessa	80,000	Three dams to be built on Didessa, Dabana, Negeso	Under construction	861.5
Beles Irrigation	Beles	140,000	Beles river and Tana transfer Upper 53,700 and lower 85,000 ha	Under construction and semi operational	1,554
Anger irrigation and HP*	Anger	14,450	Two dams to be built on the upper reaches of the river(with Nekemt)	Planned	202
Dinder Irrigation	Dinder	10,000	Transfer from Beles potential reaches to 80,000	Planned	98.2
Dabus Irrigation and HP*	Dabus	9,661		Pre feasibility	69.4
Nekemt irrigation	Anger	11,220		Planned	71.5
Birr	S/Gojjam	14,000	Feasibility study	Feasibility	
Upper Guder	Guder	6,280	Reconniasnce	Reconnaisance	
Galagu		9,860	Reconnassance	Reconnasance	
Rahad	Rahad	45,135	Reconnaissance	Reconnaissance	

* Multi-purpose scheme.

** completed and ready to operational

Hydropower generation potential

Many studies were reviewed and proposed about more than 90 hydropower potential sites in the basin; of which some of them are very promising and some of these are multipurpose, in combination with irrigation schemes. The hydropower potential in the Abby basin is estimated from about 12,000 MW up to 17,000, with major power stations on the main stem of the Abbay basin (i.e. Karadobi, Beke Abo, Mandaya ,Chemogayeda and Border or GERD) having potential installed capacities of between 3,643 MW and 7,629 MW. These sites have been identified as priority sites, there respective feasibility studies were already done; and even the construction of GERD is well under gone.

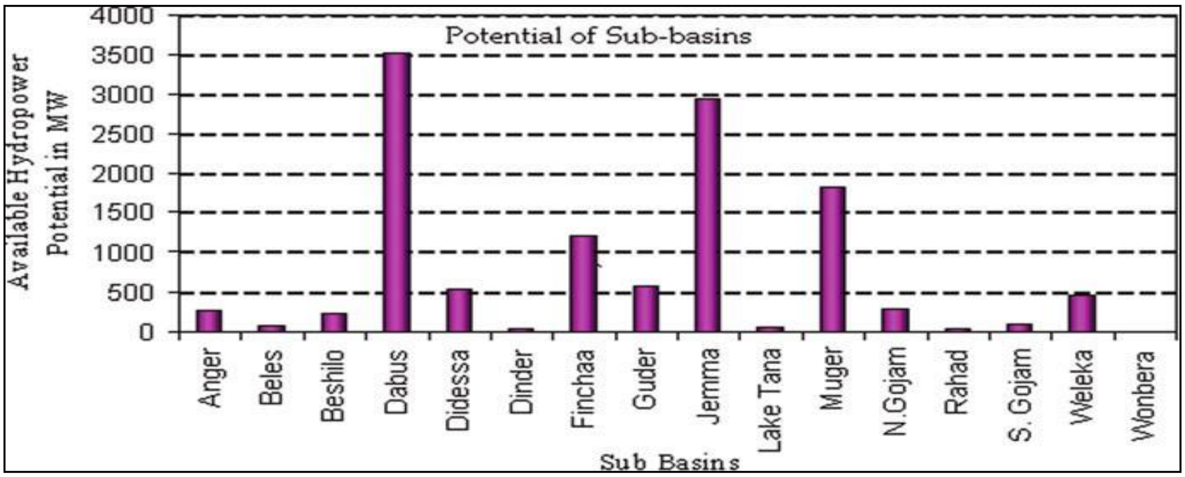


Figure 5. 3 Hydropower *potential of the sub-basins in MW*

Table 4. 1 Current hydropower developments in Abbay basin

Dam	River	Storage (Mm^3)	Installed capacity(MW)	Purpose
Tis-Abay I and II	Abay		84 (11 + 73)	Hydropower production (installed capacity 84 MW)
Finchaa	Finchaa	2,395	134	Hydropower production (installed capacity 134 MW) Sugarcane irrigation (8,145 ha) and 12,000ha expansion
Amerti Neshi			95	Hydropower
Tana-Beles	Lake Tana transfer	2,424 average annual transfer	460	Hydropower production and irrigation downstream
GERD	Abay	74,000	6450(after optimization)	Multipurpose (Fishery, ecotourism etc.) Under construction.

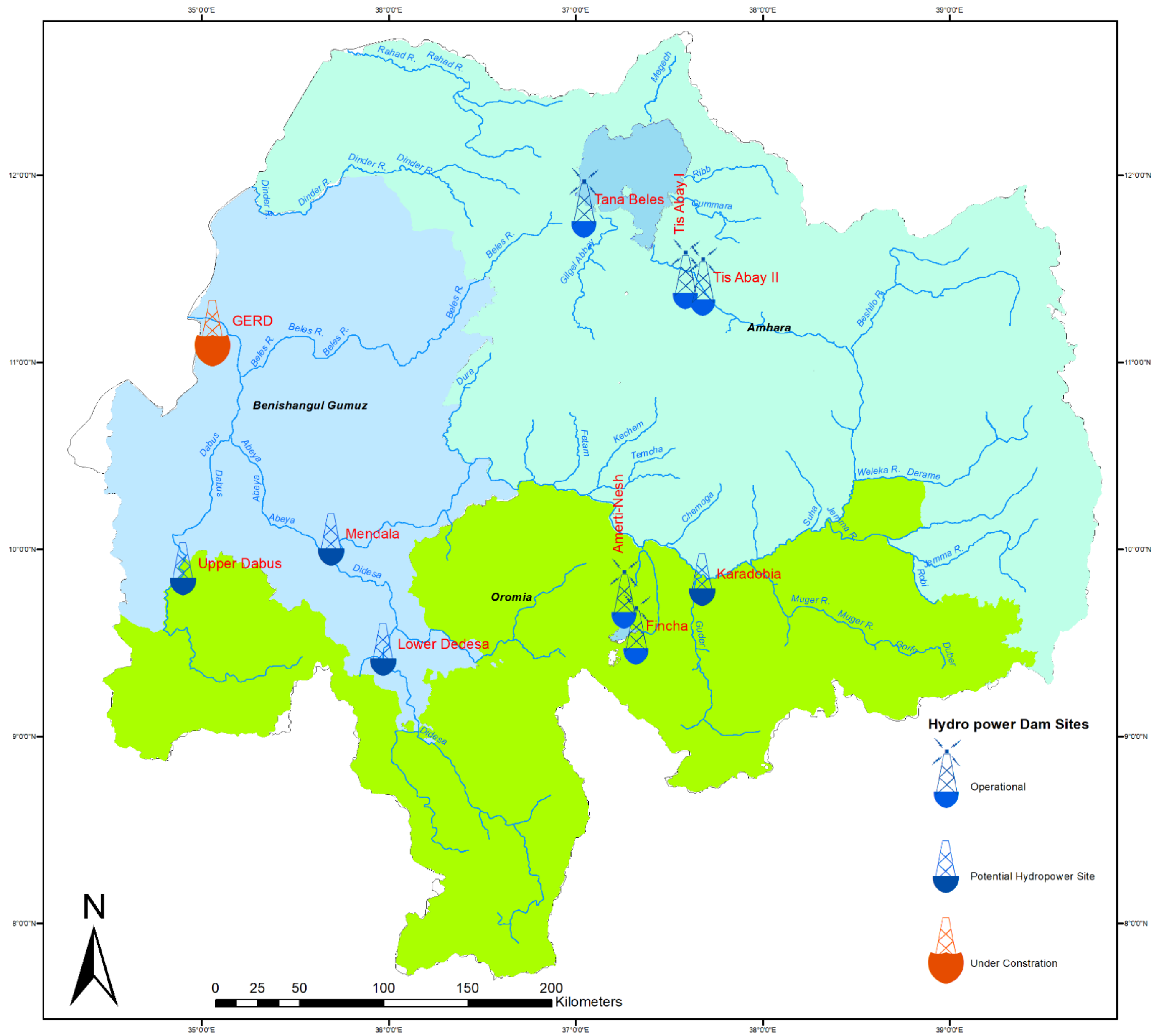


Figure 4. 2 Main hydropower potential sites of the basin

Water Use and Demand

Domestic Water Use

The Abbay river basin is a region which is characterized with the occurrence of relatively better urban centers, infrastructure, and air connectivity and tourist destination areas. This has an implication on the urban water demand of the basin is relatively high consumption. In the basin it has been identified urban centers including the major urban centers of the area Bahirdar, Gondar, Nekemit, Debrebirhan,DebreMarkos, Debretabor, Fiche, Assossa, Gimbi, Kamashi, Ambo and others. Around major center towns varies Water demand by type are established. water demand among establishments are like industries of goods or service being produced, the number of people they employ has been found to be highly correlated with water demand, Urbanization and civilization reflecting size of the scheme operation and relatively higher fragmented sartorial approach influence on water resources.

Totally in Abbay basin 338 urban water supply sources have been identified. Out of these sources the number of bore holes are about 249, hand dug wells 7, shallow well 19, springs74 and4 dams are surface water reservoirs used for water supply.

Rural domestic water demand comprises of the demand for water for the purposes of drinking, cooking, washing people and cloth small gardening etc. The rural domestic water demand is affected by many factors: population, household occupancy rates, level of service of water supply, local knowledge and indigenous practices, cultural and traditional values, climate and water quality. In the basin about 477,758 different rural water supply structures are identified, from those schemes 25,610 (53.62%) Hand dug wells, 18,406 (35.54%) developed springs, 2, 662 (5.57%) shallow wells, 479(1.00%) deep wells and 601(1.26 %) surface water serving of the rural community during the assessment 2017. Based on the assumptions of the current total water yields of each schemes, to rural domestic consumption are supplied around 286.21Mm^3.

The total urban and rural romestic water demand of the Abbay basin are 502.30Mm^3. Urban domestic water demand shares the relation among the population, connection type and per capital consumption. Currently the urban centers water demand for the basin has been summarized 134.77Mm^3.

The public, commercial and industrial water demands are estimated as percentage of domestic water demand. The rural population consumes 364.55 Mm^3, of which around286.21Mm^3 the water needs are supplied from different schemes constructed by government water supply projects. The rest 78.34 Mm^3 rural consumptions covered from open sources like river, spring and self-supplied hand dug wells.

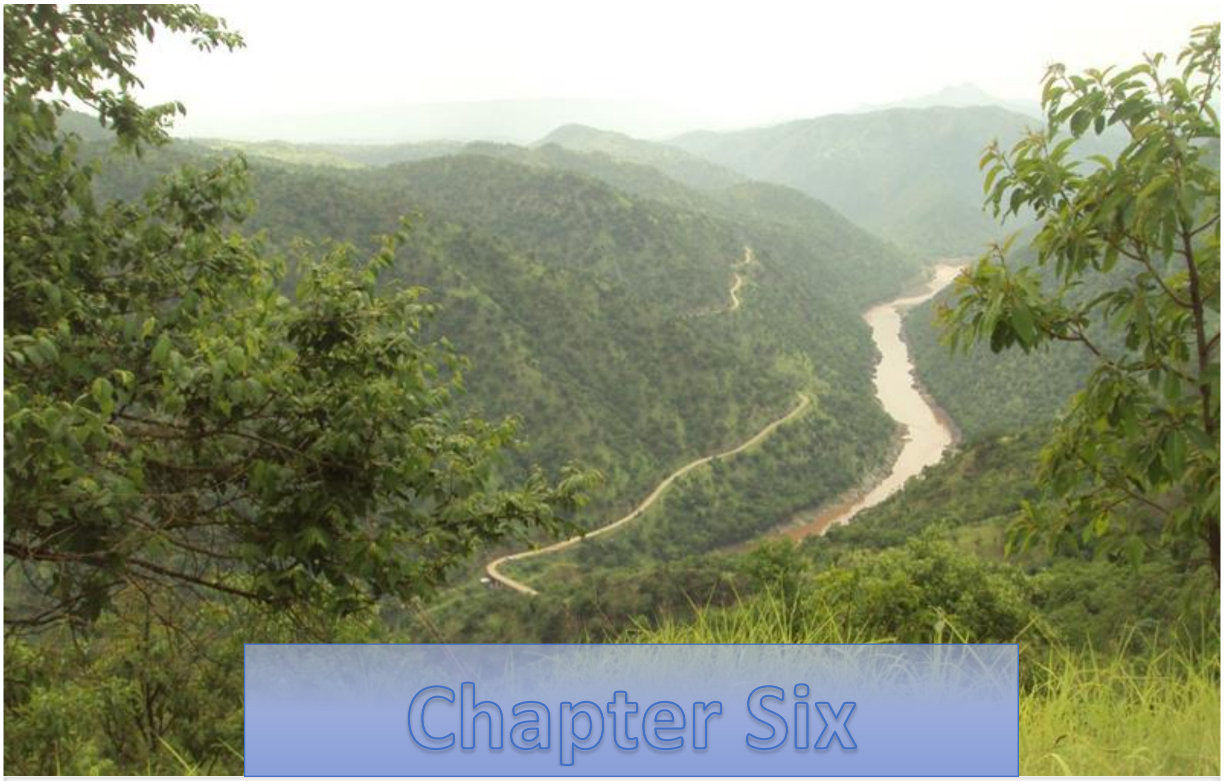
Table 4. 2 Summary of Total Domestic Water Demand

No	Description	Demand MCM
1	Urban Water demand	137.75
2	Rural Water demand	364.55
Total Domestic Water Demand		502.3

(Source: Abbay basin draft Water resources and use assessment report)

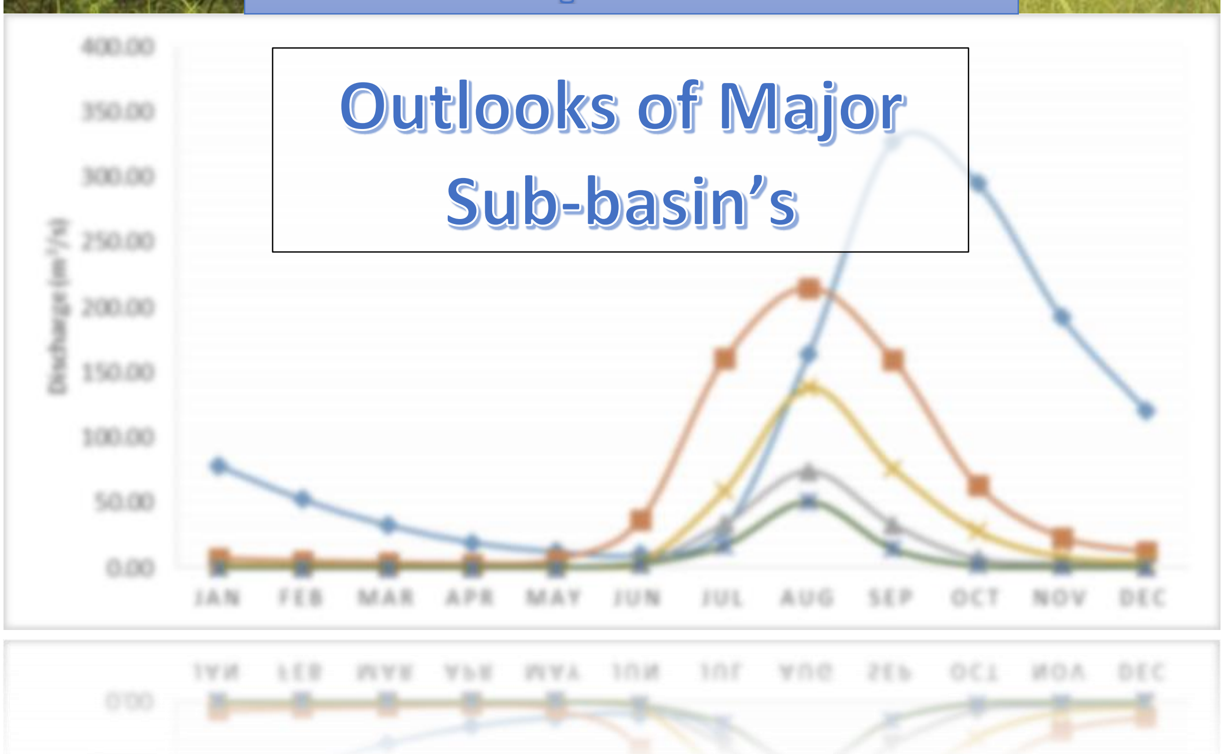
Industrial water demand and Use

One of the emerging water uses out of the growing demand is water use for industries in Abbay basin. Major water users from the industry using water as raw material for their products are drilling boreholes around, get permitting from the Authority to use the water and water working companies are also convinced to have a license for their water related works in order to align any activity in the basin with IWRM. Hence there are many companies consuming a considerable amount of water. Estimated annual water consumption by industries with their own private abstraction in the basin is about 144.5MCM until this assessment has done this figure is only for the private users having their own sources which is not from the town water supply system others are considered in town water supply systems with estimated water consumption of 13.77MCM.Therefore the total industrial water consumption is 158.27MCM.The data does not consider all industries with in the basin. Assessment report shows that bottling water companies use the major part from the total. There is a trend of many upcoming water bottling companies by investors with in the basin. Apart from licensing and permitting the industry sector is into, the water use tariff is not yet implemented so far since the tariff system is under study by consultants.



Chapter Six

Outlooks of Major Sub-basin’s



Tana Sub basin

Tana sub basin contains the largest lake in the country, Lake Tana. Lake Tana is a fresh water lake situated in the north eastern part of the Abbay (Upper Blue Nile) Basin. The lake is 3000 km2 in area, with a dimension of 78 km in length, 67 km in width and 14 km in depth. The source of the BlueNile (Abbay) is Gish Abbay in West Gojam which flows into Lake Tana as Gilgel Abbay. Other major rivers also flow into the Lake namely, Gumera, Ribb, and Megech. Tana sub basin has an area of 15,054 km2. The sub basin has a catchment area of 15,054 km2. Lake Tana flow contribution to Blue Nile is 3,500 Mm3

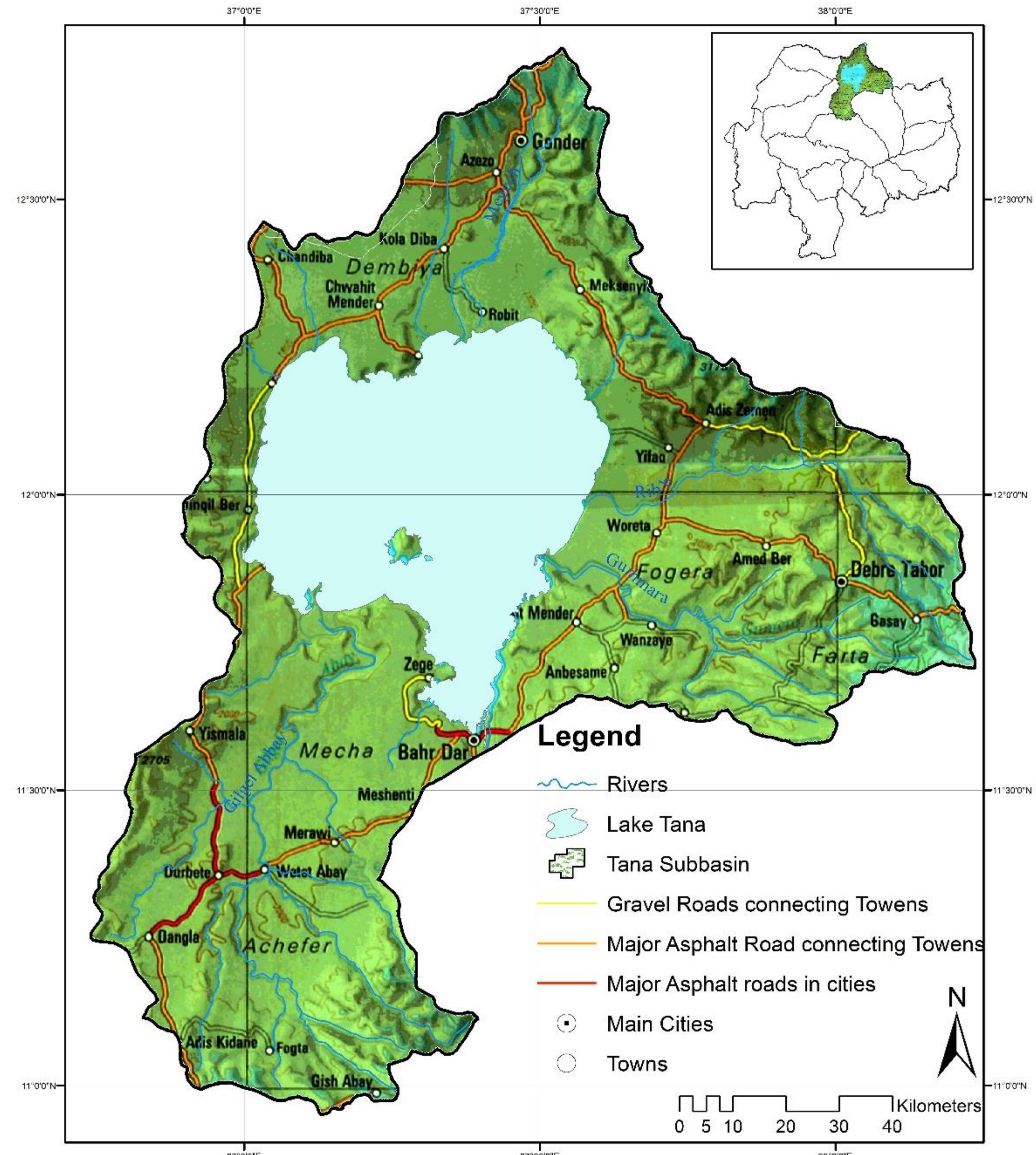


Figure 6.1. Tana Sub basin

Topography	Rainfall	Temperature	Runoff
Range: 1788– 3712 masl It is mainly flat around the lake with in a range of 1750-1850 masl, and extending to the highlands up to 3200 masl altitude.	Range: 964 – 2000 mm Lower rainfall (1100-1400 mm) in North of the basin. Higher rainfall (1400 – 2000 mm) in South of the lake, around Gilgel Abay	Max: 14 – 27°c Min: 1 – 12°c Maximum temperature is observed in lake tana, and gets cooler as it goes outward from the lake	Annual mean @ B/dar: 3576.3 MCM Peak flow is recorded in September.

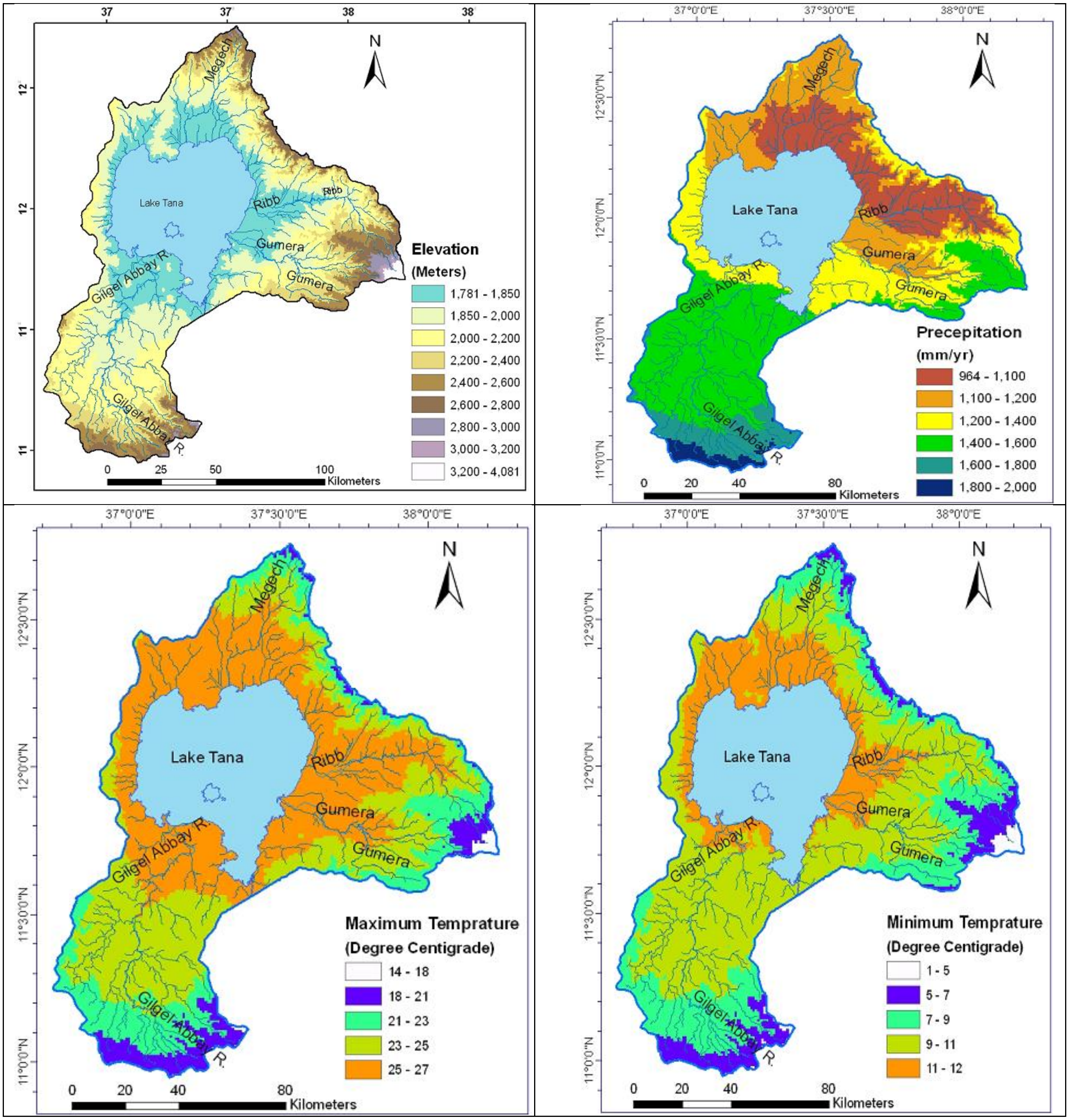


Figure 6.2. Topography and climate characteristics of Tana sub basin

Hydrologic potential in Tana Sub basin

Tana sub basin has 20 hydro gauging stations. Mean annual runoff recorded at the Station, Abbay near Bahirdar, is 3576.3 MCM. The flow is high in the months August – October, with the peak in September.

Month	Abbay at B/dar	Gilgel Abay near Merawi	Ribb at Addis Zeman	Gumara Near B/dar	Megech at Azezo
Jan	78.24	7.09	0.52	2.23	0.23
Feb	52.38	5.01	0.37	1.45	0.15
Mar	32.85	3.89	0.30	1.13	0.14
Apr	19.55	3.27	0.32	0.81	0.24
May	12.36	6.56	0.49	1.24	0.42
Jun	10.20	36.96	2.99	4.77	3.27
Jul	30.08	160.58	34.15	59.17	17.41
Aug	164.40	215.32	74.45	138.35	50.63
Sep	327.14	159.81	33.13	76.21	14.47
Oct	295.07	63.54	7.00	28.23	1.82
Nov	192.41	23.76	3.30	8.33	0.83
Dec	121.10	12.25	1.33	4.28	0.43

Table: Mean monthly discharges, in m3/s

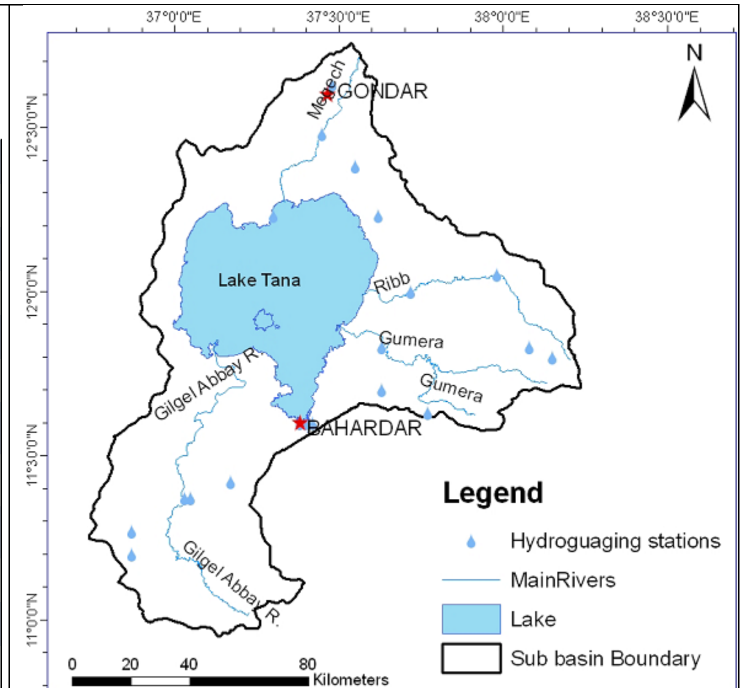


Figure: Hydrological station in Tana sub basin

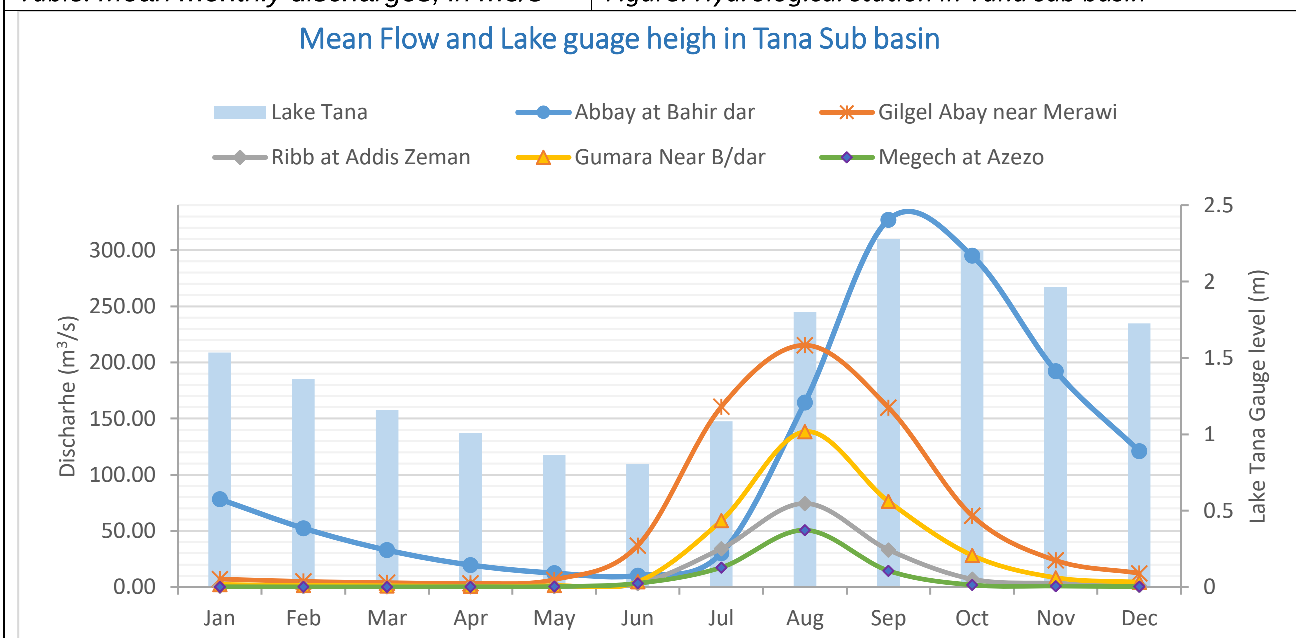
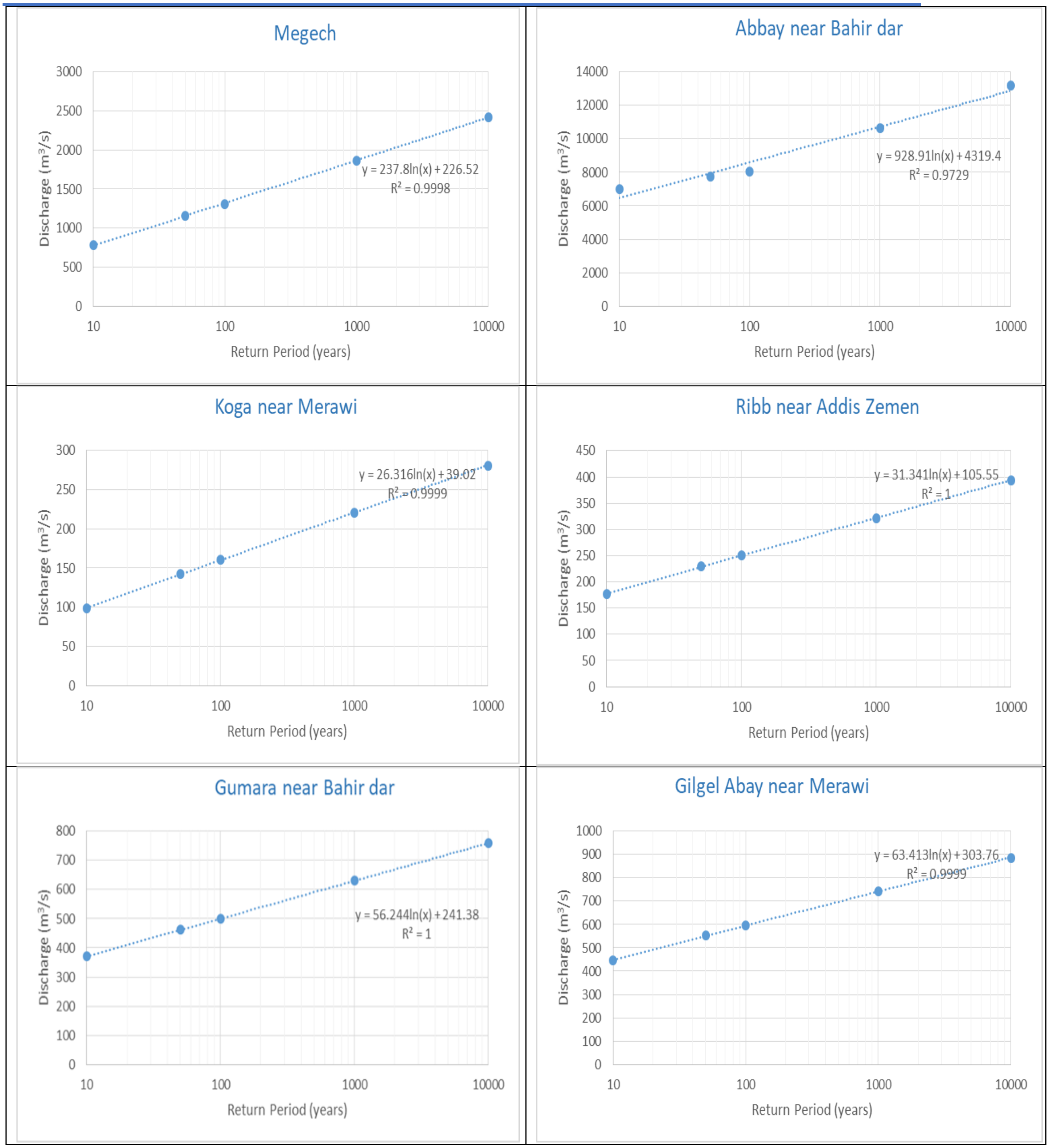


Chart: Mean monthly discharge of major rivers in Tana sub basin



Graph: Annual Maximum flood exceedance of Tana Sub basin major rivers

Beles Sub basin

The Sub- Basin is located in the west- north part of country and bordered with Amhara National regional state in east and east north and Benishangul Gumuz regional state in south, west and north - west. The sub basin covers an area of about 14,209 Km2; including catchments of a number of small rivers (totaling about 650 km2) that drain directly into the Blue Nile.

The source of Beles River is from different tributary streams start as different springs. The two main tributaries are Abat and Gilgele Beles Rivers start at Tara Kessen of Alefa woreda and Dubi Gisan- Chara of Dangila woreda High land areas respectively.

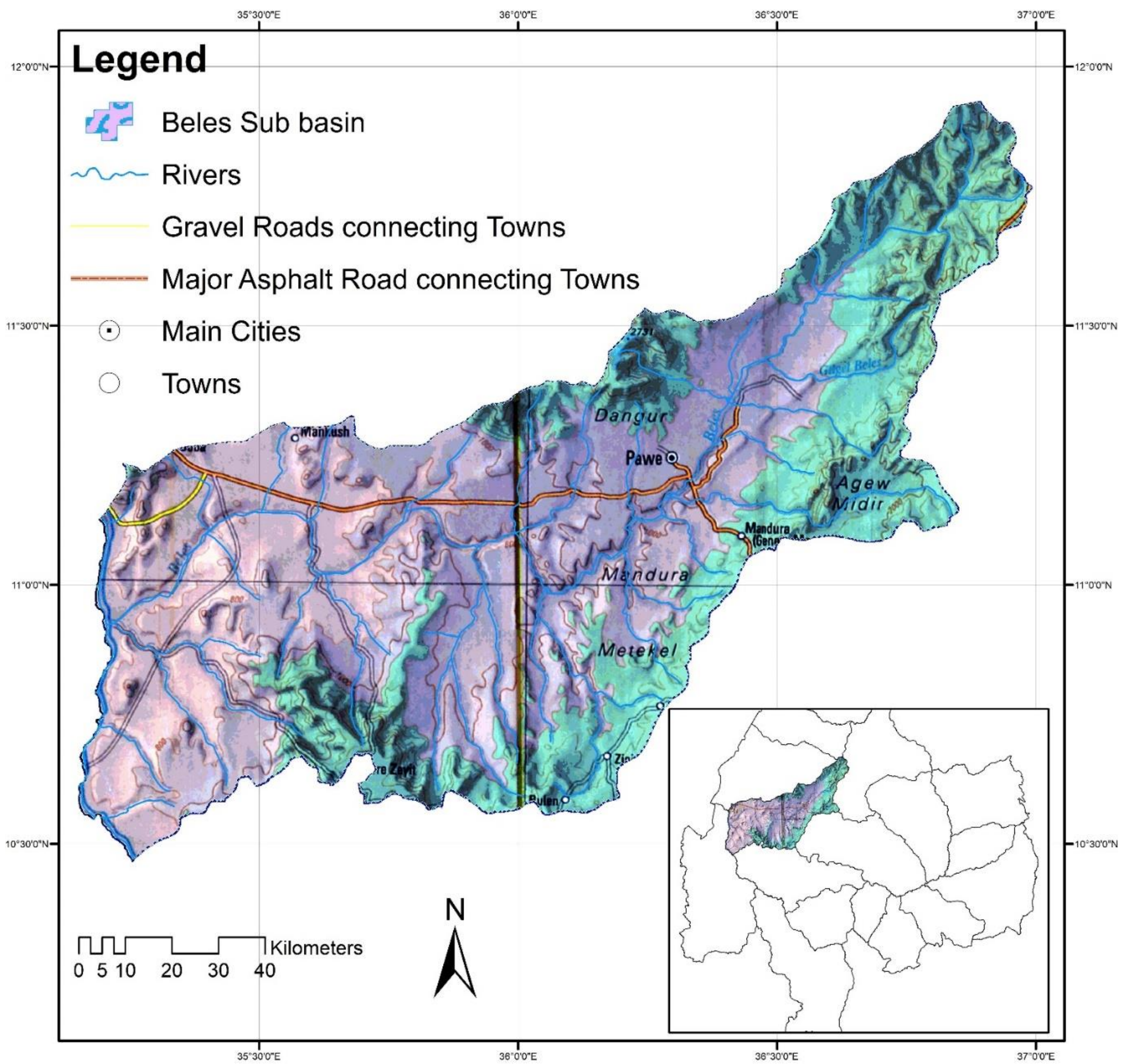


Figure 6.3 Location of Beles Sub basin

Topography	Rainfall	Temperature	Evapotranspiration
Range: 529– 2718 masl Highlands in the eastern part of the sub basin are higher in altitude (> 1200 masl). The lowlands have lower altitude (< 800 masl) in the western parts of the sub basin.	Range: 1052 – 1957mm Lower rainfall (<1300mm) in Western of the basin. Higher rainfall (>1700 mm) in South eastern highlands.	Max: 21 – 30^{o}c Min: 7 – 20^{o}c Higher temperature, with a maximum of (33 – 35^{o}c) is observed in Western lowlands of the basin.	PET:1440 - 2088 mm High PET in Western lowlands, and Low PET in eastern and south eastern highlands of the basin.

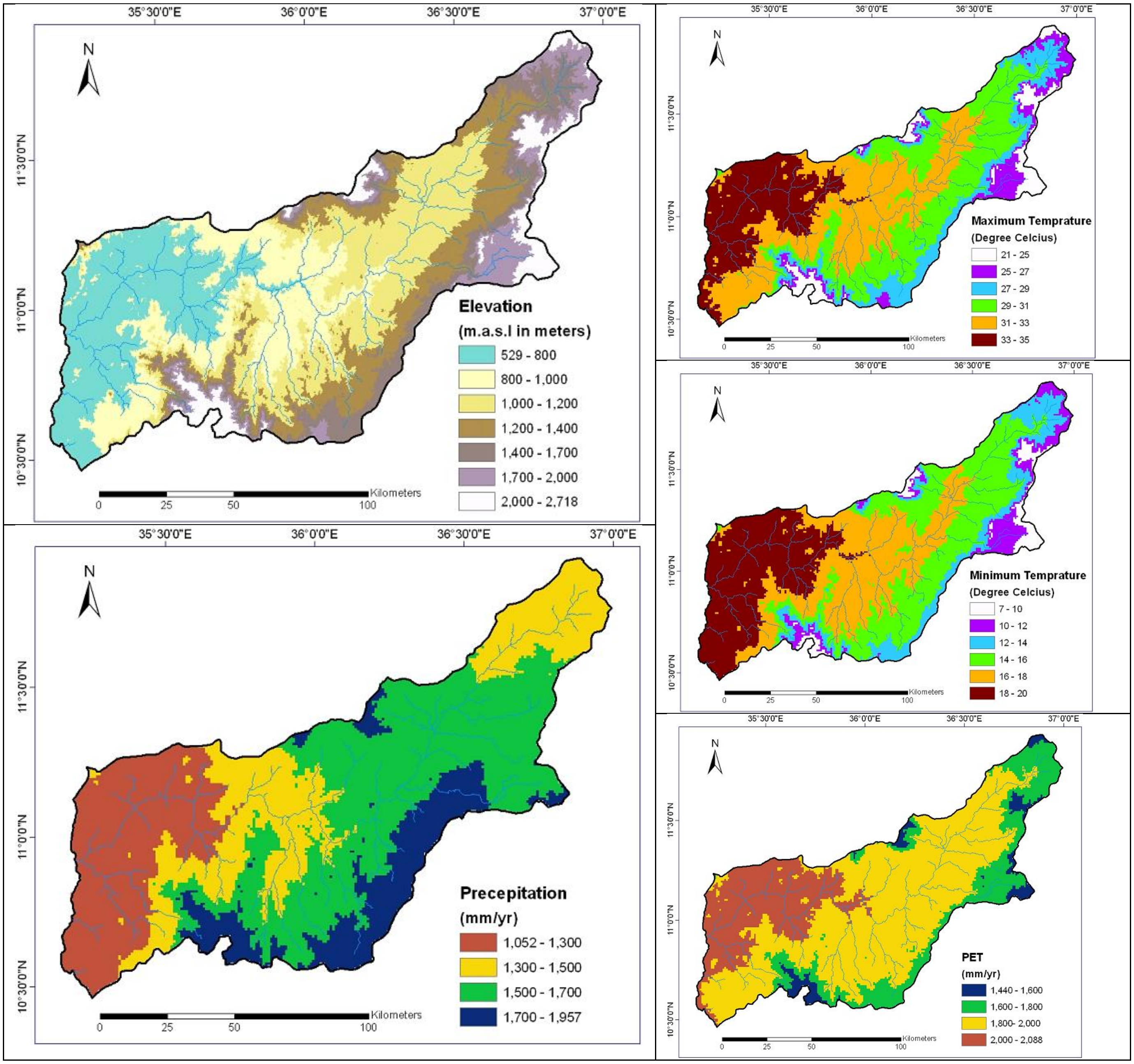


Figure 6.4. Topographic and climate characteristics of Beles sub basin

Hydrologic Potential of Beles River Sub basin

Beles River has two main rivers to be named Beles River. These are the Abat (main) and Gilgel Beles. The mean annual flow recorded at GiligelBeles near to Mandura hydrometric station was estimated 0.58 BCM and main Beles at bridge is about 1.7 BCM/annum. According to the Abbay Master Plan Study, the lowest monthly flow occurs in April with a value of 1.6 MCM and the highest in August reaching 674 MCM or about 41% of the mean annual flow. Some 88% of the annual flow occurs from July to September over a 3 months period

Month	Flow (m^3/s)
Jan	1.642778
Feb	1.11
Mar	0.923333
Apr	0.617222
May	1.295294
Jun	9.565417
Jul	120.388
Aug	251.7096
Sep	171.9436
Oct	47.21095
Nov	7.54
Dec	2.6235

Table: Mean monthly flow of Beles near Pawi

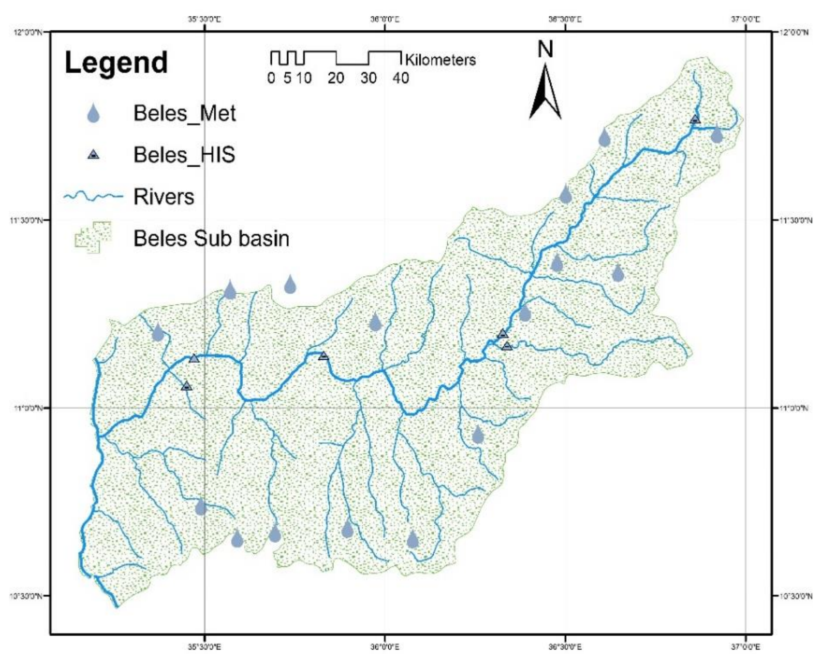
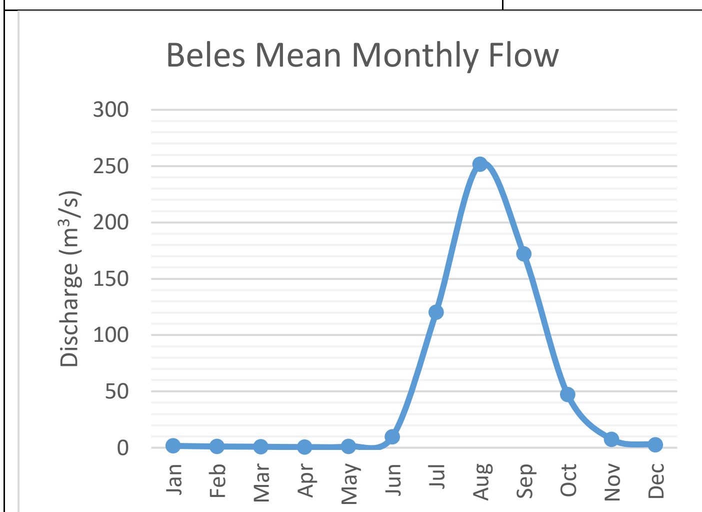
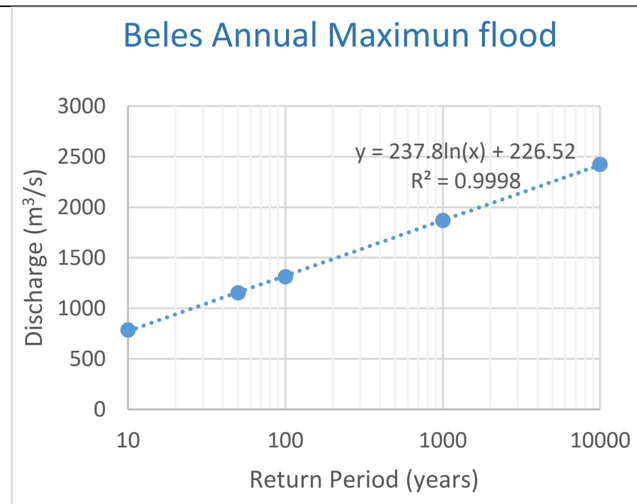


Figure: Hydrologic network of Beles Sub basin



Graph. Beles Mean monthly flow graph of Beles near Pawi



Graph: Beles river Maximum flood exceedance

Didessa Sub basin

Dhidhessa Catchment is situated in the south-west part of Abbay Basin. The catchment area at a gauging station near Arjo town is 9,981 km2, and a total area of 19,630 km2 when it reaches the Main Abbay river.

The catchment is characterized by mountainous, highly rugged and dissected topography with deep slopes. The lowest part of the catchment is characterized by valley floor with flat to gentle slopes.

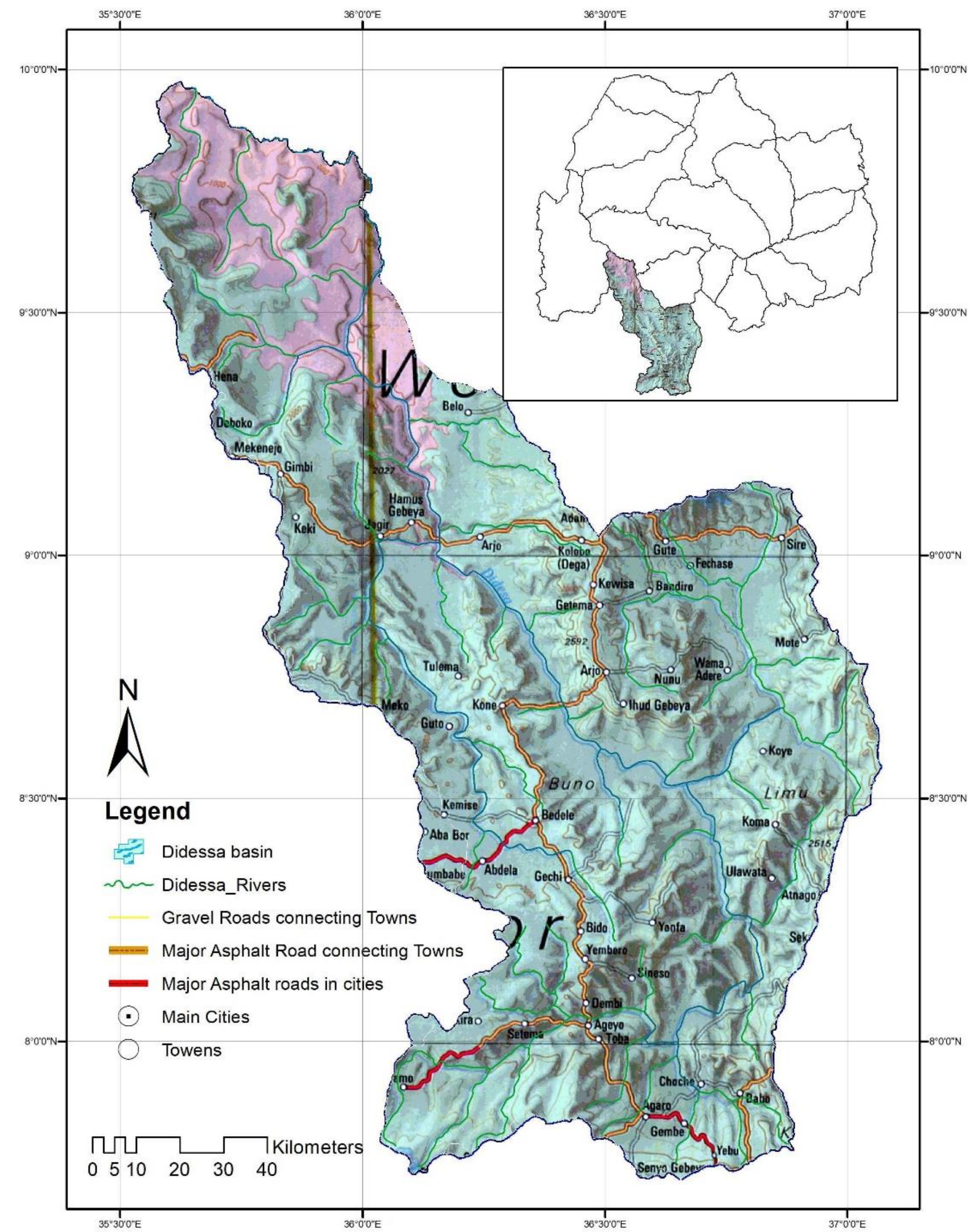


Figure : Location of Didessa Sub basin

Topography	Rainfall	Temperature	Evapotranspiration
Range: 630– 3130 masl The highlands in the southern part of the sub basin are higher in altitude (> 2100. The lowlands have lower altitude (<1100 masl) in the northern parts of the sub basin.	Range: 1200 – 2200mm Lower rainfall (<1400mm) in Northern lowlands; and Higher rainfall (>1900 mm) in South and eastern highlands of the basin.	Max: 20 – 33^{o}c Min: 6.5 – 19^{o}c Higher temperature, with a maximum of (30 – 33^{o}c) is observed in northern lowlands of the basin.	PET:1340 - 1980 mm High PET in northern lowlands, and Low PET in eastern and south eastern highlands of the basin.

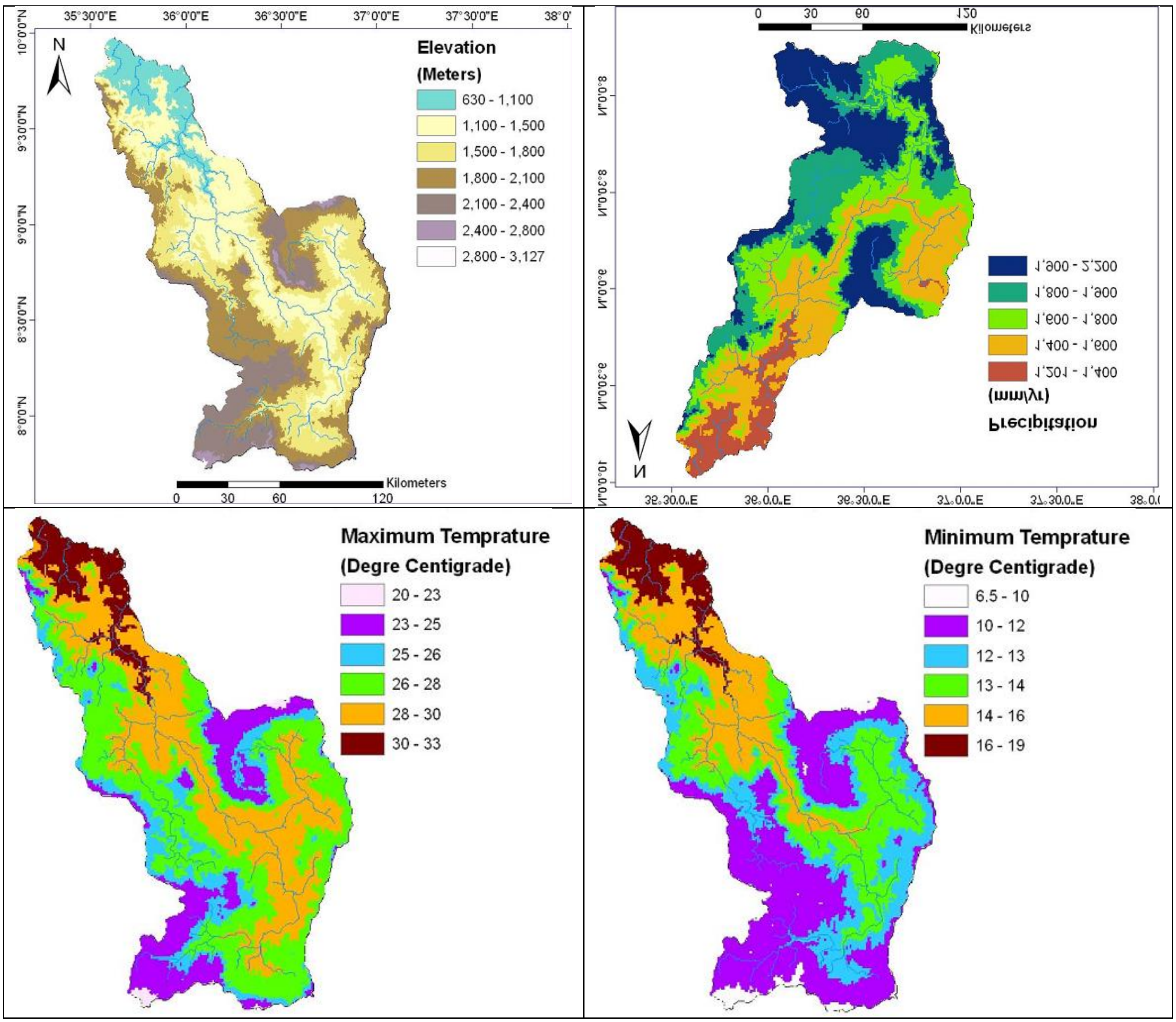


Figure 6.4. Topographic and climate characteristics of Didessa sub basin

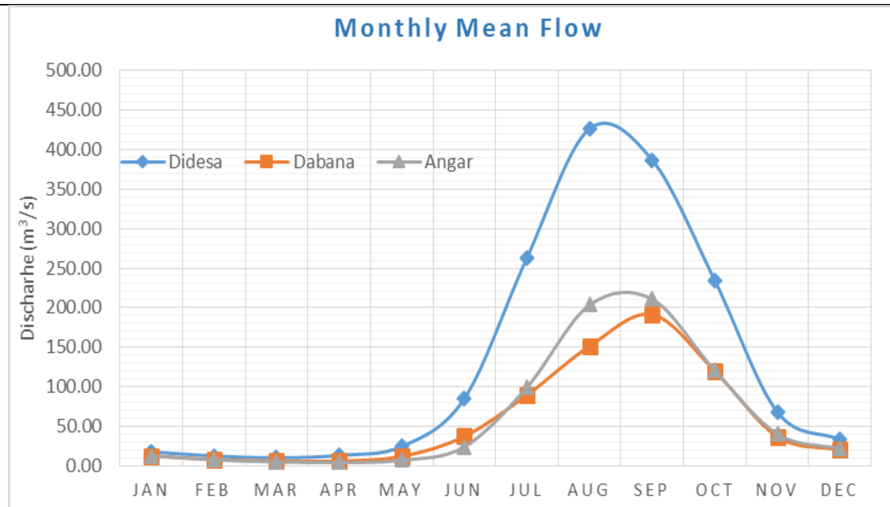
Hydrologic potential In Didessa Sub basin

The Didessa River is the largest tributary of the Abbay in terms of the volume of water contribution to the total flow of Abbay at the Sudan border. The mean annual flow of Didessa river at Arjo station is about 3,800 million m3 having its maximum flow in August and September (52 percent of the annual) and minimum flow in February and March (less than 1.5 percent of the annual).

The major tributaries of the Didessa river are the Wama, entering from the east, the Dabana from the west, and the Angar from the east.

Month	Didesa	Dabana	Angar
Jan	17.45	12.30	12.22
Feb	12.23	7.76	7.32
Mar	9.74	5.74	4.71
Apr	12.96	5.72	3.93
May	24.25	11.73	6.75
Jun	84.92	36.99	23.75
Jul	263.45	89.39	99.19
Aug	426.73	151.33	203.43
Sep	386.88	191.28	210.77
Oct	234.29	119.78	120.23
Nov	67.64	36.53	39.88
Dec	32.99	19.66	21.36

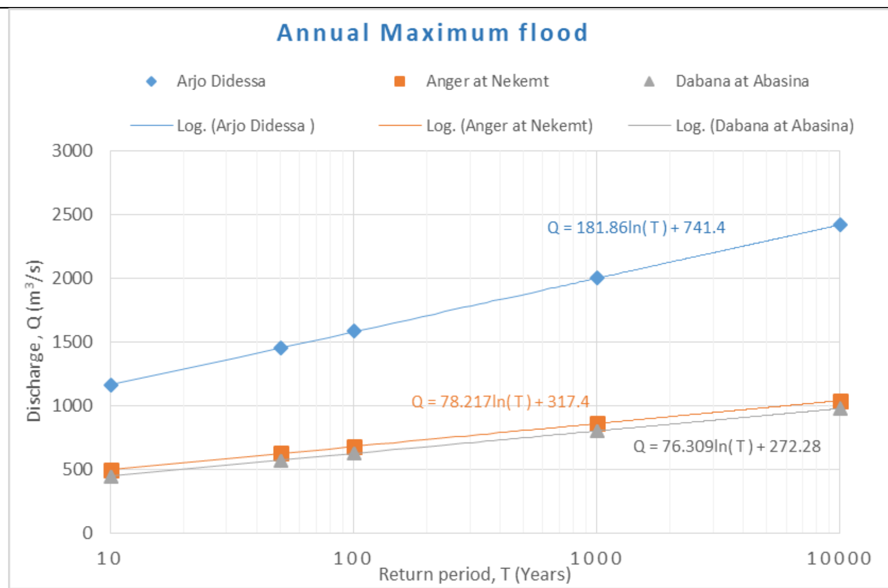
Table: Mean Monthly flow in Dhidhessa basin



Graph. Mean monthly flow in Dhidhessa sub basin

Return Period (years)	River Station		
	Dabana	Angar	Didessa
10	446	496	1,156
50	572	624	1,455
100	625	679	1,582
1000	800	858	1,999
10000	974	1,037	2,414

Table: Annual Flood Vs Return Period



Graph. Annual Maximum flood exceedence in Dhidhessa sub basin

Jemma Sub basin

Jemma watershed has an area of 15,782 km2. The major river in the basin is Jemma River. There are a number of small tributary rivers flowing into Jemma River. Jemma River flows from the West of the basin into Abbay River.

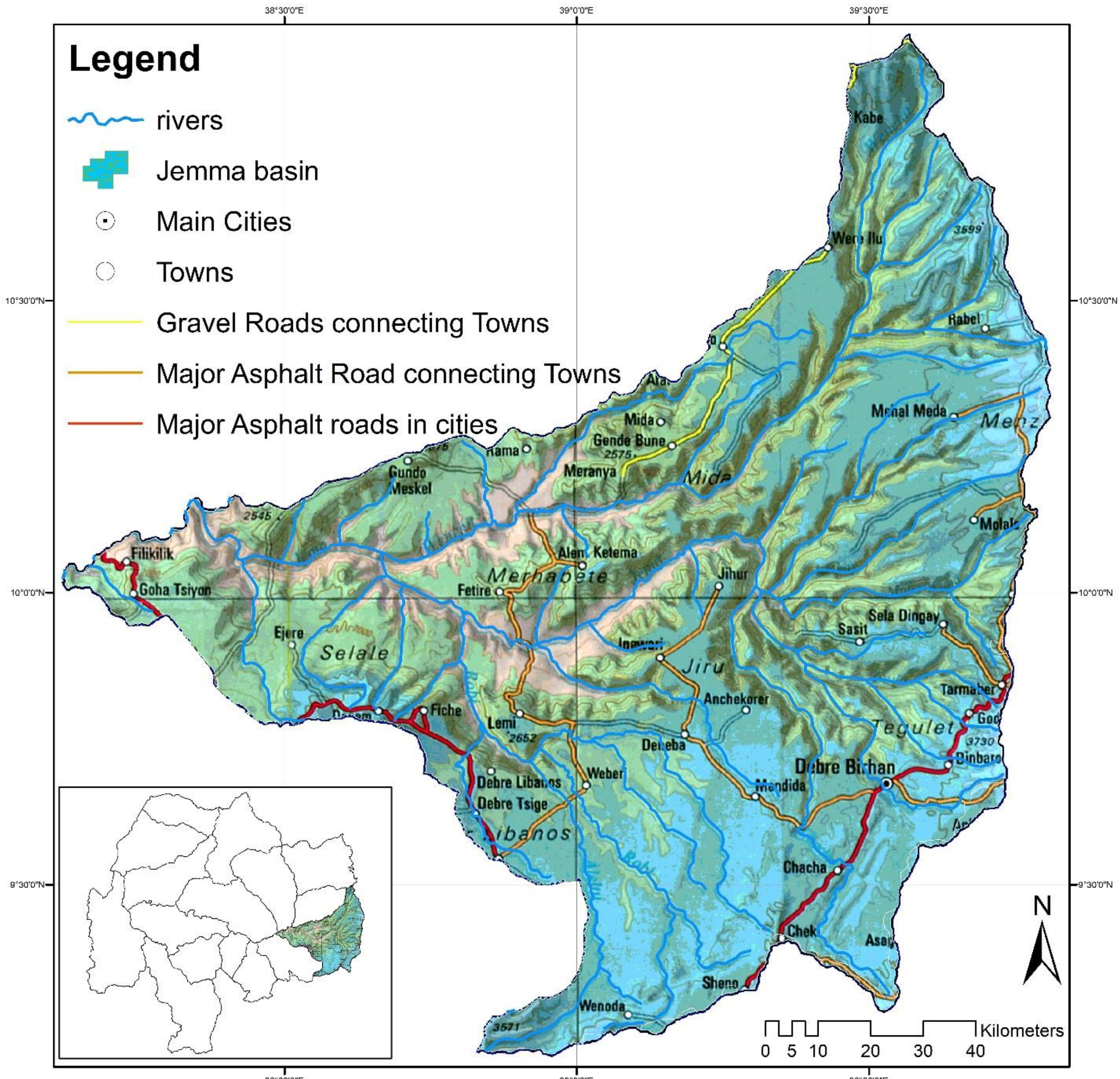


Figure 6.3. Jemma Sub basin

Topography	Rainfall	Temperature	Evaporation
Range: 1010– 3832 masl highlands in the eastern part are higher in altitude greater than 2800 masl, and lowlands along the Jemma river have lower altitude less than 1800 masl	Range: 780 – 1300 mm Lower rainfall (780-900 mm) along the river canyons and higher rainfall greater than 900 mm in the highlands.	Max: 15 – 31°c Min: 10 – 15°c Along the river gorges temperature is higher with maximum temperature greater than 24°c	Annual PET: 1182 – 1947 mm/yr PET is greater than 1700 mm/yr along the river, and the highlands in the eastern part of the basin show lower PET, less than 1400 mm/yr.

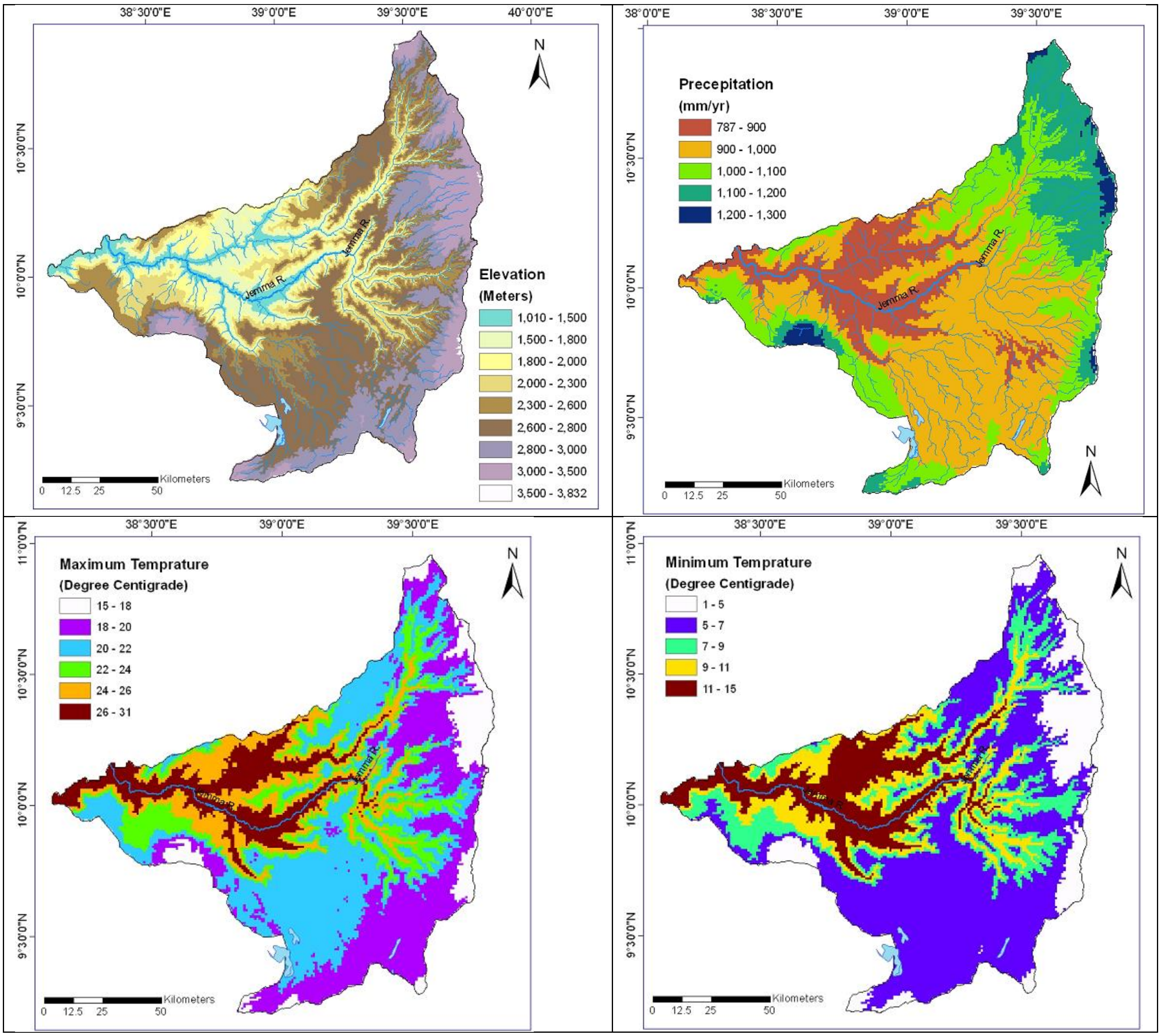


Figure. Topographic and climatic characteristics of Jemm Sub basin.

Muger Sub basin

Muger sub basin has an area of 8,188 km2. The major river in the basin is Muger River. Muger River flows from the south east of the basin into Abbay River, which is notable for its deep gorge.

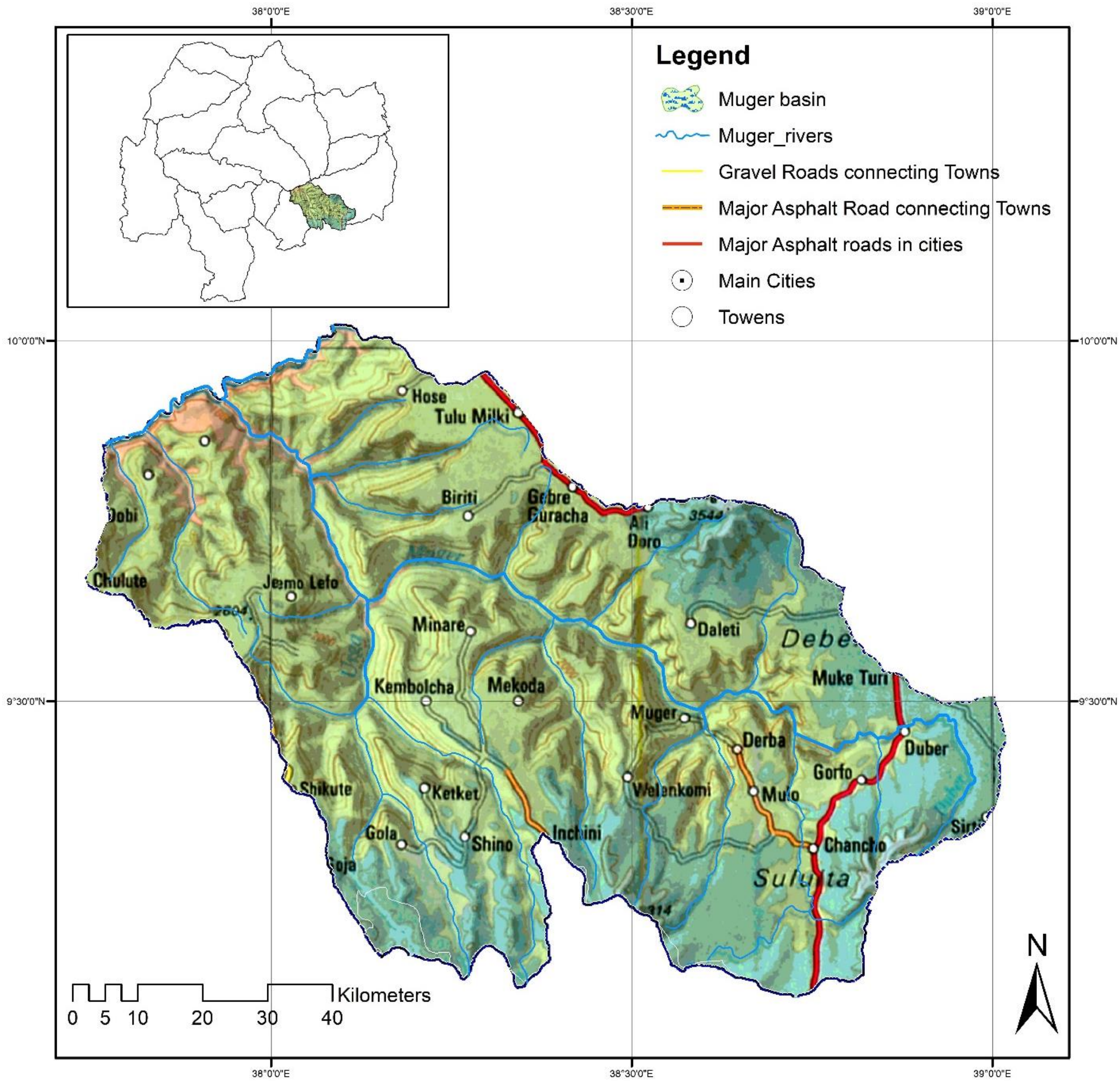


Figure. Muger Sub basin

Topography	Rainfall	Temperature	
Range: 953 – 3550 masl highlands in the eastern and southern part are higher in altitude greater than 2600 masl, and lowlands along the Muger River have lower altitude less than 1700 masl	Annual: 833 – 1326mm Lower annual rainfall (833 - 1000 mm) along the river and lowlands, and higher rainfall (>1000 mm) is observed in the highlands.	Annual Max: 16 – 31.5°c Annual Min: 3 – 16.5°c Temperature is higher along the river course.	Annual PET: 1215 – 1970 mm PET is higher along river valleys and lower in eastern highlands of the basin.

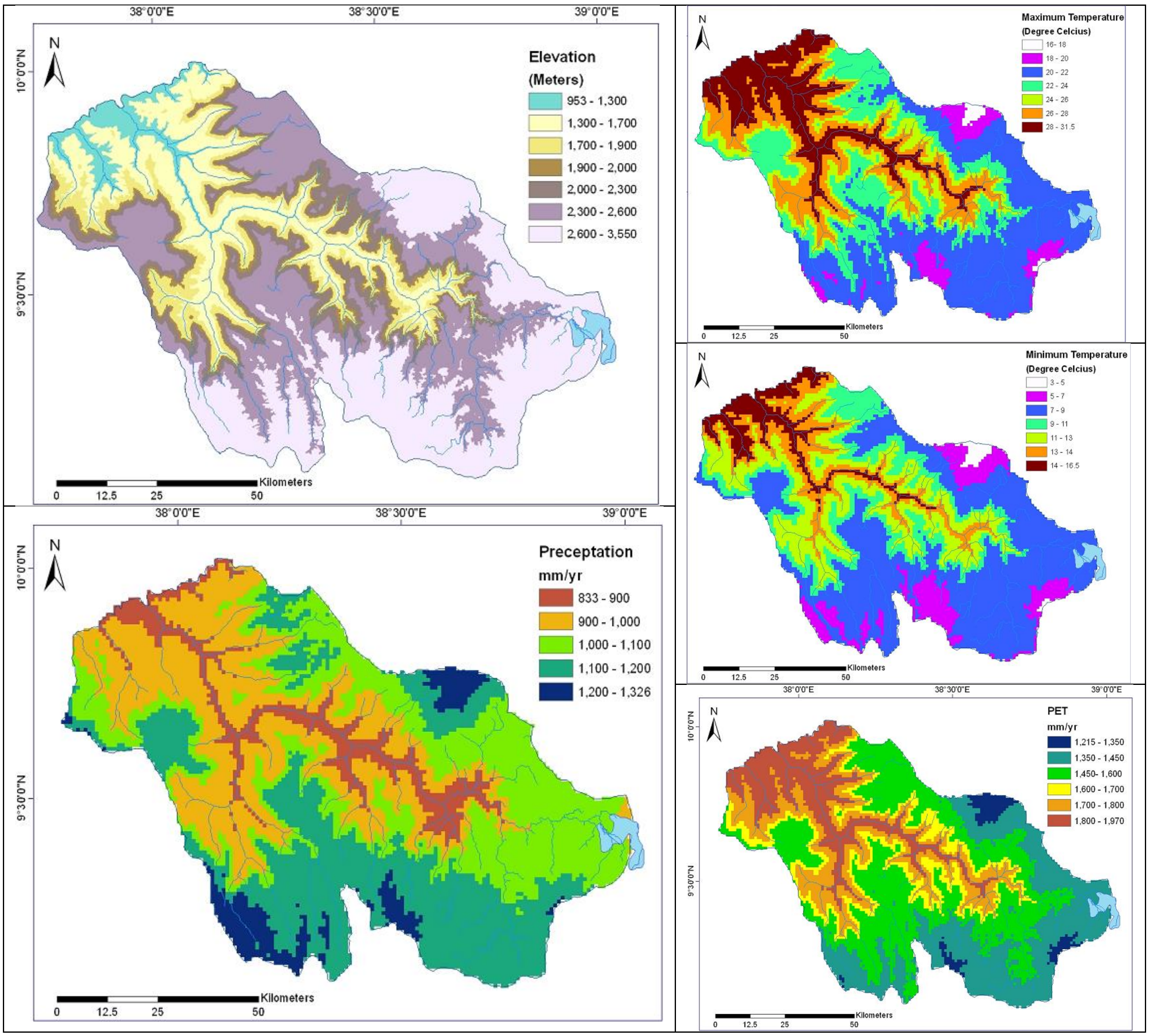


Figure Topographic and climatic characteristic of Muger Sub basin.