Flood Recession Farming: An Overview and Case Study from the Upper Awash Catchment, Ethiopia

Master thesis Hydrology, code 450122, 39 ECTS

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Contents

Abstract
Flood recession farming is practiced all over the world in floodplains of rivers, seasonal wetlands and lake margins. In this thesis an overview of flood recession agricultural practices in Africa is given. Also a case study in the Upper Awash river in Ethiopia, where flood recession farming occurs is carried out. The sites in the Becho plain and in the floodplain upstream of Lake Koka are visited several times to learn about the exact practices of the farmers by taking semi-structured interviews. The relation to the hydrology of the Upper Awash catchment was also investigated to find a relation between the floods and the productivity of flood recession agriculture. The data gathered from ministries and regional administrative units could not provide data that allowed relating the productivity of the agricultural systems to the floods in the Upper Awash basin. A list of opportunities on how to increase the productivity of flood recession agriculture systems was constructed, using the information on the exact practices in the study area, along with the examples from elsewhere. These opportunities indicate how inhabitants can optimally use the water provided by annual floods and how to benefit from the changing conditions of the flood prone areas.

Acronyms and Abbreviations

AWM	Agricultural Water Management
CSA	Central Statistical Agency
EVDSA	Ethiopian Valleys Development Studies Authority
FAO	Food and Africulture Organisation of the United Nations
GDP	Gross Domestic Product
ha	Hectare
IWMI	International Water Management Institude
kg	Kilogram
m.a.s.l.	Meters above sea level
mm	Millimeters
MoARD	Ministry of Agricultural and Rural Development
MoWR	Ministry of Water Resources
NMSA	National Meteorological Services Agency
OWRB	Oromia Water Resources Bureau
WRDA	Water Resources Development Authority
WWDSE	Water Works Design and Supervision Enterprise
ITCZ	Inter Tropical Convergence Zone

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1 Introduction

1.1 Background

Ethiopia is located in the horn of Africa between latitude of 3° and 15° North and longitude of 33° and 48° East. Its surface area is more than 1 million square kilometers and is populated by more than 93 million people, with an annual growth rate of more than 3% (Factbook, 2012). Sudan, South-Sudan, Kenya, Somalia, Djibouti and Eritrea surround the landlocked country. The country is divided in nine regional states: Tigray, Afar, Amhara, Oromia, Somalia, Benshangul-Gumuz, Southern Nations Nationalities and Peoples, Gambella, Harari and two city states of Addis Ababa and Dire Dawa. These states are subdivided in *woredas*, the *woredas* are again subdivided in *kebeles*, which are the smallest administrative units.

There were several political regime changes in the past decades in Ethiopia. Each different regime had its influence on the land rights of the Ethiopian people, combined with the resettlement program; land rights are complicated in Ethiopia. Basically there are three land tenure systems in Ethiopia connected with the ruling regimes in that period. Before 1974 there was a feudal system when different Emperors ruled Ethiopia. Individuals had the usufruct rights over the lands, and these rights were lifelong and extended over many generations. After the overthrow of the monarchy in 1974, the land was declared as collective property. Under the influence of Peasant Associations the land and resources were managed and distributed. Sharecropping and land sales were prohibited in this period. After the fall of the Derg regime in 1991 a new constitution was adopted in 1994. This constitution guarantees the rights of peasants and pastoralists of free access to land. Farmers can use the land or lease it out temporarily to other farmers, they can also transfer it to their children or mortgage it, but they cannot sell it. The state has the right to expropriate the land, if it serves the public interest (Ahmet et al., 2002). Despite this form of land tenure, farmers consider the cultivation lands as their own, since the provided rights of inheritage and management (Nippon Koei, 1996).

Several large rivers originate in the Ethiopian highlands that cover a vast area of the country. Figure 1.1 shows these rivers and their catchments. Ethiopia is often referred to as the water tower of Africa, because all the rivers that originate in the Ethiopian highlands flow to the surrounding countries.

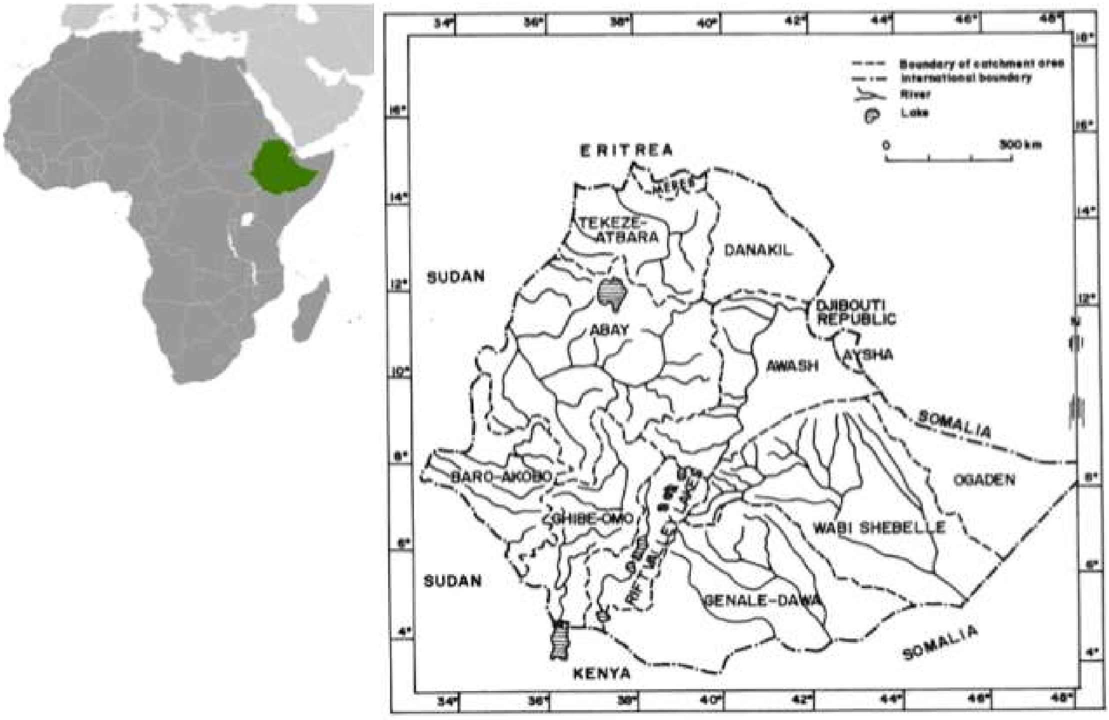


Figure 1.1. Ethiopia and its main river basins. From: Woube, 1999.

Agriculture in Ethiopia accounted for almost 45% of the GDP and about 85% of the export (Factbook, 2010). Five agricultural production systems can be distinguished in the country (Aquastat, 2005):

- The highland mixed farming system that is practiced by almost 80% of the population on 45% of the land that is above 1500 m above sea level. In this system livestock is often used for land preparation, where mainly cereals, pulses and oil crops are produced.
- The lowland mixed farming system produces mainly drought tolerant varieties of maize, sorghum, wheat and teff in areas below 1500 m above sea level.
- The pastoral complex supports only 10% of the total population in the Afar, Somali and Borena zone. Livestock is the major livelihood basis, but some cereals are cultivated on floodplains or as rain fed crops.
- Shifting cultivation is practiced in the scarcely populated areas in the southern and western parts of the country. Fields are left idle for several years and set to fire in the dry season before planting sorghum, millet, sesame, cotton and ginger.
- Commercial agriculture has been developed recently in several places where infrastructure allowed investments in this sector.

The majority of the agriculture depends on rainfall. Some small and large-scale irrigation schemes are developed or planned, but the total area under irrigation is not close to its potential of about 5.7 million ha (Aquastat, 2005). Groundwater from shallow aquifers is only used on small-scale, but several studies on the potential of productive deep aquifers have been performed (WWDSE, 2008). Average rainfall for the country is 848 mm but it varies from 2000 mm in southwestern Ethiopia to 100 mm in the Afar Lowlands (Aquastat, 2005).

The country can be divided into three major agro-climatic zones: the areas with no significant growing period, areas with one growing period in the main rainy season and areas with two growing seasons.
The highly erratic nature of the rainfall, both spatially and temporally, result in a high risk of annual droughts and intra seasonal dry spells. In the last 30 years there have been five droughts with tremendous consequences for the population (Leidreiter, 2010). The largest drought in 1984-1985 killed one million people. Around 15 million people will face severe food shortages when conditions to grow crops become poor (Rahmato, 2008), but even in good years Ethiopia cannot meet its food demands through rain-fed agriculture. Besides irrigation projects that are under development, the understanding and optimalization of flood related agricultural methods can increase the food security of Ethiopia.

1.2 Problem statement

The use of floodwater for agricultural purposes is practiced worldwide. Mostly on small-scale, farmers practice methods to cope with the annually occurring floods and use them for their benefits. Plans to develop the agriculture on the floodplains or other seasonally flooded environments often focus on large-scale, commercially viable farming methods including irrigation or drainage schemes. The productivity and the importance of the cultivation of lands that are annually flooded and the connection with the hydrology of the area are not studied extensively. There is a huge potential for flood based farming systems considering the areas that experience annual flooding. These floods, that are often relatively predictable in time, provide fertile soils where crops can grow on residual soil moisture after the rainy season. The understanding and potential of the use of these areas on floodplains or swampy areas that are seasonally inundated, can contribute to a higher income for farmers and a reduction of the food insecurity on community level or for the whole country.

1.3 Objective

The aim of this research is to understand the influence of the hydrology of the Upper Awash River catchment on the productivity of flood recession agriculture in two separate sites. An analysis of the management of water, soil and field by the farmers as well as the importance of other sources of income related to the flooded areas is used to create insight in the use of these areas that are seasonally inundated. The understanding of the potential of the use of flooded areas is completed by an overview of flood related farming systems worldwide. These examples will show possibilities and the scope for optimal use of floodwater for several income-generating activities.

1.4 Research questions

The main research question of this survey is: What is the potential of flood recession farming in the Upper Awash catchment, and how can this potential be reached?
To answer this main research question the following sub questions are answered:

How is flood recession agriculture practiced in the Bora and Ilu *woreda* in the Upper Awash catchment?
How does the variety of rainfall influence the extent of the inundated area in the Ilu and Bora *woreda*? Are there trends in the intra-annual variation?
How does the hydrological situation in the study area influence the productivity of the flood recession farming systems?
How do the flood recession practices of the farmers differ between the two study sites in the Upper Awash catchment, and how does this compare to flood-based farming practices elsewhere?

1.5 Methodology

To answer the research questions multiple sources of information are used. Secondary data about agricultural productivity over years, hydrological data and meteorological data have been collected from different institutions at different administrative levels. Field observations and interviews with farmers and agricultural experts in the study areas have been put out to complete the understanding of the practiced methods.

1.5.1 Secondary data

Information about the study area or Ethiopia from international organizations like the FAO and the World Bank has been used in this research. On national level the MoWR and NMSA offices in Addis Ababa have been visited to gather river discharge data and meteorological data. Information from the CSA has also been used. GIS maps of the geology, soils and land use of the study provided by the MoWR were used. Other GIS maps that were created for the WBISPP project by the MoARD were a source of information used during this research. At regional level several people from the Oromia WWDSE, and OWRB have been consulted and provided information about hydrology or agriculture in the sturdy area. The *woreda* offices provided information about the agricultural methods and statistics of the several *kebeles* where flood recession agriculture is practiced. Previous studies concerning the study area or hydrology or agriculture in Ethiopia from the library of the MoWR have been investigated. These include several River Basin Development Plans, as well as several groundwater, drainage and irrigation feasibility studies performed in Ethiopia and specifically the Awash River Basin. For the overview of flood based farming systems a wide selection of literature was studied.

1.5.2 Field visits

During the field visits, two *woreda* offices were visited. The agricultural experts were able to provide information about the agricultural sector and flood recession agriculture specifically, performed in several *kebeles*. The field visits were also used to observe the techniques used by the farmers. During the interviews with the farmers, the *woreda* employees were always present. This was very helpful, because they know the farmers and this helps the farmers to talk openly about their practices. Also another hydrology student from Ethiopia was present who also speaks Oromo and Amharic, which was helpful for translation purposes and the interviews generally. The interviews with the farmers were semi-structured interviews where the following topics were discussed:

- What areas are used for agriculture? Flood plains? High/low-lying areas? Depressions?
- What kind of cropping systems are used? How do they change over seasons, over time, and how do they respond to high or low floods, good years bad years. How is a good year or a bad year defined?
- Overall livelihood of the farmers. What are the sources of income (Livestock/ hunting/ gathering/fishing/etc)? What are the changes therein?
- Mapping: where are certain crops planted? Where is good soil moisture for certain crops? Where is high yield where is low yield?
- What techniques to retain or guide floods are used? How to retain soil moisture?
- Is groundwater used for agricultural purposes? Where does it come from? How much is used? How much variation between wet and dry years in wells? Are groundwater levels monitored?
- Do high groundwater levels influence soil moisture? When in the season are the groundwater levels highest? Is this similar with soil moisture? How does the size of the unsaturated zone changes through the season?
- What soils are considered good soils and what are bad soils?
- Is there water being used for domestic use or for livestock? Where does the water come from? Is this same water as used for agriculture?
- Main water issues (quality, availability, diseases).
- Who is well off who is not? Where do they live or farm? What other sources of income do they have?
- How are the crop yields throughout the season, or over different years? Is this confirmed at the markets?
- What are the effects of changes in river morphology? How do different sizes of floods affect the farm sites? What is the role of sedimentation on the farming site?
- What are the constraints of the used methods?
- How can things be improved?

1.6 Structure of the thesis

After the introduction Chapter Two will provide an overview of flood-based farming methods worldwide and Ethiopia, special attention is given to flood rise and recession agriculture. Chapter Three gives the background of the location of the study areas. Chapter Four provides the information about the flood recession farming practices and their yields in the study area, while Chapter Five focuses on hydrological situation in the study area. Finally the results are discussed in Chapter Six. This chapter will also discuss the potential of flood recession farming when the situation in the study area is compared to activities described in Chapter Two.

2 Flood recession farming overview

All over the world and also in Africa people learned to deal with floods in the most effective way. The occurrence of flood related farming systems is often linked to areas that are prone to annual flooding. This is a result of an uneven distributed annual rainfall pattern and these systems are therefore mostly found in areas with a climate that is dominated by a distinct wet and dry season. Several authors have written about the existence of flood recession in researches that cover various disciplines. There are several publications about flood related activities on floodplains in western Africa (Adams, 1993; Saarnak, 2003), there is information about *dambos* and other seasonal wetlands in southern Africa and also several activities in eastern Africa are included. Although there are several publications mentioning this type of flood based farming, these systems receive little attention. The numbers provided by the Aquastat survey (FAO, 2005) show that there are few countries where flood recession agriculture is performed. Although some numbers are estimates, the occurrence of flood recession agriculture is larger than these numbers show. An indicator of the potential of flood recession agriculture is the area of wetlands in Africa. More information on size and location of wetlands is provided on the RAMSAR website. No exact numbers on flood recession agricultures exist, but the area where it is performed in Africa may exceed 20 M ha.

Flood-based farming systems

Flood recession farming	Flood recession and flood rise farming	Spate irrigation	Dambo irrigation	Inundation canals
Flood recession farming uses the residual soil moisture that is stored in the subsurface after annual inundations of: floodplains, lake margins or seasonal wetlands.	Besides flood recession agriculture the rising flood is also used to grow flood tolerant rice or sorghum varieties.	Spate irrigation uses bunds and canals to guide flash floods to the agricultural fields.	Dambos, local depressions described in South Africa often experience seasonal water level changes. The margins of these depressions can be used for agriculture in the dry season.	The construction of canals that guide flood water across the floodplain to the agricultural fields.

Table 2.1. The categories of flood-based farming systems.

2.1 General features

Flood recession farming is a form of flood-based agriculture (Table 2.1). Flood-based agriculture can also include spate irrigation or other water management systems that guides or stores water for irrigation. Flood recession agriculture uses the residual moisture of seasonally flooded lands when the floods recede. This form of agriculture is not uniform, various adjustments and techniques have been developed to optimize the yields of the areas that are prone to annual flooding.

There are, however, some general features that are typical for flood recession agriculture systems. The annual flood that comes in the rainy season brings fertile sediment from the upper catchment. The flooded areas are often gently sloped floodplains or margins of lakes or wetlands where these sediments can settle. Organic material in the sediment acts as a natural fertilizer. The recession farmers do not have to add fertilizers and plots are suitable for continuous cropping without fallowing. The sedimentation of fine-grained material allows the development of clayey soils that have high water retention capacities. The soils that develop in these environments are often vertisols, fluvisols, gleysols and cambisols. The shallow groundwater table and residual moisture are relatively high in the floodplains, and this allows agricultural practices in the dry season. To optimize the productivity of areas that are flooded annually, a method often applied is to use the rising and receding flood and have at least two crop cycles per rainy season. Harlan and Pasquereau (1968) did research on this form of agriculture around the Niger River in Mali and call the two phases *crue* and *décrue* agriculture (crue is French for flood and décrue means the recession of the flood). There are also certain crops that are cultivated with these forms of agriculture. Flood tolerant varieties of rice and sorghum are grown with the rising floods and during the recession, often pulses, like lentil and chickpea are grown. People that live at the margins of the floodplain and have been practicing flood recession farming for generations have developed knowledge about what crops perform best on specific parts of the floodplain. Sometimes detailed classification of different geomorphological features on the floodplain exists. Besides the similarities in practices during the subsequent phases of the flood cycle, there are more similar techniques on dealing with floods. Mostly these are different methods to diminish the risks caused by the uncertainty of the timing and duration of the annual flood. Some of these measures are the use of different crops and varieties of certain crops that have different flood tolerance. Classified landforms and soil types on the floodplain can be cultivated using the crop with the ecological needs that are most suitable for that certain part of the floodplain. By practicing several activities in and around the floodplain, people can deal with the uncertainty of the floods. Sometimes farmers are also fishermen, herders or own land in higher elevated areas where rain-fed agriculture is practiced.

Country	Total agricultural area (ha)	Flood recession agricultural area (ha)	Source
Senegal	9 000 000	150 000-200 000	Adams, 1992 1960s
		15 000-20 000	Adams, 1992 1970s
Sierra Leone	3 000 000	100	Richards, 1995
Mali	40 000 000	2 000 000	Thom and Wells 1987
		3 000 000	Deltares
Zambia	26 000 000	900 000	AWM, IWMI, 2009
Botswana	26 000 000	6 500 000	VanderPost, 2009
		6 500	FAO Aquastat, 2005
Somalia	43 000 000	110 000	Basnyat, 2007
Ethiopia - Lake Tana	35 000 000	6000	McCarthy, 2010
-Omo River valley		11000	Woodroofe, 1996
-Wabi Shebelle River valley		6800	WWDSA, 2003

Table 2.2. Indication of total agricultural area per country, and area used for flood recession agriculture. Total agricultural areas are taken from The World Bank (2012).

2.2 Flood recession farming in Africa

There are several zones in Africa where flood recession practices are described. These zones are: along main rivers and wetlands in West Africa, around wetlands or *dambos* and also large rivers in Southern Africa and along rivers and wetlands in Eastern Africa. It is likely that there are more examples of flood recession agriculture, in or outside these regions. They may have not been described yet or are not included in this overview. The area of land used for flood recession agriculture, described in the literature is summarized in Table 2.2.

2.2.1 West Africa

In an overview of indigenous irrigation in West Africa by Adams (1993), the description of the agricultural methods dealing with floodwater show many similarities to descriptions in other papers on this subject. When a river retreats, water is left in the subsoil of the floodplain as soil moisture or in swamps and pools and sometimes deliberately behind embankments or pits. Table shows the size of wetlands in the western Sahel, which can give an indication of the size and distribution of flood recession farming in the region. In another publication by Adams (1992) a more detailed overview of the occurrence of flood rising and recession farming is given, focusing mainly on the western Sahel zone. This publication focuses on: the Senegal Valley, the Sokoto Valley and Hadijia–Jama'are in Nigeria, Logone Chari plains in Cameroon, and the surroundings of Lake Chad as well as the Waanje River in Sierra Leone. The different practices of people depending on seasonal flooding of the floodplains are described. Earlier mentioned general characteristics of the systems like the soil types, fertility of the soils and the methods to deal with risks are also described for these systems. The areas described below contain information from Adams (1992) and is supplemented with information from other studies.

Wetland	surface area km^2	country
1. Senegal delta	3,000	Senegal, Mauritania
2. Senegal valley	5,000	Senegal, Mauritania
3. Niger inner delta	30,000	Mali
4. Niger fringing floodplains	3,000	Nigeria
5. Sokoto and Rima valleys	1,000	Nigeria
6. Hadejia-Nguru floodplains	4,000	Nigeria
7. Logone floodplain	11,000	Cameroon, Chad
8. Lake Chad floodplain	10,000	Nigeria, Cameroon, Chad
Total	**67,000**	

Table 2.3. Major floodplain wetlands of the western Sahel (from: Loth, 2004)

Senegal Valley

The total area of the Senegal valley is about 1 million ha (Adams, 1992), although Loth (2004) gives a smaller surface area in Table 2.3. Of this area during wet years in the 1960s, 150 000 to 200 000 ha were cultivated. In dry years in the 1970s this area declined to a tenth of this. Around half a million people practice flood related cropping in the valley, many of these also have cattle and some catch fish. In the Peulaar language there are certain words that classify the different land types, or geomorphological features in the floodplain. The deep clay basins that stay wet the longest are called *hollalde*, this is the most productive land of the floodplain. The *hollalde* is mainly cultivated with 130 days sorghum and is sometimes mixed with beans. Blocks of plots up to 120 ha exist in the valley. Higher elevated areas of the floodplain are called *falo* and these are mostly cultivated with rain-fed crops (Fig.2.2). Saarnak (2003) describes flood recession agriculture practices in the Senegal River Valley where sorghum, beans and melons are cultivated on floodplains after the water recedes. The farmers use the water that is left on the surface and in the soils of the floodplain, after the floods recede. The river valley topography or morphology and land use are very important for the amount of water at the surface or in the soil and thereby the farming potential of a certain soil type. Another conclusion is that the described agricultural system is characterized by very high net returns compared to the energy input. The only inputs are needed compared to other agricultural methods are land and labor.

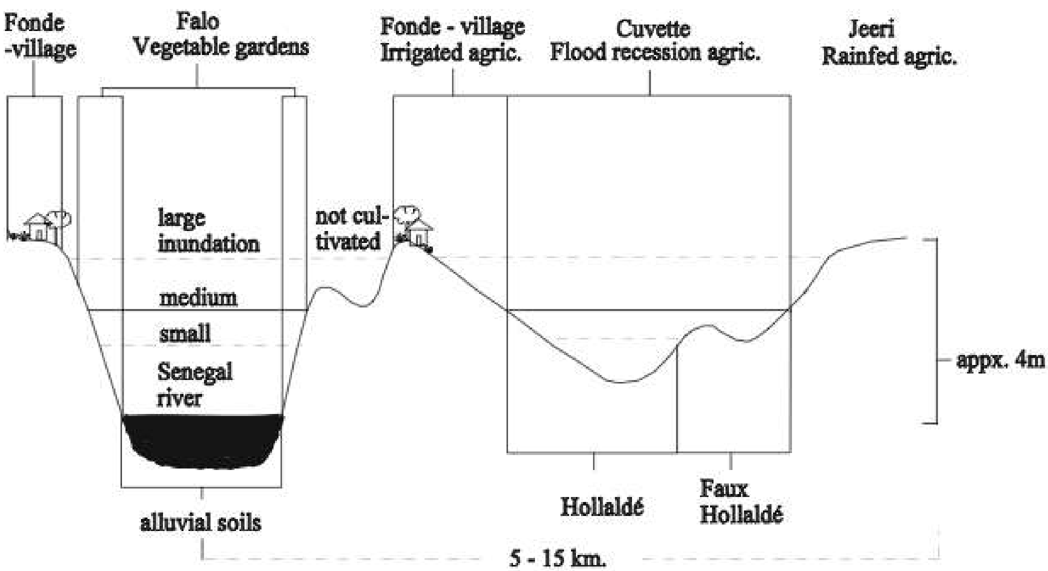


Figure 2.2. Cross-section of the middle/lower Senegal Valley showing the parts of the floodplain and their land use (from: Saarnak, 2003).

Sokoto Valley,Nigeria
In the Sokoto valley similar activities exist. The floodplains are also cultivated in synchrony with the rains. The farmers that have land on the floodplain grow several varieties of rice and sorghum that are resistant to flooding. The wet season cultivation of the land is often followed by a second crop cycle in the dry season, also on the inaccessible deep flooded lands of the floodplain. This dry season cropping involves the use of groundwater by wells or *shadoofs*. *Shadoofs* are irrigation systems where a counterweight helps a farmer to lift buckets of water from a well. They are described in studies in Egypt, Sudan and Nigeria (Kimmage and Adams, 1990; Adams, 1992).

Hadejia-Jama'are, Nigeria
In the Hadejia-Jama'are plains also different rice and sorghum varieties with different ecological requirements are grown on the seasonally flooded land. The cultivation of the land is slightly different than the systems described above; the seeds are planted when the rains start. When the rice grows up to 12 cm it can resist flooded conditions. It is essential for this system that rains precede the flood. Farmers built defensive bunds to protect their lands to early flooding that potentially can cause crop failure. Flood recession crops like cowpeas grow on cracking clay using the residual soil moisture after the floods have receded. On slightly higher land cotton and cassava are grown. In Thomas and Adams (1999) agricultural practices using floods in the Hadejia-Jama'are floodplain are described as follows: first, as floodwaters rise, rice is cultivated. In the second phase, as the water recedes, crops such as sorghum or cowpeas are planted. These crops are able to grow using only the residual moisture in the soil. Thirdly, crops such as tomatoes, onions and peppers are planted under irrigation in the dry season on the banks of rivers and where water lingers in the floodplain. Low-lying seasonally flooded areas in Nigeria are called *fadamas*. The *fadamas* are recognized for their potential productivity, especially during the dry season and there have been several projects to develop the *fadamas*. On fadama.net there is information on the third phase of the project. Thomas and Adams (1999) describes that farmers use the low-lying *fadamas*, with heavy alluvial soils in flood and recession times for agricultural purposes. During the flood of the *fadamas* they grow rice, which is 19.2 percent of the total agricultural benefit of the area. In the recession period cowpeas (often a more drought resistant variety with deep roots called 'Dan Chadi', meaning: from Chad), sweet potatoes and pumpkins are grown in the *fadamas*, contributing 20.6 percent of the net agricultural benefits (Thomas and Adams, 1999).

Logone Chari
In the Logone Chari system in Cameroon there is an extensive floodplain that eventually drains into Lake Chad. The Marba people living in the middle of the Logone plains have a detailed land classification system. There are nine categories of flooded land called *fulan*, and two categories of unflooded, seasonally damp land called *temzeina*. These people also grow crops to with certain ecological needs on the suitable lands. Bulrush millet is grown on high

grounds and sorghum on the less elevated areas that are flooded during the wet season. The sorghum grows as floods rise and is eventually harvested by canoes. The extension of the floodplain farming practices has declined after decline of floodwater that resulted from the development of a large rice irrigation scheme upstream.

Lake Chad

In the surroundings of Lake Chad the black cotton soils are cultivated with a sorghum variety called *masakwa*. The farmers in this area construct small bunds up to 40 cm to at the end of the dry season to retain water. Loth (2004) also describes dry season sorghum variety that is grown on the Waza Logone floodplain, surrounding lake Chad in Cameroon. The sorghum variety called *muskwari* is grown on the black cotton soils of the floodplain. This sorghum variety is also grown on similar soils along the Benue River.

Sierra Leone

In the floodplain of the Waanje River in Sierra Leone, seasonally flooded lands called *bati* are cultivated with floating rice called *kogbati*. This rice is planted with the rising flood and harvested with falling flood. Rain-fed rice that is grown on the higher sandy islands at the back of the river floodplain is called *sokongoe*. In these areas the people also transplant a certain rice variety when the flood falls to grow on residual soil moisture. The transplantation of rice is labour-intensive and rice growing on residual soil moisture is vulnerable to pest and bird damage. However, the people do produce rice throughout the year.

The indigenous rice farming systems in Sierra Leone that were the topic of a research by Richards (1995) show that around 100 rice farms of around one ha exist. He did his survey on a specific ethnic group that produces rice in 3 phases. On different parts of the lands along the riverbed, with varying soil moisture, fertility and drainage, different rice varieties are planted before and during the rainy season. Before the rains start a short-duration rice variety is planted on the river terraces and moisture-retentive lower-slope soils, using the starting rain and residual soil moisture. As the rains have started a medium-duration rice variety is planted on the draining upland soils. Finally in the middle of the rainy season, long-duration, floating varieties are planted on the inland valley swamps. Some farmers use small bunds to control the water. Most farmers use residual moisture by planting cassava, sweet potatoes and vegetables in their swamps in the dry season.

Niger River

An already mentioned study performed by Harlan and Pasquereau (1968) investigates the Niger inland delta in Mali. They find farmers using the floodwater of seasonal floods. They called the two phases *crue* and *décrue* agriculture. Skilled cultivators with useful practical knowledge of the crops to be planted on wet or drier soils were active in the wetlands adjacent to the river. The sequence of crops that perform best from the more upper and drier fields towards the lower and wetter parts of the floodplain is: pearl millet, long-season durra, mid-season durra, guinea corn and rice. Figure 2.3 shows a cross section of the margins of the inland delta and the type of cultivation.

The recessional crops that are used are rice, including a flood resistant variety called floating rice, sorghum, millet, maize, cowpeas, peanuts, manioc, sweet potatoes and cotton. There are several techniques to grow the rice. Some transplant the rice several times with the receding water. Other practices are to grow the rice, which becomes dormant in the dry season, and then harvest them after the first rains have started. Small dikes constructed with mud are used to either delay an incoming flood, or retain water when the floods recede. Sorghum usually yields 800 kg/ha (Thom and Wells, 1987). Besides agriculture the delta is used for pasturelands and 900 000 people depend on fishing in the inland delta for their livelihoods (Fig.2.4).

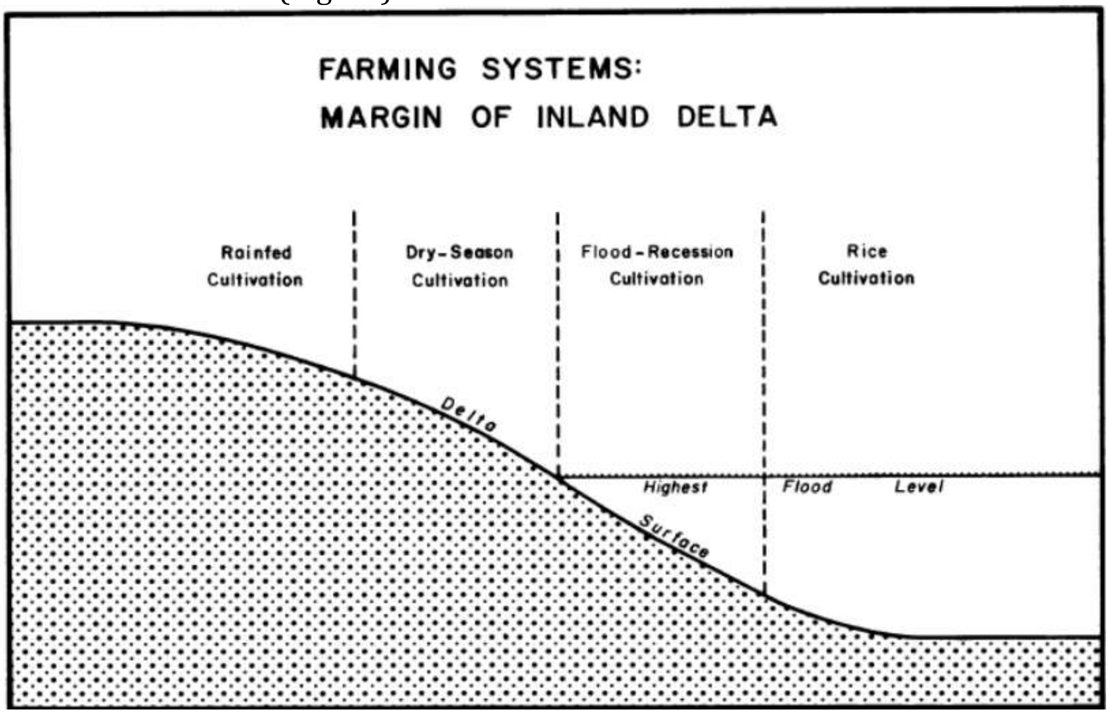


Figure 2.3. Types of cultivation at the margins of the Niger inland Delta (from: Thom and Wells, 1987).

Thom and Wells (1987) indicate that over 2 M ha are annually flooded in the Niger Inland Delta; another indication is up to 3M ha (Deltares). This shows the potential for flood recession agriculture and other flood related activities.

Figure 2.4. Inhabitant of the Niger Inland Delta fishing in the floodplains (from: Zwarts et al., 2005)

2.2.2 South Africa

Zambezi River

Beilfuss (2002) and Scudder (1972), who both did research on the Zambezi River, found that in the wet season there are two cropping periods. During the rainy season, the fertile alluvium adjacent to the river channel are planted with crops of cereals, legumes, and gourds that are harvested just prior to the river's expected annual flood. These crops use the rainwater for their growth. Farmers plant a second crop on the alluvial soils after the floodwaters begin to recede, sowing seeds just behind the retreating water line and harvesting at the end of the dry season (Beilfuss, 2002). The crops use the remaining soil water for their growth. Other activities on the floodplain include, pasturing of domestic animals during the dry season, fishing in shallow pools during drawdown of the floods, the gathering of non-timber forest products and fuel wood on the floodplain. The floods also recharge local aquifers that provide an essential source of groundwater during the dry season (Beilfuss, 2002)

On Borotse floodplain in the Western Province of Zambia, a wetland of 900 000 ha is utilized according to the timing and extend of the annual flood of the Zambezi River (AWM, IWMI, 2009). Various crops are cultivated with the rising and receding floods. These crops include: maize, sorghum, pumpkin, mango, rice, cashew and vegetables. In the plains shallow pans exist. Natural or artificial canals connect some of these pans. Locations like this with higher water tables can support winter cropping utilizing the soil moisture. There is the opportunity to use groundwater as additional irrigation in the winter season.

Okavanga Delta

In a publication by Oosterbaan et al. (1986) the seasonal swamps called *molapos*

of the Okavanga Delta are described. There is a detailed description of the use and development of *molapos*. Farmers use the lands in the delta to grow mainly maize, sorghum and millet. This occurs on the sandy soils of the uplands and in the *molapos*. The seeds are sown and germinate on residual soil moisture after the floods recede, if all goes well the rains start before the soils get too dry. Farmers also built small bunds to protect crops from unwanted floods (Fig.2.5). The risks involved in the farming methods made the people also dependant on livestock, palm-wine tapping, fishing, hunting and basket weaving. The uncultivated *molapos* are important grazing lands after the floods recede.
In a more recent publication by the Okavango Research Centre the productivity of *molapo* farming (Table 2.4) are displayed (VanderPost, 2009).

Figure 2.5. An old, abandoned bund made to retain water in the molapo (from: Oosterbaan et al., 1986).

Molapo farming is the same as flood recession farming and consists of 25% of the cultivated lands of Botswana. The main cereal crops grown are sorghum, maize, and millet. Secondary crops like beans, pumpkins and watermelons, sweet reed and peanuts are also cultivated. The publication (VanderPost, 2009) finds varying yields in different years mainly due to uncertain flood magnitude.
Molapo farming is also mentioned in a FAO publication on water resources in Botswana. An area of 6 500 ha are used for *molapo* farming, around the Okavango and Chobe enclave. Mostly maize and millet are planted (FAO Aquastat survey, 2005)

Crop	**Yield (kg/ha)**
Maize, dryland	162
Sorghum, dryland	121

Millet, dryland	144
Sorghum in Molapo	500
Sorghum in Molapo, optimal flooding	2000

Table 2.4. Cereal crop yields, dryland and molapo (from VanderPost, 2009).

Malawi

Malunga (2009) describes the practice of flood recession agriculture in the Shire valley of Malawi, in a wetland and small-scale irrigation overview. Sweet potatoes are grown in floodplains of the river at the end of the wet season on plot sizes of around 0.2 ha. The farmers also own land in higher elevated regions where they grow crops in the rainy season. Flood recession agriculture here is low cost; no fertilizers or chemicals are used and the only input is labor.

2.2.3 East Africa

Kenya

Several authors mention flood recession agriculture in Kenya. Adams (1987) finds two sources that have recorded flood recession agriculture in the River Tana basin. In a study on river discharge and sediment transport in the Tana estuary by Kitheka et al. (2004) flood recession agriculture is said to be performed in the floodplains and delta area of the Tana River. The agricultural practices are dependant on the flooding of the River Tana between April and June. Another study by Moinde-Fockler et al. (2006) on forests in the lower River Tana valley mentions the Pokomo tribe that practice riverbank and flood recession agriculture. Both forms of agriculture depend on the floodwater and fertile sediments that the floods bring. These studies do not specifically study the agricultural practices, and just mention their existence. An IUCN survey on the value of the wetlands of the River Tana, carried out to estimate the effect of a planned hydropower dam, gives an overview of activities in the floodplains and wetlands adjacent to the Tana River. This survey finds that 115 000 people are practicing riverbank and flood recession agriculture in the River Tana basin and delta. The survey finds that 2.5 million livestock and 50 000 fishermen yielding 500 tonnes of fish a year, are all dependant on the annual flood regime of the river. Terer et al. (2003) add that most of the farmers also own land in higher elevated areas. Besides farming on riverbank and floodplains, rain-fed farming is practiced on these higher elevated lands for risk spreading. The cultivation of rice during and after the flood is described, and the importance of the fishing activities is also mentioned. This article also mentions the sand and clay mining practices that can generate income and are dependant on the flood regime of the river.

Tanzania

In Tanzania, flood recession agriculture is mainly described in the Rufiji River basin. Again, Adams (1987) mentions a survey by Marsland (1938) that recorded the *mlau* cultivation that is based on the residual soil moisture in the floodplain environments. This *mlao* cultivation, which is similar to flood recession agriculture, is further described in Duvail and Hamerlynck (2007). They describe the lower floodplain area, where the floodplain is 20 km wide and maize and rice are grown traditionally. The survey finds that the people have adjusted to the floods, and that fishing and flood recession agriculture are especially good after big floods. Farmers understand how to effectively use the subtle variability in topography, and how to deal with short and long floods (Fig.2.6). Different crops are grown in the non-flooded, higher elevated areas (mango, cashew, banana, maize sorghum, sesame). In the lower lying areas the loamy and fine sandy soils of the levees are preferred for mainly the production of maize. The slightly lower lying depressions that contain more heavy clays are suitable for rice growth. Small plots are cultivated and intercropped with rice and maize by each household depending on small topographical variation. Different varieties are used depending on the timing and duration of the floods.

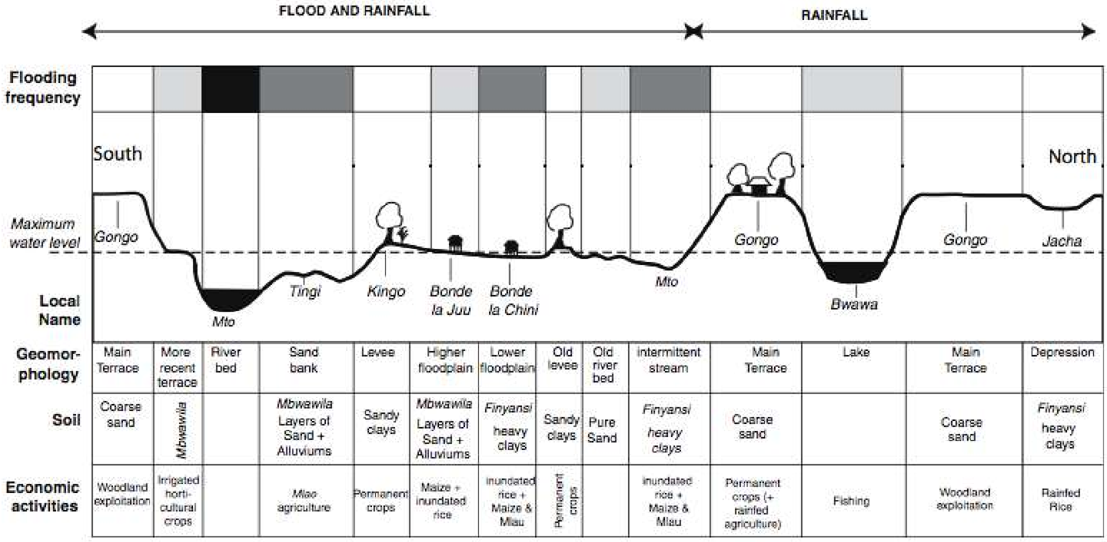


Figure 2.6. Cross section showing the geomorphology, soil and activities on different parts of the floodplain (from: Duvail and Hamerlynck, 2007).

Other locations

Similar practices are likely to be performed alongside more rivers, lakes or wetlands. More intricate systems that are more similar to spate irrigation practices are performed in the Gash Delta in Sudan (el Abadine and Robinson, 1970). There are also other planned irrigation schemes implemented in the delta, but the Hadendowa people used to grow sorghum and ranch their herds on the flood recession grounds of the delta. Also long ago in Egypt several systems developed where the seasonal floods were guided through canals to get water into the agricultural fields adjacent to the Nile (Brown, 1912). The FAO Aquastat survey (2005) also mentions the existence of flood recession practices in Somalia. In the Juba and Shabelle basin people grow mainly maize on previously flooded land. Another water resources report mentions a total area of 110 000 ha being under flood recession agriculture in the Juba and Shabelle regions (Basnyat, 2007).

2.3 Flood recession farming in Ethiopia

The areas in Ethiopia where flood recession farming is practiced all have their own history and agricultural methods. Differences concern the types of crops that are cultivated, the planting techniques, combination with other sources of income related with the flood (fishery for instance) and the methods to deal with the involved risks, are not similar all over Ethiopia. Below a characterization of main regions where people are known to practice flood recession agriculture is given: Lake Tana, Baro-Akoba, Omo Valley, Wabi Shebelle and Upper Awash. In addition there are scattered small wetland areas where during the dry season vegetables and other crops are cultivated on the drier sections.

2.3.1 Lake Tana

In the North of Ethiopia flood based farming is practiced on the shores of Lake Tana as well as along some of the tributaries feeding the Lake. An average area of approximately 15000 ha is affected by annual flooding. Since the installation of the Chara-Chara weir in 1996, the outflow of the lake is regulated. The maximum water levels are not supposed to be affected by the installation of the weir, according to the design criteria, but the duration of the low water levels is shortened. This influences the potential for flood recession agriculture along the shore (BCEOM, 1999). McCarthey et al. (2010) cite figures of a World Bank report of 2008 that estimates the extent of lakeshore flood base farming of maize and rice production to be 6000 ha.

Apart from the lakeshores low-lying plains near the lake are influenced by the flooding regime of the tributaries entering the lake. These areas are cultivated with the use of floodwater too. The prime examples are the Fogera plain east of Lake Tana, where the Ribb and Gomara rivers drain the catchment, and the Dembiya plain in the north where the Dirma and Megech rivers enter the lake.

In these areas for a long time flood recession agriculture has been practiced with maize and sorghum grown on the residual moisture after the flooding period. Yet in the last decades the system has changed from a flood recession to a flood rise system. Around the early 1990s farmers started growing rice in the wet season under flooded conditions – using the rising floods. Small bunds are constructed to retain water, they also allow regulation of the water entering and leaving the rice plots. Typically, the water is retained inside the bunds for 3 to 4 days. If the water is retained longer, it might warm up and increase the risks of the occurrence of diseases. Figure 2.7 shows the different phases of the rice cultivation. After the rainy season the previously flooded land is used for the cultivation of maize, teff, oats, lentil and chickpea depending on the local conditions. In this second planting phase there is often additional small-scale irrigation from shallow groundwater or diversion of stream water.
Then in some locations even a fully irrigated third phase of planting can be performed. In the dry season the shallow groundwater in the plain can be pumped to irrigate vegetables, cereals and pulses.
Besides agriculture there is around 4000 ha of communal and individual grazing lands for livestock.

Figure 2.7. Rice production under flooded conditions using small bunds in the Fogera plains near Lake Tana.

The productive potential of the area is recognized and there are several plans for irrigation schemes. Flood recession farming along the direct lakeshore is discouraged, in order to preserve the habitat for migrating birds.

2.3.2 Baro-Akobo

Another area where flood recession farming is practiced is in the Baro-Akobo region in the Gambela regional zone. The low-lying lands in the western part of the country near the Sudanese border are inundated for long periods of the year. The Anuak people practice different forms of farming. Besides rain-fed farming they grow crops on elevated riverbanks just after the floods retreat. There are several reasons why riverbank farming (Fig.2.8) is important. The fertile soils that are deposited with the floods are easily workable. The lands are close to water and fish resources, and river vegetation provides the picking of fruits in the dry season (Mengistu, 2005). Anuak use the backswamps mainly for dry season grazing, although they would be suitable for rice and godere production (TAMS, 1997). In January many Anuak also prepare some land in the dried up backswamps for the cultivation of the spring crops. The crops use the spring rains and the residual soil moisture for their growth (Mengistu, 2005). The Anuak often slash and burn these previously inundated areas, to enhance the fertility of the soil and make it easier to work in it. The main crops produced are maize and sorghum, but also mango, papaya, semi-wild fruits and root crops, as well as legumes are produced (Mengistu, 2005).

Figure 2.8. Flood recession farming on the riverbeds in Gambela. Adjacent to the river are marshes that can be partly cultivated later in the dry season.

2.3.3 Omo River valley

In the valley of the Omo River flood recession agriculture is extensively practiced (Adams, 1992). In a water resources study on the Omo Gibe River Basin, flood recession is as a land use class associated with the delta of the river, and is also mentioned to occur in narrow bands along the banks of the Lower Omo Valley (Woodroofe, 1996). In this study, the total area under flood recession is set at 11037 ha, but this includes riverine woodlands, open bushland and bare soil as well. Maize, sorghum and finger millet are the main crops. They are planted on the banks of the Omo River as the annual flood retreats. The crops use residual moisture for their growth. A common practice is for sorghum to be planted in groups of ten seeds together to make sure that one in these groups will grow fully mature (Fig.2.9). In certain areas inundation canals are developed that distribute the water over a more extensive area as the water level rises in the river. Cases where up to 1000 ha have been irrigated in this manner have been reported (Woodroofe, 1996). The fluctuation of the flood size over the years makes it difficult to precisely quantify the flood recession area, but it is estimated that 100 000 people depend on the system (Woodroofe, 1996).

Figure 2.9. Groups of sorghum that are planted on temporarily inundated land in the southern Omo River valley.

2.3.4 Wabi Shebele catchment

Annual flooding occurs in areas around Kelafo, Mustahil and Ferfer woredas in the downstram reach of the Wabi Shebele River (WWDSA, 2003). WWDSA (2003) refers to a study by WAPCOS that Wabi Shebele inundates 60 000 ha annually, of which 14 000 ha is flooded throughout the year. The same report indicates an area of seasonal swamps in the more upstream part of the river. An area of 6800 ha is flooded annually and is an important dry grazing area and crops are grown on residual moisture. The wetlands exist in the Bale zone in the Gasera, Gololcha, Gihir and Sweina woredas (WWDSA, 2003). The report does note that indigenous irrigation involving the diversion of spate floods is practiced in the river basin too. Though the Wabi Shebelle is one of the largest areas under annual flooding very little is known with regards the extent of flood recession farming. It is known however that further downstream in Somalia flood recession farming is well known.

This is similar to the Gelana, Denakil and Tekeze River Basins: in several reports on the river basins seasonal swamps or wetlands are identified, but no information on the use of these areas is presented. The reports do report the use of flash floods in these areas. But similar to the information on flood recession agriculture there is only limited information on the extent, productivity and history of spate irrigation in the reports.

3 Location

The focus of this study is on two sites where flooding and flood recession agriculture is practiced annually, located in the Ilu *woreda* in the Becho plain, and in the Bora *woreda* upstream of Lake Koka. Both the sites are in the upper reach of the Awash River basin situated in Central Ethiopia in the Oromia Regional State. The Becho plain is located approximately 50 km west of Addis Ababa next to the main highway from Addis Ababa to Jimma. The second site is located in the plains where the Awash River enters Lake Koka around 100 km south of Addis Ababa. The reservoir of Lake Koka was constructed in 1960 for hydroelectric power production, and the outlet of the lake at the dam is also the outlet of the upper Awash sub catchment. This Upper Awash River sub catchment has an area of around 11 500 km^2 (EVDSA, 1989) and is located between 8° and 9°N latitude and 38° and 39° E longitude (Fig3.1). The Becho plain has an average elevation of 2060 m and is surrounded by Wechecha Mountain in the east, the Guraghe highlands in the south and the Weliso highlands in the west (WWDSE, 2008). The Awash River and several tributaries rise in these mountains that reach over 3300 m.a.s.l. The Berga, Holeta, Kelina, Dilolo Dilu, Teji and Watira tributaries join the Awash River in the Becho plain that flows towards Lake Koka in southeastern direction. The catchment of this upstream part of the upper Awash reach until the gauging station at Melka Kunture is 4541 km^2 (EVDSA, 1989).

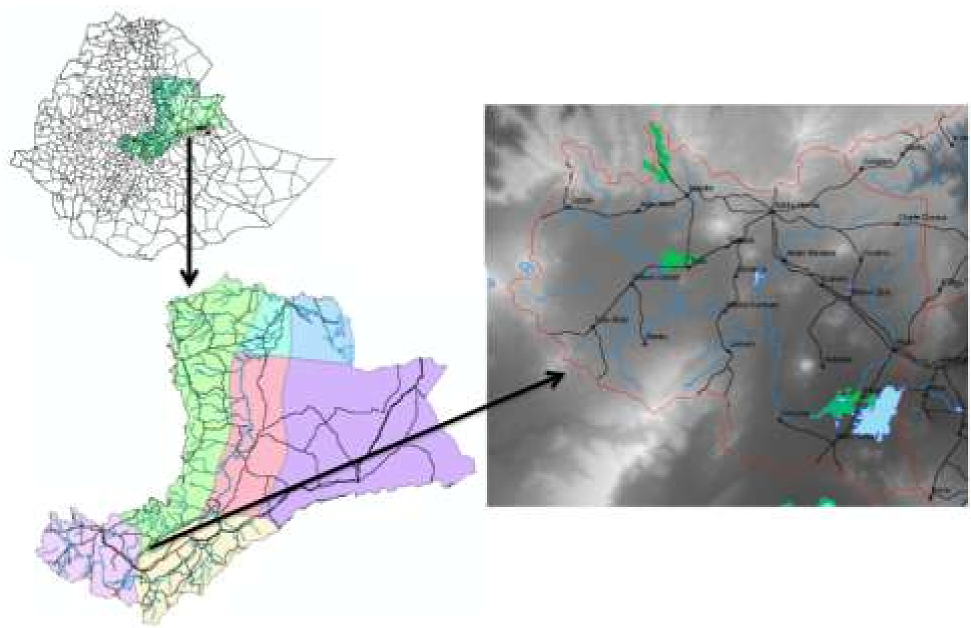


Figure 3.1. Location of the study areas in the Upper Awash Catchment. The two green areas in the center and next to Lake Koka are the seasonal wetlands.

Downstream of Mulka Kunture the Akaki, Guracha and Dukem, Lemen and other smaller tributaries join the Awash River before it enters the plain surrounding Lake Koka. The Mojo River also flows into Lake Koka. This low-lying plain at the west shore of Lake Koka that is also surrounded by volcanic hills has a mean elevation of 1590 m.

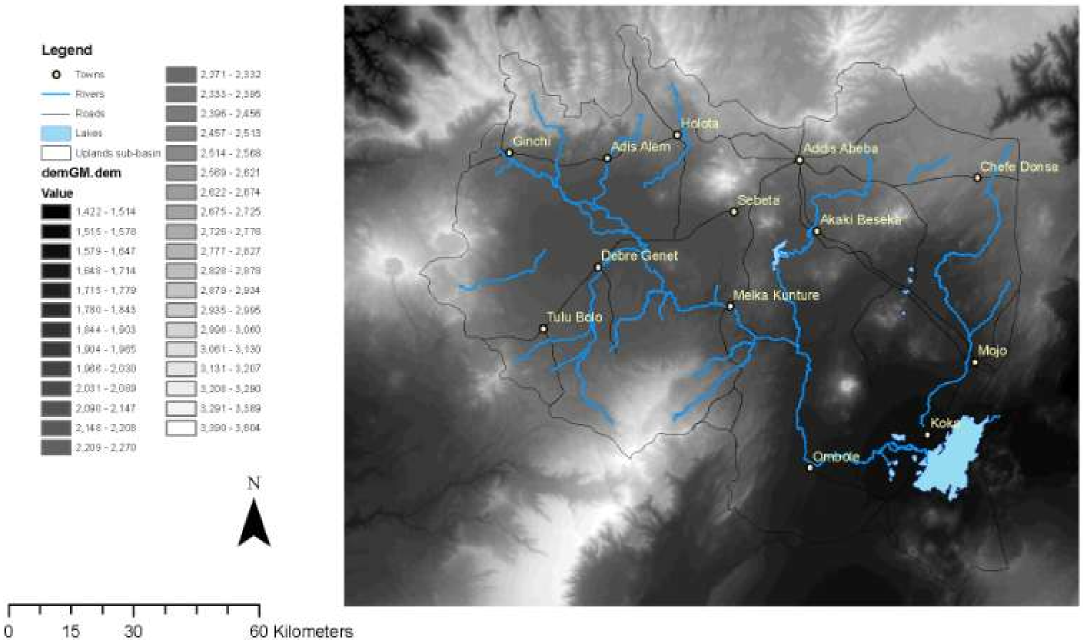


Figure 3.2. Map showing the Upper Awash catchment and the topography of the area.

3.1 Climate in the study area

The movement of the Inter Tropical Convergence Zone (ITCZ) that allows dry easterlies or moist westerlies dominates the climate of this part of Ethiopia. In March the ITCZ advances across the Awash Basin bringing spring rains in the 'Belg' season. The ITZC reaches its most northern position when heavy summer rains come from the west. This season is the main rainy season called 'Kiremt' and lasts until September. Than the dry months of the dry season called 'Bega' extend from October to February (EVDSA, 1989). The amount of rainfall is influenced by orographic features and shows a strong correlation with altitude (Fig3.2; Fig3.3)(WWDSE, 2008). Mean annual rainfall varies from over 1200 mm per year in the high-elevated uplands to below 700 mm per year in the lower areas surrounding Lake Koka. 70 to 75% of the total rainfall occurs in the main wet season.

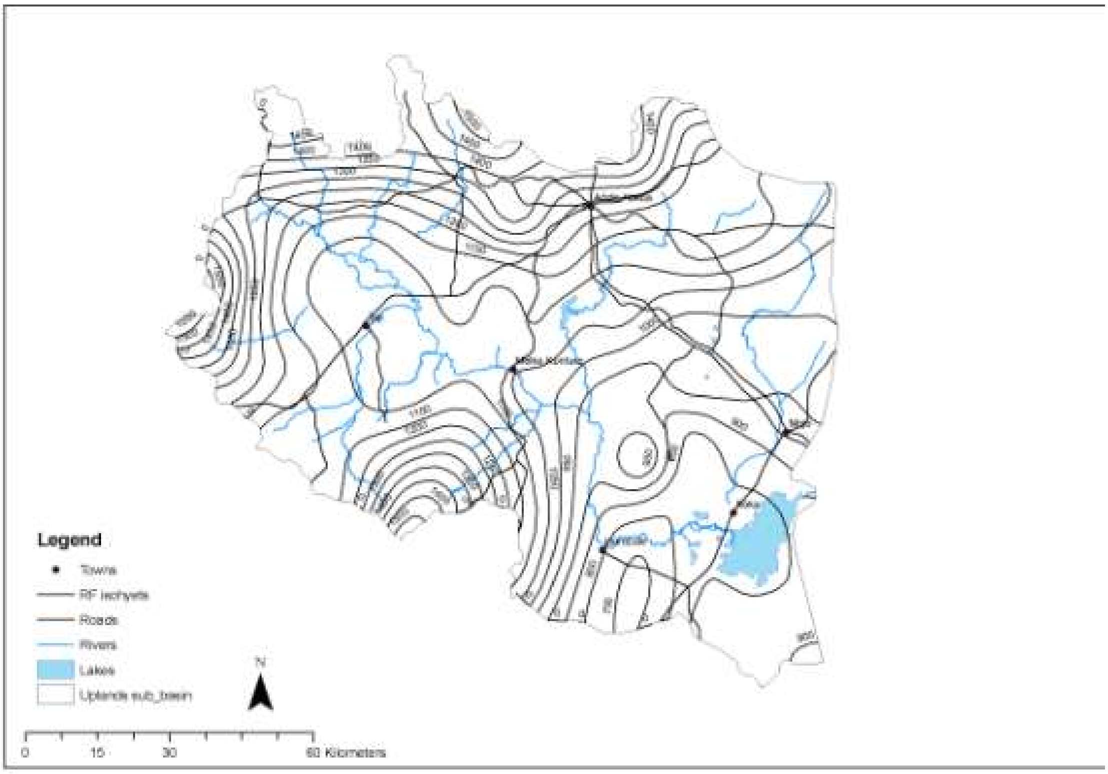


Figure 3.3. Isohyetal map of the Upper Awash catchment.

Table 3.1 shows mean climatic data for stations in and around the study area. The mean annual temperature in the study area ranges from 16 to 22 degrees Celsius and is inversely correlated with the altitude. The relative humidity is over 50% in the wet season and below 50% in the rest of the year. Wind speed is maximum, above 1 m/s, in April and May and minimum in the main rainy season. The average pan evaporation is about 180 mm during the dry season of November and 75 mm in the wet season at Addis Ababa Observatory. The evaporation is observed to increase with decreasing elevation since it is related to the temperature (WWDSE, 2008).

Climatic station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
						Mean rainfall (mm)							
Addis Ababa	17.0	43.0	67.0	89.0	83.0	121.0	254.0	284.0	175.0	37.0	9.0	7.0	1186.0
Deberzeit	11.2	41.1	37.2	70.3	60.9	91.6	242.7	245.9	119.0	18.0	8.7	4.4	951.0
Holeta	16.1	56.1	69.0	82.5	70.7	103.0	251.3	276.5	140.0	14.2	3.9	9.1	1092.4
Sululta	39.8	21.3	41.0	51.4	45.7	144.0	345.7	309.6	127.9	37.8	9.6	3.1	1176.8
						Mean Temperature (°C)							
Addis Ababa	15.7	16.6	17.7	17.6	18.0	16.6	15.5	15.4	15.7	15.6	15.1	15.0	16.2
Deberzeit	17.0	18.3	19.3	19.5	19.9	19.1	18.0	18.1	18.0	17.5	16.7	16.1	18.0
Holeta	13.3	14.8	15.6	16.0	15.9	15.0	14.4	14.2	14.0	13.1	12.2	12.1	14.1
Sululta	13.1	13.6	13.8	13.7	13.9	13.0	13.0	13.2	13.0	12.9	12.4	12.7	13.2
						Reltaive Humidity (%)							
Addis Ababa	42.6	43.3	42.6	46.4	44.6	55.2	67.1	68.3	60.6	42.3	38.8	37.6	49.1
Deberzeit	39.1	42.0	41.9	43.1	40.0	49.1	63.8	67.3	61.1	42.3	34.3	38.2	46.8
Holeta	37.7	42.9	42.7	48.4	44.1	56.4	70.5	72.4	63.4	45.0	35.4	35.3	49.5
Sululta	65.6	66.6	76.8	71.2	76.6	69.8	73.0	73.8	77.8	67.8	60.0	58.5	69.8
						Wind speed (m/sec)							
Addis Ababa	0.9	0.8	1.0	0.8	0.9	0.5	0.5	0.4	0.5	1.0	0.9	0.8	0.7
Deberzeit	1.7	1.9	2.1	2.1	2.1	1.6	1.4	1.2	1.1	1.7	1.8	1.8	1.7
Holeta	1.0	1.0	1.0	1.1	0.9	0.7	0.6	0.6	0.6	0.8	0.9	0.9	0.8
Sululta	3.0	2.0	1.7	2.7	1.7	1.5	1.4	1.4	1.1	1.5	1.4	1.8	1.8
						Sunshine duration (hr)							
Addis Ababa	8.5	8.0	7.5	6.7	6.8	5.1	3.0	3.6	5.0	8.0	9.5	9.2	6.7
Deberzeit	8.5	8.4	8.0	7.6	8.3	7.2	5.4	5.7	6.8	8.8	9.6	9.3	7.8
Holeta	8.8	7.9	7.2	6.5	6.7	5.7	3.5	3.3	5.0	8.2	9.0	9.1	6.7
Sululta	8.4	8.4	8.2	6.9	4.3	5.1	4.2	3.7	5.4	7.9	8.0	7.4	6.5

Table 3.1. Mean monthly climatic data of stations in or around the study area (from: WWDSE, 2008).

3.2 Geology and soils

The two plains of the study area have mostly recent alluvial sediments at the surface. The deposits are weathered basalts and tuffs from valleys upstream of the plains. The recent material is deposited by river water and the thickness varies between 5-15 m depth (WRDA, 1983). The alluvium covering the plains act as a seasonal aquifer. The clay content between 20 and 40% results in a permeability of around 6 m^{-3} m/day and retains water after floods in the wet season (WRDA, 1983). Groundwater levels in this shallow aquifer of the plains range between 0-5m in the wet season and 2-10 m in the dry season. The underlying and surrounding higher elevated areas consist of tertiary and quaternary volcanic units as basalts, tuffs, ignibrites and ryolites. Several faults run through the region caused by the rift system and uplift of the area allowing recharge to deep fractured volcanic aquifers (WWDSE, 2008). The layered volcanic outcrops of the escarpments surrounding the plains result in some local springs being present (Fig3.4). Data on the production and location of these springs is limited.

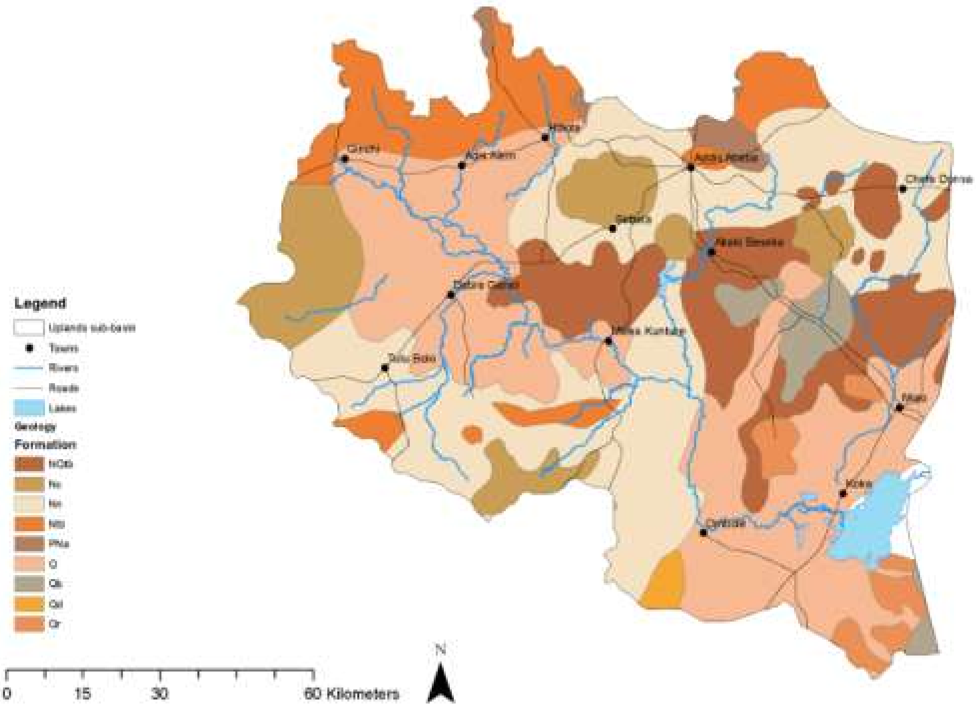


Figure 3.4. Geological map of the Upper Awash catchment. The list with detailed indication of geological units is in Annex I.

The dominant soil type in the Becho plain is vertisols (Fig.3.5). The detailed study performed by Nippon Koei (1996) shows some varieties of the vertisols of the plains, including stagni-calcic vertisols in the longer flooded areas and the more common eutric vertisol on terraces and shorter inundated areas. In small scale there are also fluvisols, cambisols and gleysols present on the levees and former channels of the Awash River and its tributaries. The vertisols in the Becho plain are black clays that are dominated by the montomorillonite clay mineral. This mineral expands when wet and contracts when dry, causing cracks at the surface in the dry season. These cracks are well developed in the inundated areas and backswamps of the plains where they can be 10 cm wide and 70 cm deep. The vertisols are chemically fertile and generally no fertilizers are used, but demand careful management. The hard state when dry and sticky, plastic state when wet (Deckers et al., 2001) makes tillage difficult and limited to certain periods. Water will infiltrate rapidly through the cracks with the first rains after the dry season, but when the clays are wet and expanded the infiltration is very low. The soils have a high water holding capacity, allowing flood recession agriculture where crops use the residual soil moisture. The study of Nippon Koei (1996) did not include the plains west of Lake Koka, but the conditions are expected to be similar to the Becho plain. The physical conditions are similar to those in the Becho plain, and the two sites are 80 km apart. The depositional environment will generally be slightly higher energetic than in the Becho plain, where large bodies of stagnant water are present for several months. This can result in slightly coarser sediments and similar soils that developed on the levees and former channels of the Awash River in the Becho plain. The soil map shows that the dominant soil type in the floodplains of the Awash River is fluvisols.

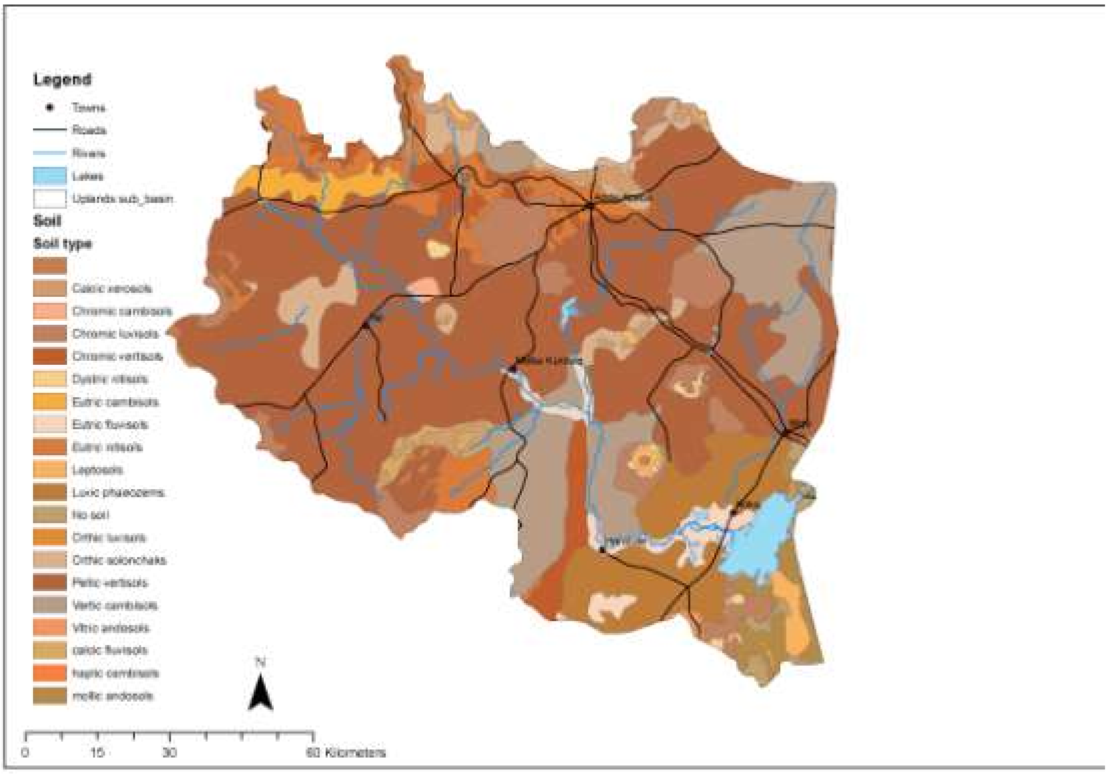


Figure 3.5. Soil map of the Upper Awash catchment.

3.3 Land use

Both the plains are situated in several *woredas*. The focus of this study is on the Ilu *woreda* in the Becho plain and the Bora *woreda* in on the plain west of Lake Koka. The population of these *woredas* are 61 238 for the Ilu *woreda* and 58 739 for the Bora *woreda* (CSA, 2008). More than 70% of the population in the study areas is involved in agriculture (Nippon Koei, 1996). In the Becho plain 78.4% of the land is agricultural land, 11.9% is used for grazing land and is seasonally inundated, the rest of the 9.7% of the land consists of villages, roads and woodlots (Nippon Koei, 1996). The main land use is agriculture; most farmers have normally 3-5 tropical livestock units, mostly oxen, primarily for draught power (EVDSA, 1989). The main crops and agricultural practices differ in the upland areas from the inundated areas. In the Becho plain all farmers have cropland in the inundated areas with an average plot size of 2.4 ha and 88% have land in the upland areas with an average plot size of 1.75 ha (Nippon Koei, 1996).

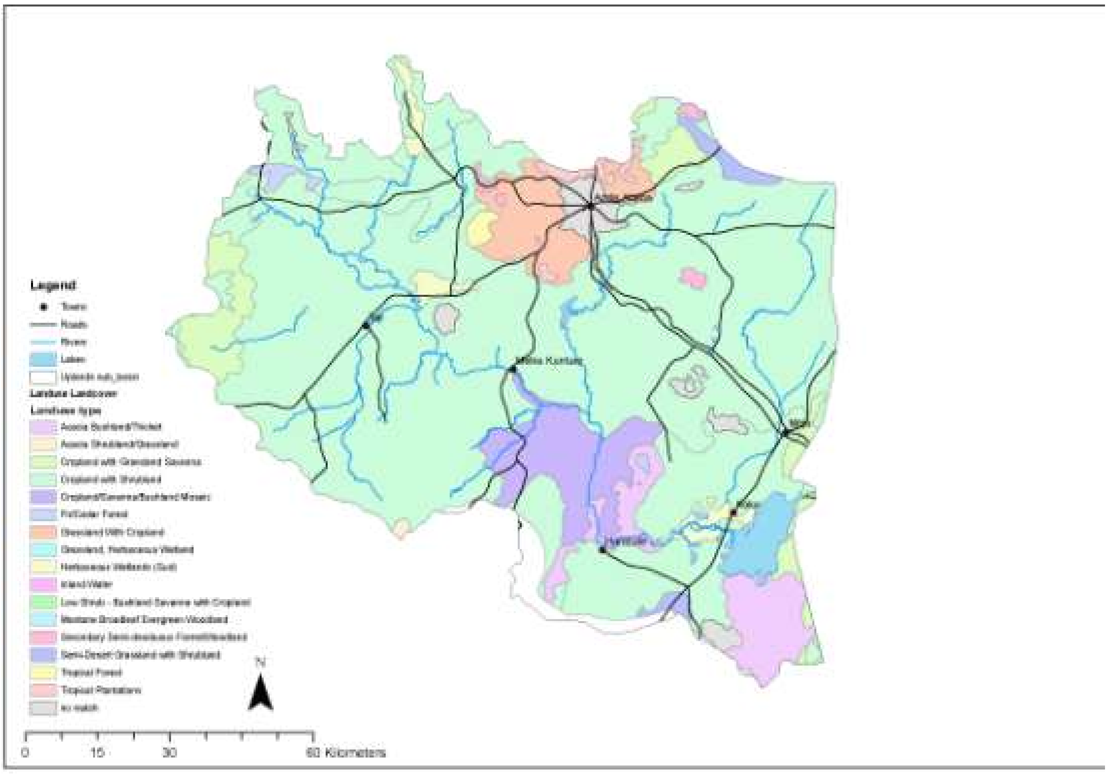


Figure 3.6. Map showing land use in the Upper Awash catchment.

In the uplands most of the land is used for the production of teff (*Eragrostis tef*)(63.85 ha), chickpea (*Cicer arietinum*) (10.65 ha) and wheat (*Triticum aestivum*)(9.77 ha). These crops are planted in the beginning of the wet season and use rainwater for their growth. The low-lying inundated areas are used for the cultivation of lentil (*Lens culinaris*) (57.06 ha), chickpea (35.13 ha) and teff (31.63 ha). These crops are planted as water recedes at the end of the wet season and use residual soil moisture for their growth (Nippon Koei, 1996). Generally the higher areas are used for teff and other grains and the low-lying areas for pulses. This corresponds with agricultural patterns of other parts of the Upper Awash basin (EVDSA, 1989) and West Africa described by Adams (1993). The teff that is grown in the low-lying temporarily inundated areas gives low yields mainly caused by the lack of water in the grain formation phase. This water deficit is due to delayed planting caused by the inundation (Nippon Koei, 1996). Teff is widely cultivated in Ethiopia, where its flower is used to make *injera*. *Injera* is thinly baked, circular bread that is the traditional dish in Ethiopia. At a small scale some lands are irrigated in the dry season. Temporary bunds are constructed in two tributaries of the Awash, to divert water to the fields to grow barley (Nippon Koei, 1996). Since three years there is also pumped irrigation from the main Awash River to areas next to the river. These areas are cultivated with vegetables.

4 Flood recession farming in the Upper Awash catchment

Flood recession farming is practiced at seasonal flooded areas in the Upper Awash Catchment – particularly in the Becho Plain and in the floodplain upstream of Lake Koka. These two sites were studied in detail for this research. During several visits to the two sites information was gathered from the *woreda* offices, where agricultural experts provided information about the region and provided data on productivity of the agricultural practices. Semi-structured interviews were carried out in the field to retrieve information about the practices from the farmers. The topics that were discussed are listed in the introduction of this report. The field visits were spread out over a three-month period from August until October, at the end of the wet season into the beginning of the dry season.

4.1 Lake Koka

Near Lake Koka the Awash River splits into several branches as it enters the plain surrounding the reservoir. The low-lying plain is inundated up to several months during high discharges of the Awash River, usually starting in July. Lake Koka also fills up during the wet season and backwater effect inundates the surrounding plain towards the end of the wet season. Elevated areas where teff, wheat, maize and haricot beans (*Phaseolus vulgaris*) are cultivated surround the plains. Certain farmers use pumps to use water from rivers to irrigate their lands, and also water from wells is pumped up for irrigation. The groundwater level around Lake Koka is relatively high and therefore accessible. The irrigation can create high yields of various crops like orange trees, mango trees and other horticultural crops throughout the year. There are farmers with up to 10 ha of land, but the average plot size of the farmers in this area is between 1 and 2 ha.

4.1.1 Land use around Lake Koka

A small village called Gora Leman, situated at the border of the floodplain and the higher elevated areas, was visited several times. The inhabitants of the village all own around one ha of land and own five to ten units of livestock, mainly oxen. The people start plowing and sowing their fixed plots when the floods recede. Before the floods arrive there is also a plowing phase. Not all the land is used for agriculture; the areas that are not plowed and cultivated are used as grazing land for animals. Also people from other *kebeles* let their cattle graze in the parts of the floodplain that are not cultivated. All the inhabitants of Gora Leman have a piece of land in the floodplain. Some more wealthy people can rent farmland in the higher elevated areas, where rain fed or irrigated agriculture is practiced. Fishing is only done in the nearby lakes. Lake Koka is a large lake formed by a hydropower dam, and Lake Elan is a smaller spring fed lake. No fishing occurs in the floodplains. Another source of income is the mining of sand in the floodplain. When the flood recedes from the floodplain, the sandy deposits are dug and sold.

4.1.2 Farming practices

When the floods are receding and the floodplains dry up at the end of September the farmers start to plow (Fig.4.1). Usually they plow several times before they sow their crops.

The plot that is used by the farmers will have different physical characteristics. The farmers plant different crops on the different parts of their plot. Small depressions in the floodplain where vertisols are developed in dark clayey sediment are called *carticha.* These local depressions are mainly used for the cultivation of chickpea and lentil. The slightly higher elevated parts of the floodplain, usually point bars or riverbanks consist of coarser, sandy and loamy sediment. These parts are used for the cultivation of mainly maize and haricot beans, but also tomatoes, unions and sometimes melons are grown.

Figure 4.1. Four stages of water retreat in Lake Koka at Gora Leman kebele. Top left is maximum inundation, top right floods are retreating, bottom left shows further retreat, bottom right shows plowing in dried floodplain (note that photos are not taken from the exact same spot).

The farmers dig small wells in the floodplain up to 2.5 meters deep to irrigate their lands using shallow groundwater. The maximum groundwater level is between two and four meters deep depending on the conditions and location in the floodplain. The crops that are grown on the sandy, loamy, slightly higher elevated parts of the floodplain, are not suitable for the clayey areas in the depressions on the floodplain. Certain worms that are present in the clayey soils will damage the roots of crops. The worms cannot harm the roots of chickpea or lentil.

The timing and size of the flood will influence the production of the crops cultivated on the floodplain. Plenty of rainfall at the start of the rainy season in the upper catchment will cause the area to flood, and fertile sediment is deposited at the floodplain. If the intense rainfall in the upper catchment will occur at the end of the dry season, when the crops are planted, the floods can damage the crops. Rainfall in the beginning of the dry season on the cultivated lands will improve the production.

Certain parts of the floodplain are covered with water hyacinth (*Eichhornia Crassipes*) as the floods retreat. These plants are removed and burned before the land is cultivated. The fibrous root of the plant collects fine soil and therefore enhances the fertility of the land.

4.1.3 Coping with floods

The floods are said to have become unpredictable over the last three years. Timing and size of the flood became different than the years before. People reported flooding of the floodplain in the dry season, after rainfall events in the upper catchment in January. Siltation of the rivers and filling of the Koka reservoir are thought to be causes of the change in the flood regime. Bad timing of the flood is considered to be a constraint of the area. There is a need for flood regulation. People would ideally have flood-protected land that they would irrigate with river water or groundwater. At the same time people fear that when flood protection will be installed, they would lose their fertile lands to the government. People that live in small villages on somewhat elevated islands inside the floodplain experience another constraint. These people and their livestock have to move during the wet season when the floods inundate also the most elevated parts of the floodplain. This moving in and out of the floodplain is considered very troublesome.

4.2 Becho plain

The Becho plain is situated in the most upper part of the Awash catchment. Several rivers drain the mountains surrounding the plain, and they join the Awash River in the alluvial plain. Different parts of the plains are inundated during the wet season. There is a distinction between two parts plain that are inundated. A more upstream area of the plain is inundated for shorter duration after intense or prolonged rainfall events and a more downstream area is flooded for weeks or months every year during the wet season.

4.2.1 Land use and flooding in the Becho plain

The duration of floods in both inundated parts of the Becho plain differ and this influences the crops that are grown in both areas. Around 80% of the land is used for agriculture, and 10% for grazing land. The inhabitants of the floodplain only have farming as source of income. Farmers have livestock mainly for farming practices. There are some designated grazing lands in the plains. Fishing is not performed in the flooded areas. There are small artificial ponds that are used to breed fish. Water from the river is pumped in these ponds and the fish from these ponds can provide extra income.

The villages next to the main road are also adjusted to the annual floods. Especially in the eastern, more downstream area, where floods are higher and longer, all houses are built on raised structures, and bridges are constructed to reach the houses. The main road is also elevated, but can still flood during extreme rainfall events.
Some farmers own land next to the river. These lands can be irrigated with river water and can be cultivated with vegetables. These farmers are the wealthiest farmers in the area. There are rules that force farmers with more than 0.5 ha of land near the river to share the land with people that do not own land near the river. Other farmers also own farming plots in the uplands where rain fed agriculture is practiced. There are no rules about this type of land ownership, these people are considered lucky to be able to grow crops in different environments, and are able to spread the risk in their farming strategy.

Figure 4.2. Four stages of flood recession in Becho plain. Top left show maximum inundation, top right the retreat of the flood, bottom left plowing after retreat, bottom right growing of the crops. These pictures are taken in the longer inundated area.

4.2.2 Farming practices
The differences between the timing and duration of the inundations determine the cropping strategies of the farmers. The more upstream area that is slightly higher elevated is suitable for teff production; the area is only inundated for a relative short period. After intense rainfall the area will be flooded from two days to a week. Continuous rainfall will inundate the area for a month. When certain farmlands are expected not to flood again, the farmers will start plowing and sowing. The crops use the soil moisture for their growth. Additional rainfall

will improve the production, while it provides extra water for the crops that use the residual soil moisture. If the plots inundate after sowing, the crops can be ruined. Large floods at the beginning of the wet season are considered to increase the production. Plenty of fertile sediment and sufficient water will improve the growth of teff.

The eastern, more downstream and less elevated area is inundated for a longer period. When in the upstream area the teff is already growing, this part of the floodplain is still inundated (Fig4.2). This demands a different strategy to flood recession farming. The floods are retreating at the end of the wet season, and crops are planted when little or no rainfall occurs. Teff is unsuitable for these areas, since teff cannot fully mature on residual soil moisture only. Pulses are often grown on the lands where floods retreat and no additional rainfall occurs. There is not a uniform strategy on cropping techniques. Farmers rely on their judgment on when to start plowing and what crop to sow. Some farmers in the long inundated area try to grow teff when floods have retreated, but rainfall is still expected to provide additional water for teff to grow (Fig.4.3). If however the plot will flood again, the crops will be destroyed. This happened during a field visit, and the farmer lost the teff seeds, and grew chickpeas later, at the end of the wet season. Most farmers in this part of the Becho plain grow pulses after the floods have retreated and no or little rain is expected to fall. Mostly chickpea, lentil and grass pea (*Lathyrus sativus*) are being cultivated. Lentil has a higher value than chickpea and grass pea and is used more often. Teff has more value than lentil and therefore farmers sometimes take the risk to plant teff before the end of the wet season.

Figure 4.3. Teff grown in a short inundated part of the Becho plain at the end of the wet season. Recent plowing occurred in the top and left part of the picture, at slightly lower and longer inundated areas.

In both of the inundated areas the farmers plow before the floods arrive. This allows the fine, fertile sediment that is brought with the flood to settle in the furrows. Farmers plow again when they expect the land not to flood again to increase to amount of soil moisture deeper in the soil. After plowing the farmers sow their seeds. All farmers recognize the benefit of not having to use any fertilizer. The crops cultivated on the inundated areas that consist of clayey deposits and vertisols are vulnerable for certain diseases. Farmers in the Becho plain also mention the occurrence of worms and pests present in the soil that can damage the crops. Farmers use pesticides to protect their crops.

Besides the difference between longer and shorter inundated areas, there is no further classification of the flooded lands. The crops that are planted on the floodplain are selected on their potential value and the timing when they are planted. There is no classification on small differences in morphology or soil types of the floodplain. Teff is preferred since it has the highest value, then lentil, chickpea and grass pea. If crops are planted before the end of the rainy season, the additional rains could provide optimal growth conditions for teff or pulse crops. Early planting is risky; some years reoccurring floods can destroy planted crops up to four times.

In the Becho plains there were small inundated plots directly adjacent to the riverbanks that were prepared for a rice-growing trail. Six different rice varieties were grown on flooded plots to see which variety will perform optimal in the present conditions. Small bunds were constructed to retain the water in the rice plots. At the beginning of the dry season the conditions in the rice plots became too dry and additional irrigation was needed to let the rice grow. When the rice would have been planted earlier in the wet season it could have grown without additional irrigation. The results of the trail are not used in this research.

4.2.3 Coping with floods

The people living in the Becho plain recognize the opportunities, but also the risks of the annual floods. The timing and duration of the floods are important to provide optimal growing conditions, but they can also destroy seeds planted too early. As described earlier the timing and crop selection are important. In the western part of the floodplain, where inundations are of shorter duration, big floods are experienced as positive. The floods recede out of the lands relatively early and big floods provide more soil moisture for the crops to grow. Additional rains at the start the end of the dry season increase the water available for the crops. During the flowering stage in the dry season, teff can experience water shortage, which reduces the productivity.

In the longer inundated area, big and long floods are considered a limiting factor for the productivity. The lack of rain in the dry season when the crops are growing disables the growth of teff, only pulse crops are being cultivated. Extreme floods can also damage properties of people living in the flood prone areas, including their livestock. The clayey soils of the longer inundated floodplain can enhance the occurrence of pests and worms that can damage crops. Hence though no fertilizer is required, pesticides are a considerable expenditure item.

4.3 Productivities of flood recession farming

The agricultural offices at the *woredas* provided the information about the cultivated crops and the areas used for flood recession agriculture. The main crops that are cultivated as well as the area of the floodplain that is used for flood recession farming in both *woredas* of the study area are listed in the table 1 and table 2 in Annex II.

4.3.1 Productivity of flood recession farming in the Ilu *woreda*

The Ilu *woreda* is located in the Becho plain. The higher elevated area is used for the cultivation of teff. Some of the teff grows under flood recession agriculture, but not all land where teff is grown inundates every year. It is not straightforward what part of the teff production was grown under flood recession conditions. The lentil, peas and beans are grown in the floodplains that are flooded annually. Farmers and agricultural experts in the *woreda* confirm this. There are certain plots along the river where small-scale irrigation is performed during the dry season. These parts of the previously inundated floodplain can be used for the cultivation of vegetables and other high value crops. Since most of the floodplain that is inundated is not irrigated, the crops grown without irrigation are used for analyzing the productivity of flood recession farming. Graphs of the area, productivity and productivity per area from 1993-2009 of flood recession agriculture crops in the Ilu *woreda* are displayed in Figure 4.4.

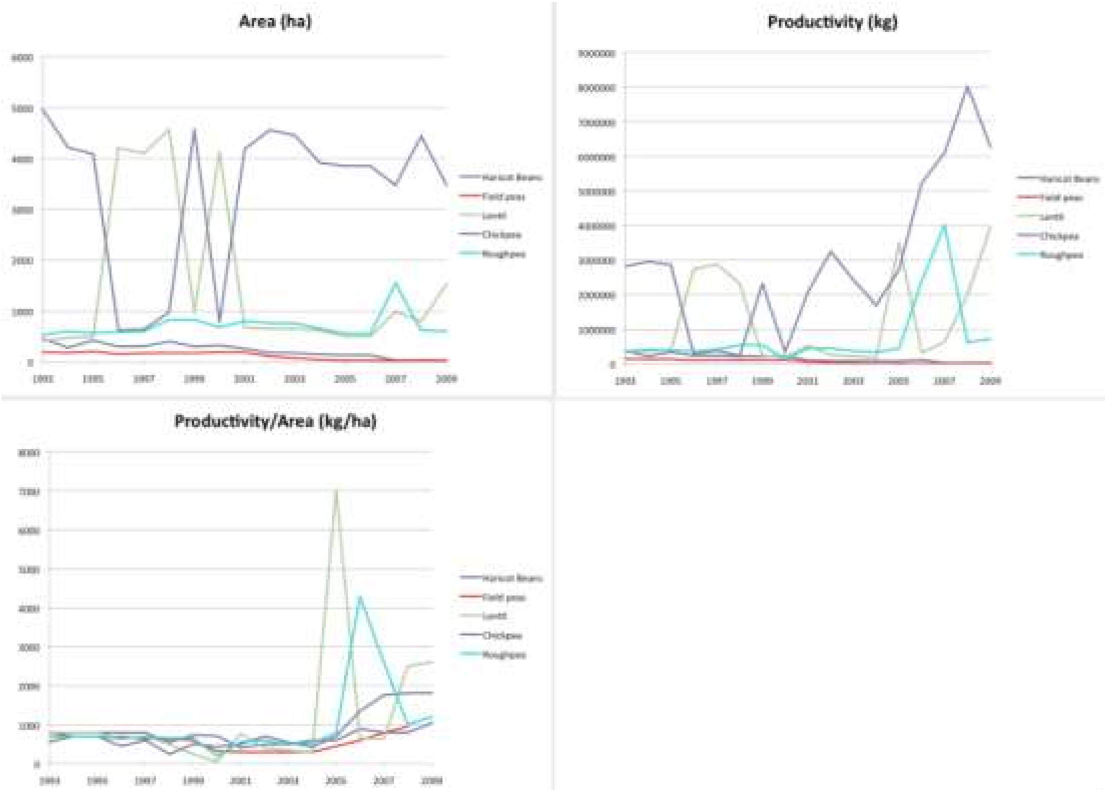


Figure 4.4. Graphs displaying the area, productivity and productivity per area for the flood recession crops in the Ilu woreda.

Field peas (*Pisum sativum*) were grown in areas ranging between 150 and 200 ha from 1993 until 2001. From 2001 there is a steady decline in the area used for the cultivation of field peas, it drops to under 20 ha in 2010. Haricot beans show the same trend, it was cultivated in areas ranging between 260 and 450 ha between 1993 and 2001, dropping to 30 from 2006 to 2009. In 2010 it is expected to have increased to above 100 ha. For both field peas and haricot beans the productivity per area is steady around 800 or 700 kg/ha between 1993 and 2000, from there the productivity per area is significantly lower for both crops. The haricot beans yield between 400 and 600 kg/ha between 2001 and 2005 and field peas productivities drop to around 300 in the same period. After 2005 the productivity per area for both crops are rising to around 1000 kg/ha in 2009. The area used for the cultivation of rough pea (*Lathyrus hirsutus*) and the productivity of this crop is steady over the years. Between 500 and 800 ha of land is used for the production of rough pea and this land yields also between 500 and 800 kg/ha. Two years show significantly different numbers. In 2000 the area used for rough pea production is 800 ha, comparable to other years, the productivity of less than 200 kg/ha however, is remarkably lower. In 2007 the area used for the cultivation of rough pea is high, compared to other years. An area of more than 1500 ha is used for rough pea growth that also yields 2600 kg/ha from that area. After 2007 the area used for rough pea are similar to other years, but the productivities show slightly higher values of more than 1000 kg/ha.

The numbers for the lentil and chickpea production show much greater variation than the crops mentioned above. There is a relation between the areas of the floodplain that is used for the cultivation for the crops. Certain years a large area between 4000 and 4500 ha is used for chickpea and between 500 and 1000 ha for lentil. Other years the opposite happens, more land is used for lentil and chickpea is only cultivated in a relative small area. The total amount of land that is used for both crops ranges between 4500 and 5500 ha for every year. The productivity of chickpea varies from year to year between values of 400 and 700 kg/ha. From 2006 it increases annually to over 1800 kg/ha. Lentil shows less consistency in the productivity. In most years productivities of 700 or 800 kg/ha are met, but in 1998, 1999 and 2000 there is a clear decline in productivity with less than 50 kg/ha produced in 2000. In 2001 there is a productivity of near 800 declining in the following years up to 2004. The area used for chickpea production is steady from 2001 to 2006, with the exception of 2005, when an extreme value of 7000 kg/ha is recorded. This is ten times more than the average productivity of chickpea.

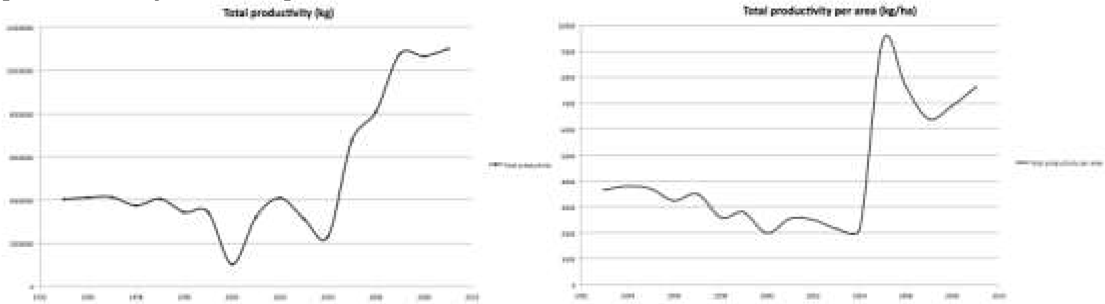


Figure 4.5. Total productivity and Total Productivity per Area for the Ilu woreda.

The total productivity and productivity per area are plotted in Figure 4.5. The productivity shows steady values between 1993 and 2003, except in 2000. Significant lower productivity of all crops are measured in 2000, this fits in with the data of certain crops showing lower yields in 2000. In 2003 and 2004 the total productivities of the flood recession crops are also lower. From 2005 there is a clear increase in the total productivity of the floodplain. This also fits the previously described higher values for the crops for the last five years. The productivity per area shows different trends and extremes. There is a declining trend in productivity per area from 1993 to 2004. Then 2005 shows the largest productivity per area and where the total productivity grew after 2005, the productivity per area drops in 2006 and slightly increases in 2007, 2008 and 2009.

4.3.2 Productivity of Flood Recession Farming in the Bora *woreda*

The agricultural office in the Bora *woreda* could provide agricultural data for the last six years from 2005 to 2010. The *woreda* is subdivided in *kebeles*, which are the smallest administrative units. Every year there the *kebeles* plan an amount of land that will be used for flood recession agriculture based on experiences of previous years. With the planned areas, estimations are made for the productivities of crops the farmers plan to grow. Three crops were indicated as being cultivated annually as flood recession crops. The planned area and planned productivity as well as the achieved area and productivity of chickpea, haricot beans and maize are indicated in Table 2 in Annex II. In Figure 4.6 the achieved area, productivity and productivity per area over the last six years are plotted.

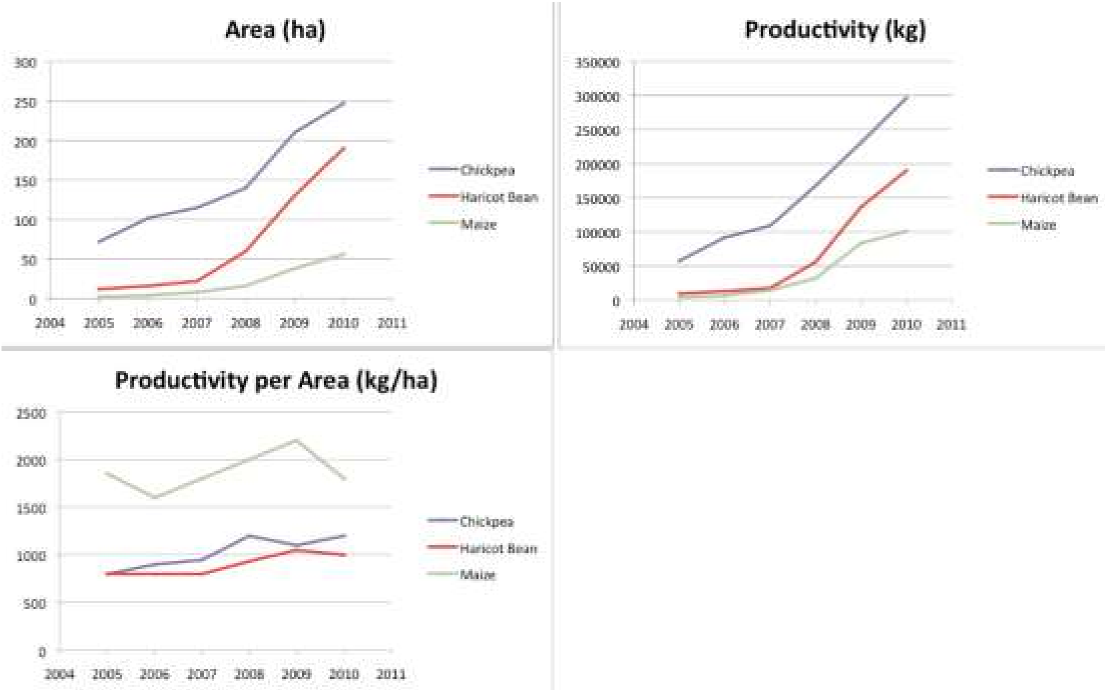


Figure 4.6. The Area, Productivity and Productivity per Area of Flood Recession Agriculture crops of the Bora woreda.

A clear trend is the increase in area and productivity of all three of the flood recession crops. The total area used for flood recession agriculture increased from 116 ha to 731 ha. The amount of crops harvested increased with the increasing cultivated area from 70 400 kg to 587 200 kg. The productivity per area does not display similar trends, small variations are observed each year. The yields of chickpea are between 800 and 1200 kg/ha, haricot bean between 800 and 1050 kg/ha and maize shows variations between 1600 and 2200 kg/ha. The total productivity per area (Fig.4.7) shows an increase in the first three years, from just over 800 kg/ha to just less than 1000 kg/ha. In the last three years the production per area is steady around 1190 kg/ha.

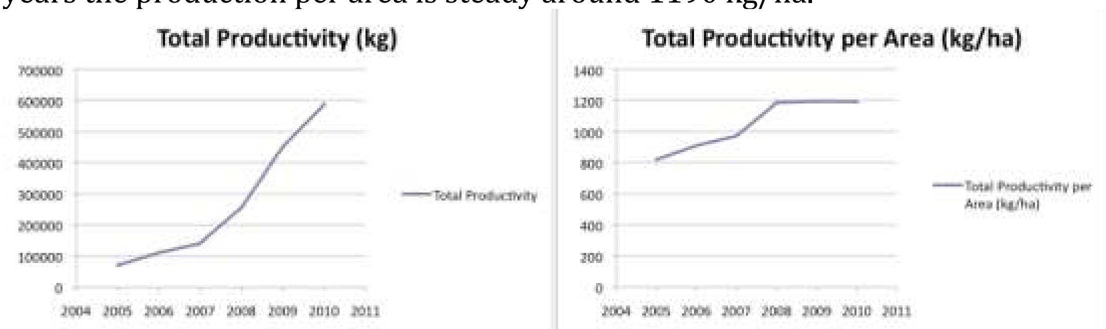


Figure 4.7. Total Productivity and Total Productivity per area in the Bora woreda.

4.3.3 Comparison of the productivity in the two *woredas*

Both of the areas show an increase in total productivity and total productivity per area of the flood recession crops from 2007 onwards. Unfortunately the data from the Bora *woreda* starts from 2005 and the comparison to other years is impossible. There is a large difference in the areas used for the flood recession crops in both *woredas*. In the Ilu *woreda* there is a total area of 731 ha being used

for the cultivation of the three flood recession crops. In the Bora *woreda* the total area used is almost 10 times as much.
The data provided does show more variation in the area used and the yields from flood recession agriculture in the Ilu *woreda* compared to the Bora *woreda*. The farmers in the Ilu *woreda* seem to be less consistent in the choice of crops to cultivate on their plots in the floodplain.
There is a large range in the total productivity per area in both study sites. Certain crops clearly yield more than others. Maize in the Bora *woreda* yields around 1800 kg/ha for most years where haricot beans and chickpea yield around or below 1000 kg/ha. In the Ilu *woreda* there are even more extreme values. Especially in the last five years the yields of lentil, chickpea and rough pea have increased significantly.
It is suspicious that for both sites the productivity per area is often a round figure of several hundred kg/ha, depending on the type of crop and its yield. This could imply that the numbers are rounded figures instead of actual measurements and therefore the reliability of the numbers is questionable.

5 Hydrology of the study area

In Chapter Two of this report the general characteristics of the study area are described. This description includes meteorological, hydrological, topographical and geological information of the Upper Awash catchment. This chapter will provide more detailed information on the hydrology of the study area and how this will influence the occurrence and potential of floods and flood recession agriculture.

5.1 Meteorology

5.1.1 Rainfall

The mean annual rainfall in the study area is 1200 mm and reaches 1500 mm in the highlands east of Addis Ababa. The majority of the rainfall, between 70 and 75% falls in the main rainy season, from June to September. The short wet season from February to May provides the rest of the rain. River discharge responds to the seasonal rainfall and high discharges are measured during the main rainy season (Tarekegn et al., 2003). The mean monthly rainfall, evapotranspiration and river runoff of the Awash River are shown in Figure 5.1. Mean monthly runoff is calculated using runoff data from the Melka Kunture station, situated in the center of the study area. The annual mean monthly runoff was calculated using the average of monthly runoff that was recorded between1975 to 2008. The annual mean monthly rainfall also derives from the Melka Kunture station. The annual mean monthly values were calculated by taking the average of monthly rainfall data also from 1975 to 2008

5.1.2 Evapotranspiration

The lack of climatological data required another method to retrieve evapotranspiration data. CROPWAT, developed by the FAO, was used to find the potential evapotranspiration for the study area. The values of potential evapotranspiration are calculated using the Penman-Monteith method. Mean monthly values for the required variables used in the Penman-Monteith equation are used to calculate the mean potential evapotranspiration for a certain station. Because of the large variation in altitude in the study area and its influence on the potential evapotranspiration two stations were used to find a mean potential evapotranspiration that would be representative for the study area. The stations in Addis Ababa and Koka (Fig.5.3) were used because of their location at high and low altitude respectively. The average of the two potential evaporation numbers, calculated by CROPWAT for the two locations, are plotted in Figure 5.1.

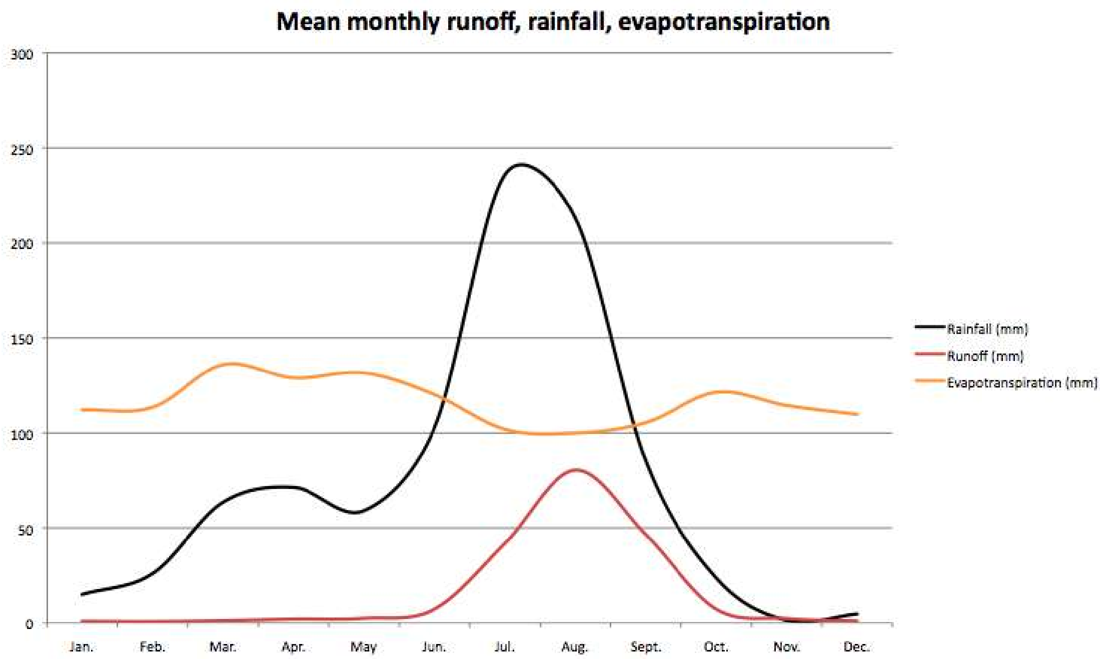


Figure 5.1. Mean monthly rainfall, evaporation and discharge of the Upper Awash basin measured at the Melka Hombole station (from: Tarekegn et al., 2003).

5.2 Rainfall in the Upper Awash basin

5.2.1 Orographic effect

Monthly rainfall data from 1992-2008 was selected from eight stations in the catchment. The orographic effect on the amount of rainfall in the selected stations are displayed in Figure 5.2, where the altitude is plotted versus the mean annual rainfall of the selected stations. The figure shows higher rainfall for stations located at a higher altitude.

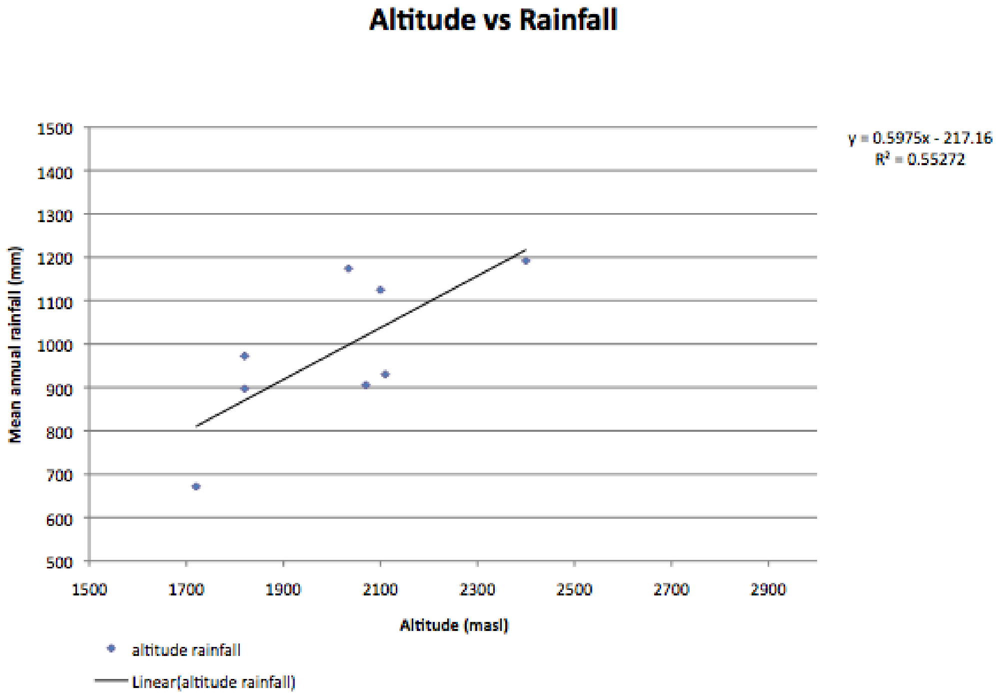


Figure 5.2. The orographic effect on rainfall of six selected stations in the study area.

5.2.2 Location of the stations

Monthly rainfall data of eight stations was selected to indicate the amount of rainfall that the study area received from 1992-2008 (Fig. 5.4). The stations are located around the study area at different altitudes (Fig. 5.3). With monthly rainfall data years can be indicated as wet or dry, and the rainfall distribution over the year can be shown. The relation between the measured rainfall and the discharges for each month can be compared with analyzing the monthly data. Individual rainfall events cannot be indicated. The influence of intense rainfall events on peak discharges is also difficult to predict. Wet years, but also wet months can be indicated, and the relation with the discharge can be investigated.

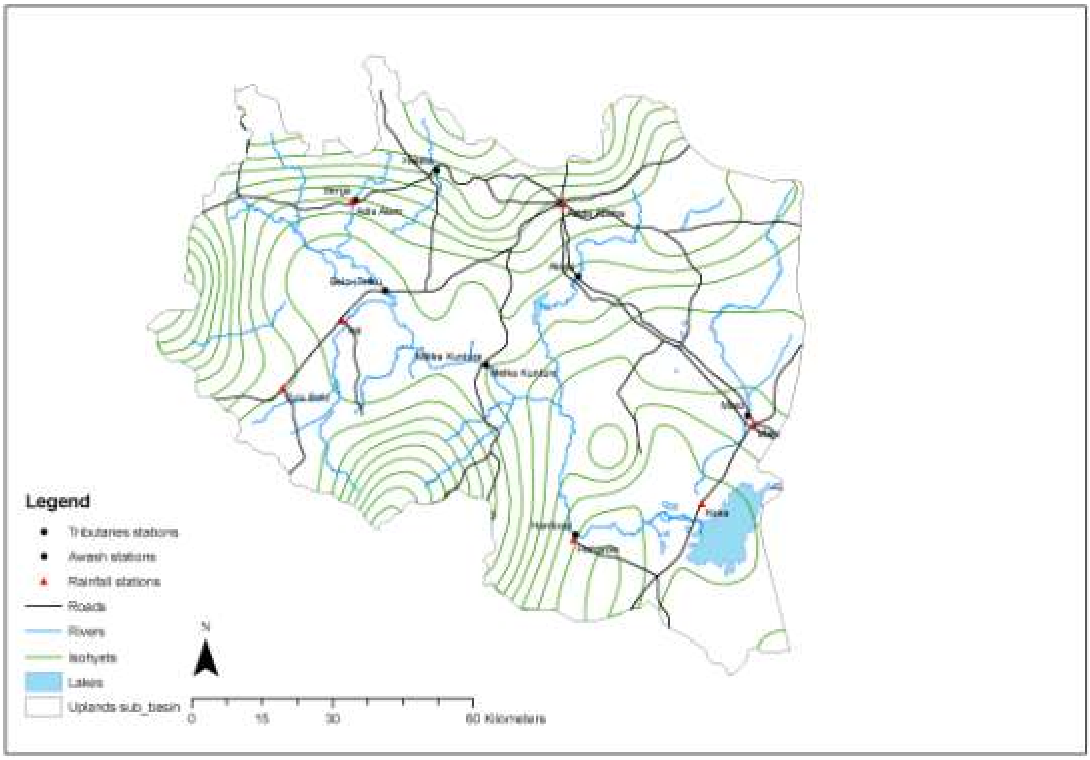
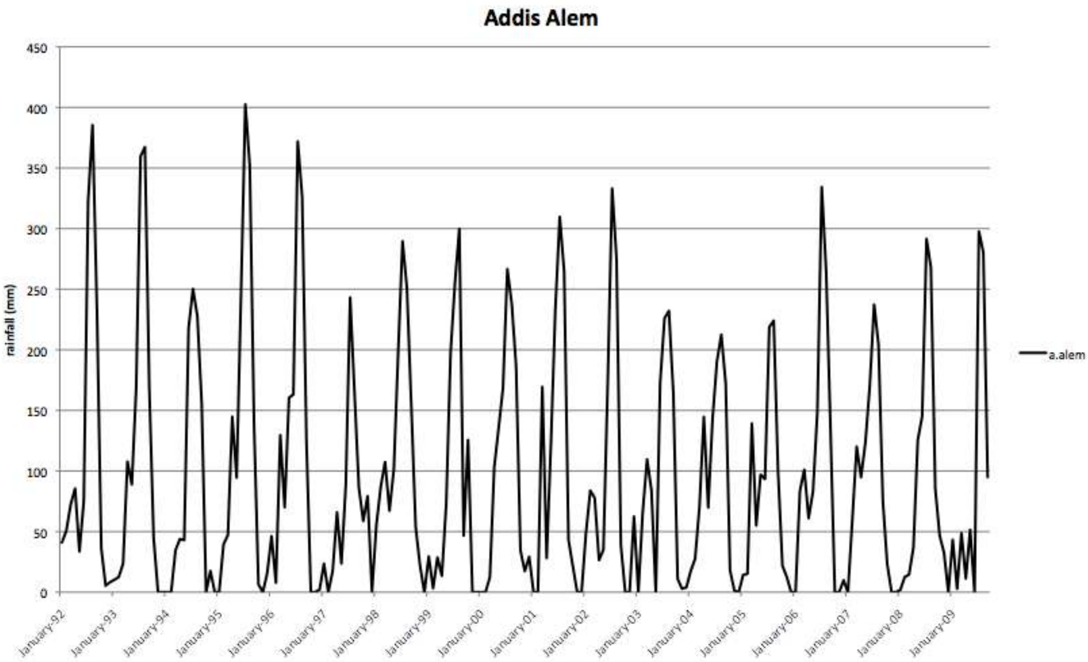


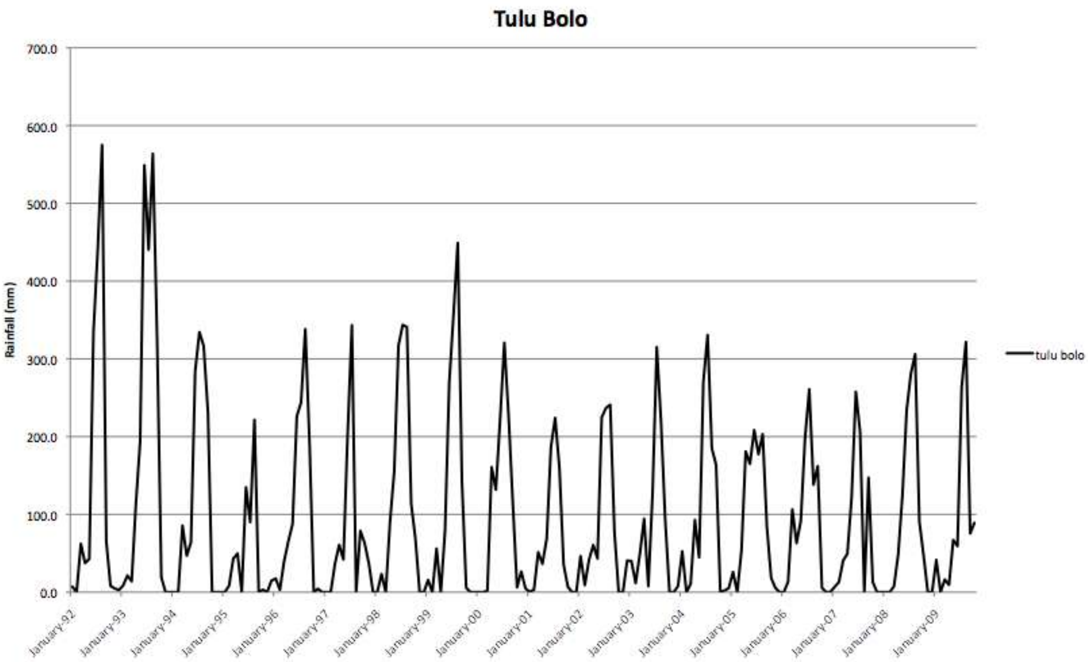
Figure 5.3. Map of the study area showing isohyets and meteorological and discharge stations.

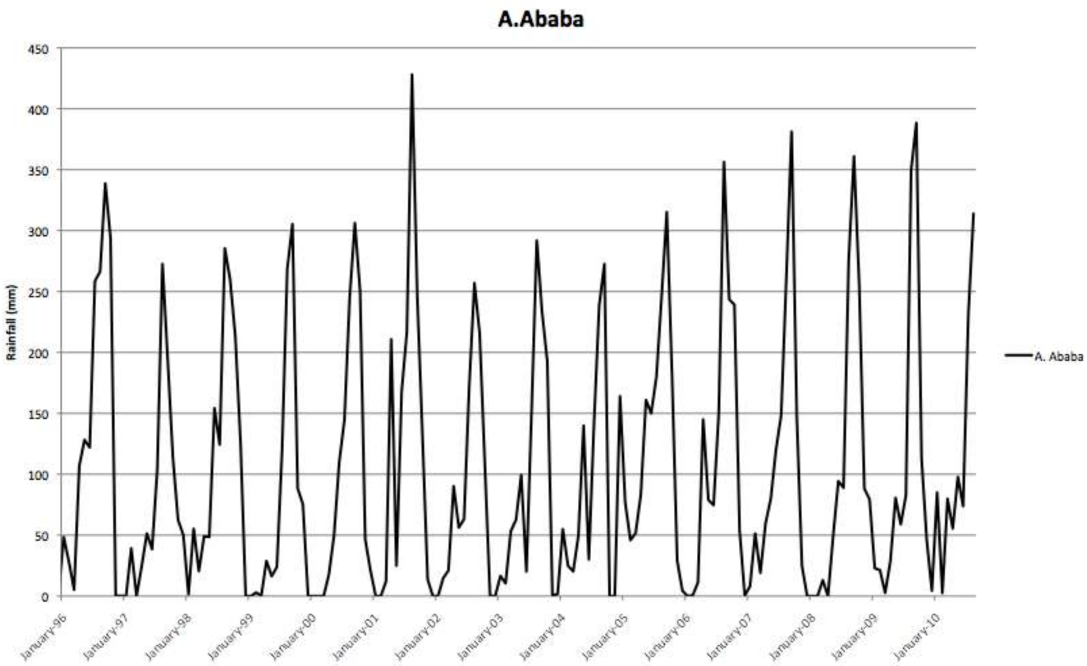
5.2.3 Extremes in rainfall measurements

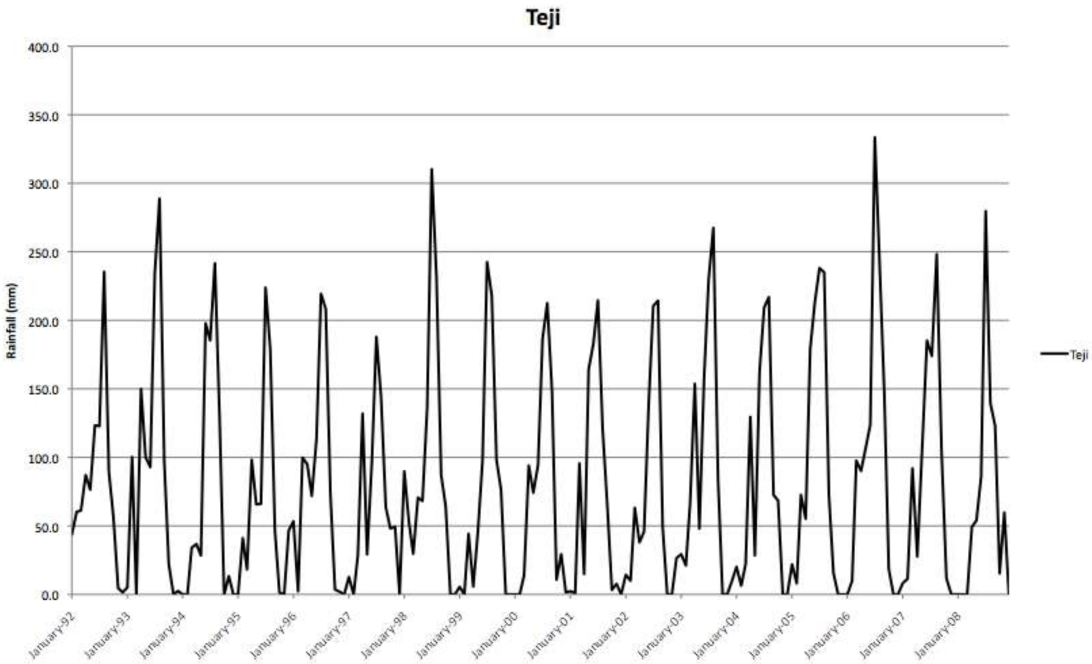
The monthly rainfall data of the eight stations show the spatial variation in the study area. There are several years with extreme high or low monthly rainfall amounts, where other stations do not show the same extremes. In Melka Hombole extreme monthly rainfall was measured in 2003 where the other stations do not show these extremes in that year. Other examples are the extremely high rainfall measured at the Mojo station in 1999 and the peak rainfall in 2001 at the Addis Ababa station (Fig. 5.4). The low rainfall peak during the wet season in 2004 at the Melka Kunture station is not observed in other stations besides Addis Alem. There are also years where the rainfall records show high peaks in most stations in the basin. In Addis Alem, Tulu Bolo, Addis Ababa and Melka Hombole high rainfall peaks are recorded in 1992. The Melka

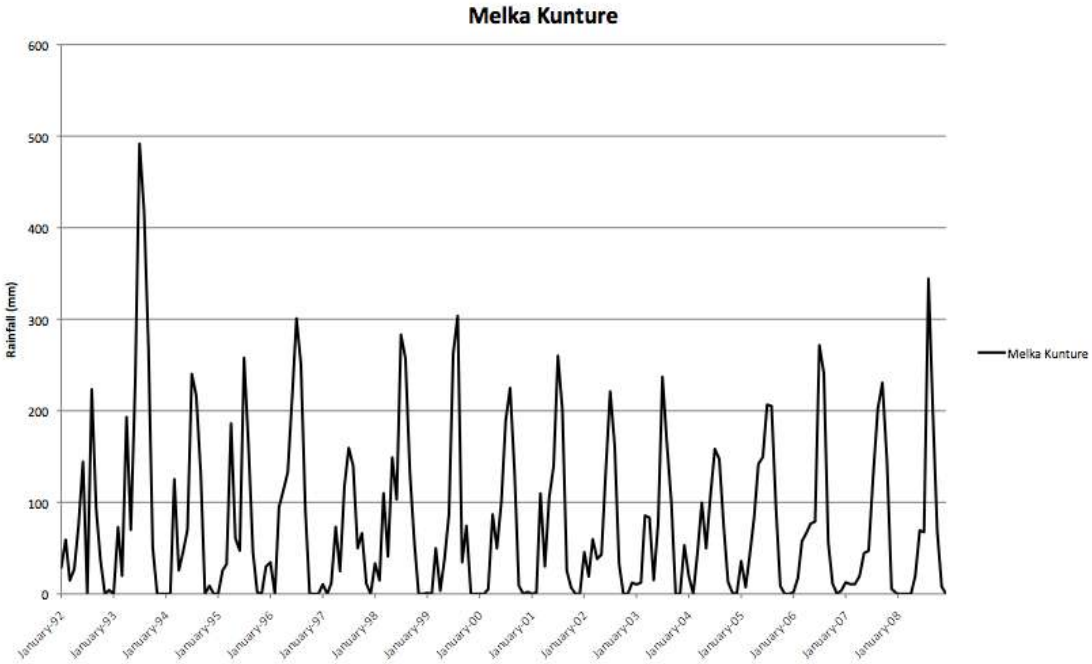
Kunture station, located in the middle of the catchment, recorded no data during the wet months of that year. Most of the stations show high rainfall peaks in 2006 and 2008. Other wet years that are recorded at more stations are 1993 and 1998. Low monthly rainfall in the wet months, that indicate dry years, is not evenly distributed over the area. Only in 1994 there is low monthly rainfall recorded in Addis Alem, Tulu Bolo, Melka Kunture, Koka and Mojo. In 1995 low peak rainfall was measured in Tulu Bolo and Mojo.

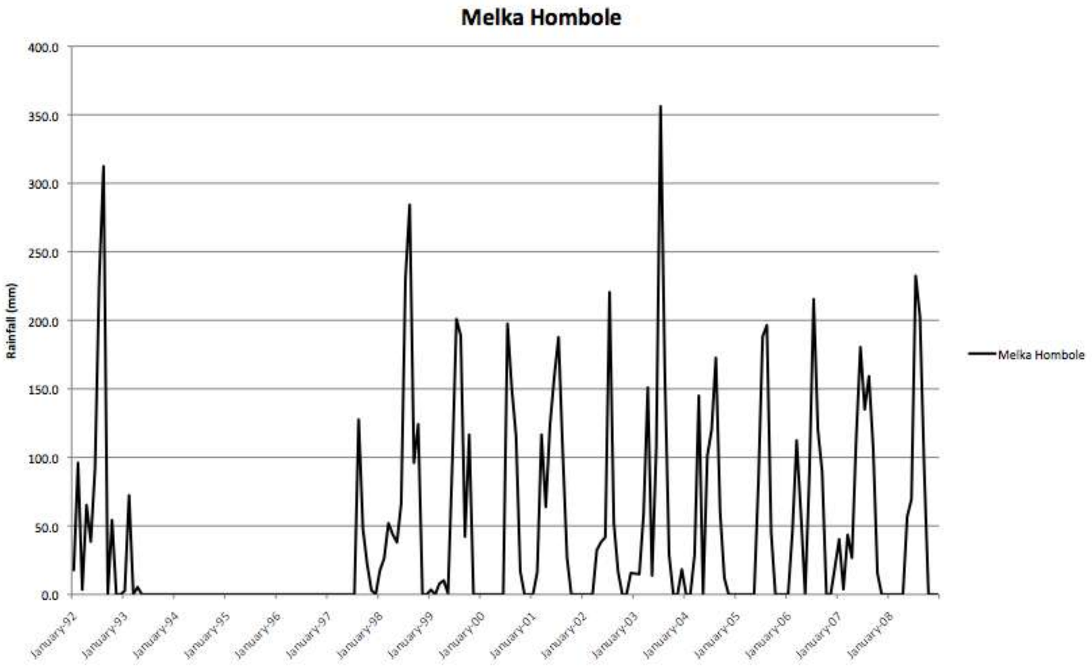





A.Ababa
Rainfall (mm)
A. Ababa
January-96
January-97
January-98
January-99
January-00
January-01
January-02
January-03
January-04
January-05
January-06
January-07
January-08
January-09
January-10


Teji
Rainfall (mm)
Teji
January-92
January-93
January-94
January-95
January-96
January-97
January-98
January-99
January-00
January-01
January-02
January-03
January-04
January-05
January-06
January-07
January-08


Melka Kunture
Rainfall (mm)
600
500
400
300
200
100
0
Melka Kunture
January-92
January-93
January-94
January-95
January-96
January-97
January-98
January-99
January-00
January-01
January-02
January-03
January-04
January-05
January-06
January-07
January-08


Melka Hombole
Rainfall (mm)
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
Melka Hombole
January-92
January-93
January-94
January-95
January-96
January-97
January-98
January-99
January-00
January-01
January-02
January-03
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January-07
January-08

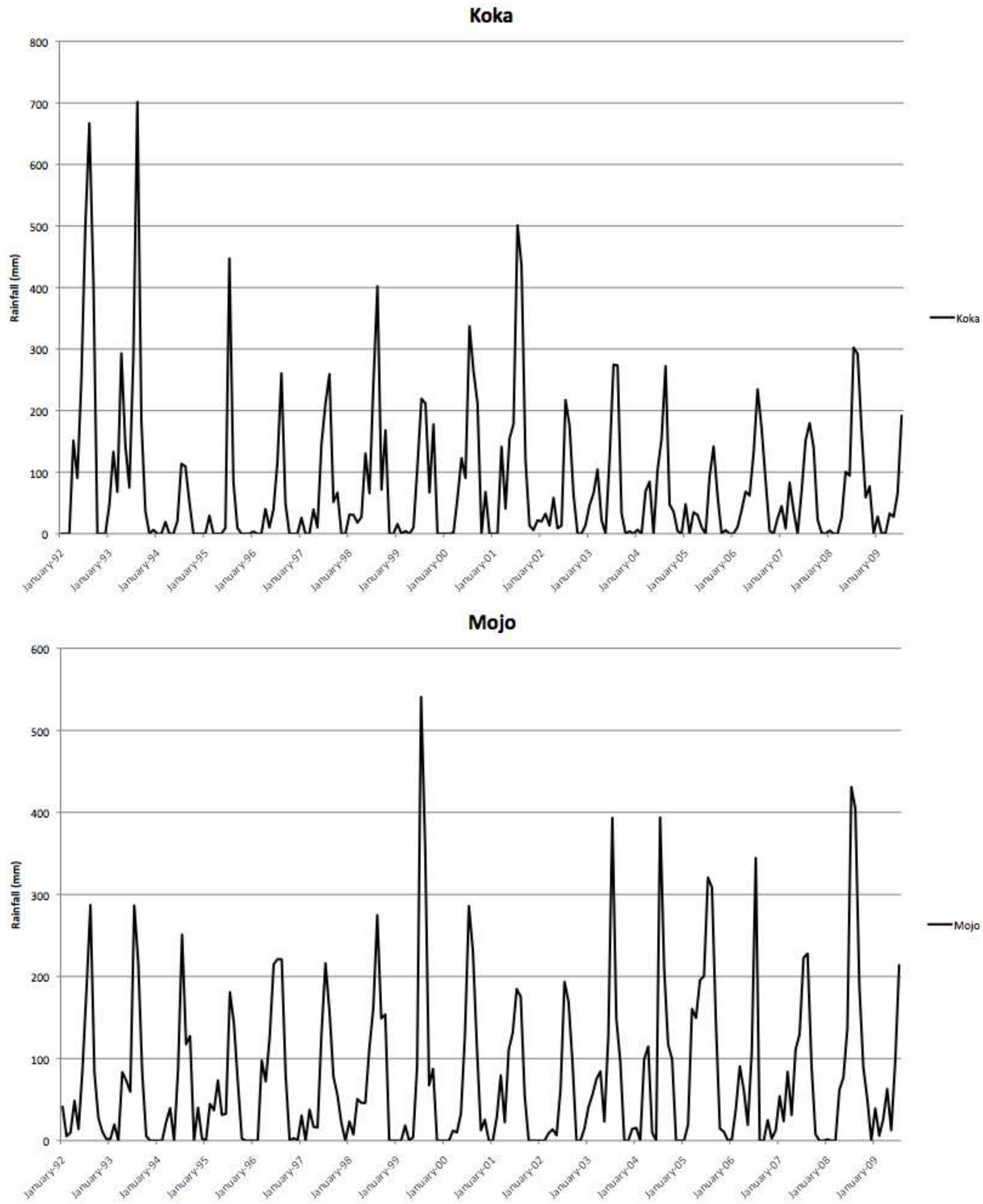


Figure 5.4. Monthly rainfall data of eight selected stations in the Upper Awash catchment.

5.3 Discharge of the Upper Awash basin

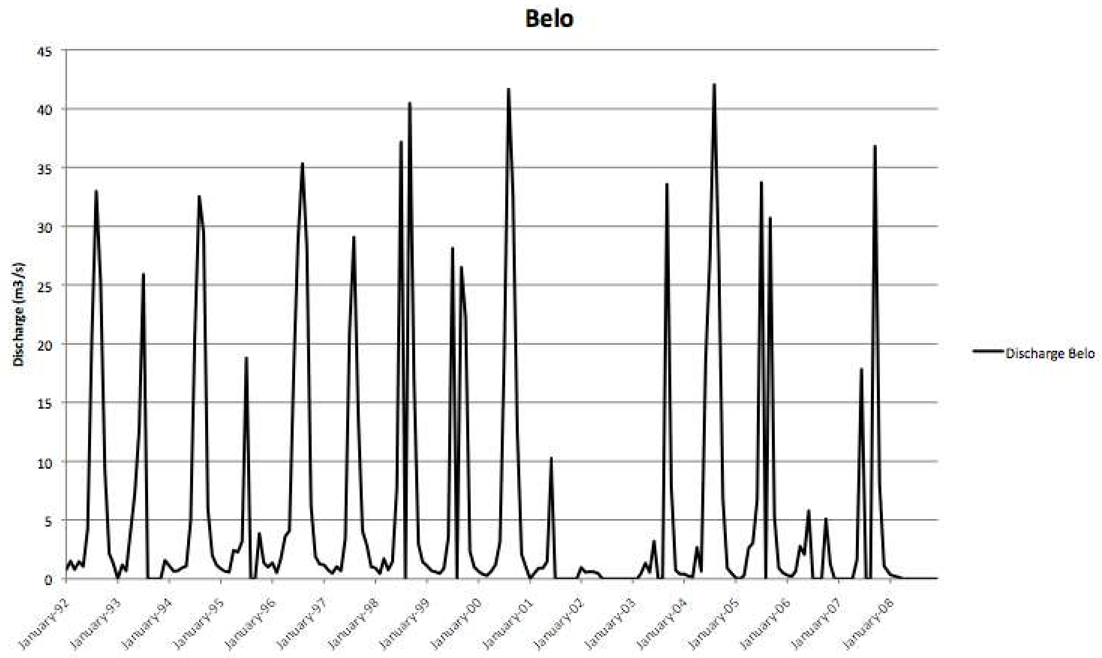
The monthly mean discharge data of the selected stations are shown in Figure 5.5. Discharge data was plotted for a period between 1992-2008. The location of the stations is indicated in Figure 5.3. There are some stations along the main Awash River and some at the tributaries, upstream and downstream. Melka Hombole is the most downstream station in the Awash River. The recorded discharges follow the wet and dry seasons that dominate the climate in the study area. Discharges start to rise in Februari, peak in July and August and decline from September. The quality of the discharge data is not good in the selected stations used in this survey, most stations show hiatus in the discharge data or other erroneous measurements.

5.3.1 Quality of the discharge data

The stations at the tributaries at Berga and Holeta show continuous records with large inter-annual variation in the annual mean peak discharges. Both of the stations are located in the mountains surrounding the Becho plain. Years that recorded high and low peak discharges during the wet season mostly coincide for the two stations. The measurements from the Awash Belo station show a lot of gaps in the data. For several years there is no data from July and August, when the highest discharges are reached. This probably has to do with the water level exceeding the level of the staff gauge at the Awash Belo station. Measurements from the Akaki and Mojo rivers show huge differences over the plotted period. Notable are the extremely low discharges recorded in the last four years at the Akaki station and the last eight years at the Mojo station. Also the difference in the baseflow at the Akaki station between 1993 and 1999, compared to the rest of the record, stand out from the other stations. The high discharges in 1995 and 1996 at the Mojo station, especially in the dry season, seem erroneous.

5.3.2 Stations with continuous records

The stations at Melka Kunture, and more downstream at Melka Hombole seem to have a continuous record. Mean monthly discharge measurements from both stations show similarities in high and low peak discharges during the wet season. The higher peak discharges at 1993, 1996 and 1998 are recorded in both of the stations. In these years the Berga and Holeta stations also show higher peak discharges. A remarkable difference between the recorded discharges at Melka Kunture and Melka Hombole is the opposite trend between 2006 and 2008. In the more downstream Melka Hombole there is a decline in the peak discharges from 2006 onwards, where at Melka Kunture the discharges increase towards 2008. Low discharges from the Akaki River or two smaller Lemen tributaries that join the Awash River downstream from Melka Kunture can cause this difference in measured discharge.


Belo
Discharge (m3/s)
Discharge Belo
45
40
35
30
25
20
15
10
5
0
January-92
January-93
January-94
January-95
January-96
January-97
January-98
January-99
January-00
January-01
January-02
January-03
January-04
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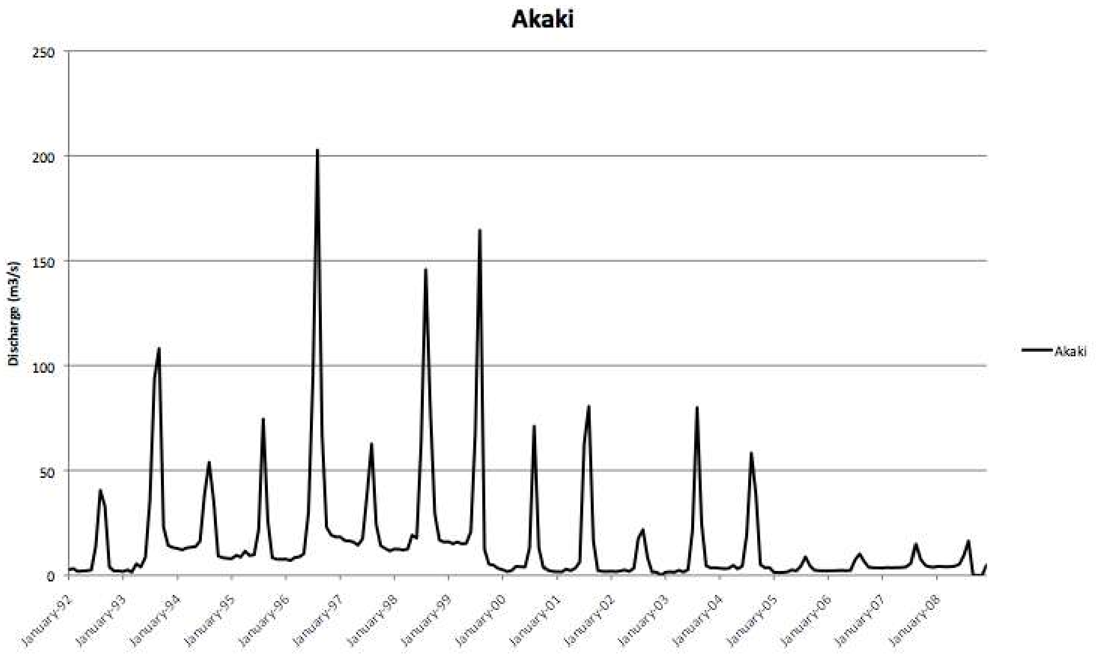
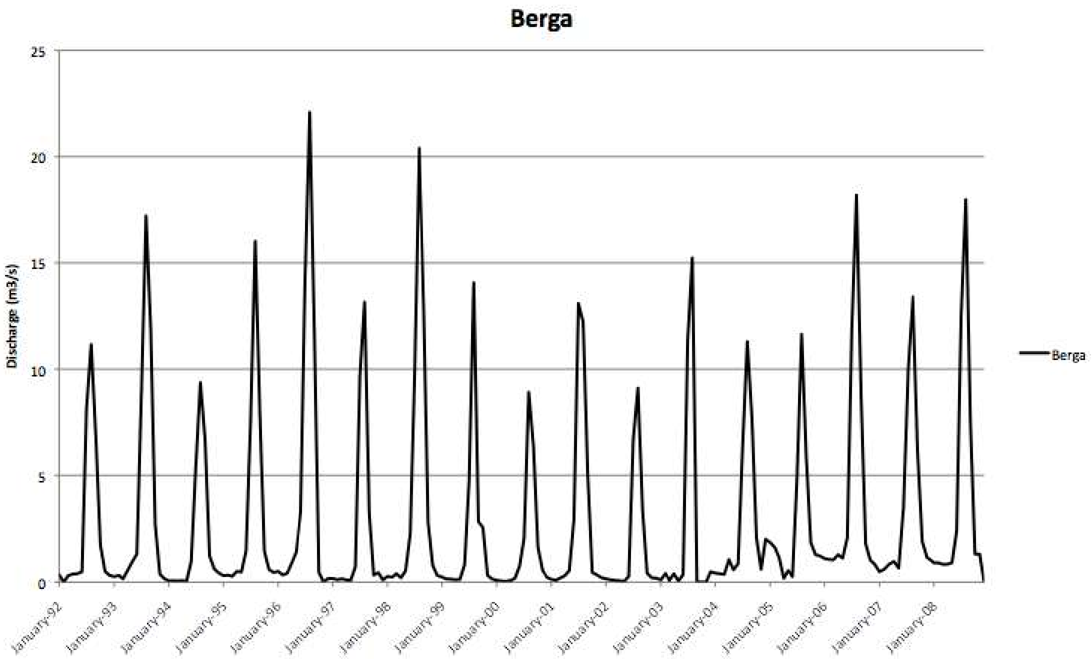
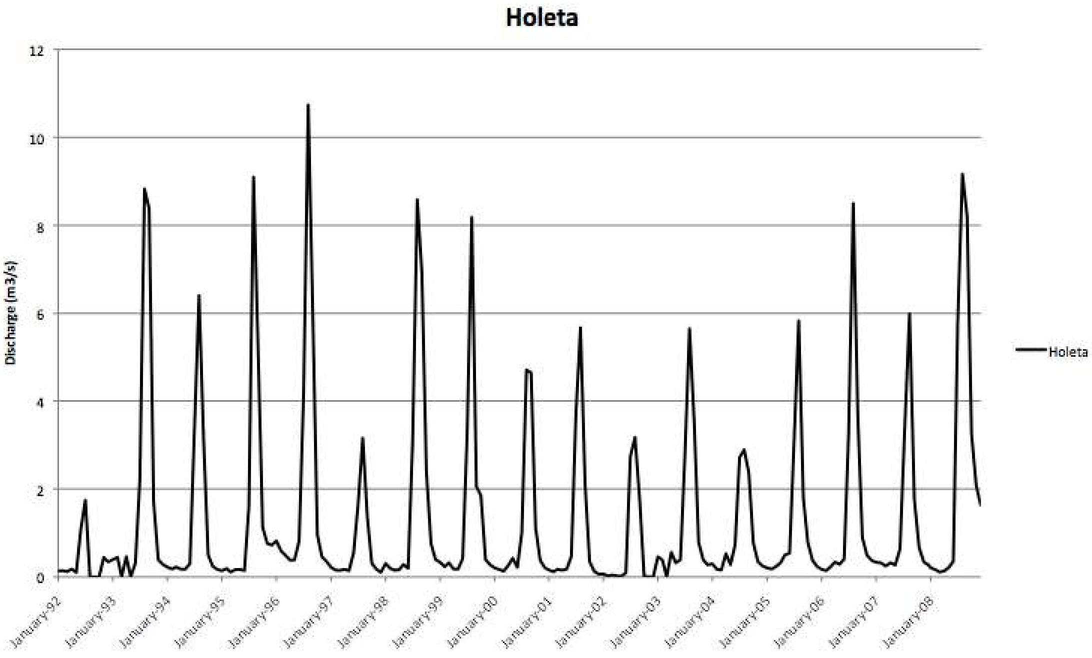
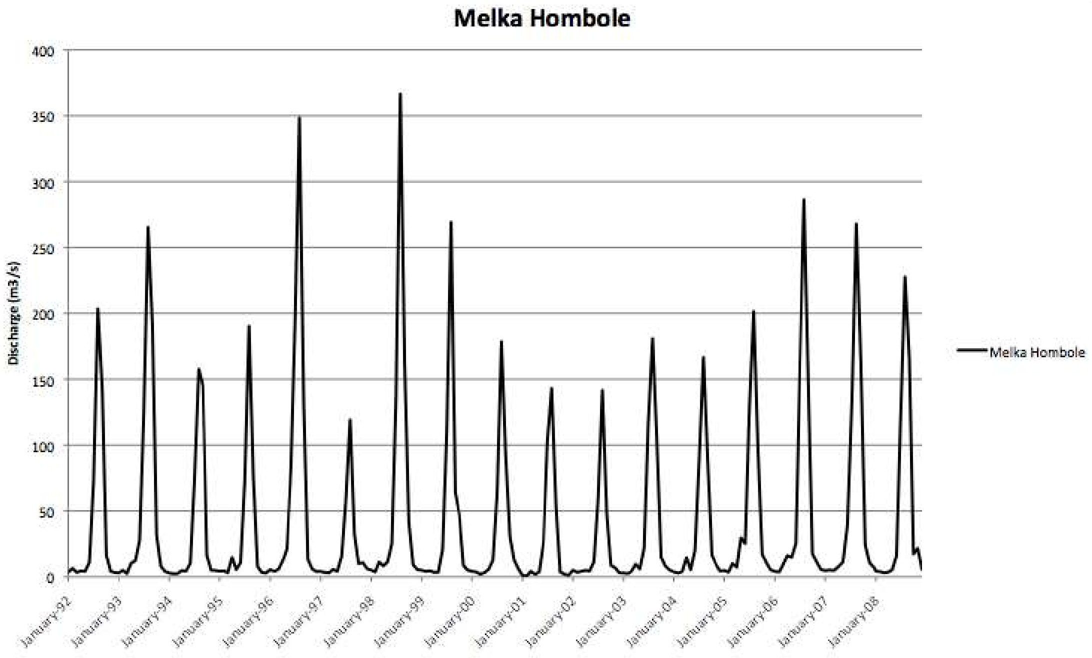
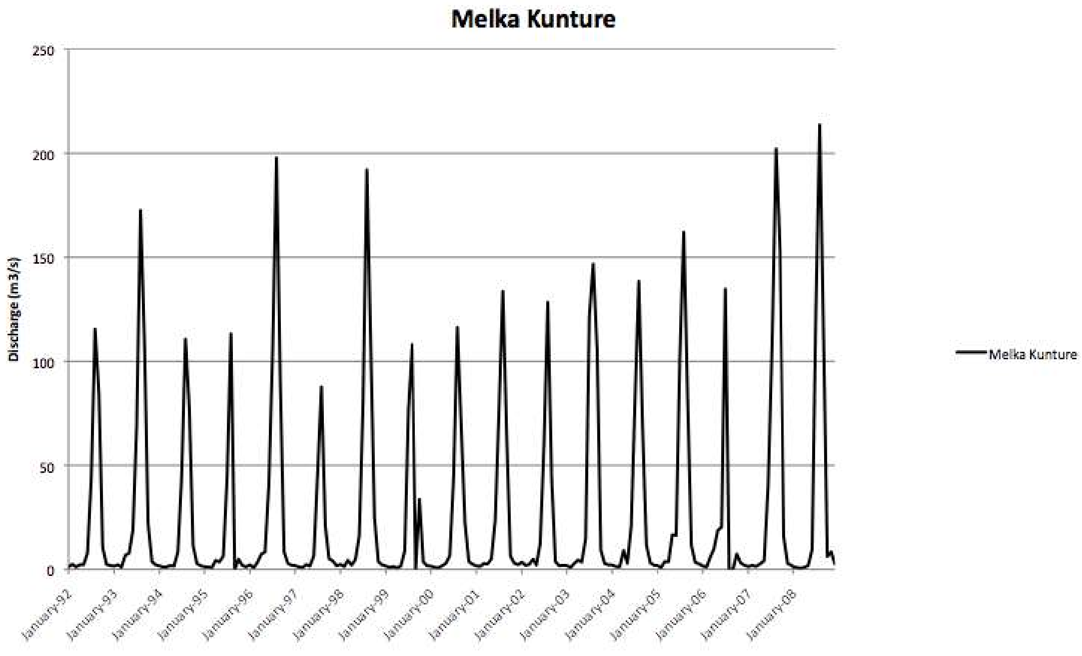
January-06
January-07
January-08


Akaki
Discharge (m3/s)
Akaki
250
200
150
100
50
0
January-92
January-93
January-94
January-95
January-96
January-97
January-98
January-99
January-00
January-01
January-02
January-03
January-04
January-05
January-06
January-07
January-08


Berga
Discharge (m3/s)
25
20
15
10
5
0
January-92
January-93
January-94
January-95
January-96
January-97
January-98
January-99
January-00
January-01
January-02
January-03
January-04
January-05
January-06
January-07
January-08
Berga


Holeta
Discharge (m3/s)
12
10
8
6
4
2
0
January-92
January-93
January-94
January-95
January-96
January-97
January-98
January-99
January-00
January-01
January-02
January-03
January-04
January-05
January-06
January-07
January-08
Holeta


Melka Hombole
Discharge (m3/s)
Melka Hombole


Melka Kunture
Discharge (m3/s)
Melka Kunture

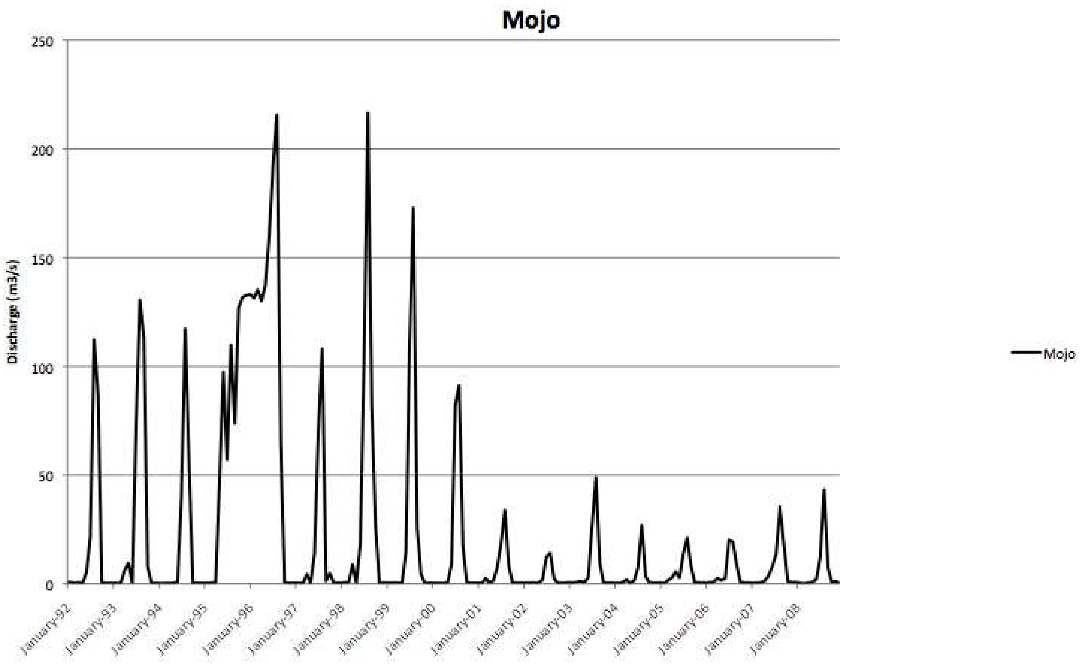


Figure 5.5. Mean monthly discharges of the Awash River and tributaries.

5.3.3 Rainfall-runoff relation

The stations of Berga, Holeta, Melka Kunture and Melka Hombole show the most reliable and consistent records. For most years in the period that was analyzed, these stations show a relation between the recorded discharges. These discharges do not show strong links with the rainfall data from the selected stations. In 1993, 1996, 1998, 2006 and 2008 above average peak discharges were recorded in the four reliable stations, but only in 1993 higher rainfall amounts are recorded in six of the eight stations. In 1993 Addis Alem, Tulu Bolo, Teji, Melka Kunture, Melka Hombole and Koka measured higher peak monthly rainfall. In 1996 higher rainfall was measured in Addis Alem and Melka Kunture, where in 1998 in Teji, Melka Kunture and Melka Hombole the rainfall peaks were above average. In 2006 and 2008 in three stations of the eight stations higher monthly rainfall was recorded. In 2006, at the stations in Teji, Addis Alem and Addis Ababa higher rainfall was recorded and in 2008 in Teji, Melka Kunture and Addis Ababa experienced more rainfall. These relations indicate that the high discharges are often caused by increased rainfall in only certain parts of the catchment. There can be local response in increased discharge by intense rainfall events, but also downstream the effects of high precipitation in the wet season can be measured. High river discharges in the flood prone areas can cause the water to overtop the riverbanks and inundate the floodplains. The quality of the rainfall and discharge data of the stations in the catchment makes it difficult to estimate or make predictions about the timing of the floods and the duration. A continuous record of daily or hourly discharge and precipitation data of more than four stations in the catchment would be beneficial to make estimations on the flood occurrence and duration. The stations near the study areas showed many hiatus in the discharge data. Continuous and preferably more detailed sample interval of discharge is necessary for prediction of the inundations.

Figure 5.6. Cracks developing in clay-rich vertisols right after the receding flood at the floodplain near Lake Koka.

5.4 Groundwater in the catchment

The recharge of the deep groundwater in the study area is restricted by the abundance of vertisols (WWDSE, 2008). Although the clay rich soils hold water well, it is also impermeable for infiltration to deeper aquifers. Cracks developing in the drying floodplain at the Bora *woreda* are shown in Figure 5.6. Two deep volcanic aquifers are identified by the study. The lower basaltic aquifer is at a depth of more than 300 m. The upper basaltic aquifer – that ranges between 80 and 400 m in thickness - is interconnected with the quaternary alluvial and lacustrine sediments that act as a shallow aquifer in the study area. These shallow aquifers are not of hydrogeological importance, but they are recharged annually by the inundations and river runoff. The shallow aquifer is easy accessible, groundwater levels are maximum 10 m deep in the Becho plain. Easy accessible, annually recharged shallow groundwater can provide water for irrigation of the floodplains in the dry season. The same study also found that the adjacent Upper Abay basin that is situated directly north of the Upper Awash basin contributes a large portion of the groundwater recharge of the lower basaltic aquifer in the Upper Awash catchment. A water balance study indicated an annual recharge of the aquifers of 965 Mm^3, with 67% contribution by the Abay plateau (WWDSE, 2008).

5.5 Other hydrological studies performed in the Upper Awash basin

The influence of the rainfall intensity on the observed river discharges is also recognized in other studies performed in the Upper Awash catchment (Tessema, 2011; Terakegn et al., 2003; Koriche, 2012; Behailu, 2004).

5.5.1 Rainfall-runoff model using SCS numbers

In Tessema (2011) a water balance for the catchment upstream of Melka Hombole is made with the use of a rainfall-runoff model. There are three methods used to find a rainfall-runoff relation. One relates rainfall to a retention parameter and runoff; the other relates the retention parameter to the Soil Conservation Service Curve Number. The retention parameter is the maximum potential difference between rainfall and runoff from the time that the storm begins, used in the daily curve number calculation. Two methods of calculating the optimal retention parameter are used. One lets the retention parameter vary with the soil moisture and the other lets the retention parameter vary with the plant evaporation. After validation and calibration of the model all three methods show other results for the water balance of the watershed, although predicted stream flow show agreement between the methods. The modeled components of the water balance are shown in Figure 5.7. All three methods show that the majority of the water balance component is evapotranspiration. The difference between the calculated components of base flow and surface runoff in the two methods that use the curve number is remarkable. The method that uses plant evaporation (middle graph) calculated 24% of the precipitation to be surface runoff and 2% base flow. While the method using soil moisture finds 3% surface runoff and 21% base flow (right graph). The water that drains from the shallow groundwater bodies in the catchment feeds the base flow component. Tessema (2011) found two papers that back up both of these scenarios. A water balance derived from a lumped conceptual rainfall-runoff model of the same area from Moreda (1999) the base flow accounted for 2% and lateral flow 13%. This agrees with the plant evaporation method that finds base flow as a relative small contributor. Another study by Chekol (2006) that also uses the soil moisture method finds base flow as the dominant contributor to the water balance with a percentage of 9.8% versus 6.8% for surface runoff.

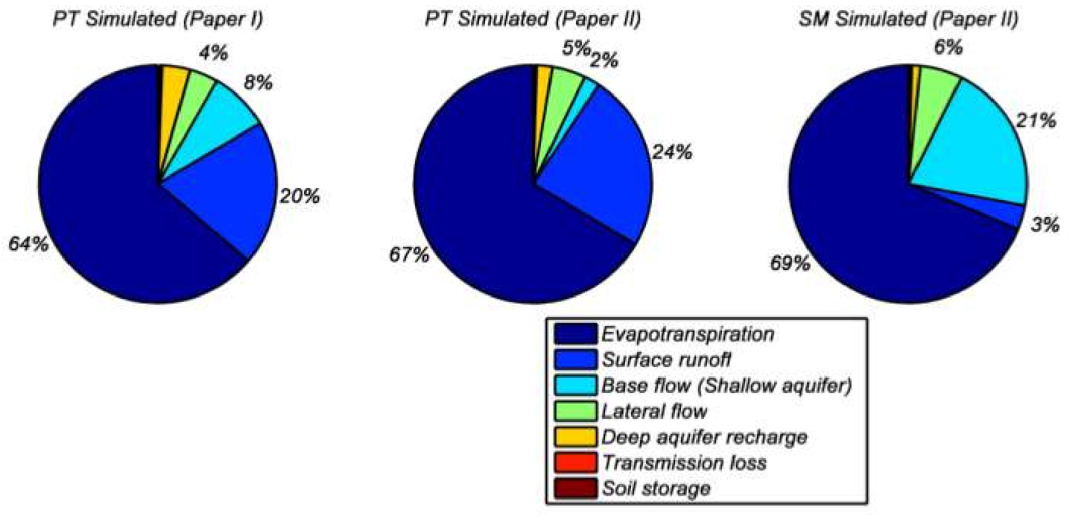


Figure 5.7. Water balance components percentages of the three different simulation methods, and derived from a 100% precipitation input (from: Tessema, 2011)

5.5.2 Flood prediction model and soil properties

All the studies performed in the study area recognize the influence of vertisols on the rainfall-runoff relation. The floodplains that are the main focus of this survey are built up from fine-grained sediments. In these fine-grained deposits the vertisols develop. In the dry season large deep cracks develop in the clay-rich soils due to the shrinkage (Fig. 5.6). During the wet season the soil will become saturated and will have low hydraulic conductivity (Behailu, 2004). Behailu (2004) also simulated stream flow in the Upper Awash catchment to predict floods. He found over- and underestimations for the small and main rainy seasons. The reasons his model do not match the observed stream flow data are caused by the absence of certain data. Soil properties play an important role in the rainfall-runoff relationship and need to be investigated in more detail. The study did divide the catchment into six sub basins. Often the sub basins have one rainfall and one discharge station. The extrapolation of the rainfall data from one station per basin can introduce some inaccuracies for simulation of the rainfall-runoff relation (Tessema, 2011; Behailu, 2004).

5.5.3 Flood prediction model using Remote Sensing

Koriche (2012) developed a model to predict floods in the Upper Awash catchment. The results of the LISFLOOD model were compared with observed data and calibrated by trail and error. For the collection of soil moisture and evapotranspiration in the studied area satellite data from several sources was used. This study also finds certain model parameters that influence base flow and certain parameters that influence quick flow or surface runoff. The parameters controlling the flow from the upper to the lower groundwater zone, and the parameter controlling the amount and timing of the outflow from the lower groundwater reservoir, influence the base flow. Whereas the parameters controlling flows influenced by the soil saturation and the parameters controlling flows of the upper groundwater zones control the surface runoff. With the model, a prediction of flooding of the flood prone areas is made using a standard precipitation index and a topographical wetness index. Two periods are found to have a high standard precipitation index and excess rainfall in those periods would cause flooding. The periods are between June 13 - 20 and July 27 – August 04. Figure 5.8 shows a graph with the predicted water levels of three flood prone areas. The study also looked at two areas downstream of Koka Dam, but only the flooded area upstream of Lake Koka in the Becho plain is included in this study. The main river depth is assumed to be 10 meters and a water level above 10 m will indicate overtopping of the riverbanks.

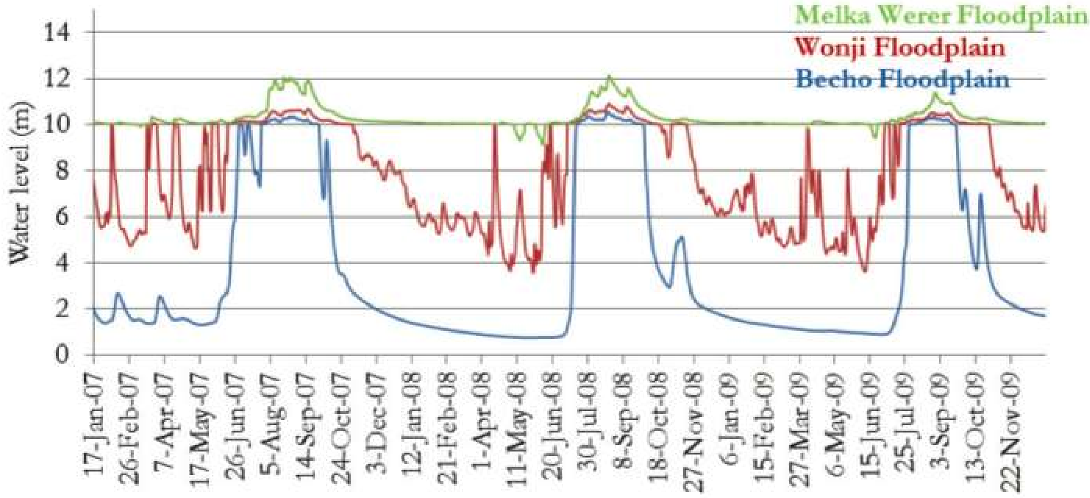


Figure 5.8. Graph indicating simulated water levels and periods of potential flooding. Water levels above 10 meters indicate flooding. In the Becho plain short inundations and in Melka Werer almost permanent inundation are simulated (from: Korniche, 2012).

To simulate the area, depth and duration of the inundation of the flood prone areas more data is needed. A model capable of simulating flood depth and inundation is required. Detailed characteristics of the flood prone area like channel geometry and detailed topographical data were unavailable for this study. Hourly rainfall and discharge data are needed for accurate peak discharges and duration of the peaks (Korniche, 2012).

6 Comparison of flood recession agriculture practices

Annual floods allow inhabitants of the floodplain to use the flood prone areas for agriculture in the dry season. Timing and duration of the flood and the geomorphology in the flooded area influence the exact practices of the farmers. Field study at two sites in the Upper Awash catchment proved that farmers developed different methods to deal with the annual inundations. The examples shown in Chapter Two also indicate the variety in methods, cropping strategies, diversification of activities and also the way that people experience the annual floods. During the field studies at the two sites there were several differences observed in flood recession farming methods.

6.1 Differences in practices

6.1.1 Timing

Farmers in the Becho plain start plowing and sowing as soon as they consider that the floods will not return. During the field study a farmer lost some seeds because his plots were flooded after the crops were sown. Around Lake Koka the farmers wait longer with their farming activities. The floodplains are drying up for between 2 and 4 weeks after the floods retreat before the farmers start plowing. The timing on when to start plowing is determined by the farmers' judgement. The farmers in the Bora *woreda* also dig wells to access the shallow groundwater. This is used for irrigation of the plots in the floodplain during the dry season. It enables the farmers to grow vegetables and fruits besides the pulse crops. This also provides water for crops at the end of the dry season when farmers in the Becho plain experience water shortages in dry years during the flowering fase of the crops. Therefore farmers in the Bora *woreda* can afford to wait with their farming activities after the wet season. The farmers in the Becho plain do not use groundwater for irrigation. Digging of wells was said to be too labor intensive. Irrigation practices in the Becho plains are strictly performed with pumps next to the river.

6.1.2 Cropping strategy

Differences in the geomorphology and size of the floodplain showed a difference in the use of the floodplain. The timing of the farming activities and type of crops that are cultivated on the different parts of the floodplain differ in both the study sites. In the Becho plain there is a distinction between a shorter and a longer inundated area. In the shorter inundated area crops can be planted earlier and crops can grow using rainwater at the end of the wet season. Teff is often chosen because of its market value. In the longer inundated area the farming activities start at the beginning of the dry season and crops grown strictly on residual soil moisture. Mostly pulses are cultivated in this more downstream part of the Becho plain. Around Lake Koka the floodplain is not occupied by farmland in the dry season, parts of the previously inundated area are used for grazing land for livestock. This is also caused by the demographic situation. There are a lot of villages along the main road in the Becho plain, whereas the floodplain around Lake Koka is less densely populated. The farmers in the Bora *woreda* have also a detailed subdivision of soils and geomorphological features in the floodplain. The farmers found the slightly higher elevated point bars or riverbanks that consist of sandy and loamy deposits to be more suitable for maize and haricot beans. The local depressions with more fine-grained sediment are used for chickpea.

6.1.3 Rice trial

An interesting development was the rice trail that was performed in the Becho plain. The agricultural office did an experiment to find the most suitable rice variety of six different varieties that were planted next to the Awash River under flooded conditions. The rice wasn't fully mature at the beginning of the wet season and extra irrigation from the river was necessary before the rice was harvested. Farmers indicated that they would be willing to grow rice in the wet season if it would yield good results and if there is a market for the crop. Rice is not a traditional crop in Ethiopia, but there are examples of rice cultivation. In Chapter Two the Fogera plain is mentioned where flood tolerant rice varieties are grown. The exact rice varieties and the outcome of the trial were not considered in this research.

6.2 Similarities in practices

6.2.1 Coping with the floods

At both study sites the negative effects of floods were also highlighted. People living in the floodplain in the Bora *woreda* have to move out of their houses when water levels peak. The floods destroy property and also livestock suffers from extreme floods. Although the villages along the main road in the Becho plain are well adapted to seasonal high water levels, floods can still be destructive. During extreme flooding events livestock can be killed and property can be destroyed.

6.2.2 Geomorphology and hydrological situation

The hydrological characterization of the study area showed that both sites have certain similarities. Both the sites are situated at a plain with a gentle slope. Several tributaries join the main Awash River in the Becho plain, and the Awash River splits up in several branches entering the plain around Lake Koka. The rainfall pattern is comparable as well as the timing of the flood. The difference is the immediate effect on an intense rainfall event in the Becho plain and the more lagged response to rainfall events in the uplands around Lake Koka. The backwater effect of Lake Koka also causes water levels to rise at the end of the wet season close to the lake. The total amount of rainfall is higher in the more elevated parts of the catchment.

6.2.3 Fertility of the floodplain

Farmers that use the floodplain for agriculture do recognize the fertility of the land. The annual deposit of fine-grained material and organic matter brought in by the floods create a fertile soil on the floodplains. No fertilizers are needed to grow the pulse crops on the clay rich soils. This type of soil can host harmful worms or pests that can be harmful for certain crops. Farmers indicate that the use of pesticides is necessary. The high water retention capacity of the soils allows pulses to grow without additional irrigation. Flood recession agriculture is therefore extremely productive when the output is related to the initial input costs. In a study on flood recession agriculture in the Senegal Valley, Saarnak (2003) also recognizes the high net returns compared to the energy input.

6.3 Hydrology and flood recession agriculture

With this study it was not possible to relate the productivity of the crops grown with flood recession agriculture to the duration, depth and timing of the inundations at the study sites. During the field campaign it was not possible to get the necessary data to simulate the annual size and duration of the flood. The available rainfall and discharge data and the quality of the available data does not allow estimation of the exact peak discharges and when the floodplain start to inundate. Also the lack of data on the channel geometry and maps of the riverbanks makes it impossible to exactly determine where the riverbanks will be overtopped with floodwater. The productivity data of the crops grown with flood recession agriculture did not show a relation with the measured monthly rainfall or monthly discharge records. The productivity record of the Bora *woreda* shows increasing productivity numbers from 2005 – 2010 where the discharge and rainfall indicated high and low peak values in those years. The longer record of the productivity of flood recession crops in the Becho plain also shows no relation with the monthly discharge or rainfall data. Longer productivity records and more detailed meteorological and hydrological data could improve the insight in the relation between the hydrology of the catchment and the productivity of flood recession farming systems.
The farmers that practice flood recession agriculture have developed different strategies for gaining optimal yields for inundations of different size and different timing. The area and productivity of chickpea and lentil in the Ilu *woreda* in the Becho plain show large variety in the cropping strategy from year to year. Very few quantitative studies exist on the productivity of flood recession systems, which makes it difficult to relate the yields of the study sites to other flood recession areas.

6.4 Potential of flood based agriculture

The total area of flood recession agriculture in Africa is hard to estimate. In Ethiopia it might be as big as 100 000 ha. There has been little attention to this form of agriculture, which is widespread worldwide, on the African continent and also in Ethiopia. The practices are often performed on a small-scale. The area of existing wetlands, floodplains, or other seasonal inundated areas can give an indication of the potential of this form of agriculture. These numbers show that there is a huge potential for this form of agriculture, the Niger Inland Delta already inundates 3 million ha annually, in the Kafue Flats in Zambia there is 60 000 ha under flood recession agriculture (Deltares) and the total area of wetlands in Zambia that annually inundates is 3 million ha (AWM, IWMI, 2009). Also in Ethiopia several lakes and wetlands have seasonal fluctuation in water level and in the Awash River basin there are several areas that flood seasonally (Halcrow, 2006; WWDSE, 2008;Korniche, 2012). When the focus is often on integrated water management plans, the utilization of seasonal wetlands or floodplains, as floods retreat can be a good opportunity. Into the wet season there is usually plenty of soil moisture retained in the soils of these fertile environments. Without utilization this water reservoir would likely evaporate and not be used at all. This form of agriculture only uses water that is available and no other users downstream will experience water shortages caused by this form of agriculture. The river discharges will not decrease significantly and this form of agriculture will not harm international agreements on river discharges across the border. The numerous varieties in the usage of water for different purposes in areas that are flooded annually, brings insight in the optimal practices for certain environments. These different activities and practices dealing with annual floodwater show opportunities to enhance existing systems and their productivity. These opportunities should be explored.

6.4.1 Water management

Flood based farming systems occur in different parts of the world and can sustain large populations. A prime example is Bangladesh, where over centuries a sophisticated system of bunds, dikes, canal and drains has developed that spread the inundation over a large area, avoids standing water and generally retains the water for a longer time. Wester and Bron (1998) describe the different ways of optimal use of floodwater in Bangladesh. The high river discharges and high amounts of rainfall in Bangladesh demand flood control and a drainage system. At places where such is not installed, farmers adapted cropping patterns to the predictable seasonal floods, but this results in low cropping intensities. Often crops are damaged by flash floods. To prevent the destruction of crops by floods, embankments are built and from the construction of embankments, also outlets and other drainage structures must be constructed.

Five-stage water control

Wester and Bron (1998) describe a five-stage water control plan that has been implemented in Bangladesh. Each stage is illustrated in Figure 6.1. First stage is to protect the floodplain from floods. In the second stage main regulators in dikes are installed to drain the floodplains. After that minor regulators and embankment cuts are implemented to optimize the water control in and out of the floodplain. The specific demands of the people using the protected lands and also the location of the land, determines the exact practices in water management. Floodplains near the coast, where shrimp and salt is produced, demand different water management than more inland floodplains. So different areas with different geomorphological characteristics and different demands for water management will develop their own flood protection and drainage systems. These systems will be adjusted to the needs of the users, by for instance retaining more floodwater for fisheries or to elevate embankments if a large flood is expected and crops are not harvested yet. If a system is protected from floods and drained sufficiently, the use of the floodplain can be optimized by rising crop yields and more variation in crops. Also floodplains can be used for farming in the dry season, this demands a new strategy in water management. Floodwater should be retained more in the wet season and water from the river or groundwater can be pumped to the protected lands. All these systems are not large-scale irrigation projects and also not perfected, but the users are able to find solutions to optimize water use, lower the risks and deal with the conflicting water demands by developing and maintaining these systems.

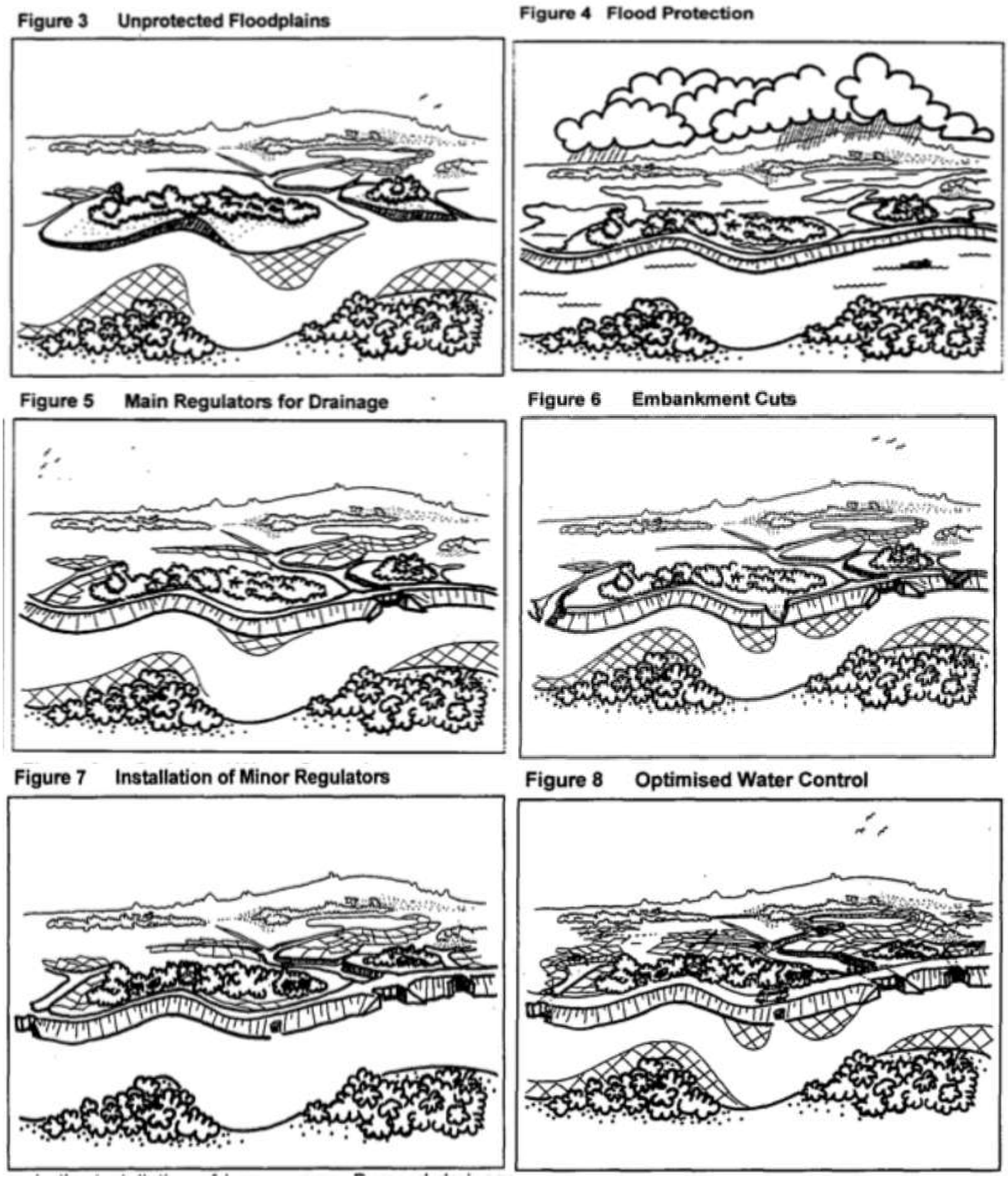


Figure 6. 1. Different stages in flood regulation in Bangladesh floodplains. Top left shows unprotected floodplains, and per stage a level of increased water management is introduced. Bottom right shows optimized water control (from: Wester and Bron, 1998)

Other examples of increased water management

Examples of simple solutions of managing floodwater that correspond with the first stages of the procedure described in Wester and Bron (1998) are described in Chapter Two. In the Okavanga Delta, Sierra Leone, around Lake Chad or in Botswana farmers construct small bunds to retain water or bunds serve as protection against unwanted floods are an example of starting with a higher level of water control in flood recession areas. The farmers in the Fogera plain around Lake Tana perform similar practices to regulate water in the floodplain. During the wet season rice is planted during the flooded conditions and water level in the floodplain is regulated by the construction of small bunds. These farmers manage to implement one and sometimes two extra crop cycles with their basic methods of regulating water in the floodplain.

6.4.2 Shift to flood rise agriculture

The use of rising flood as well as flood recession in several areas in West Africa has permitted double cropping: first rice or flood tolerant sorghum varieties grow on the rising flood and subsequently other crops – such as chickpea, lentil, and other parse crops – grow on the residual moisture. This transformation may offer opportunities for other areas too, depending on the pattern of flood rise. In some areas the introduction of floating rice varieties maybe considered. These very fast growing varieties keep up with the speed of the rising flood and can reach up to 3-5 meters in height. Floating rice varieties grow in areas as varied as Mali and Cambodia**.** In Ethiopia the production of rice during the rising floods is practiced in the Fogera plain west of Lake Tana. Rice is not cultivated in Ethiopia traditionally and is therefore not a crop farmers choose often. The farmers in the Fogera plain proved to be well of by selling the rise that was harvested after the wet season. Farmers in the study area were positive on growing rice if the conditions allow rice to grow, and if there would be a market for the crop.

6.4.3 Use of groundwater

Most flood plain areas are also areas with ample shallow groundwater resources. As there are continuously recharged from either the floods and the river flow, they constitute a highly dependable resource that is relatively easy to exploit. The farmers around Lake Koka irrigate the crops in the dry season using shallow groundwater that is accessed by hand-dug wells. The introduction of tubewells that can be sealed during the flood season would be beneficial over use of the hand-dug wells. Hand-dug wells are destroyed by the floods and need to be dug again every year. Water access by hand-dug wells is easier than tubewells. Tubewells require pumps to access the water. The use of another type of well, called *shadoofs* is mentioned in the Sokoto valley in Nigeria (Adams, 1993). The study on the groundwater situation in the study area that was performed by WWDSE (2008) shows that there are two aquifers present below the study area. Both of the deep aquifers are recharged but deep wells have to be dug to access the deep groundwater bodies. The use of groundwater for additional irrigation can increase the yields of crops grown on previously inundated area, where crops can experience water shortage at the end of the dry season.

6.4.4 Diversification of activities in the floodplain

There are more methods to deal with the uncertainty that is linked with environments that allow flood recession agriculture. Examples from Chapter Two show that in Senegal Valley and along flooded parts of the Niger River the inhabitants of the floodplain practice various activities to cope with the variable situations. Depending on the situation in the floodplain, inhabitants can be farmers of different crops, in different parts of the floodplain and adjacent lands, but also livestock herders or fishermen. The wetlands in and around flood-based farming systems often offer opportunities for non-timber products, medicines and other products. Extremely high floods might delay the start of flood recession agriculture and people can catch fish instead. During relative dry years more land can be used for grazing land for animals. The flexibility of the people living in the floodplain can help to lower the risks involved in living on the floodplain and being confronted with changing climatological conditions every year. Adaptation to changing conditions can also change the perception of the users of the floodplain towards floods. The continuously changing conditions can be viewed as opportunities for a range of activities. Market chains are however not developed to provide the farmers other sources of income.

7 Conclusions

Fieldwork in the Upper Awash catchment has provided insight into the methods of flood recession farming. The cropping strategies, timing, plowing and preparation of the plots in the floodplain as well as the productivities of the cultivated crops are described. The conditions found in the floodplains in the Upper Awash basin are comparable to the general features that are described for other locations where flood recession agriculture is practiced. Distinct wet and dry season cause seasonal change in the water level around lakes and floodplains of rivers. The clay rich soils retain water during the dry season and mainly pulse crops are able to grow using the residual soil moisture. Farmers that practice flood recession agriculture rely on their experience on when to start plowing and sowing. The exact practices of flood recession farming are site specific. The overview of flood recession farming practices has proved that farmers have developed methods to deal with the changing conditions independently. In the Ilu and Bora *woreda* in the Upper Awash catchment there are differences in timing of the start of plowing and sowing of the crops, the use of groundwater, and the general land use of the floodplain. This shows that a wide variety of methods are practiced in environments that experience annual flooding. Because of the experience of the inhabitants of the flood prone areas, there is often much practical knowledge on how to cope with the changing situations.

The literature on flood recession agriculture often only describes the occurrence and not much quantitative research on the productivity of flood recession systems exists. This study found yields of crops that were cultivated with flood recession agriculture. A literature review could not provide productivities of similar crops grown under flood recession agriculture, which makes it difficult to compare the production of the study sites with other areas where flood recession agriculture is practiced. It would be useful to know more about productivities of certain crops in relation to intensity of the annual floods. Farmers can make better decisions on what crop to cultivate in different conditions. The comparison to other areas that also experience annual flooding does provide insight in the potential of optimal use of the flood prone areas. The following opportunities are described in Chapter Two of this research and also followed from comparing the practices at the two study sites in the Upper Awash basin. Implementation of these opportunities can increase the productivity of the flood prone environments and the increase the income of the inhabitants.

- Increase the level of water management. Water levels can be regulated with simple bunds and drains. This higher level of water management can allow farmers to regulate the water level on their plots to their needs.
- Introduction of flood rise agriculture. Examples in West Africa and in the Fogera plain in North Ethiopia prove the value of having an extra crop cycle that can be grown with the rising flood. Flood tolerant varieties of rice or sorghum can be grown on as the floodplains inundate.
- Use of groundwater. Floodplains often have ample shallow groundwater resources. These water bodies are recharged annually and easy accessible. Extra irrigation at the end of the dry season can help the

productivity of the crops and in certain situation allow an extra crop cycle.
- Diversification of activities. Examples from West Africa prove that inhabitants of flood prone areas master a wide range of activities to cope with the changing conditions in the floodplains. Farmers cultivated different crops, on different parts of the floodplain or adjacent to the floodplain. Fishing activities, livestock herding and other activities can be preferred above flood recession agriculture if certain conditions are met.

The influence of the specific hydrological situation in the floodplain on flood recession farming is also not studied yet. General characterization of areas where flood recession agriculture is performed does exist, but detailed hydrological survey with the focus on the plant available water for the cultivated crops does not exist. The hydrological data that was collected during this survey makes it difficult to achieve this goal as well. General water balances of the study area have been developed in other studies. The influence of the different components of the water balance on the annual size and duration of the floods are uncertain. How flood recession agriculture is affected by different size and duration of the flood is therefore also unknown. More detailed and more specific hydrological survey can help to get a better understanding of the systems and their influence on flood recession agriculture.

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Annex I

Q	Alluvial and lacustrine deposits:Sand,silt,clay, diatomite,limestone and beach sand.
Qb	Basalt flows,spatter cones and hyaloclastites a) Transitional type between alkaline and tholeiitic. b) Alkaline olivine basalt.
Qr	Rhyolitic volcanic centers,obsidian pitchstone,pumice,ignimbrite,tuff, subordinate trachytic flows (predominantly peralkaline in composition)
Qd	Dino Formation:Ignimbrite,tuff,course pumice,waterlain pyroclastic rocks with rare intercalations of lacustrine sediments.
NQtb	Bishoftu Formation : Alkaline basalt and trachyte.
Nc	Chilalo Formation(Lower part) : Trachyte,trachy- basalt, peralkaline rhyolite with subordinate akaline. basalt.
Nn	Nazret Series : Ignimbrites,unwelded tuffs,ash flows, rhyolitic flows,domes and trachyte.
Ntb	Tarmaber Megezez Formation : Transitional and alkaline basalt.
PNa	Alage Formation : Transitional and subalkaline basalts with minor rhyolite and trachyte eruptives.

Annex II
Productivity tables

Table 1

Ilu District	1992-2010				
Year	Crop type	Area (ha)	Productivity (Qt)	Productivity (kg)	Productivity (kg/ha)
92-93	Beans	455	3640	364000	800
	Field peas	186	1488	148800	800
	lentil	415	3320	332000	800
	Chickpea	4963	28091	2809100	566.0084626
	Roughpea	524	3668	366800	700
93-94	bean	280	2240	224000	800

	field peas	176	1408	140800	800
	lentil	473	3784	378400	800
	chick pea	4217	29519	2951900	700
	rough pea	602	4214	421400	700
94-95	bean	423	3384	338400	800
	field peas	203	1421	142100	700
	lentil	494	3952	395200	800
	chick pea	4085	28595	2859500	700
	rough pea	566	3962	396200	700
95-96	bean	300	2400	240000	800
	field peas	153	1071	107100	700
	lentil	4210	27324	2732400	649.0261283
	chick pea	625	2836	283600	453.76
	rough pea	587	3723	372300	634.241908
96-97	bean	306	2448	244800	800
	field peas	171	1197	119700	700
	lentil	4100	28700	2870000	700
	chick pea	641	3846	384600	600
	rough pea	601	4207	420700	700
97-98	bean	400	2220	222000	555
	field peas	173	1103	110300	637.5722543
	lentil	4573	23097	2309700	505.0732561
	chick pea	978	2417	241700	247.1370143
	rough pea	830	5456	545600	657.3493976
98-99	bean	300	2220	222000	740
	field peas	173	1103	110300	637.5722543
	lentil	978	2417	241700	247.1370143
	chick pea	4572	23093	2309300	505.096238
	rough pea	830	5486	548600	660.9638554
99-00	bean	322	2310	231000	717.3913043
	field peas	187	1129	112900	603.7433155
	lentil	4122	1974	197400	47.88937409
	chick pea	780	3434	343400	440.2564103
	rough pea	679	1298	129800	191.1634757
2000-2001	bean	260	1060	106000	407.6923077
	field peas	185	592	59200	320
	lentil	680	5263	526300	773.9705882
	chick pea	4185	20735	2073500	495.4599761
	rough pea	800	4490	449000	561.25
2001-2002	bean	180	900	90000	500
	field peas	109	329	32900	301.8348624
	lentil	650	2600	260000	400
	chick pea	4559	32412	3241200	710.9453828
	rough pea	764	4584	458400	600

2002-2003	bean	174	870	87000	500
	field peas	75	225	22500	300
	lentil	657	2261	226100	344.1400304
	chick pea	4454	24176	2417600	542.7929951
	rough pea	758	3730	373000	492.0844327
2003-2004	bean	143	858	85800	600
	field peas	44	132	13200	300
	lentil	617	1804	180400	292.3824959
	chick pea	3912	16918	1691800	432.4642127
	rough pea	650	3385	338500	520.7692308
2004-2005	bean	132	792	79200	600
	field peas	29	87	8700	300
	lentil	500	35000	3500000	7000
	chick pea	3852	27189	2718900	705.8411215
	rough pea	560	4480	448000	800
2005-2006	bean	132	1188	118800	900
	field peas	29	130	13000	448.2758621
	lentil	500	3253	325300	650.6
	chick pea	3852	52289	5228900	1357.450675
	rough pea	560	24000	2400000	4285.714286
2006-2007	bean	30	240	24000	800
	field peas	20	120	12000	600
	lentil	988	6330	633000	640.6882591
	chick pea	3471	60967	6096700	1756.467877
	rough pea	1540	40040	4004000	2600
2007-2008	bean	35	280	28000	800
	field peas	25	200	20000	800
	lentil	800	19950	1995000	2493.75
	chick pea	4439	80014	8001400	1802.523091
	rough pea	625	6312	631200	1009.92
2008-2009	bean	30	315	31500	1050
	field peas	20	190	19000	950
	lentil	1520	39520	3952000	2600
	chick pea	3481	62804	6280400	1804.194197
	rough pea	602	7227	722700	1200.498339

Table 2

Bora District 1997-2003

Year	Crop type	Area planned (ha)	achieved (ha)	Productivity planned (Qt)	achieved (Qt)	Productivity achieved (kg)	Productivity (kg/ha)
2004-2005	Chickpea	102	72	1020	576	57600	800
	Haricot Bean	10	12	80	96	9600	800
	Maize	4	2	64	37	3700	1850
	Total	116	86	1164	704	70400	818.6046512
2005-2006	Chickpea	180	102	1800	918	91800	900
	Haricot Bean	22	16	176	128	12800	800
	Maize	10	4	300	64	6400	1600
	Total	212	122	2276	1110	111000	909.8360656
2006-2007	Chickpea	200	115	2000	1090	109000	947.826087
	Haricot Bean	25	22	250	176	17600	800
	Maize	10	8	300	144	14400	1800
	Total	135	145	2550	1410	141000	972.4137931
2007-2008	Chickpea	200	140	2000	1680	168000	1200
	Haricot Bean	50	60	500	560	56000	933.3333333
	Maize	25	16	750	320	32000	2000
	Total	275	216	3250	2560	256000	1185.185185
2008-2009	Chickpea	350	210	4200	2310	231000	1100
	Haricot Bean	247	130	2964	1365	136500	1050
	Maize	100	38	3000	836	83600	2200
	Total	697	378	10164	4511	451100	1193.386243
2009-2010	Chickpea	350	247	4900	2964	296400	1200
	Haricot Bean	281	190	3934	1900	190000	1000
	Maize	100	56	4000	1008	100800	1800
	Total	731	493	12834	5872	587200	1191.075051