Flow Regime and Land Cover Changes In the Didessa Sub-Basin of the Blue Nile River, South - Western Ethiopia:

Combining Empirical Analysis and Community Perception

Swedish University of Agricultural Sciences

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Acronyms

UNESCO – United Nations Educational, Scientific and Cultural Organization

FAO – Food and Agricultural Organization of the United Nation

EMWR – Ethiopian Ministry of Water Resources

NMAE – National Meteorological Agency of Ethiopia

WBISPP – Woody Biomass Inventory and Strategic Planning Project

PRA – Participatory Rural Appraisal

IWM – Integrated Watershed Management

BFI – Base Flow Index

CV – Coefficient of Variation

RC (c) – Runoff Coefficient

SD – Standard Deviation

AV– Annual Variation

IR – Incremental rate

AR– Average Runoff

Abstract

Defining stream flow and rainfall patterns over a period of different land use/cover changes and understanding the community's knowledge on changes in the natural resources of the Didessa sub-basin of the Blue Nile River were the main areas which this study dealt with. Based on the availability of hydrological data 8 out of 14 different gauged catchments of Didessa sub-basin were selected for further analysis. For each of these sub-basins 15 to 27 years of daily stream flow and rainfall data were collected and analyzed. Simple time series graphs, temporal homogeneity test, correlation and regression analysis were used as the main tools for comparing and illustrating the hydrological and meteorological data. For assessing the change in the land use/cover of the study area, the Blue Nile Basin map, and satellite images were examined, previous studies were considered and a field visit to the study area was undertaken. To explore the views of local people, the Participatory Rural Assessment techniques of timeline, key informant interview and focus group discussion were employed. For most catchments the results revealed that the long term stream flow and rainfall trend and variations responded in accordance with the forest change of the area. In addition the already accepted hypothesis 'forest clearing results in increasing stream flow' was observed**.** The annual variability in stream flow and rainfall values was large for all catchments. However in all cases the variability in annual stream flow was much higher than in annual rainfall. It was noted that dry season flows and Base Flow indices values showed a non-significant change for all catchments. From the communities' perception of changing natural resources, it was observed that most farmers are more aware on land use/cover dynamics than stream flow and climate changes. However farmers who use irrigation water for their farm plot appeared to have a better awareness in the stream flow changes than the ones who followed rain fed farming.

1 Introduction

1.1 Background

Human beings from their first appearance to the surface earth (whether created by God or evolved through a certain evolutionary process) in one way or another they were supposed to use the resources which exist around the environment they live in. From these resources fresh water or rivers are one of the vital means of existence not only for humans but also for any life on the planet earth. Hence defining and understanding what influences water resources is a key issue for fulfilling the consistent and ever growing demand for water. However since water by its own is not a complete system, looking at its dynamics together with other natural resources enhances our complete understanding of it.

The relationship between forests and water is often central in perceptions of water in regional, landscape and watershed scales[1]. Land use/cover is intrinsically linked with the hydrological cycle; therefore, a land use decision is often a water decision[2]. However the land use/cover change impact on the hydrologic cycle mainly depends on the characteristics of the watershed. Contrasting research findings suggest that the impacts of land cover change on water resource systems vary from place to place, depending on site specific factors[3]. The general hypothesis on this study and Integrated Watershed Management (IWM) is that changes in land use/cover patterns will influence the hydrological regime and water resources.

Despite the fact that the Didessa sub basin study area provides the largest amount of the Blue Nile River flows and is comparatively well equipped with lengthy hydrological and meteorological data series, most studies related to the Blue Nile River have focused on the northern part of the Blue Nile Basin. This makes the Didessa sub-basin one of less studied areas, and a key to better understanding the overall hydrological regime of the Blue Nile. What is especially interesting about Didessa is that in some areas deforestation has not gone as far as in the northern part of the Blue Nile Sub-basins. There is more forest here now and the amount of forest cover is also changing during a time when we have observational

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[1] Anders Malmer, Future of Forests – Responding to global challenges , Forest cover and global water governance,2010,page 76
[2] J.M.Bosch and J.D.Hewlett, A review of catchment Experiments to Determine the Effect of Vegetation changes on water yield and evapotraspiration,1981
[3] Wolddeamlak Bewket, Towards watershed management in highland Ethiopia: the Chemoga watershed case study,2003, page 50

records of rainfall and flow, while much deforestation in the north occurred before the flow region began.

Given that it is difficult to define the land use and land cover change of the entire area of the Didessa sub-basin within this study, we speculated on these changes by correlating the stakeholder perception and site observations with the existing Blue Nile river land use/cover map. Apart from helping to estimate the land use/cover changes, the community perception work which was done on the study area also helps us to see the stakeholders understanding towards the dynamics in the natural resources of the Didessa Sub-Basin.

1.2 Watershed Concept, Hydrological Cycle and Integrated Watershed Management (IWM)

1.2.1 Watershed/Catchment Concept

Ideally, surface water should be managed on a watershed/catchment basis.[4] The 'watershed' and 'catchment' are terms which commonly considered as synonyms and used interchangeably. A particular watershed/catchment refers to an area of land that drains to particular point along a stream. The boundary of a catchment is defined by the highest elevations surrounding the stream. A drop of water falling outside of the boundary will drain to another watershed.[5] The sizes of a catchment can vary from a few tenths of a km^2 to 7,050,000 km^2 (The Amazon River catchment/watershed area).[6] In this study the smallest and the largest catchments are Urgessa (19km^2) and Lower - Didessa (9981km^2) respectively. The compilation of different catchments that flow towards one big river can be called a sub-basin.

1.2.2 Hydrological Cycle

Traditionally the hydrologic cycle, as it is shown in Figure 1, is explained as the non-ending movement of water above, on, and below a given watershed/catchment. The hydrological cycle is an ever fluctuating dynamic system which is perhaps the most important phenomenon on planet earth[7]. It comprises various hydrological parameters in which their existences in one way or another rely on the watershed characteristics of the area.

Precipitation in the form of rain, snow, sleet, or hail falling on the surface of the earth can be

[4] Office of the Legislative Auditor, State of Minnesota, Watershed Management, Evaluation Report, 2007 ,page 1

[5] Mr. Ritesh Kr. Sinha, Application of Geo-informatics in Watershed Management ,2001

[6] Lev S.Kuchment, The Hydrological Cycle and Human Impact on It, Russian Academy of Sciences, page 4

[7] Ohio Department of Natural Resources Division of Water Resources Program, 1999, Fact sheet 93-18

considered as the beginning of hydrological cycle. As precipitation falls some of it may evaporate directly into the atmosphere from bodies of water, and a portion may be intercepted by vegetation.[8] The amount and type of precipitation that falls in an area ultimately affects the volume and timing of discharge from a watershed. The observable, surface discharge from a certain given watershed is generally termed **runoff or stream flow**.[9] However the sub-surface flow, in a form of **base flow**, may contribute to the total observable runoff or stream flow.

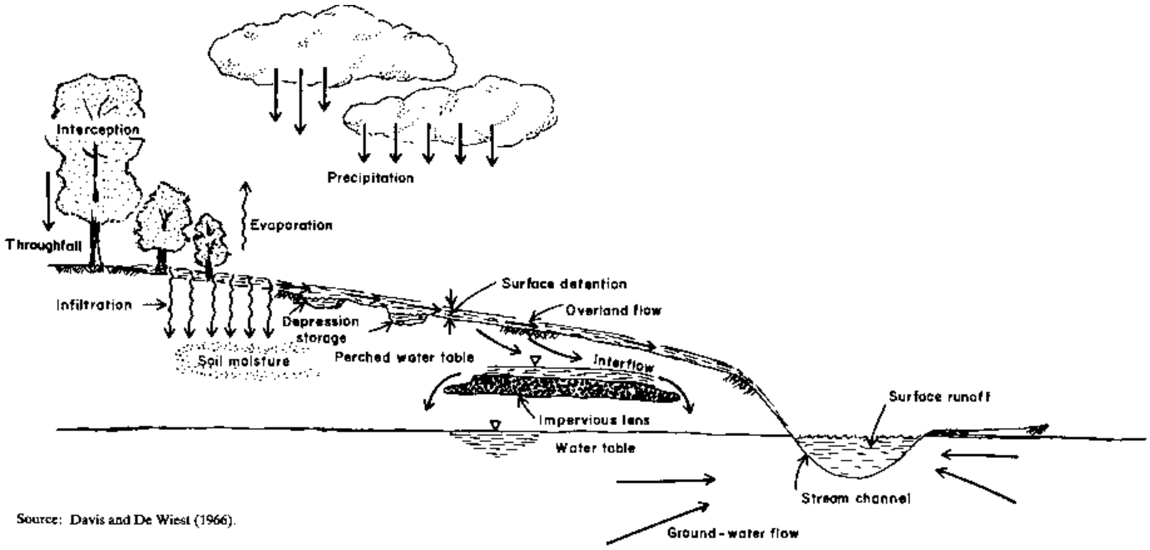


Figure 1. Hydrologic Cycle in a certain given watershed (Davis and Deist, 1996)

1.2.3 Integrated Watershed Management

In many developing countries changes in land use are rapidly taking place and the largest change in terms of land area, and arguably also in terms of water resource impacts, arises from afforestation and deforestation activities.[10] Watersheds are widely accepted as appropriate geophysical entities for natural resource management. Management of natural resources on a watershed basis is, however, a complex process involving several disciplines and institutions.[11]

[8] Land and Water, Conserving Natural Resources in Illinois, Number 13, Page 1-3
[9] Streamline, Watershed Management Bulletin, Robin Pike, Volume 7, Number 1, Page 1, 2003
[10] Ian R Calder, Blue Revolution, Integrated land and water resource management, second edition, 2005, page 5
[11] Dixit, Sreenath and Wani, Integrated Watershed Management through Consortium Approach, Open Access Journal, 2003, Page 3

IWM is the sustainable development, allocation and monitoring of land and water resource use in the context of social, economic and environmental objectives.[12] It is multi perspective and is therefore in stark contrast to the traditional sectored approach that has been used for ages. The process provides a chance for stakeholders to balance diverse goals and uses for environmental resources, and to consider how their cumulative actions may affect long-term sustainability of these resources[13]

1.3 Stakeholder Participation

A stakeholder can be defined as an interested individual, group or institution that may or may not be affected by decisions or actions pertaining to a specific resource, and may or may not be part of decision-making about the resource[14]. Stakeholders' participation can play a very important role in integrated watershed management studies. In this study, stakeholder knowledge is used as the main information source for understanding the dynamics in the natural resources of the study area. The stakeholders involved in this study are farmers, development agents, and local agriculture and rural development office staff members.

To enhance the interaction and participation of the stakeholders, the study chose Participatory Rural Appraisal (PRA) methods as its main tool. PRA is a set of tools which helps for interacting with local villagers, and which finally leads to a better understanding about the stakeholders and the issue which the researcher is looking at. At one level PRA enabled us to understand and then triangulate to fill up gaps in the empirical data, or resolve questions about some odd features and flow patterns in the observational record. But at a deeper level the PRA techniques allowed us to see how an observed record of flow related to the people's understanding of the natural resource. A major question for us was what role this flow records could have in integrated watershed management (IWM).

1.4 Deforestation in Ethiopia

Historical information on the land cover/use changes in Ethiopia is quite limited. There are a few land-use and land-cover change studies conducted in different parts of the country[15].As

[12] UNDP, Cap-Net, 2005A
[13] Global Water News, Editorial, No. 8
[14] Barbara Tapela, Stakeholder participation in the transboundary management of the Pungwe river basin, 2006, page 10
[15] Solomon Abebe, Land-Use and Land-cover change in headstream of Abbay Watershed, Blue Nile Basin, Ethiopia, 2005.

result of this finding precise data on the forest change of Ethiopia might be difficult for one to acquire. Apart from looking at the existing maps and satellite image of the area, this study uses different literature and community knowledge to come up with the most probable land use/cover figures. This helped us for looking at the effect of land use/cover change on the hydrological regime of the study area.

The late 1980 and 1990 researches concluded that most of Ethiopia had gone through a high rate of deforestation, which dragged down the forest cover of the country from 36% to 4%[16]. Most observers agreed that at one time in the past high forest cover was 36%, and a total of 66 percent was covered by high forest and savannah woodlands[17]. In the early 1950s, high forests covered 16 % of the land[18] . By the early 1980s it had dropped to 3.6 percent and 2.7 % by 1989 (MWRE, 2006). By 2001 FAO reported 4.2% forest coverage of the country.

The Figure below is the historical forest coverage of Ethiopia which is first made by Reusing, Matthias (2001) and it is updated to existing current conditions by taking into account the June, 2010 Ethiopian Agricultural Ministry Announcement.[19] This announcement is still controversial to many forest scholars in Ethiopia. Some believe the announcement overstate the existing figures just to show that the country's natural resource management programs are on the right path. Other believes the country achieved a good afforestation process over the last decade, though they consider the total forest cover increment to 9% may still be too high. This controversy will come to an end when one comes up with latest land use/cover analysis for the country in general, which no one has yet done.

[16] EFAP, Ethiopian Forestry Action Program, 1994
[17] EFAP, Ethiopian Forestry Action Program, 1994
[18] EFAP, Ethiopian Forestry Action Program, 1994
[19] http://www.arabtimesonline.com/NewsDetails/tabid/96/smid/414/ArticleID/156893/reftab/149/t/Ethiopia-s-forest-cover-triples/Default.aspx, accessed 18 July 2010.

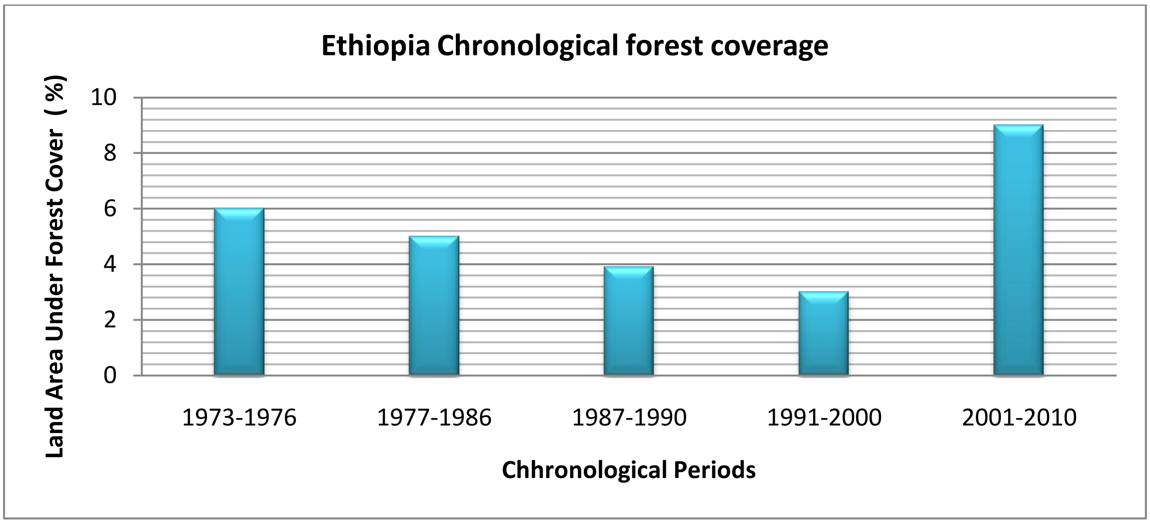


Figure 2. The historical trend of the percentage of forest covers of Ethiopia from 1973 – 2010[20]

The south western part of Ethiopia, the study area, is an area where comparatively less deforestation has been taken place. WBISPP (2002) report considered this part of the region as one of the few places of Ethiopia which is still comparatively forested. By having 25.5% forest cover out of the total area, it greatly surpasses the country's average forest cover. However the local rural development office experts of the study area argue that the region has an annual rate of deforestation of 2.6%, which is the highest in all Oromia Regional states. These experts fear that if the forest loss continues, there will not be that much forest left in a few decades[21]. Right now the average household land holding for agricultural purposes is 4 hactares and 0.76 ha per capita[22].

The main priority forest areas found in the study area are Belete Gera, Sigmo and Babya forests which are registered in the World database of protected areas[23]. Yayu forest, which is named as one of UNESCO biosphere reserve in July, 2010 is partly found in this part of the study area. Yayu forest is one of the last remaining Montane rainforest fragments with wild Coffee Arabica populations in the world[24].

[20] First made by Reusing and Matthias (2001) and it is updated to existing current conditions by taking into account the June, 2010 Ethiopian Agricultural Ministry Announcement
[21] Yukio Cheng, Journal of Forest Research: Deforestation and degradation of natural resources in Ethiopia: Forest management implications from a case study in the Belete - Gera Forest, 1998.
[22] MWRE, main report 2006
[23] http://www.wdpa.org (Accessed on July, 2010)
[24] http://portal.unesco.org/science/fr/ev.php-URL_ID=8884&URL_DO=DO_TOPIC&URL_SECTION=201.html (Accessed on July, 2010)

1.5 Objective of the study

Relating Stream flow, Rainfall and Land use/cover trends and understanding the community's knowledge on changes in the natural resources of the Didessa sub-basin of the Blue Nile River is the main areas which this study dealt with. As a sub-basin study 8 different catchments were selected for analysis. For each of these catchments 15 to 27 years of daily stream flow and rainfall data has been gathered from the Ethiopian Ministry of Water Resources (EMWR). In addition this study gave some insight about the land/use land cover changes of the study area from the perspective of the local community and previous studies.

The three basic objectives of this study are:

- To define the Didessa sub-basin river flow trends and variation over a period of deforestation.
- To comprehend the local peoples understanding of the hydro-meteorological and land use/cover chronological changes in the Didessa Sub-basin
- To see the potential for combining sources of knowledge in Integrated Watershed Management.

Therefore the research question can be defined as ‘‘How have the Didessa Sub – basin river flow dynamics changed during a period of deforestation, and to what extent does this correspond to the community's perception of changes in the natural resources?’’.

2 Research Design and Methodology

2.1 The study area

2.1.1 The Blue Nile

The Blue Nile and its tributaries all rise on the Ethiopian Plateau at an elevation of 2,000 to 3,000 meters.[25] The Blue Nile starts at Lake Tana in the Northwestern Ethiopian highlands. After leaving Lake Tana it passes through deep Ethiopian gorges and valleys for about 1609km before entering Sudan. The Blue Nile basin encompasses 14 main sub-basins with a total area of 176,650km^2. Its catchment accounts for about 20% of Ethiopian land surface. Out of the 14 sub-basins; the Didessa sub basin, which is the study area, is located in the southern most part of the Blue Nile basin.

2.1.2 Didessa Sub - Basin

Contributing roughly a quarter of the total flow of the Blue Nile as measured at the Sudan border, the Didessa River is the largest tributary of the Blue Nile in terms of volume of water[26]. It rises at Mt. Vennio and Mt. Wache ranges which are located in the South Western part of Ethiopia. Having a vast number of small and large tributaries the Didessa sub-basin drainage area is nearly 25 800km^2.[27] The drainage area touches the three administrative zones of Oromia regional state of Ethiopia: Ji mma Zones in the most upper and middle part, Illibabur Zone in the middle part and East/West Wellega in the lower part down to its confluence to the Blue Nile River.Yebu, Urgessa, Temssa, Dabana, Indris, Anger and Tato rivers are some of the dozen tributaries of the Didessa River system.

The Didessa sub-basin is geographically located between 36^0 02' and 36^0 46' East longitude, and between 7^0 43' and 8^0 13' North latitude. The mean annual rainfall in the study area ranges between 1509 mm in the southern to 2322 mm in the northern catchments. The majority of the area is characterized by a humid tropical climate with heavy rainfall and most of the total annual rainfall is received during one rainy season called kiremt. The maximum and minimum temperature varies between 21.1 – 36.5^{0}c and 7.9 -16.8^{0}c, respectively. The altitude ranges between 1720m and 2088m above sea level (excluding some top hills and mountains which can go more than 3500m above sea level).

[25] UNEP/DEWA/GRID-Geneva, Water sharing in the Nile River Valley, 1999-2000, page 21
[26] The Climate and Hydrology of the Upper Blue Nile River, Declan Conway, 1999, page 56
[27] Hydrology of the Nile Basin, Volume – 2, Mamdouh Shahin, page 42

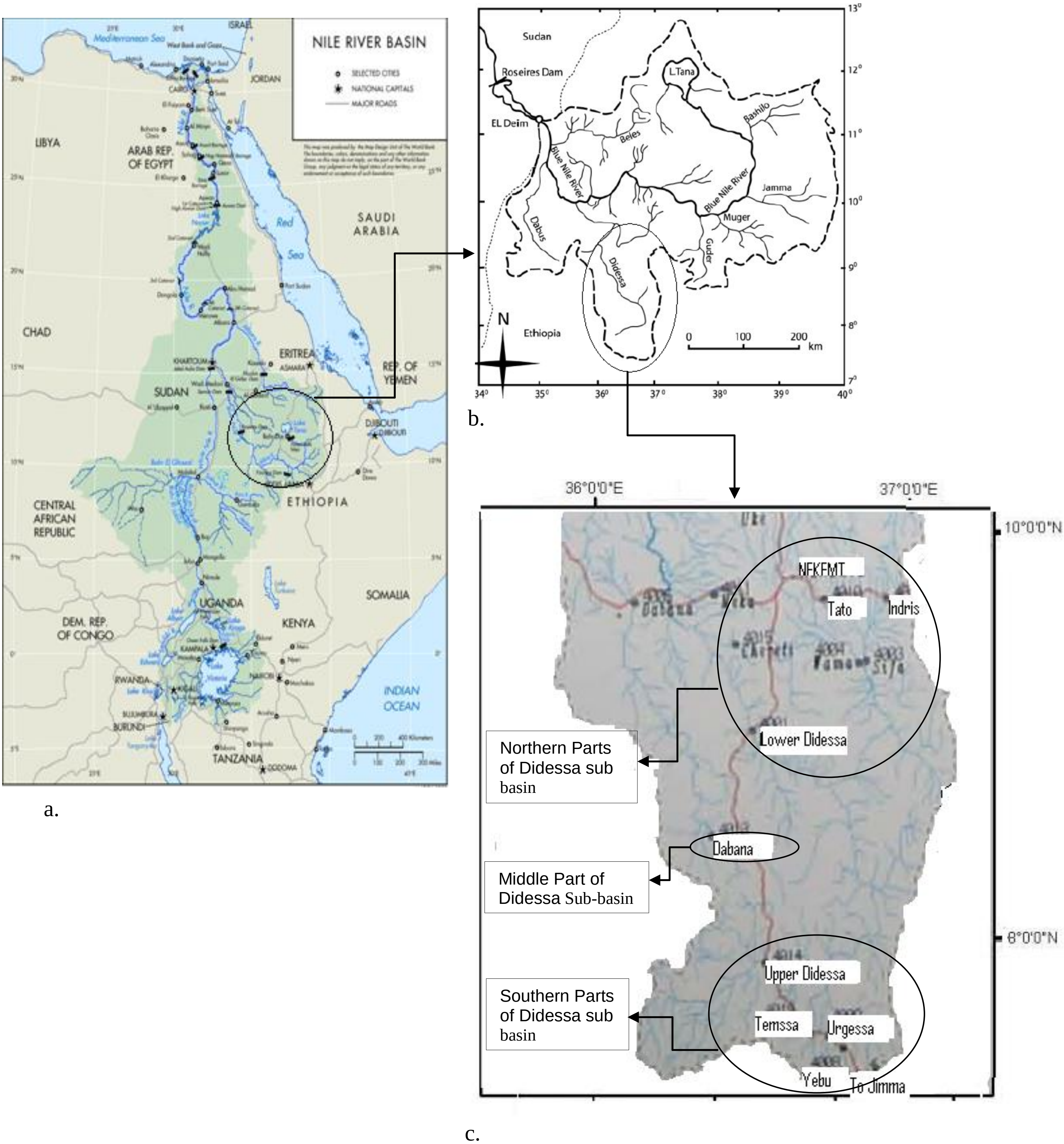


Fig 3. (a) Nile River Basin drainage System, (b) Blue Nile River Basin drainage system and (c) Didessa Sub-basin drainage system and hydrological gauging stations network.

Below, the forest cover of the Southern, Northern and Middle part of the Didessa sub-basin are classified and discussed.

2.1.3 The southern part of the Sub-basin

(Yebu, Urgessa and Upper Didessa)

Though it is still highly forested compare to the middle and northern catchments, this part of the study area suffered (especially in 1980s and 1990s) a high pressure due to expansion of agriculture with only shade trees for coffee being left after conversion to agriculture. Having Belete Gera forest on the left and Babye Fola forest on the right bank of Didessa River, this part of the catchment provides a very good amount of coffee beans to the central market that will be traded mostly for foreign exchange earnings. In the table below we can see that 17% of the forest land has been converted to cultivated land (Source WBISPP, 2002)

Table 1. Land Use/Cover of the forest Priority areas on the Southern Catchments (Source WBSISPP, 2002)

Forest name	Total area (km^2)	Natural Forest (km^2)	Wood land (km^2)	Cultivated Land (km^2)
Babiya Fola	25,000	18,169	2,723	4,392
Gera	113,360	93,774	-	19,586
Total	138,360	111943	2723	23,978
% cover	**100**	**80**	**2**	**17.3**

2.1.4 Middle part of the Sub-basin

(Dabana Buno, Part of Lower Didessa)

This part of the study area is also covered with broadleaved high forest of Sigmo, Limu Seka, Didessa weredas (provinces). On the middle-west bank of Didessa river Yayu forest takes its little share of the catchment, but its majority part tends to the Baro Akobo sub basin which is a major tributary of the White Nile. According to WBSISPP report, 18% of Sigmo forest (70,672ha) has been converted to cultivated land in the last 30 years[28].

2.1.5 The northern part of the sub-basin

(Tato, Lower Didessa, Indris Sire)

Except the Komto forest, the northern part of the Didessa sub basin which is mainly located on Illibabur and East welega Zones of Oromia Regional State are intensively cultivated and have been going through a high rate of deforestation for the last half a century. However in

[28] Woody Biomass Inventory and Strategic Planning Project (WBISPP), Ethiopia, 2001

the eastern part of the northern part of the study area we can find lowland wood lands of Borecha, Limu Seka and Gechin weredas (provinces).

2.1.6 Land use/cover change

Due to the vastness of the total study area and shortage of time, the study doesn't include empirical land use/cover change analysis. Most of the land use/cover data used on this study was obtained from the community knowledge and site visits. However different non-digitalized Blue Nile maps, which were obtained from the reconnaissance study of the Geographical Information System department of the EMWR, also helped to characterize the changes in the land use/cover of the study area.

2.2 Rainfall and Runoff

For each of these catchments 15 to 27 years daily stream flow data has been gathered from the Ethiopian ministry of water resources (EMWR). To see the general hydrological flow trends the daily flow data has been converted to monthly and annual data. From the monthly flow data the total, peak and Base Flow was identified. To define the dry season flow and base flow, Base Flow Indices (BFI) have been developed. By using Microsoft excel and JMP software package program, rainfall and runoff trends and changes were drawn for the years between 1980 to 2004.

Using the rainfall data which was obtained from the National Meteorological Agency of Ethiopia (NMAE) the runoff coefficient of each catchment was developed. The runoff coefficient helped to see the relation of precipitation and/or stream flow with the catchment's land use characteristics. For understanding the variation or dispersion in a given set of rainfall and runoff variables, Coefficient of Variation which is the ratio of the standard deviation to the mean was calculated. For future possible water resource management and to define Base Flow in relation to the total discharge, Base Flow Index (BFI) was also calculated for each catchment. The BFI is defined as the total annual runoff divided by the runoff of the driest month.

Before working on the stream flow and rainfall data, high or low monthly values were checked against the records of the nearest month that occurred at the same year. Correlation and regression analysis is used for filling up few missing daily data and extending shorter length records of some catchments which have fair and satisfactory correlation coefficients with neighboring catchment rainfall and runoff patterns.[29] After working on the long term temporal trends of rainfall, runoff and runoff coefficient, the dry Season flow, wet season flow and BFI of each catchment were analyzed.

For looking at periodic differences and short term deviations in annual stream and rainfall patterns, the long term data were divided into periods one and two. Since the number of available data for each catchment differs from one another, periods one and two of each catchment do not necessarily reflect the same length and period of time. Below Table 2 shows listed Hydrological Gauging stations and available data and the time period used for the Didessa sub-basin.

Table 2. List of Selected Hydrological Gauging Stations and available data.

Station Name	Latitude		Longitude		Catchment Area (km^2)	Available Data	
	Deg	Min	Deg	Min		Period 1	Period 2
Yebu	07	48	36	42	47	1980-1991	1992-2004
Urgessa	07	50	36	39	19	1980-1991	1992-2004
Temssa	07	51	36	35	47.5	1989-1996	1997-2004
Upper Didessa	08	03	36	27	1806	1980-1992	1993-2005
Dabana (Buno-Bedele)	08	24	36	17	47	1984-1993	1994-2005
Lower Didessa	08	41	36	25	9981	1979-1991	1992-2004
Indris-Srie	08	56	36	57	49	1987-1995	1996-2004
Tato	08	56	36	45	42	1996-2006	

2.3 Stakeholder Perception

A field visit was undertaken in the three selected catchments which are Temssa, Dabana and Tato. Three different Participatory Rural Appraisal (PRA) techniques were used for interacting with the rural peoples who are living and working in and around the selected catchments. Participatory Rural Appraisal (PRA) is a bag of tools which greatly helps in interacting with local villagers, understanding and acquiring knowledge from them. PRA involves various principles, a process of communication and a menu of methods for seeking

[29] Abebe Sine and Semu Ayalew, Hydrological homogeneity of Blue Nile, Addis Ababa University , 2003

villagers' participation in putting forward their points of view about any issue and enabling them to do their own analysis with a view to making use of such learning[30].The term PRA is originally developed out of another participatory approach called RRA in the 1980s.

Empowerment, respect, localization, enjoyment and inclusiveness are the basic principles and concepts of PRA.

- **Empowerment:**
  Through the process of sharing their local knowledge to the outsider and among themselves, PRA builds or reinforces the local people's confidence. Finally the people understand that their knowledge regarding issues related to the area they are living in is of highest importance for any research or development process.
- **Respect:**
  All process in the PRA transforms the researcher into learner and listener. The researcher should respect the locals' culture and knowledge and should break down the usual norm of acquiring knowledge.
- **Localization:**
  For avoiding a feel of externally driven research, PRA uses local resources and locally made materials for all its activities.
- **Enjoyment:**
  PRA should be enjoyable for all participants. To do so, the researcher should take an advance preparation before starting to deal with the PRA tools and methods.
- **Inclusiveness:**
  One of the best parts of PRA is that it tries to encompass all the people that directly or indirectly are affected by the chosen issue. This creates a chance for the marginalized to be heard. Usually the marginalized are poor peoples, women, illiterates, disabled etc.

Out of a dozen PRA methods, focus group discussions, key informant interview and Time line were used.

[30] Neela Mukherjee, Participatory Rural Appraisal Methodology and Applications, 2003(Page 30-31)

2.3.1 Focus group discussions

Focus Group discussion is a structured participatory group process usually applicable for exploring attitudes and feelings and to draw out precise issues on a specific topic or programme of interest. Focus groups are composed of interactive individuals having some common interest or characteristics, all representing a particular segment of a certain given population. The advantage of this qualitative research method is that participants interact and give their view in a group which they can build upon each other's views. Its flexible format allowed exploring unanticipated issues and it highly encourages interaction among participants. Usually the focus group discussion consists of 6 individuals in one focus group, however in this study because of the unavailability of some interest groups, 4 people in each focus group were used. Having irrigated or rain fed farmland, wealth and amount of total tree possession in the farmland was the main areas which were used for selecting the groups.

Figure 4. Focus group discussion at Tato.

2.3.2 Key informant interview

Key informant interview was used as a major instrument to gather very important Information/Knowledge which I could not manage to acquire from the group interview and Focus group discussion. Key informant interview helps to gather different perspectives and categories (groups, positions, functions with respect to project activities), which may provide the needed information on a given issue or subject[31].

[31] Anders Rudqvist, Field Work Methods, 1991

Even if the peoples in the study area possess more or less the same culture, language and ethnic group, their land management systems and concern and know how about the dynamics of the natural system in their living environment is different from place to place. Hence Key informants were selected from the two ends of three catchments, upstream and downstream. The selection process was mainly done with help of the Woreda rural development office and the development agents who are living and working in the farmers' community.

Figure 5.Discussion with Key Informants

2.3.3 Timeline

Timeline is one of non-popular PRA methods which helps in describing changes in land cover/use, changes in cropping patterns, chronologies of events relevant to local life[32]. In this study Timeline was applied for co-relating the empirical patterns and trends of rainfall and stream flow data with the community knowledge. In addition Timeline was used for looking at the farmers' insight on changes in land use/cover during different periods in the past.

Figure 6. Farmers drawing their Timeline graph.

[32] Ruggeri Laderchi, Participatory Methods in the Analysis of Poverty, 2001

2.3.4 Observation

Since direct observation[33] can be made at different parts and levels of the field work, it was an integral part of the entire study.

2.4 Ethical Considerations

2.4.1 Informed Consent

Before starting any kind of interventions, having the informed consent of the indigenous people who were the major actors in the process, was the first priority. It is believed that this is one of the people's broader individual and group rights; it is not usually applicable in most previous research interventions though.

Achieving active participation from all the indigenous peoples and making them the main actor of the study needs prior informing of the purpose and importance of the study for all who were participating in any of Participatory Rural Appraisal (PRA) techniques. I hope this lets the villagers to have a sense of ownership and make them active participants for every discussed issue.

2.4.2 Demand concerning Privacy

The concept of privacy is complex. What is public and what is private is rarely clear-cut.[34]In all interactions giving a mandate for all actors starting from a single farmer to the government office experts to decide themselves on anonymously reflecting on some issues which they believe sensitive was done. However; since this study doesn't rely on information that seems sensitive to individuals and any party in some way, there wasn't any respondent who claimed for his thought to be kept anonymous.

[33] Participant observation was made while having lunch and drinks with the farmers and development agents.

[34] Martyn and Paul, Ethnography, 2000

3 Results

3.1 Long term total Rainfall and Stream Flow patterns

Table 3 below shows the long term (1979-2006) temporal annual rainfall and runoff rate of change and coefficient of variation of the different catchments of the Didessa sub-basin. The total number of years of the data used for the analysis depends on the data availability for each catchment. In order to see the trends of rainfall and runoff relations, **runoff coefficient** which is a percentage ratio of runoff to rainfall has been employed. To understand the variability of the annual rainfall and runoff values, **Coefficient of Variation** which is the ratio of the standard deviation to the mean of annual rainfall and runoff records was calculated.

Table 3.Characterstic of annual rainfall and stream flow of the Didessa Sub-basin Catchments

		Average Annual rate Inc/dec Value (mm/yr)	Annual Average (mm)	Coefficient of Variation (CV) (%)	
Urgessa	Rainfall	7.5	1510	13.8	**Southern Part** **NB 1: All catchments except Temssa showed an increasing Trend of rainfall and runoff Pattern.** **NB 2: Temssa runoff decreased was judged to be not plausible - though no explanation or error could be found.** **NB 3: Yebu's average Annual Runoff appeared to be relatively very low**
	Runoff	19.7	1274	33.6	
	RC (C)	0.7%	61%	24	
Yebu	Rainfall	3.7	1509	13.5	
	Runoff	11.5	110	38.0	
	RC (C)	0.1%	7%	35	
Temssa	Rainfall	– 14.8	1531	12.8	
	Runoff	– 52.5	839	45.0	
	RC (C)	– 2.8%	54%	47	
U_ Didessa	Rainfall	9.4	2095	26.0	
	Runoff	13.0	635	32.0	
	RC (C)	0.7%	31%	34	
Dabana	Rainfall	17.6	1773	18.7	**Middle Part** **NB – Increasing Runoff and Rainfall Pattern.**
	Runoff	3.3	774	27.7	
	RC (C)	17.5%	44%	19	
Lower_Didessa	Rainfall	– 1.5	1829	15.6	**Northern Part** **NB – All showed Decreasing Rainfall and Runoff Pattern.**
	Runoff	– 1.8	485.1	26.6	
	RC (C)	– 12.2%	18%	20	
Tato	Rainfall	– 14.5	2094	11.4	
	Runoff	– 22.7	562	39.5	
	RC (C)	– 3.5%	27%	10	
Indris	Rainfall	– 4.3	1817	13.1	
	Runoff	– 40,5	764	37.6	
	RC (C)	– 2.0%	43%	39	

In the Southern part of the sub-basin (Yebu, Urgessa, Temssa and Upper Didessa) all the catchments except Temssa revealed an increase in their stream flow and rainfall pattern. While the rainfall amount of Urgessa, Yebu and Upper Didessa rainfall increased by annual average of 11 mm, their runoff amount increases 20 mm, 11.5 mm and 13 mm respectively. The runoff coefficient of all the southern catchments are also increases by average value of 0.5%. By looking at an extreme decrement starting from 1995, it may feel reasonable to think whether there is an error in the Temssa stream flow records or there has been some water holding embankment construction made in the upper side of the gauging station. The effort to come up with a possible reason for the extremely odd Temssa's stream flow pattern only resulted in discarding these possible explanations.

On the other hand the catchments which are located on the northern part of the sub-basin (Tato, Indris and Lower Didessa) all revealed a downward annual total stream flow pattern with an annual decreasing value of 22.7 mm, 40.6 mm, and 1.9 mm at Tato, Indris and Lower Didessa respectively. In addition the rainfall of Tato and Indris showed annually decreasing values of 14.5 mm and 4.3 mm respectively. The Lower Didessa annual rainfall pattern shows an insignificant increment of 1.5 mm. The annual runoff coefficient values of all the northern catchments showed a decreasing pattern of 12.2%, 3.5% and 2% at Lower Didessa, Tato and Indris correspondingly.

Dabana which is located on the middle part of the Didessa sub-basin possesses an increasing rate of annual rainfall and runoff values of 17.6 mm and 3.3 mm respectively. At the same time its runoff coefficient has an annual rate of increase of 17.5% which is the biggest of all the catchments.

3.2 Long term total Rainfall and Stream Flow Variability

The annual variability which is defined by Coefficient of Variation (CV) is higher for runoff than rainfall at all catchments. The CV for Urgessa, Yebu and upper Didessa rainfall pattern revealed 13.8%, 13.8%, and 26% respectively. However the variations in runoff amount of these three catchments are 33%, 38%, and 32% correspondingly. This shows the total annual runoff is more variable than rainfall. The runoff coefficient of all southern catchments didn't show a trend in their value.

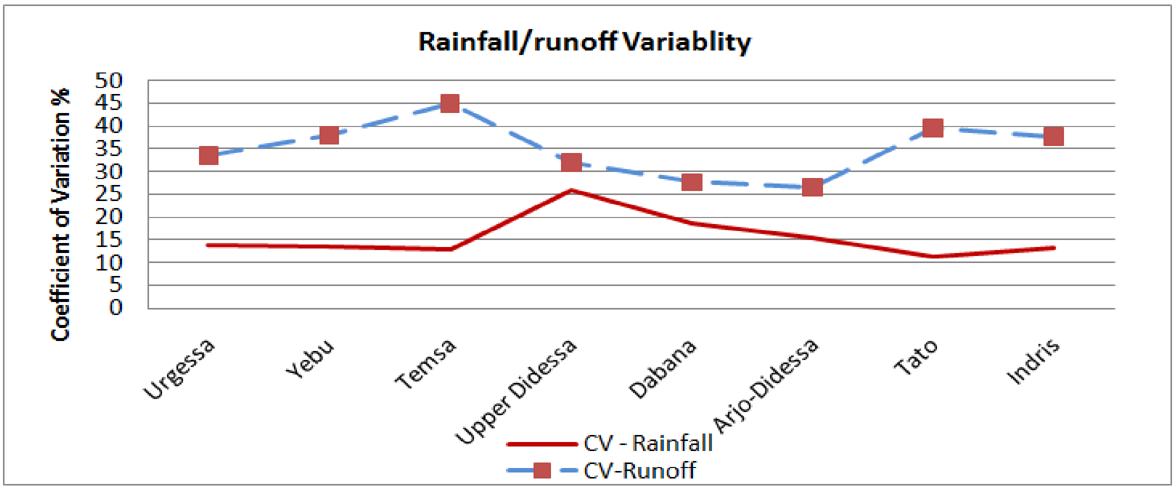


Figure 7.Variablity of Mean Annual Rainfall and Runoff of Didessa sub-basin Catchments.

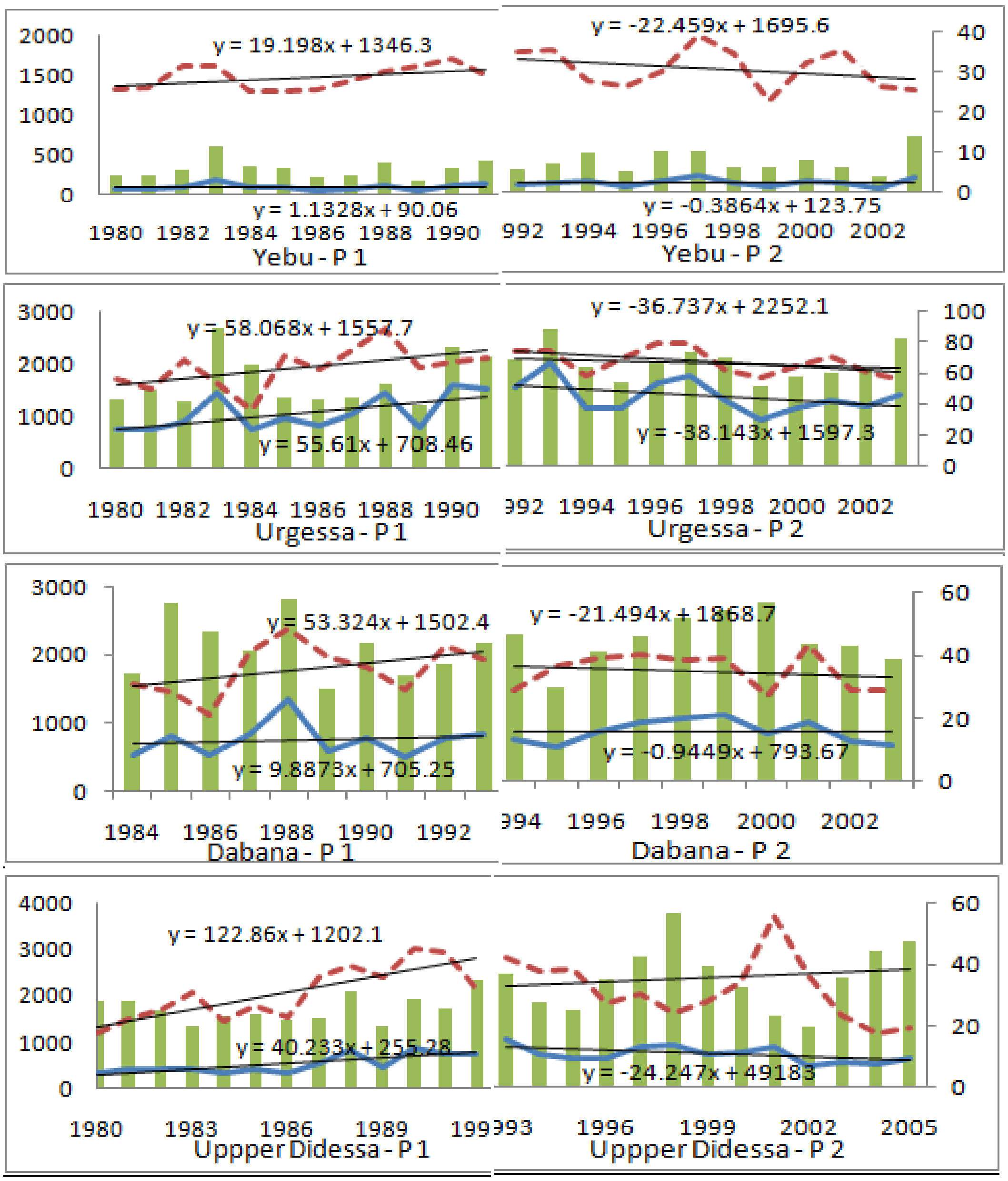
As it has been seen in the Southern Catchments, the northern catchments (Tato, Indris, and Urgessa) also showed a greater annual variability of runoff than rainfall. The rainfall CV value of Tato, Indris and Lower Didessa appeared to have a value of 11.4%, 13.1% and 15.6% respectively. However the runoff CV of Tato, Indris and Lower Didessa 39.5%, 37.6% and 26.6% correspondingly. Dabana appeared to have a CV value of 18.7% for rainfall and 27.7% for runoff.

3.3 Period One and Two rainfall and stream flow trends.

The annual total rainfall and stream flow dynamics are shown in figures 8. For each catchment, excluding Tato and Temssa, the total data series has been classified into two periods with equal number of years. In Tato and Temssa the data records were too short to calculate trends for two periods. For further studies on theses catchments, more advanced hydrological models of forecasting and estimating, which encompass different parameters, should be developed.

3.3.1 Southern Catchments (Yebu, Urgessa and Upper Didessa) trends in annual rainfall, runoff and runoff coefficient Values

In the first period of the data series three of the southern catchments; Yebu, Urgessa, and Upper Didessa, recorded an increasing runoff and rainfall trend. However these catchments appeared to have a significant annual rate of rainfall and runoff decrement in period two. The annual rainfall and runoff rate of change of period one of Yebu stands at an increasing trend of 1.3 mm and 19 mm respectively, it didn’t show any trend in its runoff coefficient value though. Urgessa possessed an increasing annual rainfall and runoff trending value of 58 mm and 56 mm at period one but it turned up to have a decreasing rate of change of 36 mm and 38 mm at period two correspondingly. However its runoff coefficient doesn't show any trend in either period. Like the above mentioned it's two other neighbors, at period one ,Upper didessa also revealed an increasing annual rainfall and runoff rate of change of 122 mm and 40 mm respectively. At period two Upper Didessa also appeared to have a decreasing annual rate of change of rainfall and runoff value of 77 mm and 24 mm.



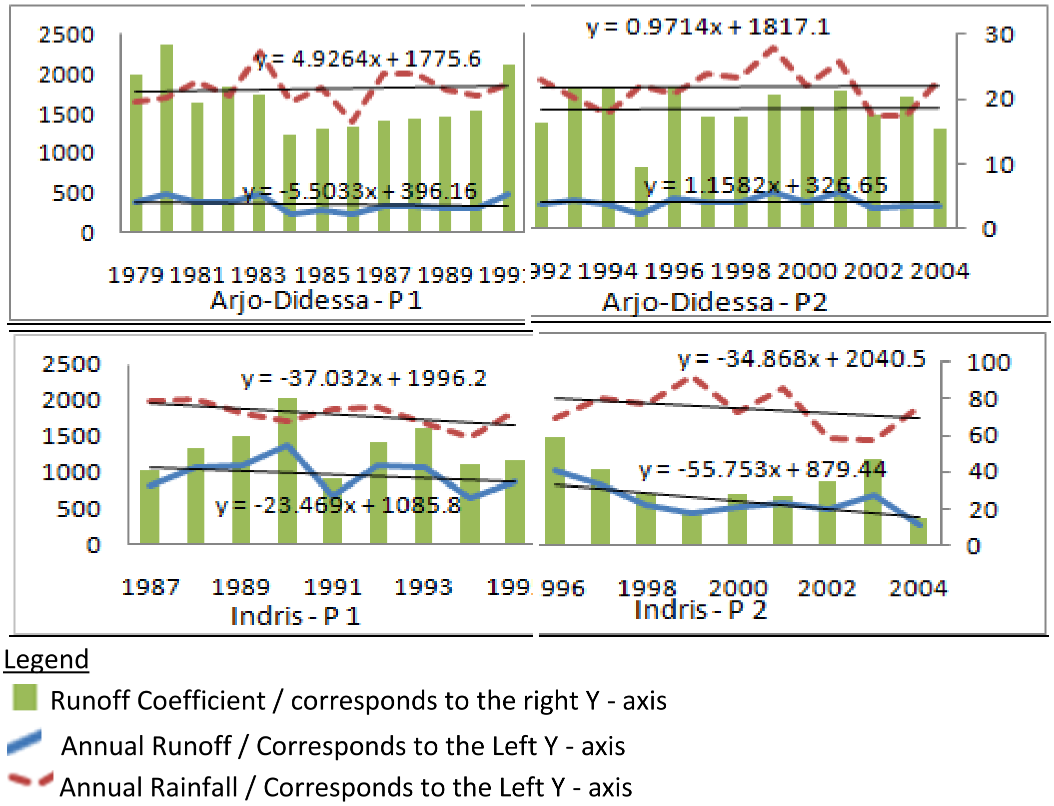


Figure 8. Period one and two time series plot for annual rainfall, stream flow and runoff coefficient of the Didessa sub-basin catchments.

3.3.2 Northern Catchments (Indris and Lower Didessa) trends in annual rainfall, runoff and runoff coefficient Values

Contrary to the Southern Catchments, at both period one and two, Indris revealed a decreasing trend of annual runoff and rainfall rate of change. Nevertheless, while Indris Shows decreasing trend of rainfall and runoff values at both periods, Lower Didessa appeared to have an almost constant rate of change of rainfall and runoff. When we see the real figures, at period one, Indris rainfall and runoff noticeably decreased annually by 37 mm and 23 mm respectively, while runoff coefficient doesn't show any trend. In period two Indris also showed an annual decreasing rainfall and runoff trending value of 34 mm and 55 mm respectively, while runoff coefficient revealed an annual decreasing pattern of 2.3 mm. During period one, Lower Didessa revealed an almost comparatively constant annual rate of change of rainfall and runoff value of 4.9 and 5.5 mm respectively. During period 2 while rainfall has an annual increasing value of 0.97 mm, runoff increases by 1.2 mm.

At Dabana catchment which is found in the middle part of the Didessa sub-basin, runoff increased 11 mm annually and rainfall increased 53 mm per year; nevertheless, runoff coefficient showed an annual decreasing value of 1 mm which can possibly be considered as a constant pattern.

Table 4. Annual Variation (AV), Annual rate of change (ARC) and Average Runoff (AR) for Didessa Sub-basin catchments.

Period (Urgessa)		June-October (Wet Season)	February (Driest Month)	August (Wettest Month)	Nov-May (Dry Season)
1980-2005	AV (%)	8.5	24.4	4.6	22.3
	ARC (mm)	11.1	0.8	2.9	6.4
	AR (mm)	220.5	27	250.1	38.7
1980-1992	AV (%)	18.5	49.5	7.7	69.2
	ARC (mm)	35.4	2	6.6	19.7
	AR (mm)	203	21.9	223	186.8
1993-2005	AV (%)	34.2	49.5	20.8	44
	ARC (mm)	– 15.7	1.8	-20.1	-13.5
	AR (mm)	241.5	32.1	270.8	46.3
Yebu					
1980-2002	AV (%)	17.8	0.1	11	0.1
	ARC (mm)	1.5	– 0.01	0.4	– 0.06
	AR (mm)	20.7	2.9	17.7	3.4
1980-1991	AV (%)	0.1	1.9	0	1.9
	ARC (mm)	0.5	0.6	-	0.43
	AR (mm)	15.2	2.7	17.8	3.2
1992-2003	AV (%)	6.1	6.3	2.4	20.8
	ARC (mm)	1.8	– 0.25	0.4	– 2.2
	AR (mm)	19.7	3.1	23	3.7
Upper Didessa					
1980-2005	AV (%)	33	2.7	19.6	11.6
	ARC (mm)	14	-0.17	4.2	0.93
	AR (mm)	108	7.2	154.6	13.6
1980-1992	AV (%)	55.4	1.7	47.6	3.1
	ARC (mm)	37.8	-1	16.5	-1.4
	AR (mm)	88.5	9.5	128.9	13.7
1992-2005	AV (%)	23.8	16.1	31.2	40.3
	ARC (mm)	-16	-0.34	-6.1	-8
	AR (mm)	123.4	5.3	172.3	10
Lower Didessa					
1979-2003	AV (%)	1.7	11	0.4	1.2
	ARC (mm)	– 1.2	- 0.06	-0.23	18.2
	AR (mm)	69.7	2.6	93.4	6
1979-1991	AV (%)	0	1.2	0.2	37
	ARC (mm)	– 0.33	-0.03	-0.4	0
	AR (mm)	72.2	2.3	92.5	5.8
1992-2003	AV (%)	0	38.4	3.1	16.2
	ARC (mm)	– 0.11	0.26	0.83	1.41
	AR (mm)	67.2	2.9	94.3	6.1

Indris					
1987-2004	AV (%)	56.7	3.2	29.5	0.5
	ARC (mm)	– 34	0.2	-9	0.5
	AR (mm)	150.7	9.9	182.6	17.3
1987-1995	AV (%)	19	19.4	17	24.8
	ARC (mm)	– 36	0.8	14	9.2
	AR (mm)	201.4	8.7	251	16.7
1996-2004	AV (%)	44	0.2	6.4	30.5
	ARC (mm)	– 39	0.1	-4	-8
	AR (mm)	108.1	11.8	130.5	18.4
Dabana		June-October (Wet Season)	February (Driest Month)	Sep/Aug.(Wettest Month)	Nov - May (Dry Season)
1984-2003	AV (%)	0.2	2.3	(Sep) 57	13.2
	ARC (mm)	2	0.1	-2	2.4
	AR (mm)	160	4	194.2	11.2
1984-1993	AV (%)	0	34.7	(Sep) 1.5	41
	ARC (mm)	2.2	0.7	-2.6	7.6
	AR (mm)	160	4.3	204	9.8
1994-2003	AV (%)	0	29.7	(Aug) 19.6	0
	ARC (mm)	– 1.4	0.2	-3.3	0.4
	AR (mm)	159.7	3.7	195.2	12.5

3.4 Changes in stream flow at the Dry and wet Season

The study area has three seasons which are the dry season, Bega (Oct-Jan); the little rain season, Belg (Feb-May) and the heavy rain season, Kiremt (June – Sep).However to make the analysis straightforward and to easily see the significant changes, two seasons which are Wet and Dry has been used in this study. Hence according to the total amount of rainfall, dry season stands for all months between November and May and the Wet season refers to June to October. In addition the long term average monthly stream flow is lowest in February and highest in August.

Looking at the seasonal variation of the stream flow may help us to understand the basin characteristics for future possible watershed management and flood controlling measures of the Didessa sub-basin. In addition to this the Base Flow Index adds another perspective to the hydrological cycle of the study area. All selected catchments, excluding Indris, possess the same range of seasonal stream flow. Indris starts and end its dry season at the same as other catchments; but its wet season starts one month later than the others. Below both the dry and wet season flow are explained separately.

3.4.1 Dry Season Flow

For all catchments as a result of the low amount of precipitation, the dry season stream flow lies in between November and May. February is the driest season in all cases, but Upper Didessa revealed its lowest flow in January. Unlike the annual stream flow, the dry season flow of the Didessa sub-basin catchments all showed an increasing or constant trend for the total observed data periods. However when we classify the total period in to two periods, all except Lower Didessa and Dabana revealed a decreasing trend at period two.

As shown in table 4, the Southern catchments Yebu, Urgessa and Upper Didessa, at period two, showed a decreasing annual dry season stream flow pattern at a rate of 2.2 mm, 17.45 mm and 8 mm respectively. Indris had a 9.2 mm increasing dry season annual stream flow trend at period one; nevertheless, it turned to have a decreasing trend of 8 mm at period two. However Lower Didessa appeared to have a constant annual dry season rate of change at period one but it showed a slight increasing trend by an annual value of 1.41 at period two. The most noticeable changes have been observsed at Urgessa with annual dry season stream flow that has an increasing trend of 19.7 mm in period one to a 17.45 mm annual decreasing trend in period two. From having an annual dry season increasing trend at a value of 7.6 mm at period one, Dabana showed an almost constant trend value of 0.4 mm at period two.

In general the southern catchments Yebu, Urgessa and Upper Didessa dry season flow responded with the same pattern as the total annual stream flow.

3.4.2 Base Flow Analysis (BFA)

Base flow is an important component of stream flow, which comes from groundwater storage or other delayed sources (shallow subsurface storage, lakes, etc).[35] In the study area, farmers use base flows for irrigating supplementary crops and daily livelihood water needs. Therefore, understanding the base flow characteristics is an important part of any hydrological study.

Since the annual precipitation and total flow has a strong influence on dry season flow, the amount of dry season stream flow was normalized to the total annual flow by calculating a Base Flow Index. This facilitated a comparison of the catchments intrinsic ability to transform a given amount of rainy season precipitation into dry season flow. The basic

[35] Smakhtin, V *Journal of Hydrology, vol. 240, issue 3-4*

assumption in BFA is that the dry season monthly minimum stream flow is equal to the base flow.[36] The base flow index (BFI), is then a non-dimensional ratio defined as the volume of base flow divided by the volume of total annual flow.[37]

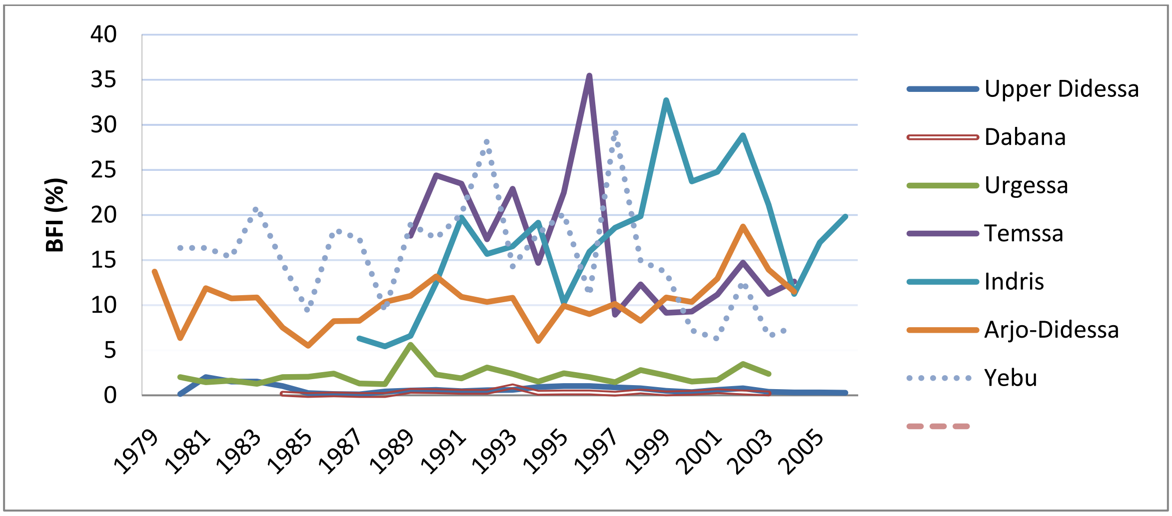


Figure 9. Long term trends in annual Base Flow Indices of Didessa Sub-basin catchments.

The Figure above shows the long term temporal trend of the Base Flow Indices (BFI) of Didessa Sub-basin catchment. For most catchments the annual Base flow index doesn't revealed a noticeable temporal trend. However compared to the total stream flow the annual variability of the base flow is very high for almost all catchments. In table 5 we can see that Upper Didessa and Dabana record an annual coefficient of variation of 70.0 and 70.7 percent respectively, which can be considered as significantly variable. Yebu, Temssa and Indris showed very high Base flow Index values. On the other hand Upper Didessa and Dabana recorded a comparative very low base flow index values.

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[36] P.J.Wood, in stream mesohabitat biodiversity in three groundwater streams under base, flow conditions, 1999.

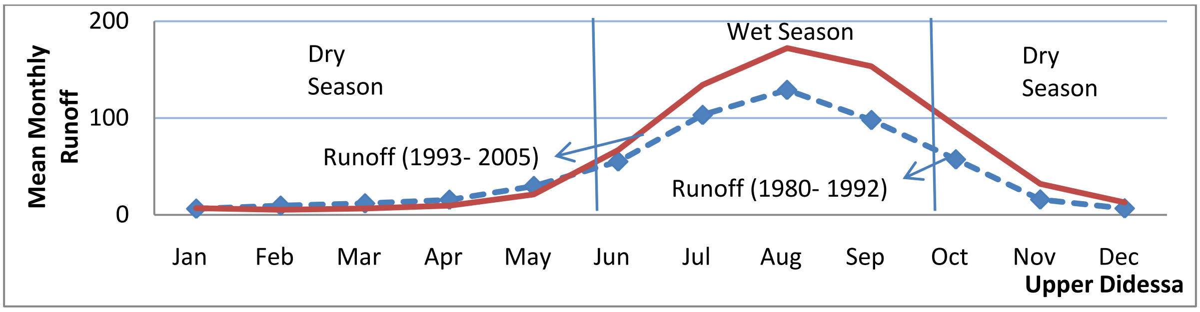
[37] Smakhtin, V *Journal of Hydrology, vol. 240, issue 3-4, pp. 147-186*

Table 5. Characteristics and changes in Base Flow Indices of Didessa Sub-basin Catchments

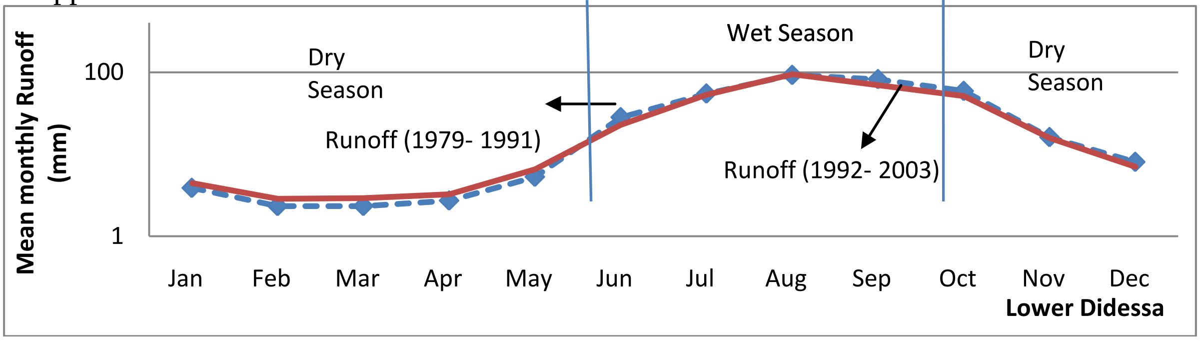
	Average Annual BFI (%)	Annual rate of change (mm)	Coefficient of Variation (%)
Urgessa (1980-2003)	2.2	0.02	43
Yebu (1980-2004)	15.4	– 0.27	39
Upper Didessa (1980-2006)	0.7	– 0.02	70
Temssa (1989-2004)	16.7	– 0.85	44
Dabana (1984-2003)	0.3	0.01	71
Lower Didessa (1979-2004)	11.4	0.12	27
Indris (1987-2006)	17.3	0.7	42
Tato (1996-2006)	1.9	– 0.14	50

3.4.3 Wet Season Flow

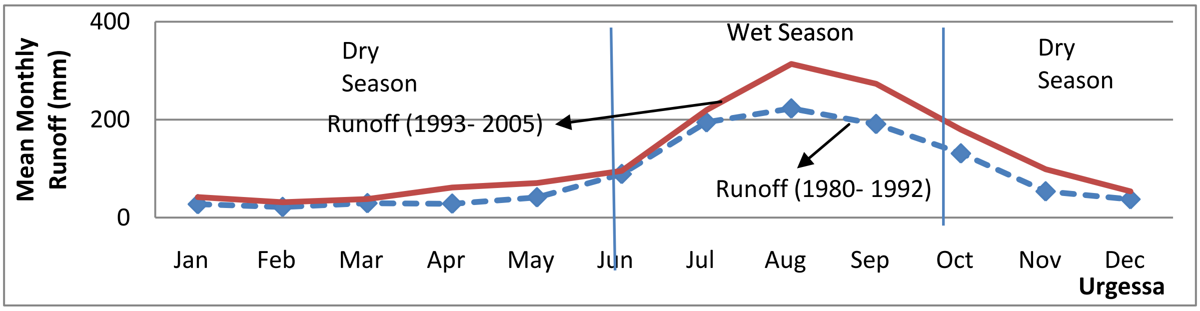
Bearing in mind the long term average monthly stream flow is highest in August, the wet season recorded between July and October for Indris and flanked between June and October for all other catchments. While Dabana's period one showed its wettest month in September, contrary to other catchments, it changed back to August on period two. Upper Didessa recorded an annual stream flow increasing pattern of 37.8 mm at period one and then unexpectedly the pattern followed a decreasing trend with annual declining value of 16 mm. Since this change to a decreasing pattern didn't show up on the rainfall and Base Flow pattern, it was probably caused either by changes in the land use/cover of the area or errors in the recorded data. As shown in the table below Urgessa possessed noticeable annual stream flow decreasing value of 35 mm and 53 mm at period one and period two respectively.



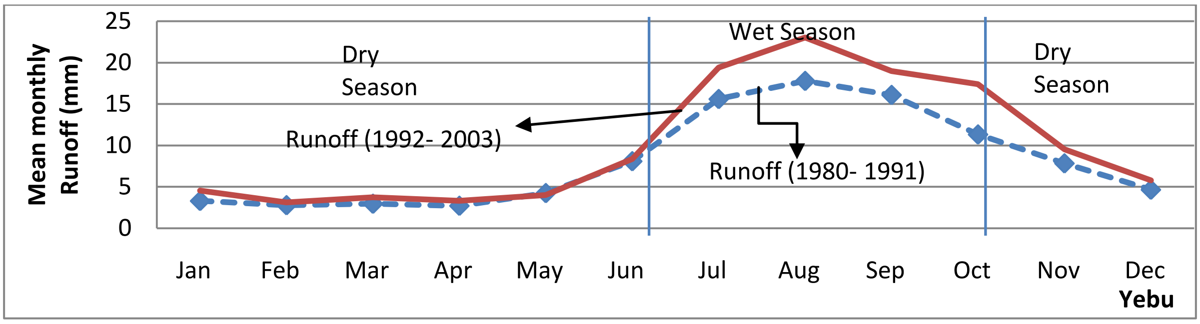
a. Upper Didessa



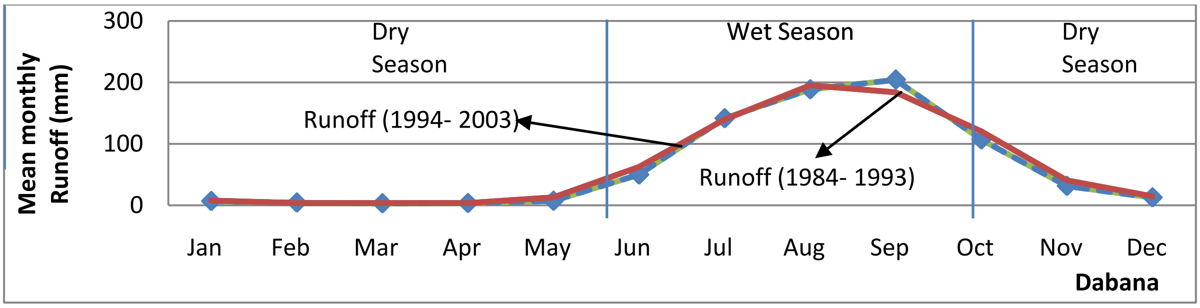
b. Lower Didessa



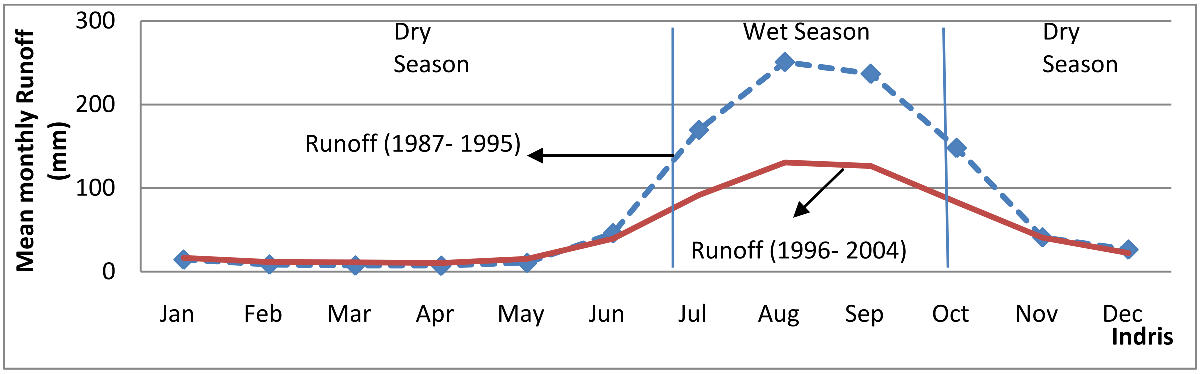
c. Urgessa



d. Yebu



e. Dabana



f. Indris

Figure 10. Flow regimens for period one and two of Didessa sub-basin catchments.

3.5 Results of the qualitative data (From Field Work)

3.5.1 Socio-Economic Issues

The flow chart below shows the different socio – economic issues which were pointed out and discussed by the stakeholders during field visit part of this study. Farmers' livelihood, education, water supply, health and gender were the main socio-economic issues discussed by the different stakeholders at different levels. The complexity of the socio-economic problems mainly laid on the interconnection of the issues one to another. Having high illiteracy rate will unquestionably worsen the other socio-economic problems and there is no doubt that unhealthy citizen wouldn't be productive. Women are the pillars of every family, the possible social - economical injustice on them can negatively affect many.

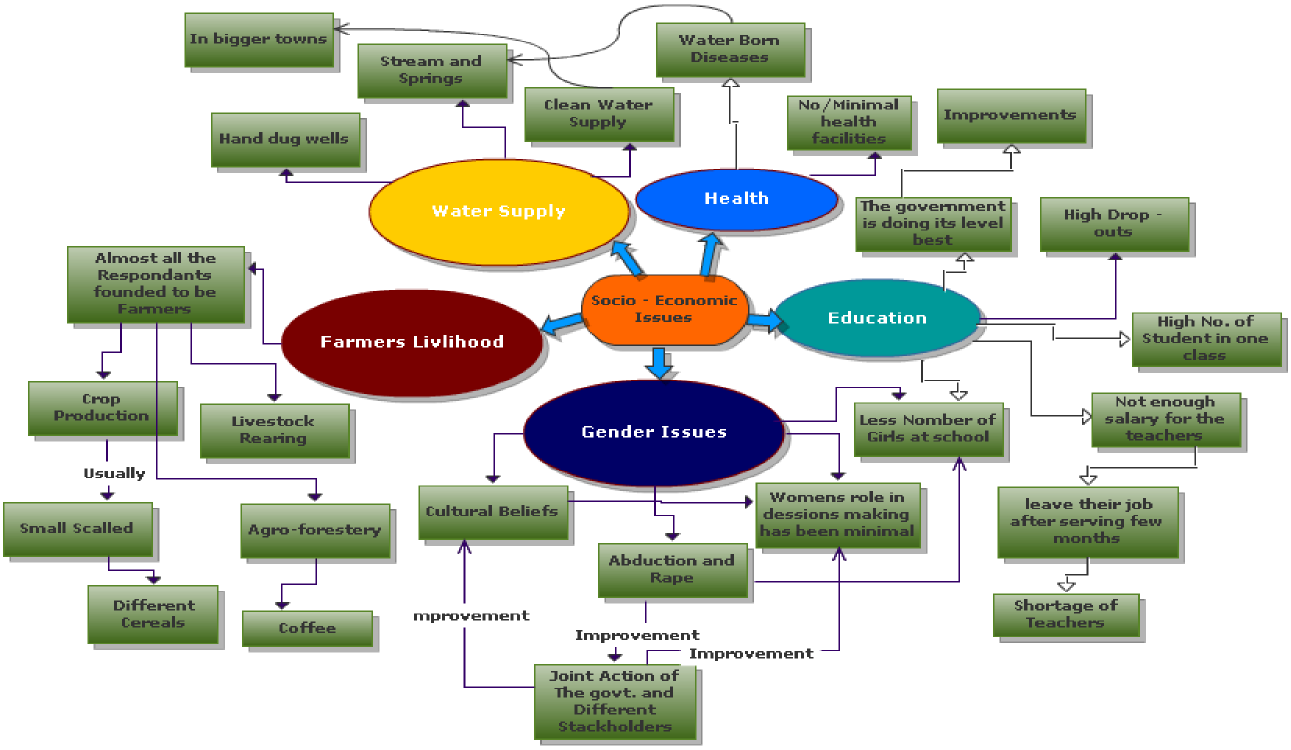


Figure 11. Flow – Chart that shows the rich picture of the socio – economic issues.

3.5.1.1 Farmers Livelihood

As is the case for most other rural parts of the country, the majority of the inhabitants of the study area are deriving their means of livelihood from mixed farming that involves both traditional crop production and livestock rearing. Farming and livestock do not manage to always satisfy the annual subsistence requirements of the household. The marginal productivity perpetuates peasant life involving a lot of toiling. On the other hand the community perception study has indicated that out of the total involved participants 95% derive their major source of income directly from crop production.[38] This indicates that the farming system is largely dominated by crops production in the area and livestock rearing a minor part.

[38] This is the data that the Development Agents in the study area estimates

3.5.1.2 Education

The total number and distribution of schools and student enrollment rates are very minimal. Lack of education institutions and high student dropout rate are results of various sorts of socioeconomic problems. High student numbers per class, high student teacher ratio and lesser participation of girls at all levels of school are the major problems identified by community participants in the study. Most of the above mentioned problems are associated mainly with poverty of the farmers in the region and the weak and fragile economy of the country in general. However a tremendous effort made by the government and the community is giving some fruitful success for overall formal educational system of the area.

3.5.1.3 Water supply and Health

There is a scarcity of potable water in the study area. Hand dug wells and drinking water directly from streams is the main source of potable water in the rural part of the area. As a result of this water born diseases are the main challenge the rural community is facing. Lack of health facilities at closer distance from the villages made the situation worse. However in big towns like Bedele and Agaro there is a clean water supply scheme by channeling from rivers and ground water. The number of drinkable water supply schemes as well as the capacity and regularity of the services of schemes is reported to be inadequate in meeting the demand of the population. Paradoxically; the studied area is rich in water resources, while the vast majority of the people have no access to drinkable water in sufficient quantity and at a reasonable distance.

3.5.1.4 Gender Issues

Like most rural parts of the country, women of the study area suffer from cultural and practical problems. For the purposes of addressing women's problems, women's Affair Offices of each Woreda are striving currently to change the traditional and wrong attitude of the people towards women, increase women's involvement in decision making of family matters and community level development interventions and alleviating traditional practices which are against women's development and well being. To mention some, the main problems are early marriage, abduction, rape and female genital organ mutilation. Besides, there are some interventions launched by Women Affaires Offices organizing women in credit and saving schemes to create access to income generation activity.

Although considerable improvement is observed regarding school enrollment of girls during the last decade or so, undoubtedly parents still prefer to send their boys to school than their daughters. Even when they are sent to school it is very likely that they are the majority among dropouts owing to early marriage and also due to the distance of schools from residences which makes the travel of girls by themselves very difficult. This latter problem has also to do with the prevalence of rape and abduction. Women have also no say in family planning, be it birth spacing or limiting the number of children. Therefore, as to the magnitude of the problem still remains much to be done in the future to solve all the loads which are burdened on the girls and woman of the study area.

3.5.2 Analyzed Timeline related to the dynamics in natural resources (Rainfall, runoff and forest change)

The Timeline below shows the dynamics in the natural resources of the Didessa sub-basin between the years 1960 - 2005. It is the combined output of three Time Tables which were made by the farmers in the Temssa, Dabana and Tato catchments. According to the respondents the driest time ever recorded was in the mid of 1980s. This had brought drought related problems to the southern part of the Didessa sub-basin. On the other hand, the mid 1980s are the times when Ethiopia experienced a widespread and catastrophic famine in most parts of the country. Due to this the government relocated peoples which were highly affected by the famine, mainly from the northern part of the country, to the northern part of the Didessa sub-basin.

The 1974 and 1991 changes in national governments caused a massive instability throughout the country. In some places of the Didessa sub-basin the instability led to actions which were a threat for the forest cover of the area. By using the instability which downsized rule of law, some farmers started to clear some part of the forest and changed them to agricultural lands. Illegal cutting of trees from the government owned forests, for personal and commercial use also took place.

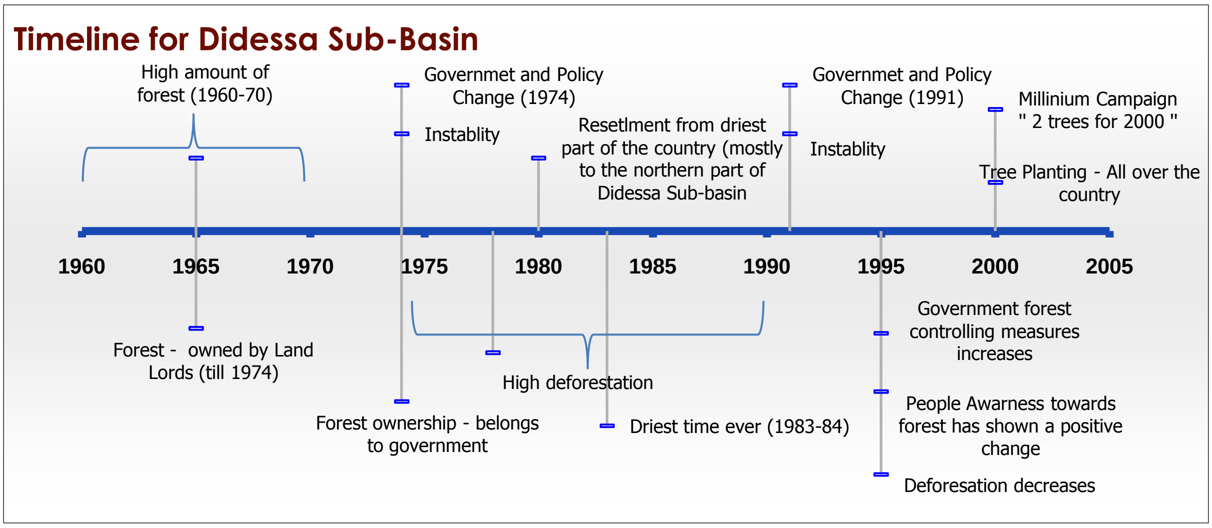


Figure 12. Chronological natural resource dynamics of Didessa Sub – basin.

According to most respondents, the other problems brought up as a result of the 1974 government collapse is the forest and wild life protection policy and land ownership declaration changes and measures taken by the new government. The pre 1974 government gave the right to own and manage forests to the local land lords. However; when the new government applied the land management reform (Rural Land Proclamation of March 1975) and all forests were considered as state owned, gaps in controlling illegal deforestation widened. This resulted in a substantial illegal forest cutting and clearing activities. Many respondents believe the 1991 government change brought instability and there were actions which were a threat to the forests, but in any scale it wasn't as likely to have been as serious as those around 1974. The communities perception related to rainfall, runoff and forest cover obtained from the field work were analyzed and developed in a table below.

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Table 6.Tabulated community perception result.

Parameter	**Temssa/Southern**
	Period one (1980-90) / Period two (1990-2000)
Rainfall	• Mentioned 1982/83 as the driest time of all time. • Majority of the participants agreed Period two experienced a decrease in rainfall amount compare to period one • Some participants reflected as rainfall amount is not changing and static for the last 30 years.
Runoff	• About half of the respondents say the amount of the flow is static and the other half said it is decreasing from the time they know the river. But all the people strongly agree that the dry season flow decreases.
Forest Cover	• Immediately after the 1983/84 drought and at the time government change (1991), there was instability which leads to increasing rate of forest cut. But after some years peoples concern about advantage of forest rises and by the mid of 1990s because of government forest controlling measures, this resulted in minimizing the rate of deforestation. • Most believed most of the deforestation occurred from the beginning of 1980s to the mid of 1990s.
	Dabana/Middle
Rainfall	• Most respondents praised the 1970s as a time of good rainfall; however they believe that the flow is gradually decreasing from that day until now. Hence they believe period one holds much higher rainfall than period two.
Runoff	• Most respondents agreed runoff amount is much lower at period two compared to the 1980s, though they agreed that the beginning years of 1980 was a dry time.
Forest Cover	• Most farmers believe more than 80% of the forest is gone during 1970s and 1980s and it is still decreasing rapidly. • About 20% of farmers believe 50% of the forest still exists now and they don’t agree with afforestation process.
	Tato/Northern
Rainfall	• Most agreed except the beginning years of the 1980s rainfall at period two is similar to period one
Runoff	• Most believe stream flow is static for all time, though Year 2001 quoted as a high flood Season by most respondents. This flooding destroyed a large area of farm land. This flood was very sporadic and they didn’t experience it before.
Forest Cover	• Majority of the farmers believed most of the forest land gone before the two periods. However they defiantly agreed that there was also some deforestation in period one and two.

4 Discussion

4.1 Rainfall vs. Runoff/Stream flow

Even if the relationship between rainfall and runoff may not necessarily refer to a direct linear relationship, in general it is rational to assume as they follow the same pattern of existence. Rainfall is the input as drops and runoff is the output as overland or stream flow. Hence as rainfall increases/decreases with a certain amount, the runoff should respond in the same manner, strictly speaking, even though not exactly with the same amount as the rainfall.

As in retrospect to the results part of this paper, all the catchments located in the southern and middle part of the Didessa sub-basin area, Yebu, Urgessa, Upper - Didessa and Dabana, followed a statistically insignificant increasing pattern of rainfall and runoff for the entire analyzed data period. Surprisingly each of the northern catchments, Tato, Lower Didessa and Indris appeared to have a downturn in the hydrological pattern of rainfall and runoff.

When we look into the short term deviations at the two specified periods of the southern catchments, it's clearly shown that the significant increasing runoff pattern of all the catchments at period one turned to a recession in period two. Apparently this is mainly because of the significant decrease in rainfall amount that was recorded at period two. In addition period two was the time where most southern community respondents agreed that deforestation practice declined to some extent, but afforestation process had not been taken place. The abolishing of deforestation practices (mainly shifting cultivation) which has been taken place might be another factor for the flow trend change.

The fact that all the northern catchments possessed a decreasing stream flow, rainfall and runoff coefficient pattern for the entire period of study is something which can be discussed in relation to different points. However as discussed before this part of the study area is an area which suffered an intense destruction of forests which basically forced the area to be predominantly cultivated land. According to public perceptions most of the deforestations around northern catchments took place before the 1980s, which is the earliest point for which we have empirical hydrological data. Because of this, this study doesn't have any clear evidence to link the decreasing flow change with the deforestation issue for most of the northern catchments. Here it is also imperative to consider the rainfall pattern which shows a similar decreasing pattern. As a result blaming the annual decreasing rainfall pattern can be the straight and the only answer to this dilemma. But one can wonder about the extent to which forest cover influences precipitation. For further studies to find out the real happening which brought the stream flow regime to a declining pattern, a more advanced hydrological modeling concept that encompasses different parameters and a detail land use/land cover analysis should be done, as well as at a longer time perspective. Eventual relationships between forest cover and rainfall would also need to be considered.

4.2 Dry Season and Wet Season Flow

The trend of the dry season stream flow for the entire data period varies from one catchment to another. Whether increasing, decreasing or no trend; all catchments do not reveal any noticeable dry season stream flow temporal changes. In contrast to most other studies on Blue Nile sub-basins, the dry season flow of all discussed catchments revealed more or less constant patterns, though we saw some extreme up and down figures during some years of the data series. As the majority of the study area farmers practiced rainfed agriculture, the consistency of the dry season flow helped them to be one of the few place in the country which doesn't suffer by drought related problems. However as it happened to its wet season flow, Urgessa's dry season flow pattern changed its 19.7 mm increasing annual rate of change in period one to a significant annual decreasing value of 17 mm in period two.

The total amount of wet season stream flow at period two is higher than at period one for most catchments, except Yebu. For all catchments the wet season monthly annual stream flow temporal changes showed a declining trend at period two of the data series. This was mainly attributed to the decreasing pattern of rainfall.

4.3 Base Flow Characteristics

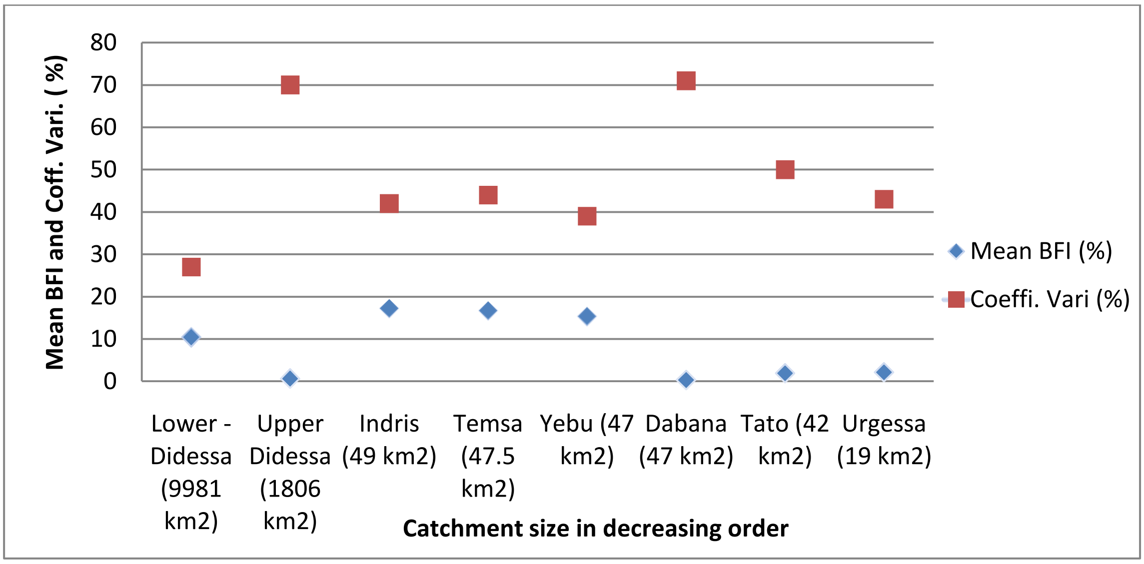
The big difference in average base flow values of each observed catchments and their high fluctuation and vulnerabilities can result from the different catchment characteristics of each site. The catchment size, soil type, geology, landscape, vegetation covers, climate etc. can be considered as the major catchment characteristics that influence the amount of the base flow contribution to the total stream flow[39]. However in this study, out of the mentioned catchment characteristics, we can only look to see the catchment size and to some extent on the land use/cover change influence the mean value and variability of the base flow indices.

[39] Adane Abebe[1] and Gerd Foerch [2], Catchment characteristics as predictors of Base Flow (BFI) in Wabi Shebele River Basin, East Africa, Ethiopia. University of Siegen, Germany 2006

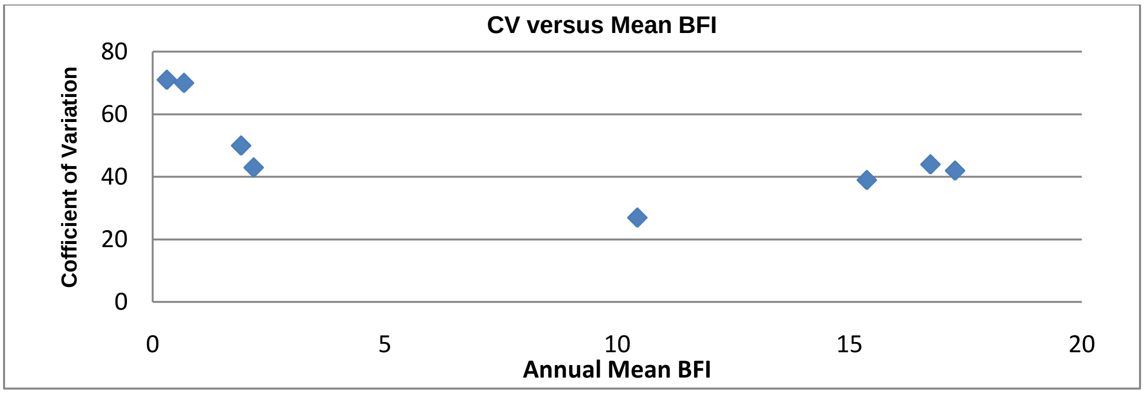
As it is shown in Figure 13a there is no a clear cut that can relate the catchment size and the amount of BFI values. Both the smaller and bigger catchments revealed high and low BFIs. However with regard to the variability of BFI, the biggest catchment, Lower Didessa showed the smallest variation in its annual BFI values, with a coefficient of variation of 27%. This suggests that the bigger the catchment, the less will be the variability in BFI values.

Table 7. Base flow index characteristics and catchment size of Didessa Sub-basin.

	Yebu (1980-2004)	Temssa (1989-2004)	Urgessa (1980-2003)	U-Didessa (1980-2006)	Dabana (1984-2003)	L–Didessa (1979-2004)	Tato (1996-2006)	Indris (1987-2006)
Mean BFI (%)	15.37	16.74	2.17	0.67	0.3	11.43	1.9	17.27
C. Variation (%)	39	44	43	70	71	27	50	42
Ca. Size (km^2)	47	47.5	19	1806	47	9981	42	49



a.



b.

Figure 13. Base Flow Index characteristics of Didessa Sub - basin.

Fig 13c shows the BFI variability depending on mean BFI values. It is clear from the figure that there is a marked increase in variability below a mean for BFI of about 3%. The highest variability shown at Upper Didessa and Dabana which revealed the lowest mean BFI values of 0.67% and 0.3% respectively. The land use/cover change doesn't show a noticeable impact on the amount of the mean BFI values and BFI variability. The comparatively well forested Yebu revealed almost the same mean BFI value and variability as the most deforested Indris. Apart from these facts, to see the apparent relationship of the catchment characteristics with the base flow, there should be a detail study that constitutes soil, geological, hydrological, meteorological and morphological data.

4.4 Rainfall and Runoff Vs Land Cover/use

(High Deforestation —› High Annual Rainfall and Runoff values)

As stated in the result part of this paper, the estimates of land cover for the northern catchments of the study area showed a high amount of deforestation before the hydrological data period we looked at (1980-2005). This probably makes it difficult to see the immediate and direct effect of the land cover change in the hydrological cycle of the study area at the specified period. The stream flow in the period one of the northern catchments showed a decreasing pattern which possibly resulted from the decreasing annual rainfall. This is shown in the runoff-rainfall ratio (runoff coefficient) values of the northern catchments. Given that the runoff responded in the same pattern as rainfall, runoff coefficient values of period one of the northern catchments revealed a trend which is constant for the entire period.

On the Southern Catchments of the Didessa sub-basin, at period one, both annual rainfall and runoff values revealed a pattern which is increasing. The increasing annual rainfall pattern unquestionably contributed to increasing runoff. We speculate that the forest loss during this period may have an impact as well. Studies in the other sub-basins of the Blue Nile River, like Chemoga catchment, revealed that a decrease in the area under tall vegetative cover (forest) implied increased surface runoff generation[40].

[40] Weldeamlak Bewket, Towards Integrated Watershed Management in the highland Ethiopia – the Chemoga watershed case study, 2003, Page 64

Table 8. Comparing Rainfall and Runoff with the land cover of the Didessa Sub-basin.

Period One	**Period Two**
Northern Catchments (Tato, Lower Didessa, Indris)	
Mainly Deforested before 1980, but still there were some tree cuttings Decreasing stream flow and rainfall	Deforested, but still there were some tree cuttings Decreasing stream flow and rainfall
Southern Catchments (Temssa,Urgessa, Yebu and Upper - Didessa)	
Deforestation mainly started at the start of 1980s Increasing rainfall and runoff pattern	Deforestation went up till the mid of 1990s Decreasing rainfall and runoff pattern

At period two, the already massively deforested northern catchments appeared to have a decreasing runoff and rainfall trends which is similar to period one. In the Southern catchments deforestation practices extended till the mid of 1990s. However, the annual rainfall and runoff which increased at period one in the southern catchments showed a decreasing trend in period two. This may be due in part to the reduction of deforestation practices which were high during period one. To confirm this and to understand the overall responses of the stream flow towards the land use/cover change, a detail paired catchment study should be done. However this study can give a general insight about the Didessa sub-basin stream flow and rainfall responses to an estimated land use/cover dynamics.

4.5 Community perception Vs Empirical data

From the active participation of farmers in the different field interviews, one can easily feel how the informants are involved and eager to discuss the situations which take place around them. Notwithstanding, this can't be an assurance for all the information which we obtained from the individual farmers as being facts. Since each farmer has individual objective and knowledge limits, triangulating the farmers' responses in different parts of the study area and cross-correlating it with empirical data were found to be necessary. On the other hand it is also important to have a critical look and speculate on the error that can be found on the objective data, especially on the runoff, as well[41].

[41] Gebrehiwot SG, Taye A, Bishop K. Forest cover and stream flow in a headwater of the Blue Nile: complementing observational data analysis with community perception, Ambio. 2010 Jun; 39(4):284-94.

4.5.1 On Land Cover Data

In most cases the elderly respondents tend to have well established narrative information related to the chronological pattern and dynamics of the natural resources, especially in relation to the land use/land cover change. Though most inhabitants perceived the forest cover in the study area as already declined or as declining very rapidly, there were some cases where some respondents maintained that the forest cover had not experienced any change at all. Indeed, from the field observations which were done in the area and by looking at the existing satellite images; the forest cover has gone through hard times in most parts (more on the north and middle part) of the Didessa sub-basin.

4.5.2 On Climate and Stream Flow Issues

(More water use from rivers —› more knowledge towards the stream flow and rainfall dynamics)

In the climate and stream flow issues there was a conflicting argument in many of the inhabitants' responses and it was not an easy topic that can be described with reference to an existing object for most respondents. For instance in Dabana catchment where the empirical data obtained from the gauge stations doesn't show any significant change in the amount of annual and dry season stream flow, most key informants responded by saying the flow went down significantly for the last two decades. However in Tato catchment which the farmers had a chance to harvest the river water by using river channels, most respondents had views in agreement with observed records of both rainfall and runoff decreasing during both periods. The empirical data most likely corresponds to the community perception on the dynamics of both rainfall and stream flow. This may help us to put forward a hypothesis that those farmers who have a better use of the river water for growing crops are closer to information related to changes in the stream flow than farmers who followed rain fed farming. Though this study observed some information gap in the communities' awareness towards their changing environment, there was also much knowledge attained from different stakeholders.

4.6 Integrated Watershed Management (IWM): as a way out for the Observed problems

In the study area where all the poverty anguished people allocate their entire resources in the land, there should be an approach that needs to be adopted in all processes of satisfying growing demands for food and to fulfil the aspiration of the resource-poor people. Some part of the living environment, especially on the northern side of Didessa sub-basin, which suffered from climax deforestation and land degradation, should have a means to be returned to its good days with more forest cover. Since the problem in hand is diversified and deep into the society, we need to make use of an approach that takes into an account both the knowledge of indigenous farmers and the empirical data which is simply collected and shelved for ages. Integrated Watershed management can be an approach that fulfils this need.

In all areas which the community/wereda expertise perception gathering was done, there are quite a number of problems reported which may offer challenges to the farmers' welfare. The major problems can be grouped as deforestation, spontaneous floods and socio economic problems which were described in the results part of this paper. Beside this the agricultural process in the study area is scantily equipped and its output is subject to the natural potential of the land without much enhancement by fertilizers or irrigation. In order to solve this IWM involves the planning and execution of need-based soil and water conservation practices and other socio-economic interventions which will consequently improve the soil, reduce the wet-season run-off and improve the livelihood of the community and thus provide more time for run-off water to infiltrate into the soil which will finally contribute to ground water. This keeps the constant trends and nature of the dry season and base flow of the area, which are the main and very important components in the farming cycle of the communities.

The dynamic process of the biosphere and the effects of vegetation and soils on the processes such as interception, evaporation, transpiration, infiltration, percolation and surface run-off, sub-surface and ground water flow, are all affected by land management activities on the watershed[42]. An improper and exploitive farming practice is a common feature of Ethiopian small holder farms. This has led to deterioration of the natural resources. In our study area, with the exception of those places where extensive deforestation was taking place, the forest cover is relatively good and natural resource loss is reported to be minimal. However the major challenge is seen to be low awareness of the community for natural resources. For that reason, by leaving narrowly and only engineered solutions and turning to IWM which to a greater degree encourages farmers' involvement, community ownership and commitment, it might be possible to have a more sustainable and prolonged solution for the problems mentioned.

[42]Mekunent and Rajender, A watershed Management Handbook for Tropical farmers,1994

4.6.1 SWOT Analysis for the Integrated Watershed Management of the Study Area

As it is shown below SWOT analysis is done to see the strength, weakness, Opportunities and threats of a potential Integrated Watershed Management program in the study area. The fact that the study area posses high forest and high amount of mean annual rainfall were put as strength for the implementation of any IWM project. The unstudied nature of the study area natural resources and the variability of stream flow have been regarded as a weakness. Good concern of the local government is one of the things which are listed as an opportunity. The potential threats listed are less credibility of local development agents by the community, less public awareness on the dynamics of natural resources, less willingness of expertise to work in the rural towns and the booming of large scale farming all over the country in which the ongoing Didessa Irrigation Project can be counted as one.

Table 9. SWOT analysis for the Integrated Watershed Management of the Didessa Sub - Basin.

Strength S • Highly forested compare to other places in the country • Comparatively the study area has consistent and high mean annual rainfall, good amount of dry season flow. • Evenly distributed hydrological and meteorological gauging stations which makes it comparatively well equipped with raw runoff and rainfall data • Public Perception towards forest is highly improving	**Weakness** W • Less Studied which results less information for management • Highly variable stream flow pattern which can sometime make it hardly predictable. • Less engagement with the Public on previous forest management issues, which makes it involvement of the community in government projects less customary.
Opportunities O • Good Concern of the local government towards forest/watershed management • Applicability of the rule of law on protecting forests is getting better • Good stability of the country in general	**Threats** T • Less credibility of local development agents by the community • Less public awareness on the dynamics of natural resources • Less willingness of expertise to work in the rural towns. • The booming of large scale farming all over the country, which can bring up massive deforestation. Didessa Irrigation Project may contribute to this effect.

5 Conclusion and Recommendation

As a general remark the total data period of all the catchments which are located in the southern and middle part of Didessa sub-basin revealed an increasing trend of rainfall and runoff. However after we classify the data into two periods, the period two records of these catchments show a decreasing pattern of rainfall and runoff. The main reason for decreasing stream flow in period two is the decline in rainfall amount. A decreasing deforestation rate may also contribute to this decline in total runoff. In contrast to all the other catchments located in Southern part of the Didessa sub-basin, the northern part of the sub-basin appeared to have a decreasing or constant trend of rainfall and runoff both for the entire period and within periods one and two. Deforestation in the northern part of the sub-basin had already occurred before 1980, however. Because of this the direct linkage between the stream flow and rainfall together with deforestation in the study data period was not possible. Nevertheless in the southern part deforestation mainly took place in the 1980s and the first years of 1990s according to the PRA. The southern catchments therefore may help us to explore the low forest – high flow hypothesis in more detailed studies.

The dry season flow, except Urgessa, did not change significantly in either period one or period two of the data series. The Base Flow Indices of most of the catchments shows a high annual variability, though their cumulative annual values haven't shown a considerable change. This shows us that the existing land use/land cover change (1980-2005) doesn't appear to have had a significant influence on the dry season flow of most of the Didessa sub-basin catchments. However it has been shown in the other Blue Nile River sub-basins that intensive and long term land cover change can affect the dry season flow significantly[43]. Hence if deforestation in Didessa sub-basin persists, we may also see its influence on the dry season flow. Since the dry season flow is a very important contribution to the welfare of the farmers, abolishing the deforestation practices should be considered as a main policy.

The community perception results which were obtained by applying PRA techniques generally do not always match to the empirical data which was recorded at the rainfall and runoff stations (Of course even the observed data needs to be regarded critically). However our main finding was that communities who use the stream water for irrigation purposes on a regular basis seemed to have perceptions closer to the empirical data. In general, though the

[43] Woldeamlak Bewket[1] and Geert Sterk[2], Dynamics in land cover and its effect on stream flow in the Chemoga watershed, Blue Nile basin, Ethiopia, *Hydrol. Process.* **19**, 445–458 (2005)

communities' perceptions of the natural resource situation are not particularly consistent with observations. Less connection of farmers to the streams and little government effort at communicating the existing data to the communities may be the main reason for the knowledge gap of the people towards their changing environment. As has happened across much of the country, most natural resource development projects are undertaken without the community having a clear picture of the hydrological and land use/cover characteristic of the area. In addition the potential for using available data in the decision making process is very minimal. As a result the vulnerability of these communities to hydrological changes are very high and most soil and water conservation structures may fail to function well at the time of both peak and Base Flow periods. This kind of failure and not enough participation by the communities may possibly develop a lack of trust and ownership in the stakeholders' attitudes. For alleviating this type of problem and protecting and conserving natural resources, as the study already recommended before, Integrated Watershed Management should be considered as a basis for future development.

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List of Peoples Participated in the Community Perception work

- Abdissa Ereda - Tato
- Girma Aleta - Tato
- Tolessa Batcha - Tato
- Abduzemed Ditcho - Dabana
- Jemal Mohammed – Dabana
- Seid Hassen - Dabana
- Airedin Fuad - Temssa
- Abba Ole - Temssa
- Ahemed Mohammed -Temssa

P.S - These are just some of the key informants; since I was thinking to avoid farmers' suspicion about the intervention; I didn't take the name of the farmers who were participating at the focus group interview.

7 Appendixes

Table 9A. Characteristics of monthly and annual rainfall (P) and Stream Flow (Q) of Lower Didessa catchment (1979-2004)

Lower Didessa

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Total	118.3	67.7	68.5	77.5	154.3	665.3	1405.7	2428.5	1976.1	1436.5	416.2	196.6	3384.6
	Max	9.9	6.0	6.6	7.4	19.1	130.0	96.5	129.1	124.6	123.3	26.5	12.3	485.1
	Min	1.2	0.5	0.3	0.8	1.3	5.3	13.0	49.2	48.7	13.1	6.0	3.7	173.2
Q	Mean	4.2	2.6	2.6	3.0	5.9	25.6	54.1	93.4	76.0	55.2	16.0	7.6	338.5
	SD	2.2	1.4	1.6	2.0	4.0	23.6	18.9	27.2	22.0	32.7	6.3	2.8	89.9
	Variance	5.0	2.0	2.4	4.2	15.8	557.6	355.5	738.2	482.4	1172.2	39.5	7.7	8078.9
	CV	53.4	54.7	59.4	68.5	66.9	92.3	34.9	29.1	28.9	59.3	39.3	36.8	26.6
	Skew	0.9	0.6	1.0	1.0	2.1	3.7	0.1	-0.4	0.9	0.9	0.1	0.4	-0.1
	Total	369.6	514.1	1923.7	2452.1	6059.0	8318.2	7851.8	7656.2	7113.7	3688.3	837.4	467.4	20118.4
	Max	52.7	66.0	209.9	208.0	430.9	447.0	498.9	467.9	370.0	328.1	99.1	140.3	2322.5
	Min	0.0	0.0	0.0	14.1	37.0	173.7	185.9	196.7	193.7	8.9	0.0	0.0	1392.7
P	Mean	14.2	19.8	74.0	94.3	233.0	319.9	302.0	294.5	273.2	141.9	32.2	18.0	1828.9
	SD	16.3	20.8	53.1	44.0	89.0	70.0	83.2	60.9	52.4	89.1	22.5	28.2	285.7
	Variance	266.9	433.4	2818.2	1939.5	7914.8	4906.4	6927.2	3709.8	2743.6	7935.9	505.2	795.2	81620.2
	CV	114.9	115.3	71.7	46.7	38.2	21.9	27.6	20.7	19.2	62.8	69.8	156.8	15.6
	Skew	1.2	1.0	1.1	0.5	-0.3	0.1	1.2	0.5	0.3	0.4	1.0	3.5	0.1

Table 9B. Characteristics of monthly and annual rainfall (P) and Stream Flow (Q) of Urgessa catchment (1980-2003)

Urgessa

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Total	832.0	643.8	812.4	1179.8	1349.4	2215.9	4968.9	6442.6	5572.4	3729.8	1830.9	1110.2	30578.2
	Mean	34.7	26.8	33.8	45.0	56.2	92.3	207.0	268.4	232.2	155.4	76.3	45.8	1274.1
Q	Max	86.5	47.2	79.7	112.3	217.7	204.5	397.5	711.2	524.6	340.7	296.4	138.9	2192.1
	Min	16.1	11.9	14.7	13.3	12.1	29.3	85.6	110.8	79.9	50.2	27.7	24.5	754.1
	SD	16.3	11.8	15.8	33.6	50.4	44.7	75.3	134.1	121.4	89.4	57.5	23.1	427.7
	Variance	265.4	139.4	249.8	1125.7	2544.9	1999.0	5677.6	17978.5	14748.0	7990.9	3308.6	534.4	182911.9
	CV	47.0	44.0	46.7	74.6	89.7	48.4	36.4	49.9	52.3	57.5	75.4	50.4	33.6
	Skew	1.5	0.5	1.0	1.2	1.9	0.8	0.5	1.6	0.6	0.9	2.8	3.0	0.6
	Total	907.1	840.3	2059.3	3358.6	4488.4	5110.0	4886.7	4973.8	4488.5	2758.7	1461.9	925.8	36249.0
	Mean	37.8	35.0	85.8	139.9	187.0	212.5	203.6	207.2	187.0	114.9	60.9	38.6	1511.4
P	Max	115.0	88.5	157.7	301.3	341.2	320.1	312.3	356.0	298.7	336.7	243.2	161.3	1966.7
	Min	0.0	0.0	11.2	56.0	12.2	113.6	96.1	91.0	127.6	11.1	1.3	0.0	1143.8
	SD	32.4	26.8	37.9	61.5	65.9	52.8	53.2	66.2	50.5	81.7	63.8	45.1	208.6
	Variance	1152.3	720.0	1436.8	3786.0	4337.9	2785.2	2828.9	4377.6	2548.5	6671.3	4071.1	2031.0	43499.5
	CV	85.8	76.6	44.2	44.0	35.2	24.8	26.1	31.9	27.0	71.1	114.7	116.8	13.8
	Skew	0.8	0.5	0.0	0.7	-0.3	0.3	0.0	0.3	0.9	0.9	1.7	1.6	0.3

Table 9C. Characteristics of monthly and annual rainfall (P) and Stream Flow (Q) of Upper Didessa catchment (1980-2003)

Upper Didessa

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Total	177.8	194.3	245.3	315.8	673.3	1644.8	3278.5	4174.1	3470.3	2028.9	669.1	271.5	17143.6
	Mean	6.6	7.2	9.1	12.1	24.9	60.9	121.4	154.6	128.5	75.1	24.8	11.1	634.9
	Max	15.6	47.5	42.7	42.7	71.3	139.4	189.9	312.2	270.7	182.0	114.0	31.1	1129.8
Q	Min	1.0	1.9	1.7	1.6	3.6	17.4	47.4	36.0	27.2	17.5	2.8	0.5	335.0
	SD	3.0	8.4	8.4	9.6	17.2	27.5	39.8	75.8	67.2	44.8	21.4	6.4	203.1
	Variance	9.2	71.3	70.5	92.4	294.6	757.3	1585.6	5752.6	4513.4	2004.8	458.7	41.1	41246.8
	CV	46.2	117.4	92.4	79.1	68.8	45.2	32.8	49.1	52.3	59.6	86.4	63.8	32.0
	Skew	1.0	4.5	2.9	1.7	1.0	1.2	-0.1	0.3	-0.2	0.7	2.1	1.3	0.1
	Total	972.5	1121.7	2418.6	3850.7	6125.7	8395.7	8248.3	8963.5	7723.8	4644.3	1188.5	906.2	54459.5
	Mean	37.4	39.3	93.0	148.1	235.6	322.9	317.2	344.8	297.1	178.6	45.7	34.9	2094.6
P	Max	148.3	159.8	267.0	322.2	455.3	547.7	746.5	758.9	669.0	563.0	151.4	201.8	3705.7
	Min	0.0	0.0	8.1	35.6	36.9	213.0	54.7	158.3	65.0	16.1	0.0	0.0	1173.0
	SD	34.1	40.7	62.4	74.4	111.4	93.2	134.0	159.6	144.5	131.9	36.6	49.5	634.4
	Variance	1161.7	1656.9	3898.0	5533.4	11275.9	8687.0	17951.1	25469.7	20891.6	17393.4	1336.5	2446.6	402512.7
	CV	91.1	113.6	67.1	50.2	43.0	28.9	42.2	46.3	48.7	73.8	80.0	141.9	30.3
	Skew	1.5	1.4	1.2	0.6	0.5	1.3	0.9	0.9	1.3	1.2	1.1	2.5	0.6

Table 9D. Characteristics of monthly and annual rainfall (P) and Stream Flow (Q) of Yebu catchment (1980-2004)

Yebu

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Total	96.5	72.5	81.9	74.0	111.5	200.9	431.2	518.6	443.0	381.6	222.2	129.1	2753.0
	Mean	3.9	2.9	3.3	3.0	4.1	8.0	17.2	20.7	17.7	15.3	8.9	5.2	111.1
Q	Max	18.5	13.9	14.6	7.9	12.3	24.0	53.8	37.5	31.3	36.7	25.0	13.7	199.7
	Min	1.5	0.7	0.9	0.9	1.3	2.6	6.6	6.8	6.4	6.3	3.0	2.8	55.4
	SD	3.6	2.7	2.8	1.7	2.6	5.8	11.3	8.9	7.6	9.0	5.8	2.9	41.8
	Variance	13.2	7.1	7.9	2.9	6.9	33.8	116.5	80.1	57.3	81.3	33.1	8.2	1748.4
	CV	94.0	91.7	85.8	57.4	64.8	72.3	59.8	43.1	42.7	59.1	64.7	55.5	38.0
	Skew	3.1	3.3	3.0	1.4	1.7	1.6	2.1	0.2	0.0	1.4	1.4	1.8	0.6
	Total	958.1	868.7	2115.4	3489.7	4650.3	5228.4	5113.0	5193.2	4698.5	2891.9	1529.2	1115.0	37731.3
	Mean	38.3	34.7	84.2	139.6	186.0	209.1	204.1	207.7	187.9	115.7	61.2	40.6	1509.3
P	Max	115.0	88.5	157.7	301.3	341.2	320.1	312.3	356.0	298.7	336.7	243.2	161.3	1966.7
	Min	0.0	0.0	11.2	56.0	12.2	113.6	96.1	91.0	127.6	11.1	1.3	0.0	1143.8
	SD	31.9	26.3	37.9	60.3	64.7	54.3	52.1	64.8	49.6	80.0	62.5	45.3	204.3
	Variance	1115.5	691.8	1440.0	3631.4	4182.4	2952.1	2717.5	4201.1	2463.4	6406.6	3903.1	2048.9	41718.6
	CV	83.1	75.7	45.1	43.2	34.8	26.0	25.5	31.2	26.4	69.2	112.1	111.5	13.5
	Skew	0.8	0.5	0.1	0.7	-0.3	0.3	0.0	0.3	0.9	0.8	1.7	1.5	0.3

Table 9E. Characteristics of monthly and annual rainfall (P) and Stream Flow (Q) of Dabana catchment (1984-2003)

Dabana

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Total	146.3	80.7	67.9	69.1	204.3	1120.9	2808.2	3836.1	3883.8	2270.0	720.6	273.1	15481.1
	Max	14.6	12.8	8.3	11.3	38.1	140.0	230.2	279.9	297.4	314.8	78.0	29.1	1346.0
	Min	2.7	0.9	0.4	0.5	0.5	19.4	81.2	124.9	118.9	31.2	11.8	5.8	511.4
Q	Mean	7.3	4.0	3.4	3.5	11.2	56.0	140.4	191.8	194.2	113.5	36.0	13.7	774.1
	SD	3.2	2.6	2.0	2.4	9.1	35.8	40.6	35.1	50.2	79.4	24.4	7.2	214.0
	Variance	11.1	6.7	4.1	5.9	82.9	1280.8	1644.4	1233.1	2517.5	6311.2	593.5	51.6	45816.6
	CV	43.4	64.3	59.9	70.5	89.1	63.9	28.9	18.3	25.8	70.0	67.6	52.6	27.7
	Skew	0.4	2.0	0.6	1.7	1.9	1.0	0.4	0.3	0.6	1.3	0.6	0.7	0.9
	Total	361.7	408.4	1361.0	1930.1	4384.8	5842.4	5850.0	5763.3	5787.4	2812.0	545.7	415.2	35462.0
	Max	85.8	66.0	164.6	187.3	426.3	419.8	511.6	377.7	481.7	312.1	113.1	157.9	2387.8
	Min	0.0	0.0	1.4	21.6	37.0	141.6	151.8	145.9	197.0	13.7	0.0	0.0	1119.9
P	Mean	18.1	20.4	71.6	96.5	219.2	292.1	292.5	288.2	289.4	140.6	27.3	20.8	1773.1
	SD	23.4	16.2	41.2	49.4	91.4	70.5	84.5	65.7	79.7	96.7	26.5	36.1	330.9
	Variance	549.1	261.0	1698.7	2439.7	8362.8	4969.1	7133.4	4316.6	6355.2	9345.2	702.5	1303.6	119464.2
	CV	129.6	79.1	57.5	51.2	41.7	24.1	28.9	22.8	27.5	68.8	97.1	173.9	18.7
	Skew	1.8	0.9	0.6	0.5	0.1	-0.1	0.8	-0.6	1.1	0.4	1.7	3.2	-0.2

Table 9F. Characteristics of monthly and annual rainfall (P) and Stream Flow (Q) of Indris catchment (1987-2004)

Indris

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		Annual
	Total	282.6	185.1	167.4	159.3	234.7	772.6	2354.0	3433.4	3272.1	2082.8	736.8	441.3		14122.1
	Mean	15.1	9.9	9.0	8.5	12.7	40.1	122.6	182.6	183.0	114.5	42.1	23.9		764.0
Q	Max	27.0	19.3	21.3	17.8	32.1	134.1	343.3	387.1	468.4	394.2	80.1	51.8		1387.8
	Min	0.5	0.1	0.0	0.3	3.4	6.0	29.7	59.5	63.6	50.6	16.9	1.1		279.5
	SD	7.3	5.6	5.5	5.3	7.3	29.3	87.9	93.2	95.2	83.3	19.1	11.6		286.9
	Variance	53.5	31.8	30.7	27.9	53.1	858.1	7722.6	8680.1	9065.1	6933.1	363.9	135.1		82332.7
	CV	48.6	57.0	61.4	62.2	57.4	73.1	71.7	51.0	52.0	72.7	45.3	48.6		37.6
	Skew	-0.1	0.0	0.4	0.1	0.8	2.0	1.1	1.1	1.5	2.4	0.7	0.3		0.3
	Total	298.4	401.9	1417.2	1704.1	4169.7	5889.7	5130.7	5332.0	4911.5	2918.7	524.9	397.3	0.0	33095.1
	Mean	16.6	22.3	78.7	94.7	231.6	327.2	285.0	296.2	272.8	162.2	29.2	22.1		1817.0
P	Max	52.7	66.0	209.9	208.0	430.9	447.0	498.9	467.9	370.0	328.1	99.1	140.3		2322.5
	Min	0.0	0.0	0.0	14.1	37.0	173.7	185.9	196.7	193.7	8.9	0.0	0.0		1392.7
	SD	16.3	20.8	53.1	44.0	89.0	70.0	83.2	60.9	52.4	89.1	22.5	28.2		237.8
	Variance	266.9	433.4	2818.2	1939.5	7914.8	4906.4	6927.2	3709.8	2743.6	7935.9	505.2	795.2		56535.4
	CV	98.5	93.2	67.4	46.5	38.4	21.4	29.2	20.6	19.2	54.9	77.1	127.8		13.1
	Skew	1.2	1.0	1.1	0.5	-0.3	0.1	1.2	0.5	0.3	0.4	1.0	3.5		0.2

Table 9G. Characteristics of monthly and annual rainfall (P) and Stream Flow (Q) of Temssa catchment (1989-2004)

Temssa

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Total	361.6	267.3	315.4	373.6	570.7	1134.4	1902.6	2756.5	2611.7	1701.5	918.8	504.8	13418.9
	Mean	22.6	16.7	19.7	23.4	35.7	70.9	118.9	172.3	163.2	116.3	57.4	31.6	838.7
Q	**Max**	48.9	37.9	38.7	69.2	116.8	165.4	227.0	323.2	297.5	213.0	118.9	64.1	1364.8
	Min	2.9	2.3	1.8	2.6	5.5	7.4	32.3	63.7	43.7	27.6	6.2	6.3	344.3
	SD	15.8	12.8	13.7	19.3	31.4	40.6	63.0	77.7	86.8	50.4	32.6	19.0	384.4
	Variance	249.4	163.6	188.2	372.2	987.1	1645.0	3968.0	6039.5	7526.4	2537.1	1165.2	361.4	147729.1
	CV	69.9	76.5	69.6	82.6	88.1	57.2	53.0	45.1	53.1	47.4	56.8	60.3	45.8
	Skew	0.4	0.5	0.0	1.0	1.1	0.8	0.3	0.2	-0.2	0.6	0.1	0.3	0.2
	Total	651.9	511.1	1331.6	2338.2	2931.5	3578.2	3417.9	3413.3	3032.4	2063.6	861.4	781.4	24912.5
	Mean	38.3	40.0	92.3	146.0	186.6	208.3	201.9	219.2	185.0	114.4	68.4	39.1	1531.4
P	Max	115.0	88.5	157.7	301.3	341.2	320.1	312.3	356.0	298.7	336.7	243.2	161.3	1966.7
	Min	0.0	0.0	11.2	56.0	12.2	113.6	96.1	91.0	127.6	11.1	1.3	0.0	1143.8
	SD	31.9	25.5	36.9	64.5	47.0	51.1	48.1	66.1	51.4	82.9	68.7	43.1	196.3
	Variance	1115.5	694.6	1715.6	5005.8	3830.4	6273.8	4225.7	6537.0	4214.3	7054.9	4699.2	1836.0	153765.8
	CV	83.1	63.7	40.0	44.2	25.2	24.5	23.8	30.1	27.8	79.4	110.3	111.3	12.8
	Skew	0.8	0.4	0.1	0.5	-0.2	0.5	-0.5	0.1	1.1	1.2	1.4	1.7	0.5

Table 9H. Characteristics of monthly and annual rainfall (P) and Stream Flow (Q) of Tato catchment (1996-2004)

Tato

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Total	201.9	124.3	111.5	119.2	162.9	485.2	966.7	1392.9	1264.5	714.4	401.7	235.2	6179.2
	Mean	18.4	12.4	11.0	11.8	14.8	44.1	87.9	126.6	115.0	64.9	36.5	21.4	561.7
	Max	62.3	46.0	19.1	19.6	26.9	119.4	202.8	240.5	338.1	150.0	115.0	43.5	981.1
Q	Min	7.9	3.0	4.9	4.9	4.5	13.7	45.4	50.2	35.3	21.2	13.6	11.5	262.1
	SD	15.4	12.4	4.7	5.0	7.1	32.6	47.5	55.0	87.5	40.3	28.1	9.5	222.0
	Variance	237.4	153.3	22.6	25.2	50.0	1163.1	2259.2	3020.9	7649.1	1623.0	787.4	90.0	49286.9
	CV	84.0	99.6	47.3	46.4	47.8	73.9	54.1	43.4	76.1	62.0	76.8	44.4	39.5
	Skew	2.7	2.6	0.7	0.6	0.1	1.5	1.7	0.6	1.8	0.9	2.5	1.3	0.8
	Total	225.0	335.1	1284.3	2111.4	5217.5	8341.0	8632.1	7798.2	5654.2	3023.4	976.4	375.0	43972.5
	Mean	11.7	16.8	61.2	110.5	248.5	397.2	411.1	371.3	269.2	144.0	48.8	17.9	2093.9
	Max	42.4	111.2	178.2	244.2	383.7	567.2	563.5	540.9	432.5	338.7	137.1	120.8	2551.4
P	Min	0.0	0.0	0.6	0.0	119.3	263.2	194.9	226.6	151.9	11.9	0.0	0.0	1696.9
	SD	11.6	25.6	38.5	67.1	64.4	86.0	87.0	82.8	67.9	93.0	33.0	26.1	237.9
	Variance	134.3	653.5	1483.2	4507.4	4151.6	7395.6	7567.3	6863.8	4615.2	8653.5	1190.5	679.1	56592.0
	CV	118.2	152.6	63.0	66.8	25.9	21.7	21.2	22.3	25.2	64.6	67.6	145.9	11.4
	Skew	1.9	2.8	1.1	0.9	0.1	0.7	-0.6	0.2	0.7	0.6	1.1	3.3	0.5

Table 11A. Runoff Coefficient (RC) and Base Flow Indices (BFI) of Temssa Catchment at two different periods of 1989-2004.

Temssa	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
LQ	2.9	2.3	1.8	2.6	5.5	7.4	32.3	63.7	43.7	27.6	6.2	6.3	344.3
Q	361.6	267.3	315.4	373.6	570.7	1134.4	1902.6	2756.5	2611.7	1701.5	918.8	504.8	13418.9
P	651.9	511.1	1331.6	2338.2	2931.5	3578.2	3417.9	3413.3	3032.4	2063.6	861.4	781.4	24912.5
RC	55.5	52.3	23.7	16.0	19.5	31.7	55.7	80.8	86.1	82.5	116.7	64.6	53.9
BFI	0.8	0.9	0.6	0.7	1.0	0.7	1.7	2.3	1.7	1.6	0.7	1.3	2.6
LQ1	2.9	2.7	25.5	25.7	29.6	37.5	47.5	65.1	81.9	27.6	11.4	6.3	418.2
Q1	274.0	211.0	257.7	309.1	480.0	730.4	1215.8	1733.4	1727.8	1182.9	593.8	365.0	8981.0
P1	288.8	379.7	814.6	1351.6	1369.3	1848.6	1780.1	1823.0	1500.7	618.0	342.5	471.0	12587.9
RC-1	94.9	55.6	31.6	22.9	35.1	39.5	68.3	95.1	115.1	175.2	173.4	77.5	71.3
BFI-1	1.0	1.3	9.9	8.3	6.2	5.1	3.9	3.8	4.7	2.5	1.8	1.7	4.7
LQ2	5.3	2.3	1.8	2.6	5.5	7.4	32.3	63.7	43.7	46.6	6.2	11.2	344.3
Q2	87.6	56.3	57.7	64.5	90.6	404.0	686.8	1123.1	883.9	618.6	325.1	139.8	4437.9
P2	363.1	131.4	517.0	986.6	1562.2	1729.6	1637.8	1590.3	1531.7	1445.6	518.9	311.4	12324.6
RC-2	24.1	42.9	11.2	6.5	5.8	23.4	41.9	64.3	57.7	42.8	62.6	45.0	36.0
BFI-2	6.1	4.1	3.1	4.1	6.0	1.8	4.7	6.2	4.9	7.5	1.9	7.3	7.8

Table 11B. Runoff Coefficient (RC) and Base Flow Indices (BFI) of Yebu Catchment at two different periods of 1980-2004.

Yebu	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
LQ	1.5	0.7	0.9	0.9	1.3	2.6	6.6	6.8	6.4	6.3	3.0	2.8	55.4
Q	96.5	72.5	81.9	74.0	111.5	200.9	431.2	518.6	443.0	381.6	222.2	129.1	2753.0
P	958.1	868.7	2115.4	3489.7	4650.3	5228.4	5113.0	5193.2	4698.5	2891.9	1529.2	1115.0	37731.3
RC	11.1	8.3	3.9	2.1	2.2	3.8	8.5	11.0	9.4	13.2	14.5	12.7	7.3
BFI	1.6	1.0	1.1	1.3	1.3	1.3	1.5	1.3	1.5	1.6	1.3	2.2	2.0
LQ1	3.3	2.8	3.0	2.7	4.2	8.1	15.6	17.8	16.1	11.3	7.8	4.7	97.4
Q1	39.6	33.4	35.5	32.5	51.0	97.1	187.3	213.6	193.3	136.0	94.0	55.8	1169.1
P1	438	531	1117	1555	2205	2353	2396	2518	2254	1108	796	492	17653
RC-1	9.0	6.3	3.2	2.1	2.3	4.1	7.8	8.5	8.6	13.5	11.8	11.4	6.6
BFI-1	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
LQ2	1.6	0.7	0.9	1.2	1.3	2.9	6.8	11.1	9.6	6.6	3.0	2.8	55.4
Q2	54.5	37.5	45.1	39.5	48.0	110.6	232.8	276.3	227.7	209.0	114.6	69.3	1454.8
P2	469.1	309.3	952.5	1803.2	2283.4	2747.0	2490.3	2456.1	2234.2	1751.0	665.5	434.1	18595.7
RC-2	11.6	12.1	4.7	2.2	2.1	3.7	9.3	11.3	11.2	11.9	17.2	16.0	7.8
BFI-2	2.9	2.0	1.9	2.9	2.7	2.9	2.9	4.0	4.2	3.2	2.6	4.0	3.8

Table 11C. Runoff Coefficient (RC) and Base Flow Indices (BFI) of Urgessa Catchment at two different periods of 1980-2003.

Urgessa	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
LQ	16.1	11.9	14.7	13.3	12.1	29.3	85.6	110.8	79.9	50.2	27.7	24.5	754.1
Q	832.0	643.8	812.4	1179.8	1349.4	2215.9	4968.9	6442.6	5572.4	3729.8	1830.9	1110.2	30578.2
P	907.1	840.3	2059.3	3358.6	4488.4	5110.0	4886.7	4973.8	4488.5	2758.7	1461.9	925.8	36249.0
RC	91.7	76.6	39.4	32.1	30.1	43.4	111.7	129.5	124.1	135.2	125.2	118.8	84.4
BFI	1.9	1.7	1.8	1.2	0.9	1.3	1.7	1.6	1.4	1.3	1.5	2.2	2.5
LQ1	16.1	11.9	14.7	13.3	12.1	41.1	85.6	110.8	79.9	50.2	33.7	24.5	754.1
Q1	330.5	262.4	354.9	343.2	499.2	1170.4	2336.1	2676.3	2295.0	1574.9	644.7	451.3	12839.1
P1	438.0	531.0	1116.8	1555.4	2205.0	2353.0	2396.4	2517.7	2254.3	1107.7	796.4	491.7	17653.3
RC	75.5	49.4	32.1	22.1	22.6	45.5	97.5	116.3	111.8	156.3	80.9	91.8	72.7
BFI	4.9	4.1	4.1	3.9	2.4	3.8	3.7	3.8	3.5	3.2	5.2	5.4	5.9
LQ2	21.5	13.4	17.0	20.1	23.9	29.3	112.9	128.8	114.5	70.8	27.7	31.7	886.7
Q2	501.5	381.4	457.5	736.5	850.2	1145.5	2632.9	3766.3	3277.4	2154.9	1186.2	648.9	17739.1
P2	469.1	309.3	952.5	1803.2	2283.4	2747.0	2490.3	2456.1	2234.2	1751.0	665.5	434.1	18595.7
RC	116.9	123.3	48.0	40.8	37.2	41.7	115.7	153.3	146.7	123.1	178.2	149.5	95.4
BFI	4.3	3.5	3.7	2.7	2.8	2.6	4.3	3.4	3.5	3.3	2.3	4.9	5.0

Table 11D. Runoff Coefficient (RC) and Base Flow Indices (BFI) of Dabana Catchment at two different periods of 1989-2004.

Dabana	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
LQ	1.0	1.9	1.7	1.6	3.6	17.4	47.4	36.0	27.2	17.5	2.8	0.5	335.0
Q	177.8	194.3	245.3	315.8	673.3	1644.8	3278.5	4174.1	3470.3	2028.9	669.1	271.5	17143.6
P	972.5	1121.7	2418.6	3850.7	6125.7	8395.7	8248.3	8963.5	7723.8	4644.3	1188.5	906.2	54459.5
RC	18.3	19.0	11.1	8.2	11.0	19.6	39.7	46.6	44.9	43.7	56.3	30.0	31.5
BFI	0.6	1.0	0.7	0.5	0.5	1.1	1.4	0.9	0.8	0.9	0.4	0.2	2.0
LQ1	6.4	9.5	11.9	15.7	29.8	55.1	113.1	129.0	97.9	57.3	15.9	6.7	536.9
Q1	83.0	123.7	154.2	187.9	386.9	716.4	1340.6	1676.8	1272.2	744.6	206.4	87.1	6979.8
P1	440.7	556.8	1229.6	1745.2	2806.9	4361.2	4225.2	4597.8	3754.6	1906.8	736.5	445.8	26807.0
RC-1	18.8	22.2	12.5	11.8	13.8	16.4	31.7	36.5	33.9	39.1	28.0	19.5	26.0
BFI-1	7.7	7.7	7.7	8.3	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
LQ2	3.6	1.9	1.7	1.6	3.6	32.6	88.5	111.7	117.9	32.8	11.2	5.5	473.0
Q2	90.9	68.3	88.0	124.4	276.3	871.3	1748.0	2240.4	1995.5	1190.5	416.9	168.3	9278.7
P2	531.8	464.9	1189.0	2115.5	3318.8	4034.5	4023.1	4365.7	3969.2	2737.5	452.0	460.4	27652.5
RC-2	17.1	14.7	7.4	5.9	8.3	21.6	43.4	51.3	50.3	43.5	92.2	36.6	33.6
BFI-2	4.0	2.8	1.9	1.3	1.3	3.7	5.1	5.0	5.4	2.8	2.7	3.3	5.1

Table 11E. Runoff Coefficient (RC) and Base Flow Indices (BFI) of Indris Catchment at two different periods of 1987-2004.

Indris	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
LQ	0.5	0.1	0.0	0.3	3.4	6.0	29.7	59.5	63.6	50.6	16.9	1.1	279.5
Q	282.6	185.1	167.4	159.3	234.7	772.6	2354.0	6125.1	9486.1	2899.1	736.8	441.3	23844.1
P	298.4	401.9	1417.2	1704.1	4169.7	5889.7	5130.7	5332.0	4911.5	2918.7	524.9	397.3	33095.1
RC	94.7	46.1	11.8	9.3	5.6	13.1	45.9	114.9	193.2	99.3	140.4	111.1	885.4
BFI	0.2	0.0	0.0	0.2	1.5	0.8	1.3	1.0	0.7	1.7	2.3	0.3	9.8
LQ1	6.8	2.7	2.4	1.4	3.4	17.8	78.6	159.4	154.1	60.2	20.3	11.1	652.1
Q1	131.3	78.6	67.6	65.5	96.5	414.9	1527.4	4950.3	8345.9	2150.0	370.7	239.4	18438.1
P1	126.5	242.5	773.6	829.2	1887.0	2702.9	2631.5	2932.8	2448.4	1230.8	239.8	254.8	16299.8
													0.0
RC-1	113.8	32.4	8.7	7.9	5.1	15.4	58.0	168.8	340.9	174.7	154.6	94.0	1164.3
BFI-1	5.1	3.5	3.5	2.1	3.6	4.3	5.1	3.2	1.8	2.8	5.5	4.6	45.2
LQ2	0.5	0.1	0.0	0.3	4.6	6.0	29.7	59.5	63.6	50.6	16.9	1.1	279.5
Q2	151.3	116.5	99.8	93.9	138.2	357.6	826.6	1174.9	1140.2	749.2	366.1	201.9	5406.1
P2	171.9	159.4	643.6	874.9	2282.7	3186.8	2499.2	2399.2	2462.1	1687.9	285.1	142.5	16795.3
RC-2	88.0	66.8	15.5	11.7	6.1	11.2	33.1	49.0	46.3	44.4	128.4	141.7	641.1
BFI-2	0.3	0.1	0.0	0.3	3.3	1.7	3.6	5.1	5.6	6.7	4.6	0.6	31.9

Table 11F. Runoff Coefficient (RC) and Base Flow Indices (BFI) of Lower Didessa Catchment at two different periods of 1979-2004.

Lower Didessa	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
LQ	1.2	0.5	0.3	0.8	1.3	5.3	13.0	49.2	48.7	13.1	6.0	3.7	173.2
Q	118.3	67.7	68.5	77.5	154.3	665.3	1405.7	2428.5	1976.1	1436.5	416.2	196.6	3384.6
P	369.6	514.1	1923.7	2452.1	6059.0	8318.2	7851.8	7656.2	7113.7	3688.3	837.4	467.4	20118.4
RC	29.3	13.2	3.6	3.2	2.5	8.0	17.9	31.7	27.8	38.9	49.7	42.1	16.8
BFI	1.1	0.8	0.4	1.0	0.8	0.8	0.9	2.0	2.5	0.9	1.4	1.9	5.1
LQ1	1.2	0.5	0.3	0.8	1.3	5.3	13.0	49.2	52.1	13.1	6.8	3.7	221.4
Q1	50.4	30.3	30.3	35.4	68.9	366.7	713.4	1202.9	1169.0	767.3	209.9	114.8	4649.3
P1	143.5	263.1	962.0	1163.4	2848.6	4077.5	4339.0	4044.2	3557.4	1506.1	456.9	269.7	23531.5
RC-1	35.1	11.5	3.2	3.3	2.4	9.0	16.4	29.7	30.0	50.9	45.9	38.8	19.8
BFI-1	2.4	1.8	0.9	2.2	1.9	1.5	1.8	4.1	4.9	1.7	3.2	3.5	4.8
LQ2	1.3	0.6	1.2	0.8	3.7	8.3	22.5	57.0	48.7	15.7	6.0	3.7	173.2
Q2	57.9	37.4	38.1	42.1	85.4	298.6	692.3	1225.6	907.2	669.1	206.3	91.8	4056.3
P2	226.1	251.0	961.7	1388.7	3211.4	4240.7	3512.8	3612.0	3546.3	2182.2	380.5	197.7	23711.1
RC-2	25.6	14.9	4.0	3.0	2.7	7.0	19.7	33.9	25.6	30.7	54.2	46.4	17.1
BFI-2	2.2	1.6	3.3	1.8	4.3	2.8	3.3	4.7	5.4	2.3	2.9	4.0	4.3