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Regional Sediment Yield Estimate for Abbay River Basin

By

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In partial fulfillment of the requirements for the Masters of Science Degree in Civil Engineering Major Hydraulics Engineering

Advisor: Dr. Yilma Seleshi

Addis Ababa, Ethiopia

January, 2010

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Certification

I the undersigned certify that I have read and hereby recommend for acceptance by Addis Ababa University a thesis entitled: **Regional Sediment yield Estimate for Abbay River basin**; in partial fulfillment of the requirements for the Masters of Science Degree in Civil Engineering Major Hydraulics Engineering.

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Dr. Yilma Seleshi

(Advisor)

Date: ……………………

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Dedication

Dedicated: ***To my Honor Mother, Ayane Kura, who is not … by now.***

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List of abbreviations

A	Catchment area
AGNPS	Agricultural None Point Source model
ANSWERS	Areal Nonpoint Source Watershed Environmental Response Simulation
ASCE	Americans Society of Civil Engineers
AVSWAT	Arc view SWAT
CREAMS	Chemicals, Runoff, and Erosion from Agricultural Management Systems
EPIC	Erosion Productivity Impact Calculator
EUROSEM	European Soil Erosion Model
GIS	Geographical Information Systems
HRU	Hydrologic Response Units
HSPF	Hydrologic Simulation Program –Fortran
KM^2	Kilo meter square
m^3 /s	Meter cube per second
masl	Meter above sea level
Mg/l	Milligrams per liter
Mha	Million hectares
MoWR	Ministry of Water Resources
MUSLE	Modified Universal Soil Loss Equation
NMSA	National Meteorological Service Agency
P	Precipitation

Q_{sy}	Annual Sediment yield
RUSLE	Revised Universal Soil Loss Equation
SIDX	Soil indices
SLDX	Slope indices
SSC	Suspended sediment concentration
SWAT	Soil and Water Assessment Tool
t/d	Tonnes per day
t/ha/yr	Tonnes per hectare per year
USDA-ARS	United States Department of Agriculture-Agricultural Research Service
USLE	Universal Soil Loss Equation
VIDX	Vegetation indices
WEPP	Water Erosion Prediction Project

ABSTRACT

Abbay basin is one of the largest basins of the western drainage system located in the north west of Ethiopia. It accounts 17.5% of land area and 50% of annual average surface water resources of Ethiopia. It is also characterized by high population pressure, improper land-use planning, over dependency on agriculture as source of livelihood, which is causing deforestation, overgrazing, expansion of agriculture to marginal lands and steep slopes. These have resulted in declining agricultural productivity and resources use conflicts in many parts of the Abbay basin. As a consequence of poor land use practices and improper management systems there are high soil erosion rates, sediment transport, and loss of agricultural nutrients. The total soil eroded within the landscape in the Abbay Basin is estimated to be 302.8 million tones per annum. In contrary, currently the government has multitude plan to implement development projects with regard to Irrigation, Hydropower and water supply to ensure food security and sustainable development. Therefore, knowing the estimate of annual sediment withdrawal is important in the planning, design and operation of water resources development projects. Generally, this study is aimed at conducting regional sediment yield estimates for Abbay River basin using statistical multiple regression relationships based on catchment characteristics and Rainfall. Sediment yield of about 27 selected sub basins/stations are computed from suspended sediment concentration (SSC) and daily flow records. Other factors affecting sediment yield (catchment area (A), precipitation (P) is obtained from rainfall data of the station, whereas vegetation index (VIDX), slope index (SLDX), soil index (SIDX) are catchment characteristics determined by running SWAT2005 for the basin. The statistical multiple regression models, for estimating the regional sediment yield is applied, using sediment yield, precipitation and catchment characteristics data once the selected sub basins are regionalized. Hence the regression parameters are obtained for the regression equation with coefficient of determination near to unity. Generally the equation developed will give preliminary sediment yield estimate for concerned individuals, institutions, stakeholders, etc for any water resource development project.

CHAPTER ONE

1. INTRODUCTION

1.1. Background

High population pressure, improper land-use planning, over dependency on agriculture as source of livelihood, and extreme dependence on natural resources are causing deforestation, overgrazing, expansion of agriculture to marginal lands and steep slopes, declining agricultural productivity and resource-use conflicts in many parts of the Blue Nile. As a consequence of these, land and water resources degradation becomes the major problems on Ethiopian highlands especially the Abbay basin. Also poor land use practices and improper management systems have in turn contributed to high soil erosion rates, sediment transport, and loss of agricultural nutrients.

The total soil eroded within the landscape in the Abbay Basin is estimated to be 302.8 million tonnes per annum and from that cultivated land is estimated to be 101.8 million tonnes per annum. Thus, the remaining 201 million tonnes per annum of soil being eroded is from non-cultivated land (i.e., mainly from communal grazing and settlement areas). The area of cropland subject to "unsustainable" losses (i.e., where loss exceeds soil formation or 12.5 tonnes/ha/yr) are 968,900, 104,000 and 956,900 ha in the Amhara, Benishangul Gumuz and Oromiya areas of the Basin, respectively. Thus, a total of about 2.03 million hectares (Mha) of cultivated land have unsustainable soil loss rates (Sileshi et al., 2008).

Abbay basin is one of the largest basins of the western drainage system located in the north west of Ethiopia, which accounts 17.5% of land area and 50% of annual average surface water resources of Ethiopia. Even though the river basin and its tributaries have experienced a huge amount of annual sediment transport until it reaches the Sudan border, because of higher water resources potential, currently the government has multitude plan to implement huge development projects in the aspect of Irrigation, Hydropower and water supply, so that many dams are constructed in the basin to ensure food security and sustainable development. Over 60% of flow and sediment of the Nile is caused by the Blue Nile, aggravating poverty and loss of livelihood in upstream-downstream areas, and requires urgent interventions. Therefore, it is compulsory to know the estimate of annual sediment withdrawal which is important in the planning, design and operation of any water resources projects. Further more, estimates of sediment yield are essential in water resources analysis, modeling and engineering, investigation of continental denudations rates, and studies of drainage basins response to change in climate and land use.

This study is aimed at conducting regional sediment yield estimates for Abbay River basin using statistical multiple regression relationships based on catchment characteristics and climate. Sediment yield of selected sub basins are computed from suspended sediment concentration (SSC) and daily flow records. Other factors affecting sediment yield (catchment area (A), precipitation (P) is obtained from climatology (rainfall) data of the station, whereas vegetation index (VIDX), slope index (SLDX), soil index (SIDX) are catchment characteristics determined by running SWAT2005 for the basin. The statistical multiple regression models for estimating the regional sediment yield is thoroughly applied using sediment yield, climate and catchment characteristic data from about 27 gauging stations in the river basin. Basically there are many factors affecting sediment yield though concern is given to the more important ones.

Generally inadequate Knowledge of precise regional sediment yield estimates leads to poor planning, design and operation of water resources projects, which in turn affects the economic development of the country.

1.2. Statement of the Problems

- Even though, assessment of soil erosion, sediment transport and deposition of sediments in the reservoirs, irrigation and hydropower systems are considered essential for the land and water management, there is no in-depth study in the basin so far.
- The magnitude of the regional sediment yield estimate transported by the river Basin has become a serious concern for planning, design and implementation of numerous national development projects in the area.
- Furthermore reduction in soil production capacity, reservoir siltation, change in river bank and flooding due to sediment deposition are problems calling for estimation of annual sediment yield in the basin.

1.3. Objectives

General objective

To conduct regional sediment yield estimate for Abbay river basin using multiple regression model.

Specific objectives

- To determine the sediment yield estimate for Abbay basin based on catchment characteristics and rainfall.
- To produce regional empirical equation for the sub basin, by fixing parameters for each factors considered in this study, for early sediment yield prediction.
- To show direction for up coming researchers.

1.4. Description of the Project area

1.4.1. Location

The Abbay (Blue Nile) River Basin originates from Lake Tana in Ethiopia and flows south from Lake Tana, then west across Ethiopia and North West into Sudan. It lies between $7^0$45'-$12^0$45'N latitude and $34^0$05'-$39^0$45'E longitude with a drainage area of 199,812 km^2. It receives on its right bank from Gojam highlands several medium (Abeya,Suha, Chemoga,Birr, Fettam,dura, and small tributaries, and , on its left bank from the wollo, Shewa, and Wollega major ones (Beshilo, Welaka, Jemma, Muger, Guder, Fincha, Diddessa). Before the Sudanese border it receives in the low lands its last two tributaries :Dabus from the left and Beles the only major right bank tributary (Abbay River Basin integrated development master plan project, phase II, part II –Hydrology).

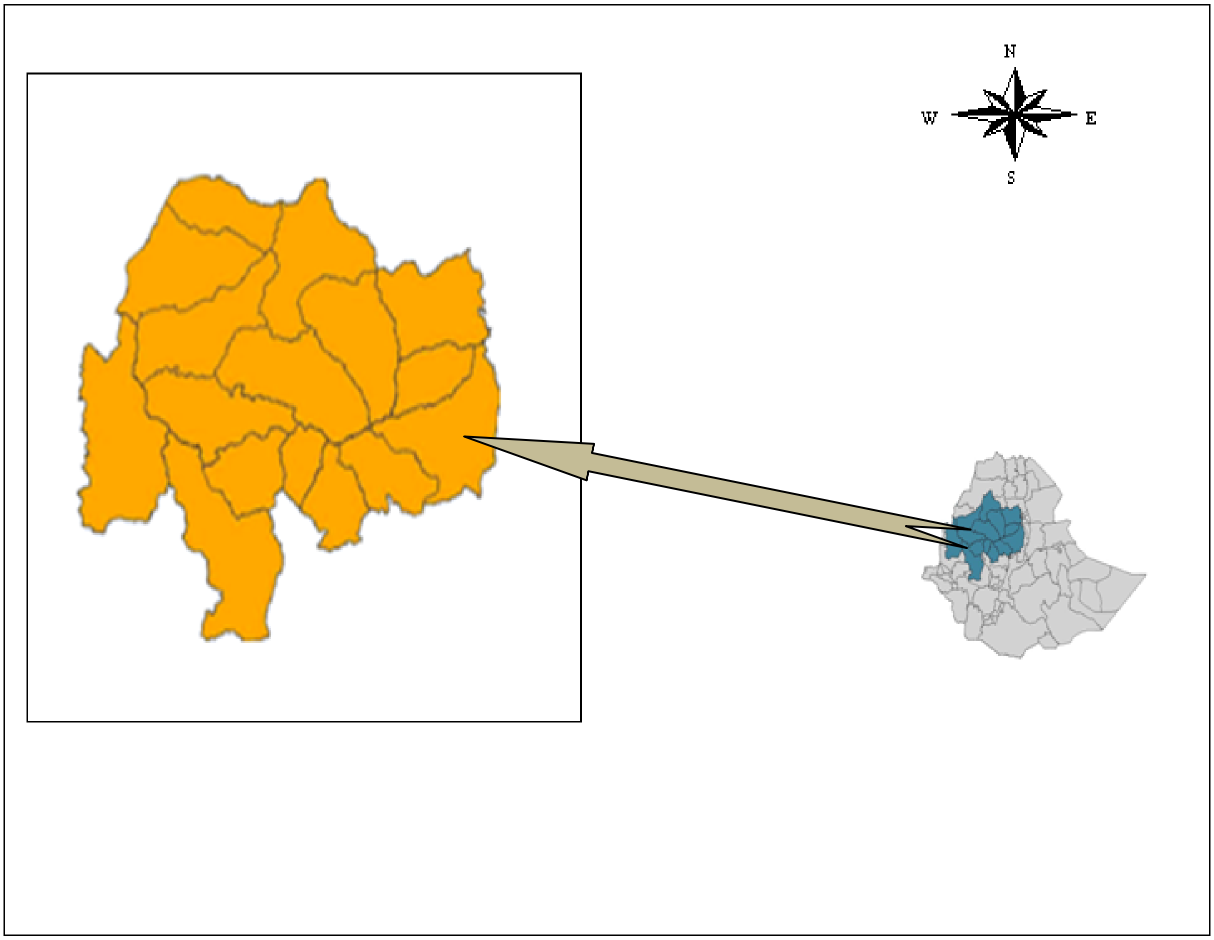

Figure 1.1 Location map of Abbay basin

1.4.2. Physiography

The Abbay basin is made up of three major physiographic types-plateau, gorge and low land plain. The plateau highlands lie between elevation 2100 to 2700masl and cover a vast area in the eastern portion of the basin. The streams flowing along valleys on the plateau mostly fall sharply into deep gorges and canyons, ultimately joining the Abbay River. Along the western border of the high plateau, the topography drops off sharply by about 600 meters below the general level of the plateau and then drops gently towards the Ethio-Sudan border.

The gorges and canyons occur along the course of Abbay river and its main tributaries between elevation of 1000 to 2500 masl.The streams flowing along the gorges and canyons incised the plateau basalt and the underlying strata.

The lowlands plains are mostly found in the western and north western parts of the basin. The plain consists of eroded hills and occur between elevations of about 400 to 1100 masl.

1.4.3. Geology

The Abbay basin contains three main groups of rocks igneous, sedimentary and metamorphic rocks. The igneous rocks occur as capping and comprises younger and older volcanic. The younger volcanic consists of basaltic lava flows interbedded with ash and tuff which are often weathered. Older volcanic usually consists of massive basalt. Generally the three major geologic units correspond more or less to the physiographic units, viz. igneous rocks are to lowlands; sedimentary rocks are exposed in the mid slope of Abbay river gorges; and the volcanic belongs to highland plateau.

1.4.4. Climate

The climate of the basin is strongly related to the altitude and the proximity to equatorial monsoon systems. The basin is thus characterized by a wide variety of climates ranging from semi-arid to alpine.

The mean annual rainfall of the basin varies from 800 to 2000 mm generally increasing with an increase in altitude. Rainfall in most of the basin is unimodal with much of the rain falling from June to September. The dry season extends from October to March while a period of small rain (Belg) occurs from April to may bring about by the south-east Indian Ocean monsoon. The eastern fringes areas of the basin can have a bimodal rainfall in which the Belg rains are nearly 50% of the' kiremt' rains. Lowest temperatures are recorded in December and January while highest temperatures are recorded during the month of April and May.

1.4.5. Land use/Land cover

As to the land use cultivated land accounts for 33% of the total area of the basin while grazing land constitutes 16%. Also most of the climax vegetation of the Abbay river basin has disappeared. Much forest is cleared for agriculture, fuel wood and charcoal production and construction resulting in progressive depletion of forest which is a major natural resources problem. The highland forest occurring between 1400 and 2600 masl consists of trees, the plateau consists remnant forests , disturbed forests occurring in the southern part of the basin, the savanna wood land in the pastoral and agro pastoral zones, and the woodland, bush land and wooded grassland occupy larger areas in the west and southwest of Abbay basin(MoWR,1998).

1.4.6. Soil

The reconnaissance study of the basin enabled identification of the major soil groupings. Such as Vertisols,Leptosols,Nitisols,Luvisols,Cambisols,Acrisols,Regosols,Fluvisols,Arenosols,Alisols and Phaeozems.About 16% of the basin is covered with Nitisols and 21% by Alisols. Leptosols cover 22% of the basin. On the flat plateaus in the Ethiopian Highlands are extensive areas of Vertisols. On the deep soils in the high rainfall areas around Lake Tana there are extensive areas of Luvisols(MoWR,1998).

CHAPTER TWO

2. LITERATURE REVIEW

2.1. General

Currently there are emerged considerable interests in the measurement and estimation of sediment yields in streams. A quarter of a century ago studies of soils erosion and sediment were initiated in response to concern regarding the loss of productive soil and siltation of streams and reservoirs. Soil erosion is one of the most critical environmental hazards of modern times. Vast areas of land now being cultivated may be rendered economically unproductive if erosion of soil continues unabated. The information on sources of sediment yield within a catchment can be used as a perspective on the rate of soil erosion occurring within that catchment.

The process of soil erosion involves detachment, transport and subsequent deposition (Meyer & Wischmeier, 1969). Sediment is detached from the soil surface both by raindrop impact and by the shearing force of flowing water. The detached sediment is transported down slope primarily by flowing water, although there is also a small amount of down slope transport by raindrop splash (Walling, 1988). Once runoff starts over the surface areas and in the streams, the quantity and size of material transported increases with the velocity of the runoff. At some point, the slope may decrease, resulting in a decreased velocity and hence a decreased transport capacity (Haan *et al.,* 1994). The sediment is then deposited, starting with the large primary particles and aggregates. Smaller particles are transported further down slope, resulting in the enrichment of fines. Apart from rainfall and runoff, the rate of soil erosion from an area is also strongly dependent upon its soil, vegetation and topographic characteristics. In real situations, these characteristics are found to vary greatly within the various sub-areas of a catchment. The amount of sediment load passing the outlet of a catchment forms its sediment yield. In addition to the effects of rapidly changing land-use patterns, the sediment load from large catchments also depends on catchment size, slope and physiography, and parent material.

Simple methods such as the Universal Soil Loss Equation (USLE) the Modified Universal Soil Loss Equation (MUSLE) (Williams, 1975), or the Revised Universal Soil Loss Equation

(RUSLE) are frequently used for the estimation of surface erosion and sediment yield from catchment areas (Menbere, 2007).

Erosion rates for major river basins in Africa have been reported by many researchers. Some of the data are at least 20 years old and were certainly obtained before the implementation of large-scale land development schemes. The estimates of sediment load reported are, therefore, in many cases low and obsolete. Some researchers have also related suspended sediment yield to other controlling factors, including mean annual runoff, a rainfall aggressivity index, land use and vegetation cover (Lal,1985). It is, in fact, difficult to relate sediment yield to any one controlling environmental factor. Fournier (1960, 1966), for example, observed that suspended sediment yield was related to three environmental factors, namely, mean altitude, mean slope, and an index of rainfall aggressivity, viz.

$$\log E = 2.65 \log \frac{p^2}{P} + 0.46 \log H \tan \phi - 1.56 \quad \text{---------------} \ (2.1)$$

Where, E = suspended sediment yield in t $km^{-2}year^{-1}$ H = mean altitude; Φ = mean slope; p = monthly rainfall in mm; and P =annual rainfall in mm.

Also researchers have developed a relationship between rainfall, evaporation and runoff for equatorial Africa. Yet another empirical relationship was developed for humid regions relating annual sediment yield to four controlling factors, viz

$$\log S = 4.4 + 1.5 \log D - 0.3A + 0.3 \log R - 3.4 \log T \quad \text{--------------} \ (2.2)$$

Where, S = sediment yield (t $km^{-2}year^{-1}$); D = annual runoff discharge (m^3km^{-2}); A = basin area (km^2); R = relief-length ratio (m km^{-1}); and T = mean annual temperature (°C).

2.2. Modeling soil Erosion and Sediment yield

Soil erosion is a complex process and pervasive geomorphologic hazard “earth cancer” and its rate is counted as a comprehensive index for assessing degree of development and sustainability of land management programs of the countries. Due to the strong dependence of pedogenesis on geomorphic systems, there is a close relationship between geomorphic units and erosion rate at different spatial levels. Sediment is a natural component of riverine environments and its presence in river systems is essential. However, in many ways and many places river systems and the landscape have been strongly affected by human activities which have destroyed naturally balanced sediment supply and sediment transport within catchments. As a consequence a number of severe environmental problems and failures have been identified.

Sediment yield is not an accurate measure of all the products of erosion and mechanical denudation, since a considerable part of the latter is accumulated in the form of slope, proluvial, and alluvial deposits and is not transported to the outlet of the drainage basin. Nevertheless, sediment yield directly depends on the intensity of erosion and the overall mechanical denudation in the river basin and can be used for comparative assessments of the intensity of these processes under different conditions. Generally soil erosion and sedimentation problems are strongly related to land use policy, natural resource management, level of development and degradation/deforestation of the basin as well as cultivation practices, conservation measures, etc.

Nowadays simulation programs implementing watershed hydrology and river water quality models are important tools for watershed management for both applied and operational research purposes. For this purpose several available empirical, physically based or conceptual models could be used. Empirical models are based on defining important factors through field observation, measurement, experiments and statistical methods. They are useful in predicting the hydrology or soil erosion, but are site specific and require long-term data. Physically based models are based on knowledge of the fundamental processes and incorporate the laws of conservation of mass and energy. These physical processes vary both temporally and spatially. They consider the spatial and temporal changes of different factors. Physically based distributed watershed models play a major role in analyzing the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds (Shimeles, 2008).

Many hydrological and soil erosion models are developed to describe the hydrology, erosion and sedimentation processes. These models are generally meant to describe the physical processes controlling the transformation of precipitation to runoff and detachment and transport of sediments.

Erosion modeling is based on understanding the physical laws of landscape processes that occur in the natural environment. Erosion models can provide a better understanding of natural phenomena such as transport and deposition of sediment by overland flow and allow for reasonable prediction and forecasting. Many different models have been proposed to describe and predict soil erosion by water and associated sediment yield. They vary considerably in their objectives, time and spatial scales involved.

In recent years, distributed watershed models are increasingly used to implement alternative management strategies in the areas of water resources allocation, flood control, impact of land use change and climate change, and finally environmental pollution control. Many of these models share a common base in their attempt to incorporate the heterogeneity of the watershed and spatial distribution of topography, vegetation, land use, soil characteristics, rainfall and evaporation. Some of the watershed models developed in the last two decades are CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management Systems) EPIC - Erosion Productivity Impact Calculator (Williams, 1995), AGNPS (Agricultural None Point Source model)), SWAT (Soil and Water Assessment Tool) and HSPF (Hydrologic Simulation Program –Fortran),ANSWERS (Areal Nonpoint Source Watershed Environmental Response Simulation), EROSION-3D,EUROSEM (European Soil Erosion Model), WEPP (Water Erosion Prediction Project) etc. Also the most widely used empirical model is the universal soil loss equation (USLE). The USLE model estimates average annual soil loss by sheet and rill on those portions of landscape profiles where erosion but not deposition is occurring. The model neither predicts single storm loss nor does it predict gully erosion (Dilnesaw, 2006). USLE or Modified/Revised method (M/RUSLE) estimate erosion at small catchments based on relationship established on soil conservation site data. Applying such relationships in the basin such as the Blue Nile is difficult, as such models are not primarily designed for such large-scale systems and obtaining pertinent data for calibration, validation and impact evaluation are also difficult to obtain. Suspended sediment rating represents the relationships between suspended sediment concentration and water discharge in a river. They are typically used to simulate time series of sediment concentration or load from a discharge record. This can then be integrated to obtain an estimate of the average annual sediment yield over the period of discharge record. Sediment yields so estimated for basins within a region can often be related to various physical and hydrological parameters, leading to a regional model predicting sediment yield from basins for which there is no information. This approach is convenient for estimating the time-averaged sediment yield for unsampled basins. Similarly for Blue Nile the suspended sediment yield estimation can be done and related to catchments and climate characteristics so that a regional estimate is possible.

2.3. Sediment Transport

Sediment transport refers to the displacement of granular materials by flowing water. That means eroded material derived from the watershed, riverbed and banks will be transported with the flow as sediment transport, either in suspension or as bed load. Ultimately, this sediment is redeposited, often causing problems in downstream areas. Generally, the sediment transport phenomenon is a function of many processes that are in the form of sheet erosion, rill and inter-rill erosion, and gulley erosion. Eroded sediment particles that are transported to the river are called delivered sediment or sediment yield from a given watershed. The delivered sediment travels with the flow as suspended material. The other component of the sediment transport comes from the bed and bank material and travels with the flow as suspended or bed load. The transported particles move downstream as far as the hydraulic conditions permit. These conditions depend on the slope of the river, velocity, discharge, cross sections, etc (Garde & Raju, 1985).

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2.3.1. Sediment Transport Equations

For both bed load and suspended load, the source of the sediment is movable alluvial bed. Hence, the sum of the bed load and suspended load gives the total bed material load. It does not include the wash load, consisting of small size particles which do not settle in the running water. Wash load more or less depends on the solid material supply from a catchment (Garde & Raju, 1985).

Plenty of sediment transport equations available but employing them for similar conditions will yield transport rates which might differ by diverse degree of gap. The reason, of course, is that each equation was developed for some special condition, such as for fine uniform sand moving at very low Froude numbers, or very broad sediment mixtures, including coarse gravel material, moving at extremely high values of relative roughness, etc (Shen, 1972). It is therefore difficult to develop a general sediment transport equation. However for existing equations and those once to be developed in the future, the field of application of each equation whatever the parameters might be should be limited. There seems to be a specific need for a transport equation which describes conditions for sediment mixtures including coarse material. Not only should such an equation give the rate of sediment transport, but it should also predict with some reliability the grain size distribution of the moving material. The only equation which gives grain size distribution is Einstein's (1950) equation. However, it was developed for sand bed rivers and there is some agreement between measured and computed grain size distribution. The few equations used toward coarse material transport in mountainous stream, like the Meyer- Peter and Muller equation. These equations do not include the effects of the sediment mixture beyond employing mean grain size. Nevertheless, the time scale of aggradations and degradation processes will greatly depend on the availability of grains of any size (Teshager, 2006).

2.3.1.1. Suspended load

In the case of suspended load determination from large watersheds measurements are reasonably good whereas calculations are tedious and difficult.

2.3.1.2 Bed load

In the analysis of bed load calculations, semi empirical formulas derived from experimental channels are used. Also results differ appreciably and measurements are difficult.

Generally, total load is the summation of Bed material load and wash load, where in bed material load is also summation of suspended load and Bed load.

CHAPTER THREE

3. METHODOLOGIES

This study concerned with estimation of regional sediment yield is carried out based on multiple regression equation, and SWAT 2005 model. The method involves development of rating curve, simulation, sensitivity analysis, calibration, verification and validation and finally regression analysis by regionalizing the sub basins.

3.1. Description of Multiple Regression models

Regression is an analytical procedure that derives estimation or prediction equations for a variable (dependent) based on given values of one or more other variables (independent). Commonly, the principle of minimum squared error (least squares) is used in the derivation. In other definition regression analysis is a statistical technique for modeling and investigating relationships between two or more dependent and independent variables. Also it is a collection of statistical tools for finding estimates of the parameters in the regression model.

In this study multiple regression model was developed based on the sediment yield (Qsy) as the response/predicted (dependant) variable and catchment area (A), Precipitation (P), vegetation index (VIDX), Soil index (SIDX) and slope index (SLDX) as the regressors/predictors (independent variables). Where, $\alpha, \beta, \lambda, \psi, \phi, and \theta$ are parameters of the above factors to be estimated by regression analysis.

$$Q_{sy} = \alpha A^{\beta} P^{\lambda} (VIDX)^{\psi} (SIDX)^{\phi} (SLDX)^{\theta} \quad \text{----------- (3.1)}$$

Where, Qsy=annual sediment yield (ton/km^2/yr), A=catchment area(km^2), P=annual precipitation (mm), VIDX=Vegetation Index, SIDX=Soil Index and SLDX=Slope Index are catchment characteristics.

Generally regression relationships are valid only for values of the regressor variables within the range of the original data (regression models are not necessarily valid for extrapolation purpose).

3.2. Description of the Soil and Water Assessment Tool (SWAT 2005 model)

SWAT 2005 is a public domain model strongly supported by the USDA (United States Department of Agriculture) – ARS (Agricultural Research Service) at the Grass-land, Soil and Water Research Laboratory in Temple, Texas, USA. SWAT is a river basin scale, a continuous time, a spatially distributed model developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time (Neitsch *et al*., 2005). SWAT can analyze both small and large watersheds by subdividing the area into homogenous parts (which has similar landcover, soil and slope). It is a physically-based model that uses hydrologic response units (HRUs) to describe spatial heterogeneity in terms of land cover, soil type and slope within a watershed. The SWAT system embedded within geographic information system (GIS) that can integrate various spatial environmental data including soil, land cover, climate and topographic features. It is computationally efficient, uses readily available inputs and enables users to study long-term impacts.

The ultimate purpose of employing SWAT 2005 model in this study is to extract catchment characteristics, VIDX, SIDX and SLDX.

3.2.1. The Sediment Component of SWAT model

SWAT calculates the soil erosion and sediment yield with the Modified Universal Soil Loss Equation (MUSLE) (Williams and Berndt, 1977).

$$Sed = 11.8(Q_{surf}\, q_{peak}\, A_{hru})^{0.56} * K_{USLE} * C_{USLE} * P_{USLE} * LS_{USLE} * CFRG \quad \text{------ (3.2)}$$

Where, Sed is the sediment yield on a given day (metric tons), Q_{surf} is the surface runoff volume (mm /ha), q_{peak} is the peak runoff rate (m^3/s), $Area_{hru}$ is the area of the HRU (ha), K_{USLE} is the soil erodibility factor (metric ton m^2 hr/(m^3-metric ton cm)), C_{USLE} is the cover and management factor, P_{USLE} is the support practice factor, LS_{USLE} is the topographic factor and CFRG is the coarse fragment factor. The details of the USLE factors and the descriptions of the different model components can be found in (Neitsch *et al*., 2005).

3.3. Data collection and Analysis

3.3.1. Data collection

Generally for this study the required data is suspended sediment concentration (SSC) data for selected sub basins, and data on daily flow at the gauging stations, data on monthly Precipitation, and catchment areas. The other data is vegetation index, slope and soil index which are determined by using SWAT 2005 for selected sub basins. Also the annual sediment yield of the basin is determined by initially determining the suspended sediment load and correlating it with daily flow so that a sediment rating curve is developed. Also the data on catchment area can be determined using Arc View SWAT (AVSWAT) model for the respective gauging stations.

3.3.1.1. Suspended Sediment Concentration

Data on suspended sediment concentrations (mg/l) for selected stations were obtained from MOWR .But the length of observation/record are very few for some stations.

3.3.1.2. Flow

Daily flow data for the selected sub basins are collected from MoWR with a record length of 10 to 20 years. This flow data is used for calculating suspended sediment discharge at selected stations. Throughout the Blue Nile Basin, river flow data are generally limited because of the remoteness of many of the catchments and the lack of economic resources and infrastructure to build and maintain monitoring sites. Although there are over 100 flow gauging stations in the basin, most of these are located on relatively small tributaries and/or near the headwaters of the main rivers.

Very few gauged catchments are over 1,000 km^2 and very few gauging stations are located on the main stem of the river or on the major tributaries close to their confluence with the Blue Nile.

3.3.1.3. Rainfall

Annual mean precipitation (mm) for all stations corresponding to the selected sub basin stations are calculated from monthly rainfall data obtained from National Meteorological Service agency (NMSA).The rainfall data are considered for 10 to 20 years with many stations are 10 years.

3.3.1.4. Temperature

The maximum and minimum daily temperatures for the basin are obtained from NMSA for the basins and are used as input data in SWAT model.

3.3.1.5. DEM

The data of Abbay DEM (digital elevation model) is obtained from Water Works Design and Super vision Enterprise (WWDSE) for processing grid for watershed delineation so that SWAT model is run.

3.3.1.6. Land use/Land cover and Soil

GIS Shape files of land use/ land cover and soil is also obtained from WWDSE.

3.4. Data analysis

3.4.1. Sediment rating curve and Annual Sediment yield

3.4.1.1. Sediment rating curve

In this study about 27 sub basins/stations were selected based on geographical location in the basin, availability of sediment concentration data record, and availability of flow and rainfall data. The sediment discharge rate can be calculated for the days that the sediment concentration is measured:

$$q_s = 0.864 * C * Q \text{ -- } (3.3)$$

Where, qs = suspended sediment load in tons/day, C=Sediment concentration in mg/l, Q =water flow rate (m^3/s) and, 0.0864 is conversion factor.

As the water flow rate is measured in all days of the year, the sediment load can be estimated from the equation $q_S=aQ_w^b$ produced by correlating q_s with Q_w on log log scale for selected sub basins, where q_s is sediment load and Q flow and a and b are coefficients and exponent of the rating curve equation respectively (Mahmud et al., 2007). For illustration, the Sediment rating curve is developed for Gilgel Abbay at Merawi as shown in table 3.1.

Table 3.1 Suspended sediment rating curve -station 1002 Gilgel Abbay (Merawi)

Year	Month	Day	Flow (Q) m^3/s	Sediment Concentration mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1968	6	28	70.840	1868	11434
1968	7	22	150.681	1462	19035
1968	8	12	171.700	1090	16164
1968	8	26	195.940	1367	23146
1983	8	18	117.900	821	8360
1985	8	30	75.960	2009	13185
1986	2	10	3.450	145	43
1986	4	11	1.940	77	13
1987	4	25	2.180	31	6
1987	10	23	48.800	532	2242
1988	5	20	10.944	220	208
1988	7	20	213.450	2164	39902
1988	9	8	123.640	883	9436
1990	8	2	195.940	3299	55847
1993	5	7	3.586	177	55
1995	8	23	173.500	1638	24548
1996	2	17	2.546	121	27
2004	8	19	149.530	3378	43646
2004	8	22	119.430	2492	25714
2004	8	23	179.490	3480	53968
2005	2	17	2.770	123	29

Table3.2 Flow and Sediment load for rating curve –G Abbay

flow(m^3/s)	70.8	150.7	171.7	195.9	117.9	76.0	3.5	1.9	2.2	48.8	10.9
sediment load(t/day)	11434.2	19034.9	16164.2	23146.0	8360.0	13185.0	43.3	13.0	5.9	2241.8	208.0

flow(m^3/s)	213.5	123.6	195.9	3.6	173.5	2.5	149.5	119.4	179.5	2.8
Sediment load(t/day)	39902.0	9436.3	55847.0	55.0	24548.3	26.6	43646.4	25713.6	53967.7	29.4

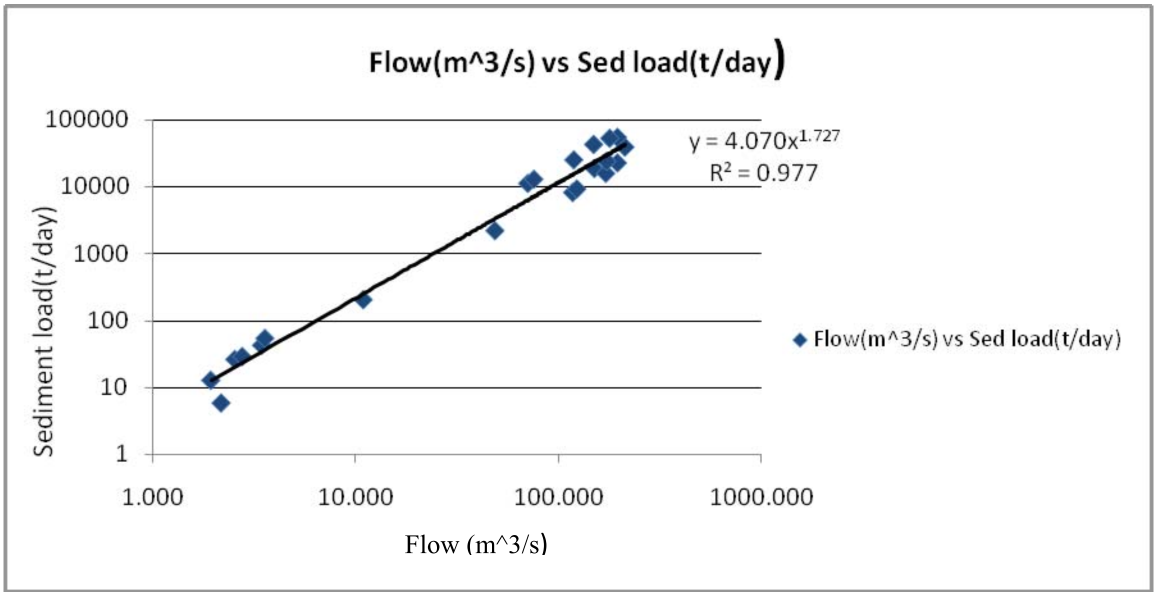

Figure3.1 Sediment rating curve-Gilgel Abbay

Similar steps were followed to produce sediment rating curve for remaining sub basins as shown in the appendix A.

In developing the rating curve equations for the selected sub basins comparison were made between present value and that of master plan value .For some stations significant differences were observed. This difference is due to small record length of sediment concentration and the other is the master plan record were up to the year 1996, whereas the present value is using record sediment data up to year 2008.

Table 3.3 Summary of suspended sediment rating curve for Abbay basin $q_s=aQ_w^b$

Station code	Station name	River	Present value			*Master plan (MoWR)			Remark
			a	b	r^2	a	b	r^2	
1002	Merawi	G.Abbay	4.070	1.727	0.977	4.020	1.695	0.978	Significant difference is due to record length difference.
1005	Addis zemen	Ribb	27.040	1.535	0.897	30.010	1.591	0.934	
1006	Bahir Dar	Gumara	44.000	1.460	0.968	17.480	1.481	0.883	
1007	Azezo	Megech	30.500	1.057	0.898	15.050	1.353	0.882	
2001	Kessie	Abbay	15.730	1.497	0.844	22.840	1.382	0.762	
2003	Bahir Dar	Abbay	16.170	1.072	0.611	10.860	1.163	0.717	
2004	Bahir Dar	Andassa	19.890	1.887	0.998	17.470	1.736	0.848	
2007	D. Brehan	Berresa	17.630	1.423	0.938	17.620	1.423	0.955	
2017	Bichena	Muga	24.660	1.399	0.891	24.540	1.401	0.903	
2018	Motta	Azuari	26.350	1.492	0.830	26.590	1.489	0.902	
2027	Muke Turi	Aleltu	14.100	1.214	0.928	13.500	1.229	0.929	
2028	Muke Turi	Robi Jida	8.982	1.243	0.961	8.850	1.246	0.954	
2030	Motta	Teme	39.090	1.351	0.864	39.710	1.347	0.911	
2031	Bichena	Suha	42.910	1.472	0.906	43.480	1.468	0.893	
2036	Tis Abbay	Mendel	38.480	1.186	0.697	38.070	1.186	0.740	
2038	Amber	Yeda	122.100	1.155	0.850	118.670	1.167	0.866	
3001	Guder	Bello	3.999	0.786	0.697	8.040	1.128	0.943	
3005	Guder	Guder	5.620	1.168	0.919	5.850	1.155	0.899	
3012	Gudla	Dembecha	18.900	1.361	0.922	18.970	1.360	0.923	
3014	Temcha	Dembecha	21.220	1.278	0.850	21.070	1.280	0.883	
3026	Neshi	Shambu	6.940	1.652	0.866	5.730	1.720	0.862	
3029	Chagni	Ardy	14.720	1.181	0.717	16.980	1.315	0.863	
3036	Galibed	L.Fettam	14.730	1.415	0.720	14.780	1.412	0.719	
4014	Toba-Dembi	U.Diddessa	7.244	1.169	0.946	4.080	1.330	0.928	
4007	Guttin	Anger	22.350	1.068	0.814	1.740	1.725	0.930	
4010	Gutie	Tato	20.390	1.522	0.898	19.090	1.547	0.877	
5005	Asossa	Hafa	8.704	1.077	0.875	8.240	1.085	0.822	
5009	Nedjo	Dilla	10.680	1.877	0.903	10.390	1.886	0.861	
6005	Chagni	M.Beles	8.035	1.400	0.679	16.06	1.212	0.878	

3.4.1.2. Annual Sediment Yield

Using the equation $q_s=aQw^b$ an annual sediment yield (Q_{sy}) (t/ yr/km^2) has been calculated for each sub basins using 10 to 20 years series of daily flow records. A sample analysis of sediment yield for Gilgel Abbay has been shown below. Also annual Sediment yield analysis for each sub basins has been shown in appendix B.

Table3.4 Suspended Sediment yield in ton- Station 1002 Gilgel Abbay (Merawi)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	1912	1609	856	381	393	43043	582551	700619	564486	140658	8427	3793	2048728
1987	1382	759	681	503	13003	142668	653715	859583	563780	170291	23772	6022	2436160
1988	2692	1418	718	366	1662	47386	834417	1281975	763376	224540	22308	5070	3185928
1989	2004	780	984	840	5269	87581	1272693	1585846	647200	104782	10786	5322	3724087
1990	2099	1052	668	396	931	21878	461230	1033110	611995	100920	6412	2378	2243071
1991	1213	559	438	1911	6573	168797	1158104	1425588	928896	90674	9059	3102	3794913
1992	1509	767	528	1890	5671	64052	539961	1237743	705080	317435	47606	8245	2930486
1993	2439	1132	971	2199	10392	230934	1190914	1005334	807635	359857	29459	4882	3646149
1994	1912	936	597	449	5596	215236	722987	1006464	528252	31611	7324	3255	2524618
1995	1138	566	381	426	18290	105477	342318	1317358	605075	36814	7184	2516	2437540
1996	1152	500	3482	2411	36737	300386	1309938	1506765	677680	311631	192220	101385	4444286
1997	819	359	338	318	31875	176219	897687	1216682	539367	186469	67465	8972	3126569
1998	1709	575	371	192	19080	230317	711169	1073856	760909	398384	20431	3344	3220337
1999	1232	428	237	431	8534	169868	896374	1093264	545221	566319	22907	4346	3309162
2000	1086	404	252	1075	4514	132794	731681	1306737	610159	590038	72342	5793	3456875
2001	1305	492	353	354	4057	219378	806544	1283481	599225	84819	12818	2407	3015233
2002	903	316	229	132	152	88138	761106	928925	371599	49269	6994	1541	2209304
2003	507	232	176	62	164	122577	1042611	1103398	957324	67617	7657	1454	3303780
2004	543	211	114	873	186	53173	696968	904163	676245	224775	8467	2207	2567925
2005	672	225	368	162	527	82284	647076	496268	496364	135820	21979	12436	1894181

Annual mean 2975966.57 ton

Catchment area 1664 km^2

Sediment yield 1788.44 ton/ km^2/yr

By following Similar steps the annual sediment yield in (tons/km^2/yr) of each selected sub basins has been calculated as shown in appendix.

3.4.1.3. Rainfall

Annual mean precipitation (mm) for all stations corresponding to the selected sub basins stations is calculated from monthly rainfall data obtained from NMSA.The rainfall data are considered for 10 to 20 years record.

Table3.5 Summary of annual mean rainfall for selected stations (From appendix C).

Station	Merawi	Addis zemen	Bahir Dar	Gonder	Dejen	Debre Brehan	Bichena	Motta	Muka Turi	Tis Abbay
Annual mean RF (mm)	1624.9	1081.9	1420.2	1201.2	1470.8	925.6	908.5	1199.2	987.6	1188.9

Station	Debre markos	Guder	Dembec ha	Shambu	Chagni	Enjibar	Nekemte	Dembi	Asossa	Nedjo
Annual mean RF (mm)	1332.3	1409.4	1376.0	1506.4	1625.9	2295.1	2050.2	1908.4	1269.6	1546.9

3.4.2. Determination of Catchment characteristics

Catchment characteristics VIDX, SIDX, and SLDX are determined by running SWAT 2005 model for the Abbay basin. These catchment characteristics are extracted from the out put for each sub basins after sensitivity analysis and calibration are made for flow and sediment.

3.4.2.1 Utilization of SWAT Model

The soil and water assessment tool was exhaustively used for determination of catchment characteristics such as VIDX, SIDX and SLDX. To determine these characteristics input data on Land use/Land cover and soil of the basin, and DEM data of the basin are crucial. The other is the daily meteorological data (precipitation, minimum and maximum temperatures, wind speed relative humidity, and sunshine hours)daily, of the basin. Then watershed and sub basin delineation and simulation are done accordingly.

3.4.2.2 Model Data Preparation

3.4.2.2.1 DEM Data

The DEM data gives information on the topography of specific area in specific spatial resolution. Blue Nile Digital Elevation model data was used and it is processed on Global mapper for use in AVSWAT. The DEM is prepared with a resolution of 200x200.Then the watershed delineation is performed which later shows the distribution of sub basins in the basin.

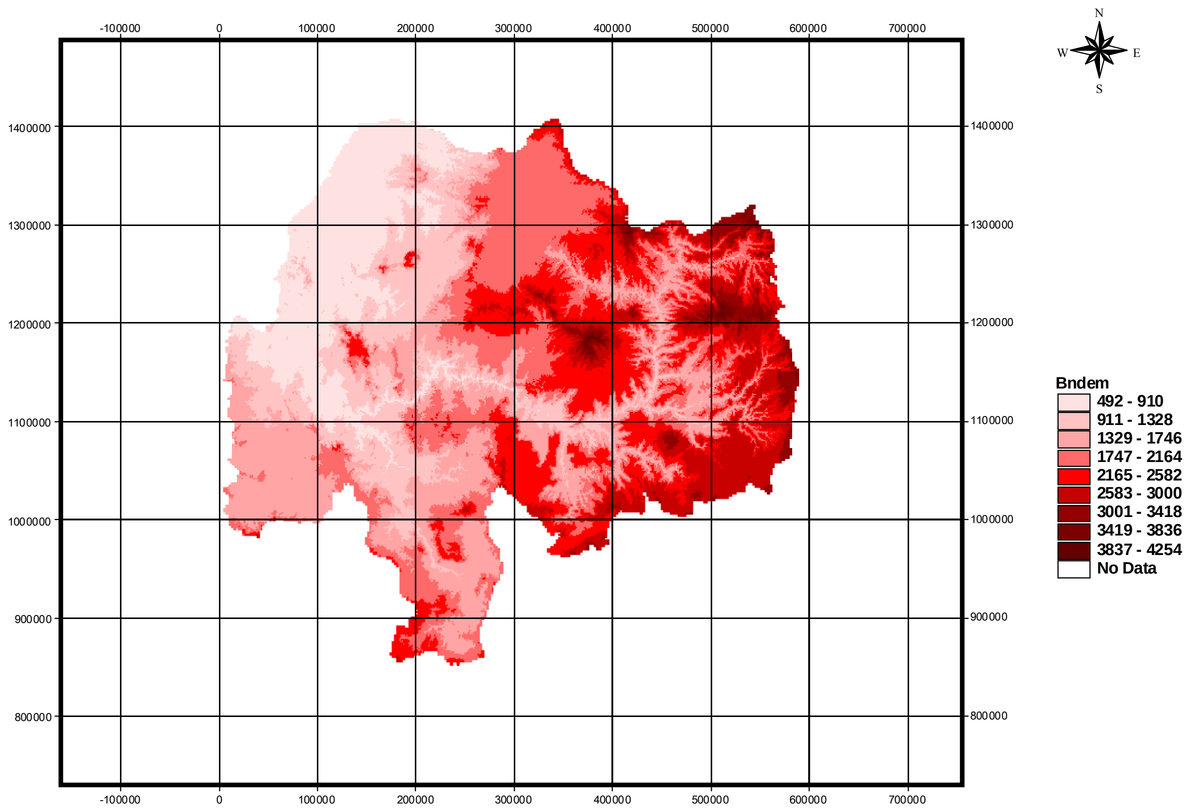

Figure **3.2** Blue Nile Digital Elevation Model (DEM)

On the DEM shown above the watershed has been delineated as it is presented below. The entire stream network is clearly visible. For this particular study the out lets for the selected sub basins are entered in table.

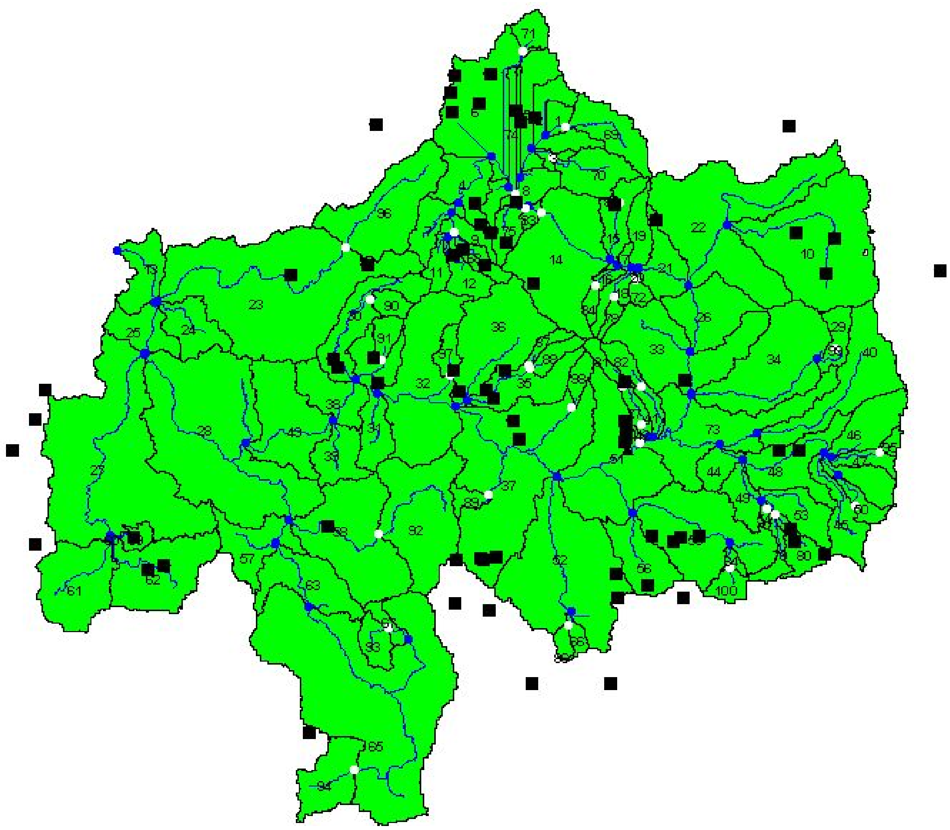

Figure 3.3 Abbay basin delineated watershed map

3.4.2.2.2 Land use/Land cover

The land use/cover shape file data is used for defining the land use/cover of the basin. After the watershed has been delineated and streams are clearly defined on the watershed the land use/cover has been overlain successfully.

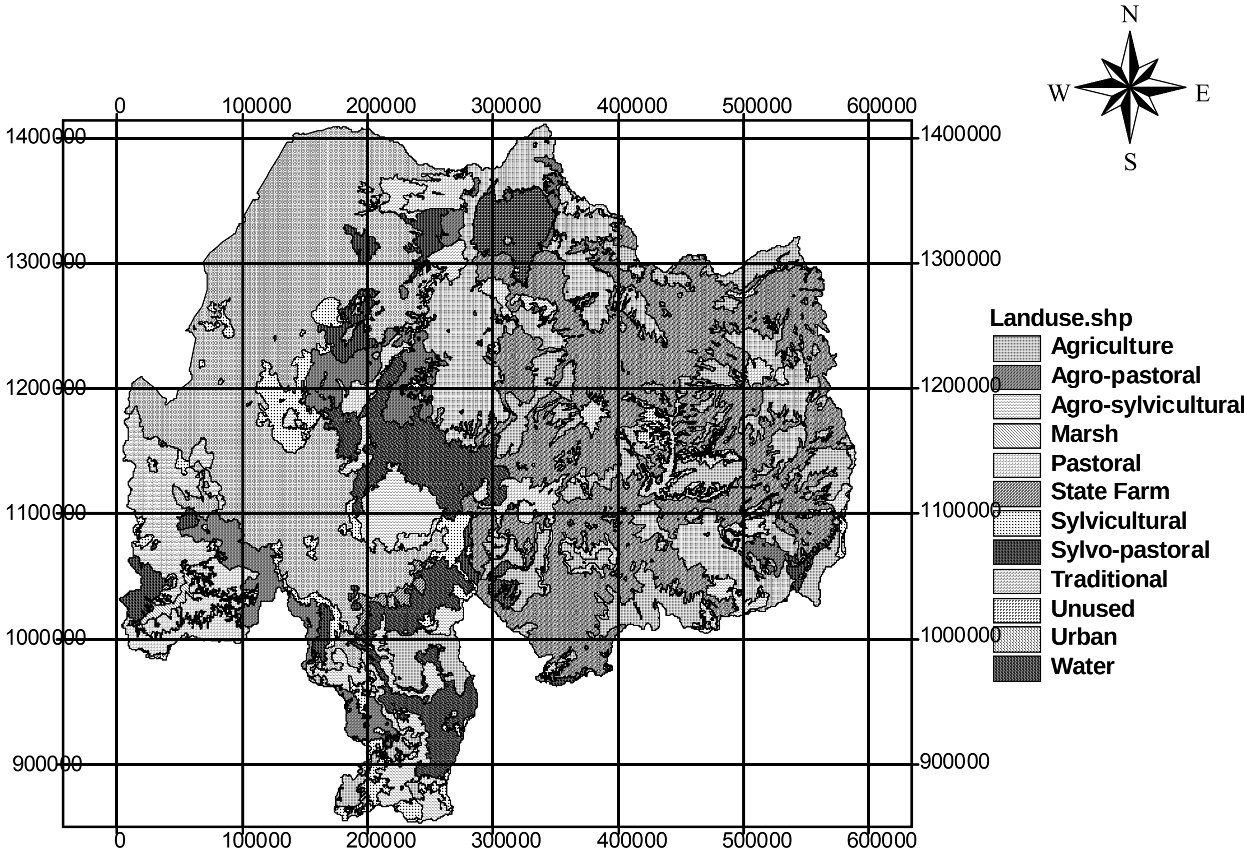

Figure 3.4 Abbay basin land use map

3.4.2.2.3 Soil Data

Similarly the soil data in shape file is defined by overlaying on the watershed. The different appearance of the soil describes the distribution of different soil types in the basin.

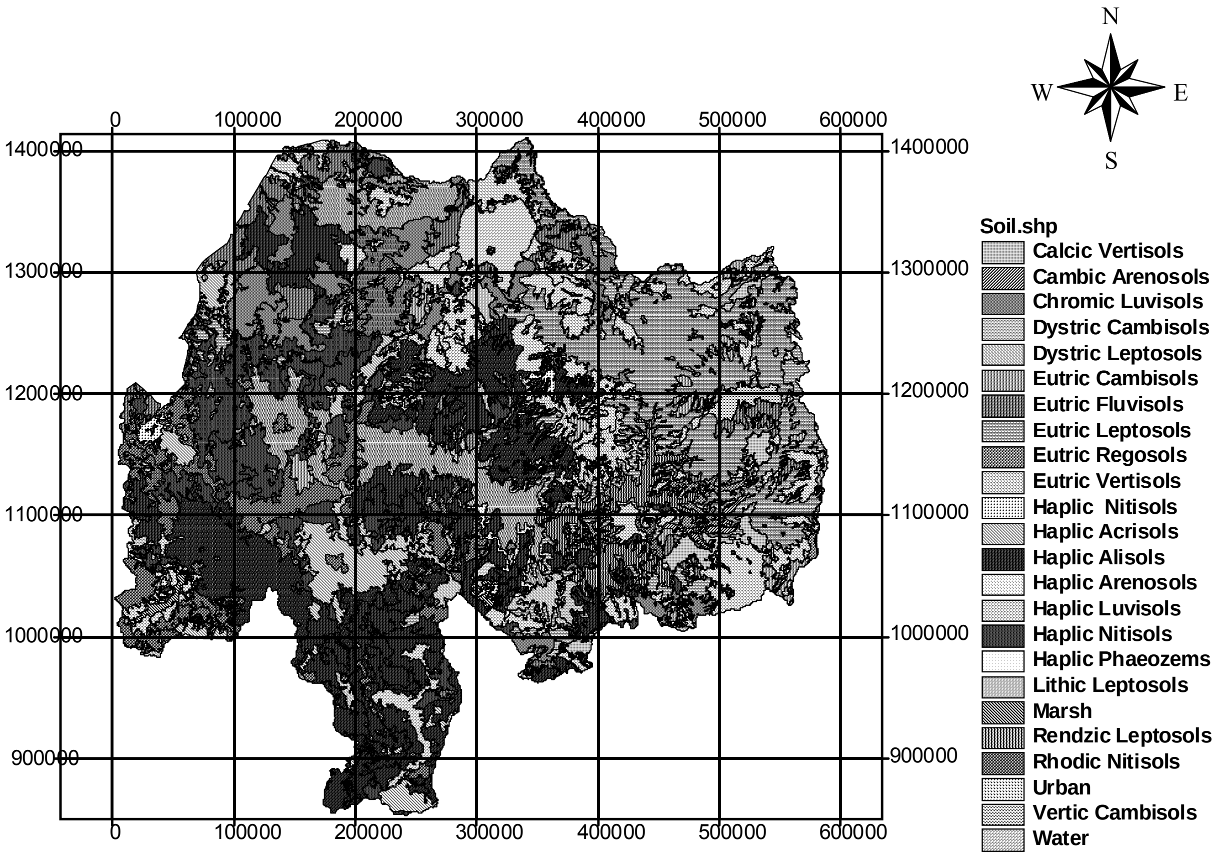

Figure 3.5 Abbay basin soil maps

Once the land use/land cover definition and overlaying is completed weather in put data are entered .That means rainfall stations, temperature stations and weather generators (for filling missing data) are entered. Finally, SWAT simulation was ordered so that flow and sediment output could be viewed in the output tables as the model run is successfully completed.

3.4.3 Analysis of Multiple regression equation

Once the required variables (sediment yield, catchment characteristics and rainfall) are determined for respective sub basins regression analysis was followed. The sub basins are regionalized based on dominant land use patterns- physiographical and geographical location proximity in the basin. Statistical regression model is applied as follows for estimating the regression parameters between annual sediment yield and catchment characteristics, and climate. In using the multiple regressions, the degree of correlation of a dependent variable to considered independent variables is measured by any of the following parameters: the standard deviation of residual, multiple correlation coefficients, and the coefficient of multiple determinations, the partial correlation coefficients, and the beta coefficients (Yevjevich, 1972)

Table 3.6 Region1 (Agricultural land-close grown) covering greater than 50% of sub basin area

Sr.no.	Station	River	Qsy ($t/km^2/yr$)	A(km^2)	P(mm)	VIDX	SIDX	Slp (m/m)
1	Merawi	G.Abbay	1788.4	1664.0	1624.9	0.071	0.240	0.073
2	Addis Zemen	Ribb	790.8	1592.0	1081.9	0.068	0.214	0.140
3	Bahir Dar	Gumara	3494.1	1394.0	1420.2	0.089	0.237	0.129
4	Azezo	Megech	168.9	462.0	1201.2	0.030	0.250	0.206
5	Bahir Dar	Andassa	2508.4	573.0	1420.2	0.108	0.236	0.103
6	Muke Turi	Robi Jida	52.3	762.0	987.6	0.030	0.200	0.054
7	Galibed	L Fettam	689.9	757.0	1332.3	0.030	0.230	0.048

Table 3.7 Region 2 (Agricultural land-Generic) up to 50-70% of the sub basin area

Sr.no.	Station	River	Qsy ($t/km^2/yr$)	A(km^2)	P(mm)	VIDX	SIDX	Slp (m/m)
1	Bichena	Muga	494.8	375.0	908.5	0.105	0.212	0.191
2	Bichena	Suha	438.4	359.0	908.5	0.115	0.213	0.145
3	Dembecha	Gudla	1133.0	242.0	1376.0	0.145	0.240	0.215
4	Dembecha	Temcha	365.0	406.0	1376.0	0.130	0.239	0.219
5	Amber	Yeda	1097.3	125.0	1332.3	0.127	0.201	0.146
6	Chagni	Ardy	405.2	209.0	1625.9	0.147	0.230	0.145
7	Tis Abbay	Mendel	89.5	72	1188.9	0.119	0.241	0.150

Table 3.8 Region 3 (Agricultural land -generic) with greater than 70% of sub basin area

Sr.no.	Station	River	Qsy ($t/km^2/yr$)	A(km^2)	P(mm)	VIDX	SIDX	Slp (m/m)
1	Motta	Azuari	1008.3	209	1199.2	0.200	0.235	0.293
2	Motta	Teme	821.6	156.3	1199.2	0.200	0.227	0.139
3	Kessie	Abbay	1509.1	65784	1470.8	0.115	0.228	0.203
4	Guder	Bello	17.3	290	1409.4	0.200	0.210	0.140
5	Guder	Guder	83.2	524	1409.4	0.200	0.229	0.188
6	Muke Turi	Aleltu	106.0	447	987.6	0.020	0.203	0.094

Table 3.9 Region 4 (Agricultural land and good forest, pasture and range grasses covered area)

Sr.no.	Station	River	Qsy ($t/km^2/yr$)	A (km^2)	P(mm)	VIDX	SIDX	Slp (m/m)
1	Toba-Dembi	U.Diddessa	130.3	1806	1908.4	0.015	0.230	0.108
2	Gutie	Tato	180.6	42.5	2050.2	0.102	0.207	0.113
3	Asossa	Hafa	27.4	194	1269.6	0.002	0.230	0.085
4	Nedjo	Dilla	889.7	69	1546.9	0.051	0.216	0.090
5	Chagni	M.Beles	421.6	3431	1625.9	0.009	0.188	0.134
6	D. Brehan	Berresa	702.6	211	925.6	0.088	0.248	0.310
7	Neshi	Shambu	606.0	322	1506.4	0.126	0.230	0.168

The model indicated below is not linear but to make the treatment easier logarithmic transformation is applied to get a linear equation (Chow, 1964). Finally in the data analysis the variables values indicated in the table above for respective regions, after their values are changed to logarithms, are entered in to the regression equation. Then, entering the logarithmic values of each region/group into regression analysis resulted in the required regression parameters.

$$Q_{sy} = \alpha A^{\beta} P^{\lambda} (VIDX)^{\psi} (SIDX)^{\phi} (SLDX)^{\theta} \text{ ----------------------------- (3.4a)}$$

Or

$$\log Qsy = \log\alpha + \beta\log A + \lambda\log P + \psi\log(VIDX) + \phi\log(SIDX) + \theta\log(SLDX) \text{ ………… (3.4b)}$$

Where, Qsy=annual sediment yield (ton/km^2/yr),

A=catchment area (km^2),

P=annual precipitation (mm),

VIDX=Vegetation Index,

SIDX=Soil Index and

SLDX=Slope Index are catchment characteristics;

$\alpha, \beta, \lambda, \psi, \phi, and \theta$ Are parameters of the above factors, to be determined from the regression equations.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. Annual Sediment yield

In the determination of Annual sediment yield for selected sub basins flow and suspended sediment concentration data were collected from MoWR. Using these data the daily sediment loads were determined by converting the sediment concentrations to daily loads with the help of equation

$$q_s = 0.0864 * C * Q \text{ -- } (4.1)$$

Where, qs = suspended sediment load in tons/day, C=Sediment concentration in mg/l, Q =water flow rate (m^3/s) and, 0.0864 is conversion factor.

Then, by correlating the flow with corresponding sediment load at specified times the sediment rating curves were developed for the selected stations as described above in Table 3.3.

Lastly using the formula from the sediment rating curve developed above for the selected sub basins as $q_S=aQw^b$, the sediment yield is calculated from daily flow records which is based on more than 10 to 20 years of flow records as shown in appendix B for respective sub basins/stations. The summarized annual sediment yields of the selected sub basins is shown as follows.

Table 4.1 Summary of annual Suspended sediment yield for selected sub basins.

Station code	Station name	River	Annual Sediment in tons/yr	Catchment area (km^2)	Annual Sediment in tons/km^2/yr
1002	Merawi	G.Abbay	2975967	1664	1788
1005	Addis Zemen	Ribb	1259003	1592	791
1006	Bahir Dar	Gumara	4870710	1394	3494
1007	Azezo	Megech	78046	462	169
2001	Kessie	Abbay	99276664	65784	1509
2003	Bahir Dar	Abbay	1104952	15321	72
2004	Bahir Dar	Andassa	1437334	573	2508
2007	D. Brehan	Berresa	148244	211	703
2017	Bichena	Muga	185551	375	495
2018	Motta	Azuari	210726	209	1008
2027	Muke Turi	Aleltu	47365	447	106
2028	Muke Turi	Robi Jida	39847	762	52
2030	Motta	Teme	128421	156.3	822
2031	Bichena	Suha	157398	359	438
2036	Tis Abbay	Mendel	6446	72	89
2038	Amber	Yeda	137167	125	1097
3001	Guder	Bello	5014	290	17
3005	Guder	Guder	43582	524	83
3012	Gudla	Dembecha	274196	242	1133
3014	Temcha	Dembecha	148184	406	365
3026	Neshi	Shambu	195120	322	606
3029	Chagni	Ardy	84685	209	405
3036	Galibed	L.Fettam	522268	757	690
4014	Toba-Dembi	U.Diddessa	235360	1806	130
4007	Guttin	Anger	244019	3742	65
4010	Gutie	Tato	7674	42.5	181
5005	Asossa	Hafa	5317	194	27
5009	Nedjo	Dilla	61388	69	890
6005	Chagni	M.Beles	1446588	3431	422

As it could be seen from the table 4.1the sediment yield result obtained implies huge removal of productive soil from the basins in the lake Tana(G.Abbay,Andassa,Ribb)which might be attributed to intensive cultivation which has resulted in larger erosion and sedimentation. Also around L.Fettam,Neshi and Dilla the sediment yield figure are large which are attributed to extensive agricultural land. Generally the basin as a whole needs urgent interventions on sediment minimization for sustainable national development.

4.2. Catchment Characteristics

In this study the catchment characteristics which affect the sediment yield such as vegetation index, soil index and slope index are considered. These catchment characteristics which are to be involved in the final analysis of the regression equation are extracted from the SWAT analysis. Their weighed values are presented in the table below.

Table 4.2 Catchment characteristics values obtained from SWAT simulation.

Station code	Station	River	Vegetation indices (USLE-C)	Soil Indices (USLE-K)	Slope indices
1002	Merawi	G.Abbay	0.071	0.240	0.073
1005	Addis Zemen	Ribb	0.068	0.214	0.140
1006	Bahir Dar	Gumara	0.089	0.237	0.129
1007	Azezo	Megech	0.030	0.250	0.206
2001	Kessie	Abbay	0.115	0.228	0.203
2004	Bahir Dar	Andassa	0.108	0.236	0.103
2007	D. Brehan	Berresa	0.088	0.248	0.310
2017	Bichena	Muga	0.105	0.212	0.191
2018	Motta	Azuari	0.200	0.235	0.293
2027	Muke Turi	Aleltu	0.020	0.203	0.094
2028	Muke Turi	Robi Jida	0.030	0.200	0.054
2030	Motta	Teme	0.200	0.227	0.139
2031	Bichena	Suha	0.115	0.213	0.145
2036	Tis Abbay	Mendel	0.119	0.241	0.150
2038	Amber	Yeda	0.127	0.201	0.146
3001	Guder	Bello	0.200	0.210	0.140
3005	Guder	Guder	0.200	0.229	0.188
3012	Dembecha	Gudla	0.145	0.240	0.215
3014	Dembecha	Temcha	0.130	0.239	0.219
3026	Neshi	Shambu	0.126	0.230	0.168
3029	Chagni	Ardy	0.147	0.230	0.145
3036	Galibed	L.Fettam	0.030	0.230	0.048
4014	Toba-Dembi	U.Diddessa	0.015	0.230	0.108
4007	Guttin	Anger	0.117	0.222	0.144
4010	Gutie	Tato	0.102	0.207	0.113
5005	Asossa	Hafa	0.002	0.230	0.085
5009	Nedjo	Dilla	0.051	0.216	0.090
6005	Chagni	M.Beles	0.009	0.188	0.134

The catchment characteristics result in table 4.2 shows that the slope index are the dominant factor for serious erosion. Also the soil index value shows high soil erodibility which in combination with the slope shown can lead to extensive erosion. The vegetation index shows good land cover with lower contribution to sediment yield. Generally the catchment characteristics are major factors in sediment yield estimation. Vegetation index values shows the extent of canopy cover and land cover to minimize the soil erosion through rain fall interception, runoff abstraction and enhancement of infiltration. The soil index also determines the extent of erodibility of the soil which is attributed to texture and structure of the soil. Also the slope index implies the level of erosion occurrences based on steepness and flatness.

4.3. Parameter estimates

For parameter estimation as it is shown in the tables above the sub basins have been regionalized as agricultural land generic means where cropping is sparse and vegetation index values are larger, agricultural land closely grown are sub basins with minimal vegetation index values. In the regression analysis for respective groups after transforming the variables into logarithmic the variables are put to the regression equation. Finally the statistical regression analysis has given the following parameter estimates for each region/group.

Table 4.3 Estimated Regression Parameters.

Group	Regression parameters						
	α	β	λ	ψ	ϕ	θ	R^2
1	$10^{175.014}$	3.108	-38.778	6.569	94.893	-8.021	0.995
2	$10^{15.018}$	-0.219	-2.895	9.982	-13.254	3.3	0.999
3	$10^{77.585}$	1.133	-21.930	2.755	12.997	-0.770	1
4	$10^{15.26}$	0.680	-6.172	1.504	-6.913	-3.249	0.977

By putting the regression parameters in to the sediment yield equation given in the methodology section the regional equations for the respective regions/groups assumed for the basin respectively are shown below.

The regional equation for region 1, for example, is

$$Q_{sye} = 10^{175.014} A^{3.108} P^{-38.778} (VIDX)^{6.569} (SIDX)^{94.893} (SLDX)^{-8.021} \quad \text{------- (4.1)}$$

Where, Q_{sye}=Estimated annual sediment yield ton/km^2/yr. A=catchment area (km^2) P=precipitation (mm), VIDX=vegetation index (non dimensional), SIDX=Soil index (non dimensional) and S LDX=slope index (m/m) are catchment characteristics

After developing the regression equation, the observed and estimated sediment yields were compared as follows.

T able 4.4 Observed and estimated annual sediment yield for region1

Sr.no.	Station	River	Observed annual sediment yield (t/km^2/y)	Estimated annual sediment yield (t/km^2/yr)	Relative error ((Oi-Ei)/Oi)*100 (%)
1	Merawi	G.Abbay	1788	1986	-11.0
2	Addis Zemen	Ribb	791	886	-12.0
3	Bahir Dar	Gumara	3494	2831	19.0
4	Azezo	Megech	169	173	-2.6
5	Bahir Dar	Andassa	2508	2654	-5.8
6	Muke Turi	Robi Jida	52	50	4.4
7	Galibed	L Fettam	690	691	-0.1

* Oi=Observed sediment yield ;Ei=Estimated sediment yield

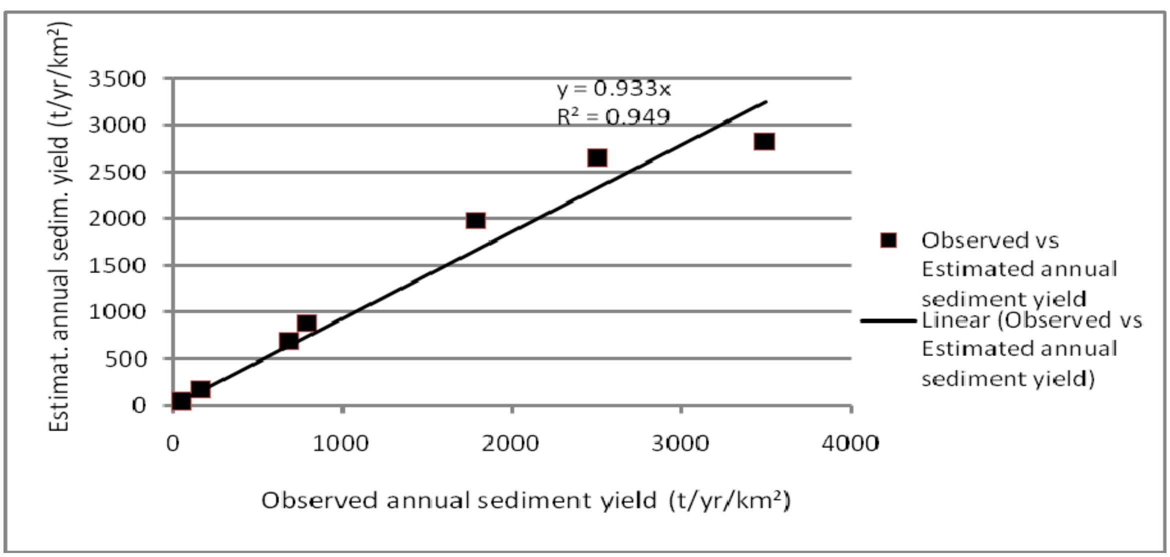

Figure 4-1 Observed vs. estimated annual sediment yield for region 1

The regional equation for region 2 is

$$Q_{sye} = 10^{15.018} A^{-0.219} P^{-2.895} (VIDX)^{9.982} (SIDX)^{-13.254} (SLDX)^{3.3} \quad \text{---------} \ (4.2)$$

Where, Q_{sye}=Estimated annual sediment yield ton/km2/yr., A=catchment area (km2), P=precipitation (mm), VIDX=vegetation index (non dimensional), SIDX=Soil index (non dimensional) and S LDX=slope index (m/m) are catchment characteristics

Table 4.5 Observed and estimated annual sediment yield for region 2

Sr.no.	Station	River	Observed annual sediment yield ($t/km^2/y$)	Estimated annual sediment yield ($t/km^2/yr$)	Relative error ((Oi-Ei)/Oi)*100 (%)
1	Bichena	Muga	494.8	476	3.8
2	Bichena	Suha	438.4	449	-2.4
3	Dembecha	Gudla	1133	1122	0.9
4	Dembecha	Temcha	365	377	-3.3
5	Amber	Yeda	1097.3	1116	-1.7
6	Chagni	Ardy	405.2	393	3.1
7	Tis Abbay	Mendel	89.5	90	-0.2

* Oi=Observed sediment yield ;Ei=Estimated sediment yield

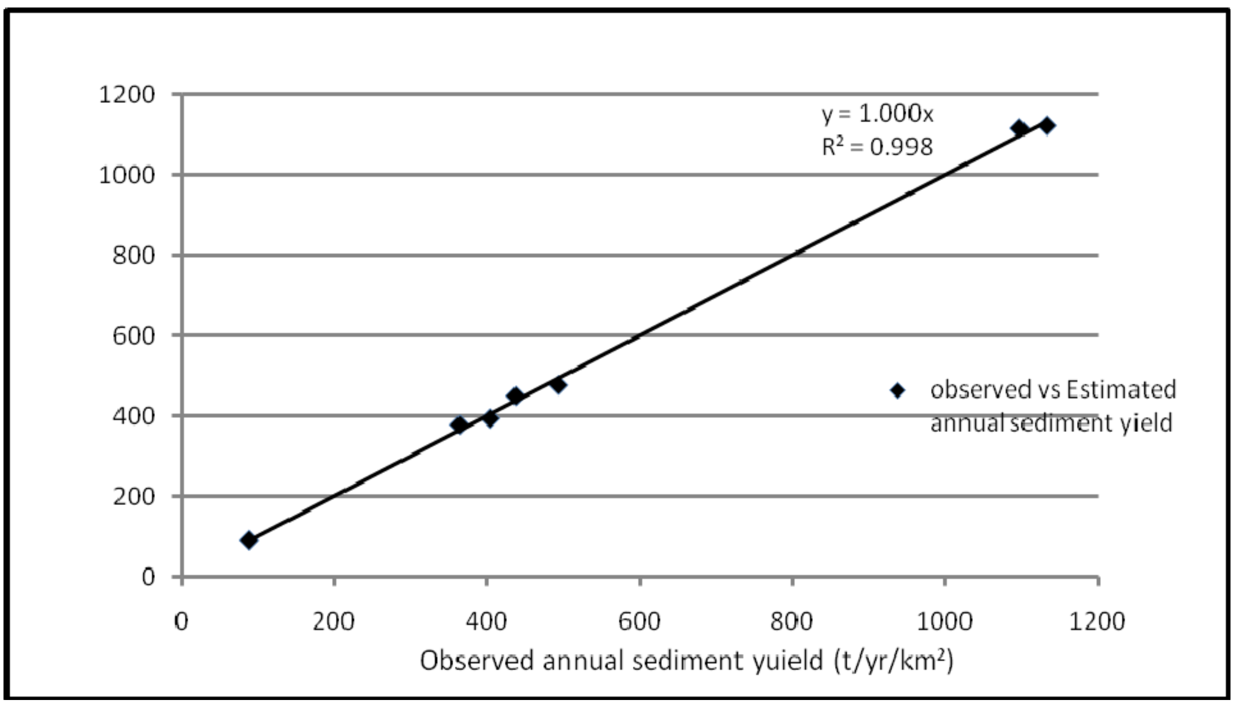

Figure 4-2 Observed vs. estimated annual sediment yield for region 2

The regional equation for region 3 is

$$Q_{sye} = 10^{77.585} A^{1.133} P^{-21.93} (VIDX)^{2.755} (SIDX)^{12.997} (SLDX)^{-0.770} \text{------------ (4.3)}$$

Where, Q_{sye}=Estimated annual sediment yield ton/km2/yr. A=catchment area (km2) P=precipitation (mm), VIDX=vegetation index (non dimensional) SIDX=Soil index (non dimensional) and S LDX=slope index (m/m) are catchment characteristics

Table 4.6 Observed and estimated annual sediment yield for region 3

Sr.no.	Station	River	Observed annual sediment yield ($t/km^2/y$)	Estimated annual sediment yield ($t/km^2/yr$)	Relative error ((Oi-Ei)/Oi)*100 (%)
1	Motta	Azuari	1008	1012	-0.3
2	Motta	Teme	822	824	-0.3
3	Kessie	Abbay	1509	1517	-0.5
4	Guder	Bello	17	17	-0.3
5	Guder	Guder	83	83	-0.3
6	Muke Turi	Aleltu	106	106	-0.3

* Oi=Observed sediment yield ;Ei=Estimated sediment yield

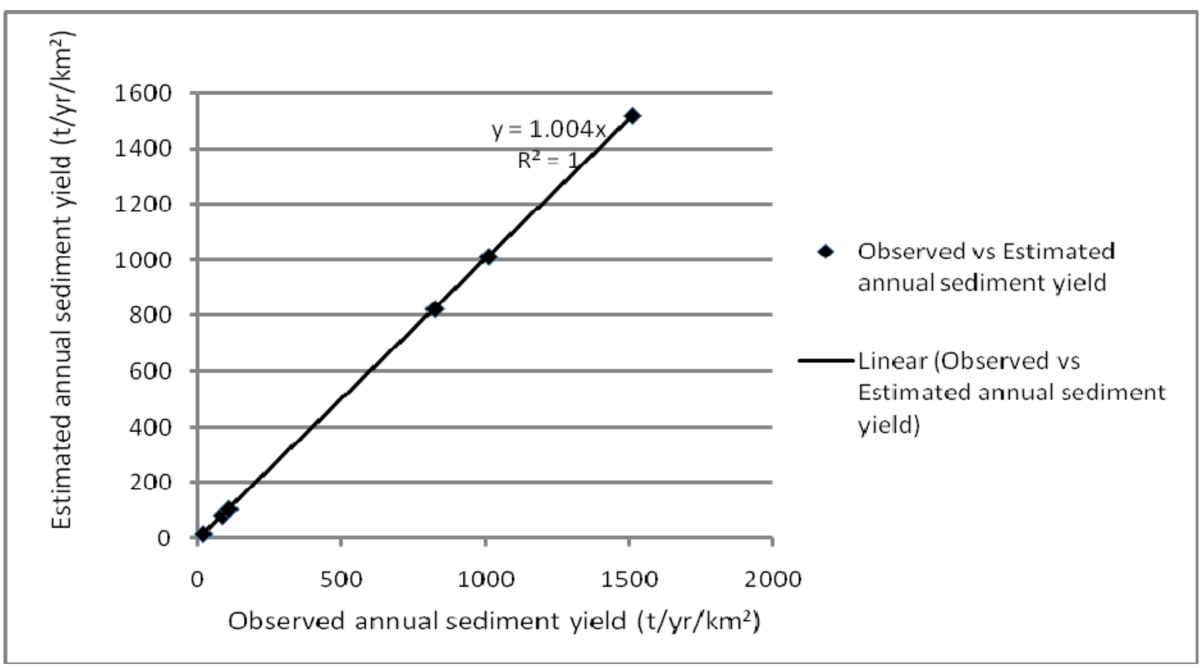

Figure 4-3 Observed vs. estimated annual sediment yield for region 3

The regional equation for region 4 is

$$Q_{sye} = 10^{15.26} A^{0.68} P^{-6.172} (VIDX)^{1.504} (SIDX)^{-6.913} (SLDX)^{-3.249} \text{ ---------- } (4.4)$$

Where, Q_{sye}=Estimated annual sediment yield ton/km2/yr. A=catchment area (km2) P=precipitation (mm), VIDX=vegetation index (non dimensional) SIDX=Soil index (non dimensional) and S LDX=slope index (m/m) are catchment characteristics

Table 4.7 Observed and estimated annual sediment yield for region 4

Sr.no.	Station	River	Observed annual sediment yield ($t/km^2/y$)	Estimated annual sediment yield ($t/km^2/yr$)	Relative error ((Oi-Ei)/Oi)*100 (%)
1	Toba-Dembi	U.Diddessa	130	110	15.4
2	Gutie	Tato	181	177	2.1
3	Asossa	Hafa	27	31	-13.2
4	Nedjo	Dilla	890	758	14.8
5	Chagni	M.Beles	422	422	0.0
6	D. Brehan	Berresa	703	607	13.7
7	Neshi	Shambu	606	754	-24.5

* Oi=Observed sediment yield ;Ei=Estimated sediment yield

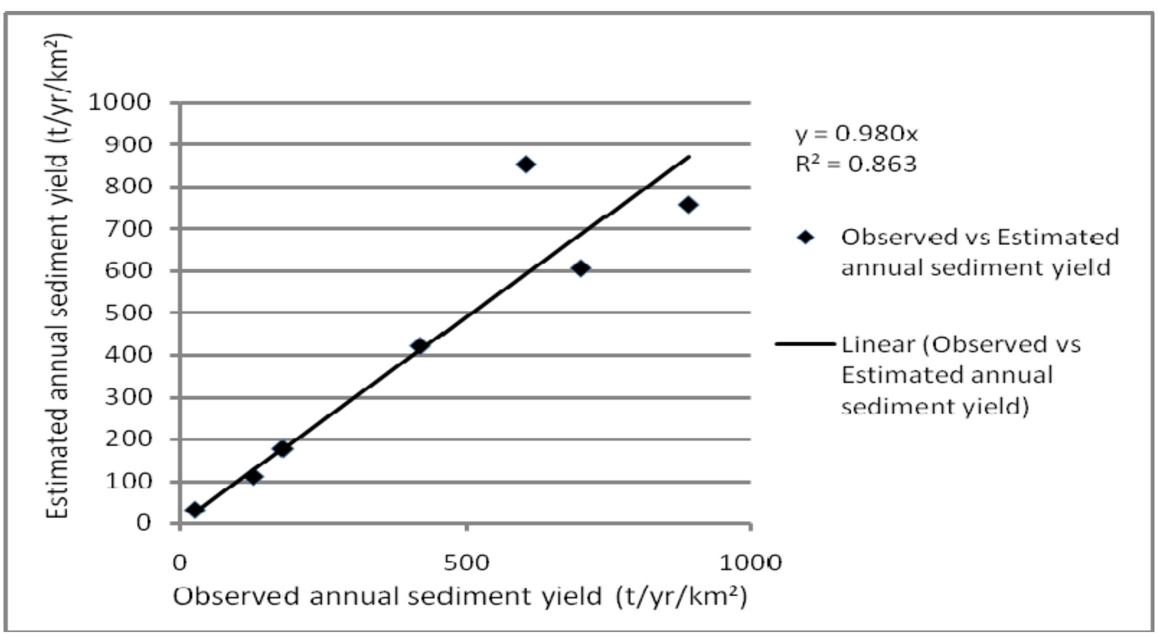

Figure 4-4 Observed vs. estimated annual sediment yield for region 4

4.4. Initial Comparison of Model Results

Using the regional empirical equation developed in this study the results of the model were compared with the sediment yields estimate made currently by different designing organizations. The following dam sites are considered for comparisons.

Table 4.8 Comparison of model results with others studies

Name of Dams	TAHAL /WWDSE Estimate (ton/km^2/yr.	Present study					
		Area (A) km^2	Precipitation (P) mm	Vegetation Index (VIDX)	Soil Index (SIDX)	Slope Index (SLDX)	Model Estimate (ton/km^2/yr.)
Ribb	897	715	1082	0.068	0.22	0.14	1009
Gumara	1643	410	1316	0.089	0.237	0.129	1193
Megech	1170	424	1201	0.03	0.25	0.165	799.5
G.Abbay	2037	1664	1425	0.071	0.24	0.073	1986
Jemma	2037	218	1425	0.102	0.242	0.096	1453
Karra Dobi	720 -1150 (Norplan)	82300	1471	0.115	0.228	0.203	1945

*TAHAL-Israel's consulting organization. * Norplan Kara Dobi study organization.

From the table above the results of this study was compared with previous study on the sediment yield. For stations with nearly in equal watershed area the results are closer, where as for those stations where the watershed area varies due to the location of dam site the result is not good. This is because the other study has used composite analysis of the neighbor Rivers for the sediment yield estimation. They also warned not to use the approach of master plan study but this study has used the master plan approaches with additional consideration of watershed characteristics to develop regional regression equation. So while using this result for preliminary estimate of sediment yield at specified location it is better to take only estimates at previous hydrometric stations where the sediment concentration data is available.

CHAPTER FIVE

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary and Conclusions

In this study regional sediment yield was estimated for Abbay basin by relating sediment yield with catchment characteristics and rainfall. An attempt was also made to cover the whole basin by considering a total of 27 important contributing tributaries/stations in upstream and downstream given that the suspended sediment concentration records and daily flow data are available for certain periods. For the selected sub basins 10 to 20 years flow data from 1986-2005 (for most sub basins) and more than 10 years for other few sub basins was considered. Sediment yield was initially estimated from suspended sediment concentration and corresponding flow records. Also long year rainfall data has been used for estimation of annual mean rainfall. On the other hand, for the catchments characteristics determination SWAT2005 model is employed. Ones these variables are determined, and then these variables are put into the multiple regression equations for further analysis. Also those selected sub basins are further regionalized/grouped based on the dominant land use/land cover-physiographic information obtained from SWAT model report and geographic location. The selected sub basins are regionalized/grouped in to four regions. Then by putting the variables of each region/group in to the multiple regression equation the required parameters are estimated. This is done by using statistical regression. Further these parameters are put in the equation so that is possible to estimate annual sediment yield for the sub basins. Generally through the aforementioned processes it possible to reach in to regional equation for first hand estimation of sediment yields from the area.

From this study it might be possible to conclude the followings.

- Generally the regional equation developed gives preliminary estimates of sediment yield for provision of insight to demanding individuals, institutions, stakeholders in the aspect of water resources development projects.

- In the regression analysis the coefficient of determination is near to unity indicating that almost for most sub basins the regression model predicts better.

- The sediment yield estimate results obtained were compared with the results of the master plan study. It is found to be approximately the same for most sub basins. While few differences are attributed to the variation in length of observed sediment and flow records used for the analysis.

- In the regression analysis it is observed that as the number of sub basins falling in a group becomes smaller, the model excludes some variables but by considering practical effect of the selected variables on sediment yield an effort was made to consider all variables.

- The catchment characteristics for down stream areas are weighted values of the included sub basins in the upstream so as to enhance precision of the estimate.

Generally the regional equation for estimation of Sediment yield for respective regions, respectively is

$$Q_{sye} = 10^{175.014} A^{3.108} P^{-38.778} (VIDX)^{6.569} (SIDX)^{94.893} (SLDX)^{-8.021} \text{ ------- } (4.1)$$

$$Q_{sye} = 10^{15.018} A^{-0.219} P^{-2.895} (VIDX)^{9.982} (SIDX)^{-13.254} (SLDX)^{3.3} \text{ --------- } (4.2)$$

$$Q_{sye} = 10^{77.585} A^{1.133} P^{-21.93} (VIDX)^{2.755} (SIDX)^{12.997} (SLDX)^{-0.770} \text{ ----- } (4.3)$$

$$Q_{sye} = 10^{15.26} A^{0.68} P^{-6.172} (VIDX)^{1.504} (SIDX)^{-6.913} (SLDX)^{-3.249} \text{ ------- } (4.4)$$

5.2. Recommendations

Based on this study the following points are recommended for better results.

- For more detailed result of the regional sediment yield estimate it is better to take in to account the data from all sub basins in the basins.
- Checking alternative methods for estimating sediment yield for instance using model and scrutinizing the result with the current method is appreciable.
- The sediment yield figure in the basin indicates huge removal of productive soil from the area which needs urgent control measure for sustainable development.
- In the study sediment concentration data was the limiting factor for not considering additional sub basins in the study so it is better to enhance flow and sediment record spatially and temporally in the basin to come up with a better prediction.
- Incorporating more detailed catchment homogeneity study will ensure better regionalization so that a better result may be obtained.
- Generally the project entitled Regional sediment yield estimate for Abbay basin is a large scope study. Therefore it should be further studied in a broad and wide context with consideration of additional variables in the sediment yield estimate.

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APPENDICES

APPENDIX-A

Table A-1 Flow and Sediment load for rating curve-Gilgel Abbay (Merawi)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1968	6	28	70.840	1868	11434
1968	7	22	150.681	1462	19035
1968	8	12	171.700	1089	16164
1968	8	26	195.940	1367	23146
1983	8	18	117.900	821	8360
1985	8	30	75.960	2009	13185
1986	2	10	3.450	145	43
1986	4	11	1.940	77	13
1987	4	25	2.180	31	6
1987	10	23	48.800	532	2242
1988	5	20	10.944	220	208
1988	7	20	213.450	2164	39902
1988	9	8	123.640	883	9436
1990	8	2	195.940	3299	55847
1993	5	7	3.586	177	55
1995	8	23	173.500	1638	24548
1996	2	17	2.546	121	27
2004	8	19	149.530	3378	43646
2004	8	22	119.430	2492	25714
2004	8	23	179.490	3480	53968
2005	2	17	2.770	123	29

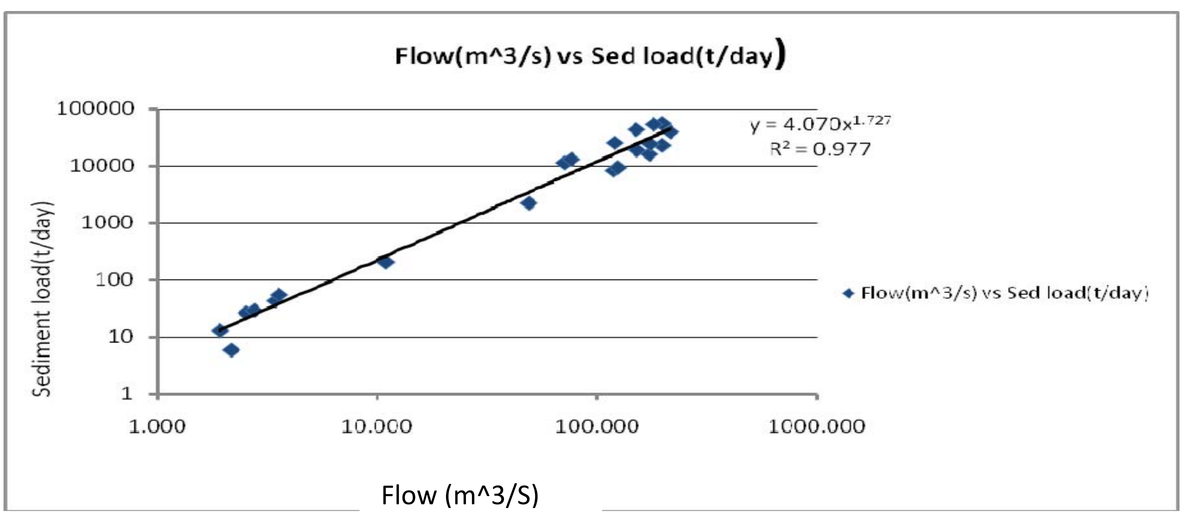

Figure A-1 Sediment rating curve -Station 1002 Gilgel Abbay (Merawi)

Table A-2 Flow and Sediment load for rating curve-Ribb (Addis Zemen)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (Q_S) t/d qs=0.0864*Q*Cc
1960	6	16	0.25	2145	47
1964	7	28	171.17	3452	51052
1968	7	3	32.5	7713	21659
1968	7	23	44.7	2878	11114
1968	8	7	96.7	3544	29608
1968	8	20	123	3713	39455
1968	9	3	320	3515	97194
1980	8	7	34.56	2230	6658
1980	9	24	6.84	178	105
1983	8	15	134.95	3287	38323
1985	9	3	27.31	3179	7500
1986	2	11	0.09	2	0
1986	8	7	77.73	4730	31764
1986	9	5	24.58	2577	5473
1987	4	29	0.71	232	14
1987	10	29	16	390	539
1988	5	25	0.1	2165	19
1988	7	22	60.25	3527	18361
1988	9	2	56.03	4076	19734
1988	11	18	2.61	173	39
1988	12	22	1.08	95	9
1989	2	11	0.58	104	5
1990	2	12	0.39	282	9
1990	7	6	46.1	3531	14064
1992	5	23	0.49	987	42
1992	7	20	36.3	2996	9396
1992	8	25	62.17	3126	16791
1993	5	12	0.26	373	8
1993	7	20	90.64	4557	35687
1994	8	26	113.85	8777	86336
1995	8	3	138.17	3269	39026
1996	8	24	212.69	8102	148892
1996	8	12	57.6	2770	13783
1996	10	2	2.07	26	5

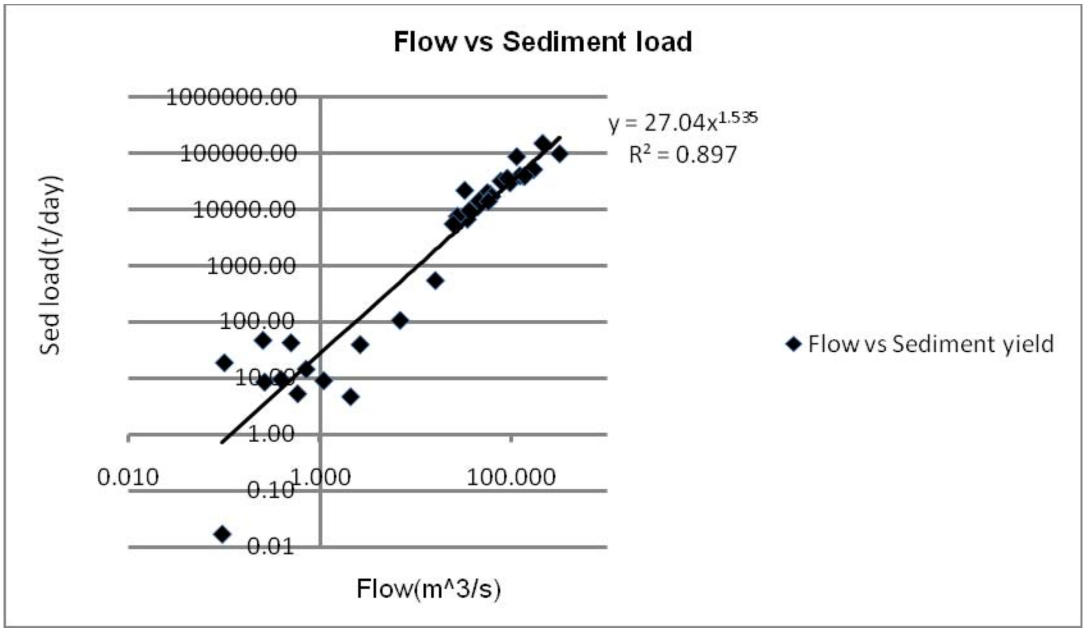

Figure A-2 Sediment rating curve- Station 1005 Ribb (Addis zemen)

Table A-3 Flow and Sediment load for rating curve-Gumara (Bahir Dar)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1990	2	10	1.283	166	18
1992	6	1	0.306	369	10
1992	7	20	37.64	10069	32744
1993	5	1	0.45	537	21
2004	8	16	117.096	3108	31447
2004	8	17	207.798	5371	96438
2005	9	5	95.126	5039	41415
2005	9	6	146.495	3357	42487
2005	9	7	152.712	3870	51066
2006	7	17	50.117	2632	11396
2006	7	18	62.986	5945	32354
2006	7	28	73.704	3264	20786

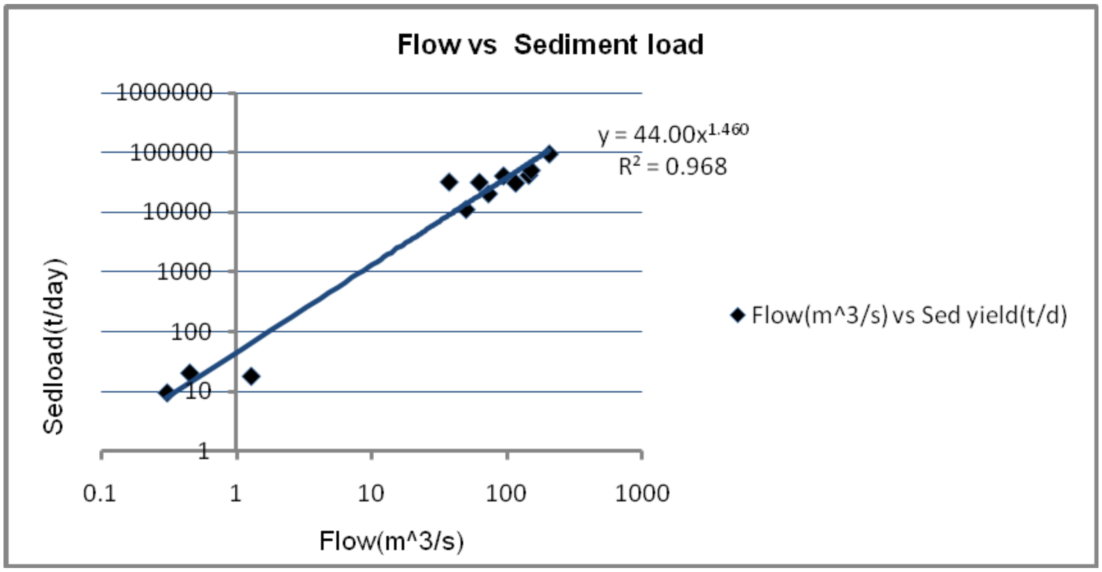

Figure A-3 Sediment rating curve-Station 1006 Gumara(Bahir Dar)

Table A-4 FLow and Sediment load for rating curve-Megech (Azezo)

Year	Mo nth	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1990	2	21	0.044	198	1
1990	8	10	8.96	3118	2413
1992	5	27	0.046	350	1
1993	5	14	0.192	537	9
1994	10	6	2.61	229	52
2005	3	11	0.108	295	3
2005	9	2	9.614	254	211
2005	9	3	9.782	205	174
2005	9	4	8.665	206	154

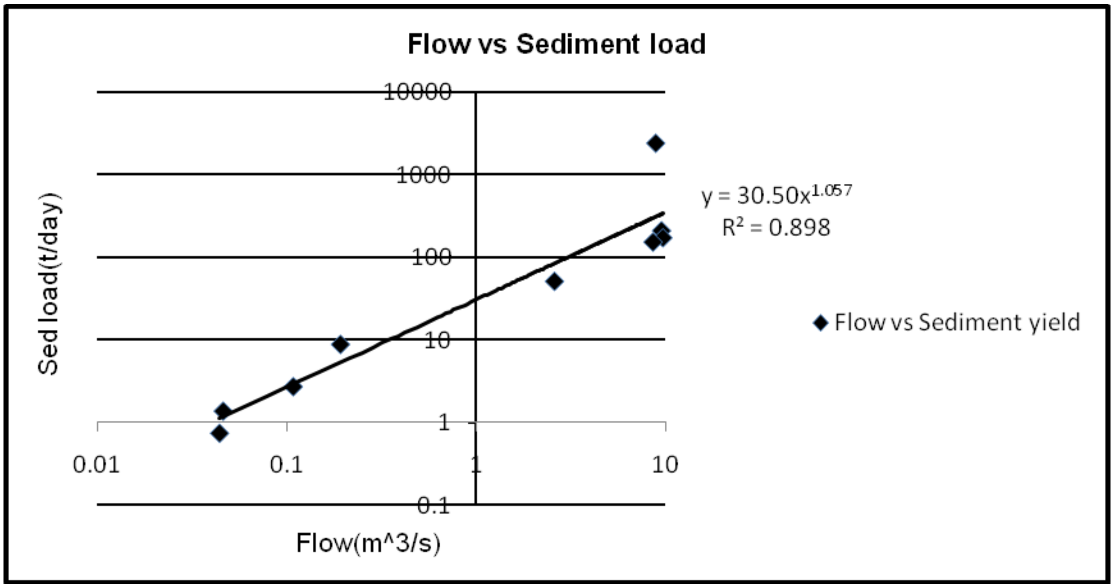

Figure A-4 Sediment rating curve-Station 1007 Megech (Azezo)

Table A-5 Flow and Sediment load for rating curve-Abbay (Kessie)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration mg/l	Daily sediment yield (q_S) t/d qs=0.0864*Q*Cc
1990	3	3	58.957	302	1536
1990	5	8	22.96	483	958
1990	10	20	330.729	63749	1821639
1992	9	26	290	1287	32244
1995	7	18	712.744	31529	1941565
1995	8	25	1926.443	4899	815484
1995	9	21	627.324	15166	822018
2003	5	24	0.81	251	18
2004	8	13	1637	17930	2535912
2004	8	28	980.22	4996	423084
2004	9	18	3982.25	2022	695867
2004	10	1	2433.86	2516	529099
2004	10	7	335	3391	98157
2004	10	22	165.488	372	5321
2008	7	14	1025.13	14567	1290186

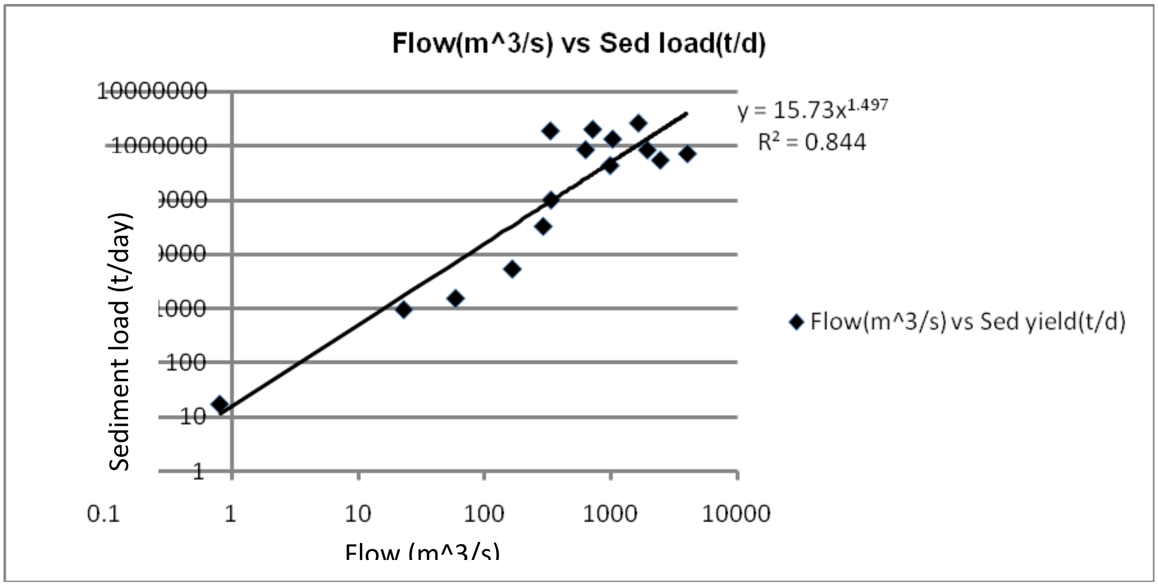

Figure A-5 Sediment rating curve-Station 2001 Abbay (Kessie)

Table A-6 Flow and Sediment load for rating curve-Abbay (Bahir Dar)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration(Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1961	5	9	1.77	170	26
1961	7	5	42.13	467	1699
1961	8	12	180.2	1906	29673
1961	9	23	158.1	986	13471
1961	10	7	94	765	6211
1961	11	8	21.1	245	447
1964	7	24	174	585	8793
1964	8	11	216.9	469	8793
1968	8	11	170	453	6660
1968	8	30	384.3	560	18594
1983	8	11	47.75	166	686
1983	8	24	109.23	61	579
1985	8	22	87.46	199	1507
1986	4	7	19.89	315	542
1986	6	19	27.95	64	154
1986	8	14	110.05	595	5657
1986	10	18	83.12	129	927
1987	4	25	14.88	51	66
1987	10	19	181.63	408	6401
1988	6	15	6.59	4908	2794
1988	7	1	20.98	388	703
1988	10	3	558.92	140	6770
1988	11	11	311.94	42	1131
1990	11	1	31.09	243	652
1990	8	3	153.87	248	3294

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration(Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1993	4	28	18.071	50	79
1995	8	1	61.41	120	635
1996	2	20	19.935	75	130
2004	9	15	116.41	219	2203
2004	9	22	146.38	159	2011

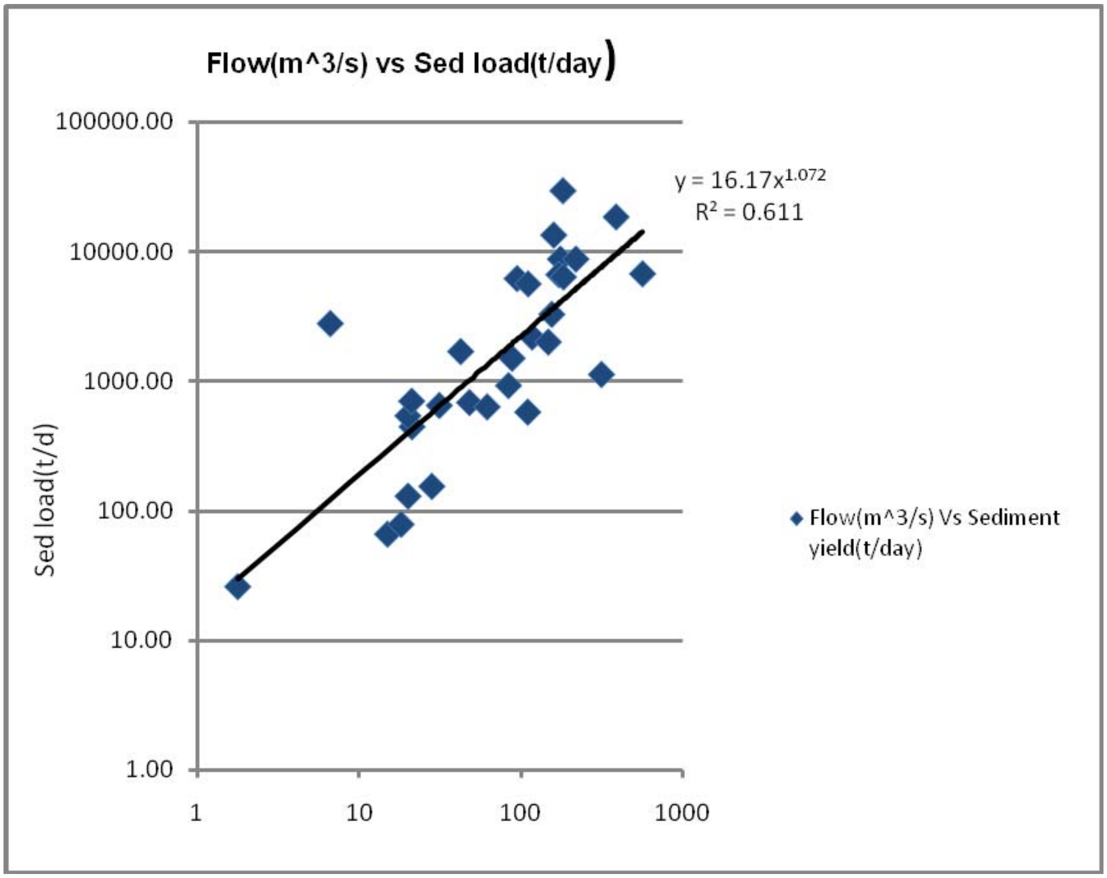

Figure A-6 Sediment rating curve-Station 2003 Abbay (Bahir Dar)

Table A-7 Flow and Sediment load for rating curve-Andassa (Bahir Dar)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1990	8	1	37.53	5722	18553
1993	4	30	1.417	365	45
2005	2	23	1.325	255	30

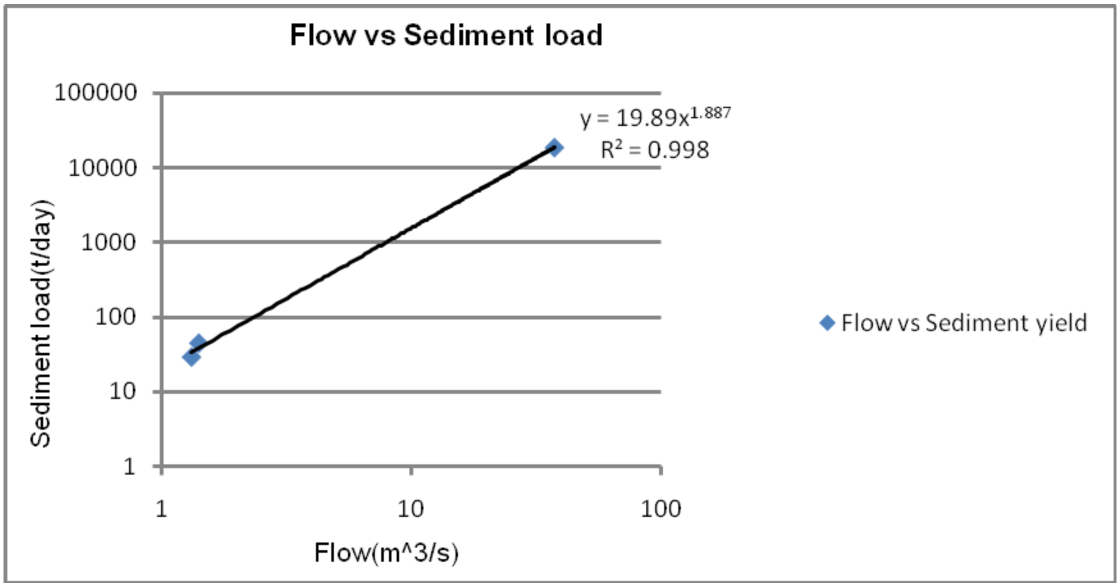

Figure A-7 Sediment rating curve-Station 2004 Andassa (Bahir Dar)

Table A-8 Flow and Sediment load for rating curve-Beressa (Debre Brehan)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1968	7	22	98.28	12345	104826
1968	8	4	35.71	963	2972
1989	8	15	7.184	191	119
1990	2	8	0.164	143	2
1992	10	12	1.187	184	19
1992	11	11	0.206	172	3
1994	8	19	6.046	398	208
1995	5	22	2.003	353	61
1995	2	4	0.291	133	3
1995	8	1	0.127	112	1
1995	8	14	18.392	443	704
1995	8	16	7.42	273	175
1995	8	30	21.597	315	588
1995	8	28	0.42	131	5
1995	8	3	10.691	873	807
1995	7	1	12.467	549	591
1995	7	25	2.9	861	216
1995	7	23	4.052	1056	370
1996	4	18	0.367	92	3
1996	6	20	0.971	373	31
1996	8	4	5.574	128	62
1996	8	17	16.326	473	668
1996	8	21	68.136	958	5640
1997	9	2	1.125	93	9
1997	9	4	1.324	112	13
1998	8	10	23.377	1048	2117
1998	8	11	56.989	704	3465
2002	10	1	0.634	170	9

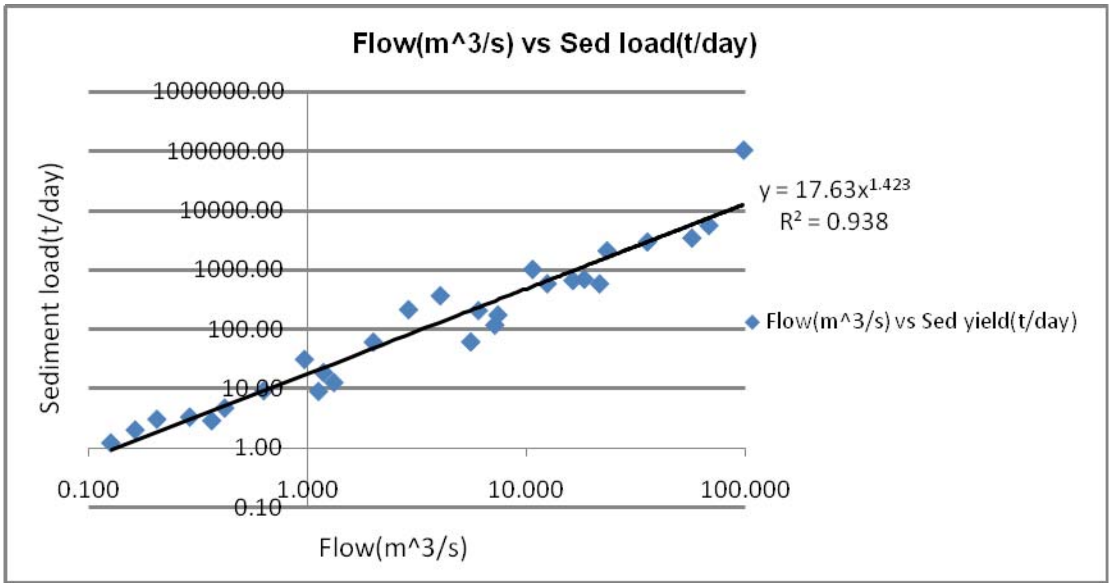

Figure A-8 Sediment rating curve-Station 2007 Berresa (Debre Brehan)

Table A-9 Flow and Sediment load for rating curve-Muga (Bichena)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1983	7	28	23.190	2948	5907
1983	8	2	18.030	939	1462
1983	9	20	7.300	249	157
1983	9	24	28.460	2707	6658
1984	9	17	5.440	184	87
1984	9	18	4.170	153	55
1984	9	21	8.590	291	216
1985	8	28	10.040	356	309
1985	9	1	39.760	691	2375
1985	10	2	0.860	321	24
1985	10	5	4.920	88	37
1985	11	13	0.490	82	3
1986	1	27	0.150	1306	17
1986	2	22	0.260	268	6
1986	3	30	0.080	78	0.5
1986	4	29	0.185	343	5
1986	5	25	0.040	366	1
1986	6	30	5.970	603	311
1986	7	10	10.510	1407	1278
1986	9	10	17.970	739	1148
1986	9	13	9.560	647	534
1986	10	30	0.960	99	8
1986	12	29	0.200	144	2
1987	3	27	0.140	16	0.2
1987	6	5	1.150	215	21
1987	7	30	27.280	3323	7833
1987	8	6	29.920	3432	8872
1987	8	7	9.640	1385	1154
1987	9	22	1.490	146	19

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1987	9	26	4.000	759	262
1987	10	30	0.480	323	13
1987	12	24	0.35	43	1
1988	1	30	0.1	169	1
1988	5	13	0.800	186	12
1988	6	28	0.430	163	6
1988	7	25	33.810	2131	6225
1988	9	5	22.500	1020	1982
1988	10	29	1.560	157	21
1989	1	10	0.190	104	2
1989	3	27	0.020	130	0.22
1989	5	5	0.526	688	31
1989	7	25	10.020	2420	2095
1989	9	20	7.820	239	161
1989	11	12	0.180	385	6
1993	10	8	2.340	776	157
1994	10	9	1.700	205	30
1995	8	3	18.450	2852	4546
1995	8	5	11.150	1162	1120
1995	8	11	4.920	867	368
1995	10	6	1.480	137	17.
1995	10	7	1.370	200	24
2002	9	20	1.770	113	17
2002	9	21	1.550	142	19
2002	9	26	1.450	139	17
2004	8	5	2.320	1388	278
2005	9	28	0.970	1043	87
2006	10	12	0.530	181	8

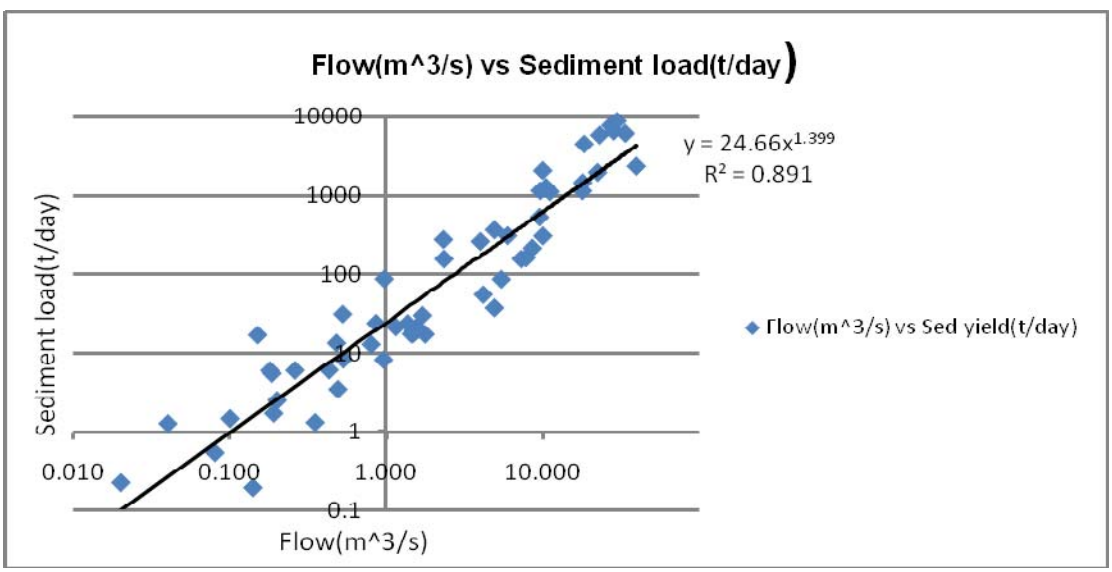

Figure A-9 Sediment rating curve-Station 2017 Muga (Bichena)

Table A-10 Flow and Sediment load for rating curving-Azuari (Motta)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1985	8	29	14.500	367	459
1985	8	30	22.800	469	923
1985	9	24	44.910	750	2910
1985	10	3	0.330	145	4
1985	10	4	2.510	135	29
1985	11	14	0.450	70	3
1986	1	26	0.100	2900	25
1986	2	22	0.320	250	7
1986	3	30	0.123	110	1
1986	4	29	0.180	160	2
1986	7	9	3.920	227	77
1986	9	14	7.220	905	565
1986	9	15	11.440	2423	2395
1986	9	16	5.270	611	278
1986	10	30	0.600	148	8
1986	12	31	0.280	180	4
1987	2	28	0.240	400	8
1987	4	17	0.360	388	12
1987	6	27	1.940	5284	886
1987	8	2	5.060	1278	558
1987	8	3	10.550	3135	2858
1987	8	4	5.870	930	472
1987	8	6	8.200	2863	2028
1987	9	25	1.110	132	13
1987	9	27	0.710	172	10
1987	10	31	0.890	100	8
1987	11	23	0.390	60	2
1988	1	30	0.300	60	1
1988	5	21	0.184	173	3
1988	6	27	0.770	1121	75
1988	7	26	9.180	1902	1509
1988	8	14	28.52	464	1145
1988	8	16	15.01	1747	2265
1988	8	18	26.880	4243	9853
1988	8	19	37.690	2656	8650
1988	8	21	4.520	2323	907
1988	8	28	7.230	428	267
1988	8	29	9.790	3939	3332
1988	8	30	2.020	432	75
1988	9	3	2.020	405	70

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1988	10	30	1.470	176	22
1989	3	25	0.270	8	0.20
1989	5	7	0.230	155	3
1989	7	26	6.240	2276	1227
1989	9	22	6.580	959	545
1989	10	13	0.640	185	10
1992	7	23	1.700	29	4
1993	10	6	3.090	304	81
1994	10	10	0.753	227	15
1995	8	6	9.050	500	391
1995	8	8	6.470	868	485
1995	8	13	3.100	2048	548
1995	10	8	1.350	289	33

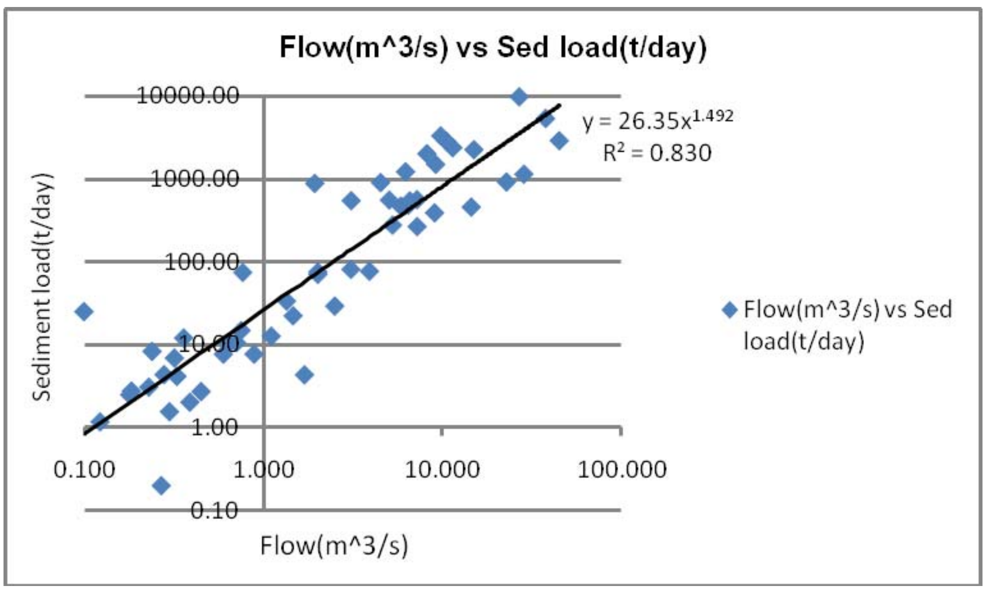

Figure A-10 Sediment rating curve-Station 2018 Azuari (Motta)

Table A-11 Flow and Sediment load for rating curve-Aleltu (Muke Turi)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration(Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1985	6	2	0.701	34	2
1988	1	9	0.063	44	0
1988	7	22	12.084	112	117
1988	8	21	29.14	175	440
1988	8	22	31.9	178	491
1988	8	25	17.276	157	234
1988	8	27	17.74	167	256
1988	8	29	16.89	214	312
1989	1	24	0.048	33	0
1989	5	3	0.353	81	2
1989	6	21	0.052	103	0
1989	12	24	0.131	138	2
1990	3	2	0.42	117	4
1990	5	5	0.122	55	1
1992	7	18	5.446	649	305
1992	7	24	10.495	458	415
1992	7	28	24.076	784	1632
1992	8	4	26.255	379	861
1992	8	14	14.6	137	172
1992	8	20	10.719	234	217
1992	8	31	25.471	315	694
1992	9	5	26.997	110	256
1992	9	10	18.5	340	543
1992	9	19	6.999	204	123
1992	9	25	3.952	162	55
1992	9	25	3.558	200	61
1992	11	7	0.08	169	1
1992	11	7	0.285	179	4
1994	8	16	50.033	230	993
1995	1	28	0.021	175	0
1995	4	29	1.41	457	56
1995	7	17	8.213	4401	3123
1995	7	19	9.889	1352	1155
1995	7	29	7.796	400	269
1995	8	10	95.702	1220	10085
1995	8	11	49.509	350	1498
1995	8	21	19.413	800	1342
1995	8	24	23.556	210	428
1995	8	26	36.277	132	413
1995	8	30	5.058	265	116
1995	9	20	3.076	289	77
1995	9	22	2.37	191	39
1995	10	1	0.75	77	5
1995	10	2	0.716	73	5
1996	2	26	0.049	137	1
1996	6	14	1.62	267	37
1996	12	20	0.06	101	1

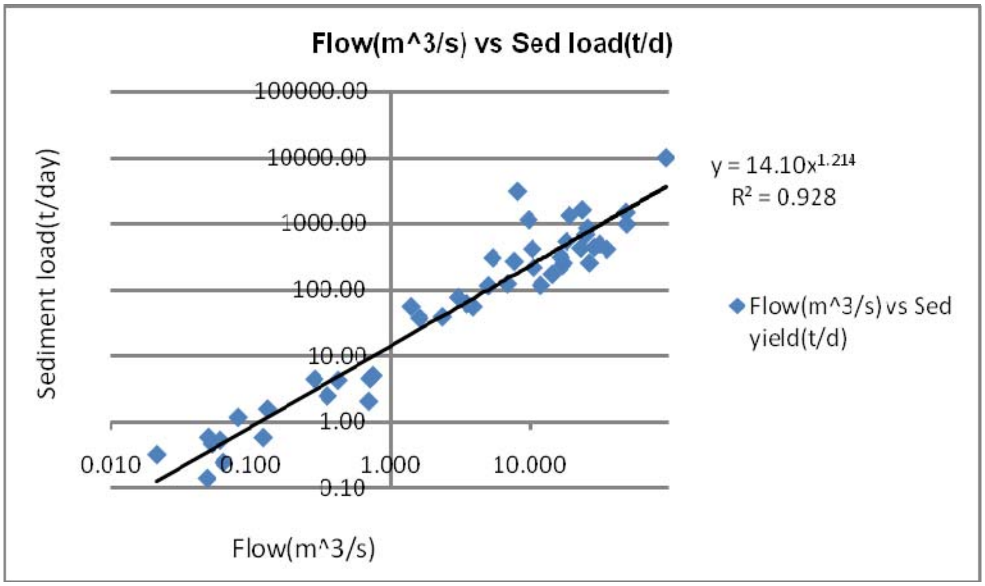

Figure A-11 Sediment rating curve-Station 2027 Aleltu (Muke Turi)

Table A-12 Flow and Sediment load for rating curve-Robi Jida (Muke Turi)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1985	6	1	0.061	35	0.2
1985	7	22	11.077	52	49
1988	8	25	12.712	54	59
1988	8	29	11.650	90	91
1989	1	24	0.096	23	0.2
1989	2	2	0.243	89	2
1989	5	5	0.019	53	0.1
1989	6	21	0.007	76	0.1
1989	8	9	8.547	93	68
1989	9	23	3.600	68	21
1989	10	19	0.641	124	7
1989	12	24	0.196	57	1
1990	7	19	10.883	308	289
1992	7	25	12.99	359	403
1992	7	29	71.78	1210	7506
1992	8	13	20.760	427	766
1992	8	16	26.820	180	417
1992	8	21	51.930	205	920
1992	8	31	16.280	118	165
1992	9	4	21.190	274	502
1992	9	10	18.150	199	312
1992	9	18	8.180	134	95
1992	9	24	3.520	159	48
1992	9	25	2.933	227	57
1994	8	16	32.599	357	1004
1995	1	28	0.037	102	0.3

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1995	4	29	0.439	43	2
1995	7	17	19.025	287	471
1995	7	19	13.348	179	207
1995	7	20	21.161	570	1043
1995	7	30	7.161	497	308
1995	8	10	53.366	344	1586
1995	8	21	27.343	293	692
1995	8	24	18.022	118	183
1995	9	9	25.677	217	482
1995	9	20	2.424	117	24
1995	9	22	2.041	105	18
1995	10	1	0.836	66	5
1995	10	2	0.706	80	5
1996	3	4	0.017	49	0.1
1996	6	14	0.499	78	3
1996	8	17	1.510	102	13
1996	12	20	0.138	53	0.6

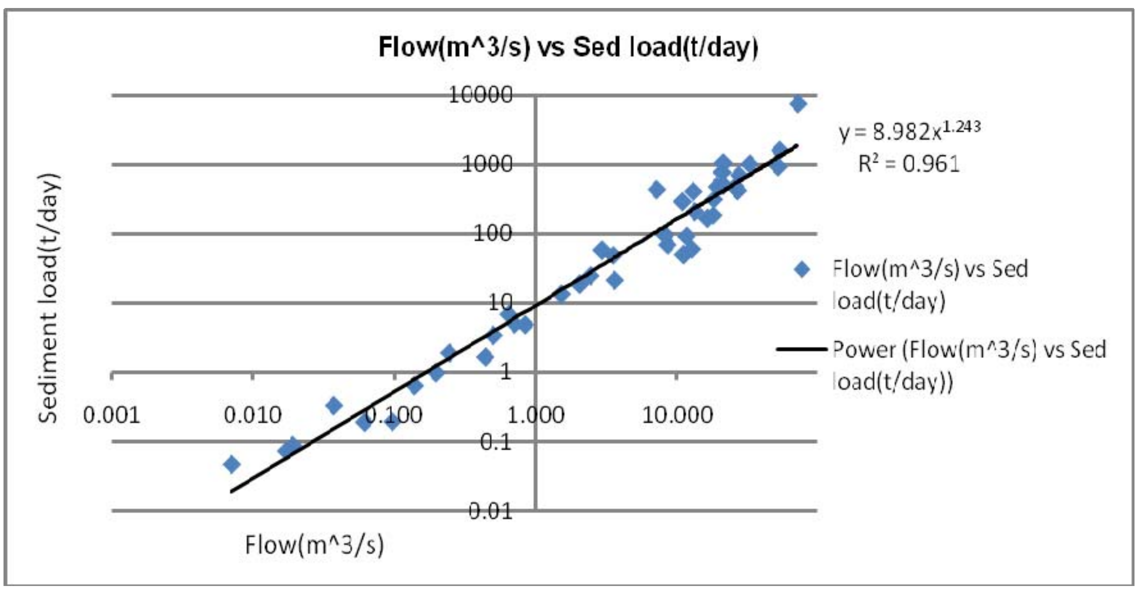

Figure A-12 Sediment rating curve-Station 2027 Robi Jida (Muke Turi)

Table A-13 Flow and Sediment load for rating curve -Teme (Motta)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_s) t/d qs=0.0864*Q*Cc
1985	8	29	12.840	293	325
1985	8	30	14.530	441	553
1985	10	3	0.550	85	4
1985	10	4	2.350	256	52
1985	11	14	0.240	166	3
1986	1	26	0.085	75	0.5
1986	2	22	0.120	543	6
1986	3	30	0.017	506	0.7
1986	4	29	0.069	469	3
1986	5	24	0.022	746	1
1986	7	9	3.190	4145	1142
1986	9	14	4.950	1385	592
1986	9	14	4.120	1188	423
1986	9	15	9.110	1423	1120
1986	9	16	6.140	1564	830
1986	10	3	0.440	93	3
1986	12	31	0.080	185	1
1987	2	28	0.020	84	0.2
1987	4	16	0.160	276	4
1987	6	27	1.570	9329	1265
1987	8	2	4.310	828	308
1987	8	3	7.860	3575	2428
1987	8	5	4.670	734	296
1987	10	31	0.610	277	15
1987	12	23	0.180	129	2
1988	1	30	0.100	96	0.8
1988	5	21	0.152	5220	68
1988	6	27	0.600	3630	188
1988	7	26	25.280	4544	9924
1988	8	13	16.040	2151	2981
1988	8	13	11.230	1067	1035
1988	8	14	7.23	675	4221
1988	8	16	8.32	796	572
1988	8	17	7.240	869	543
1988	8	18	16.730	1385	2003
1988	8	18	19.840	2924	5012
1988	8	21	24.430	2245	4738
1988	8	21	11.370	709	697
1988	8	23	6.510	558	314
1988	8	23	24.350	1873	3940
1988	8	25	29.560	1894	4837
1988	8	28	6.150	1419	754
1988	8	31	3.440	252	75
1988	9	1	3.990	449	155
1988	10	20	0.930	100	8
1989	1	12	0.920	70	5
1989	3	25	0.180	166	3
1989	5	7	0.110	11	0.1
1989	6	26	4.810	848	352
1989	11	13	0.270	127	3

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1993	10	6	2.220	312	60
1994	10	10	0.762	264	17
1995	8	6	6.830	723	427
1995	8	7	21.710	1691	3172
1995	8	8	4.209	541	197
1995	8	12	4.070	728	256
1995	8	13	2.792	377	91
1995	9	8	3.730	162	52

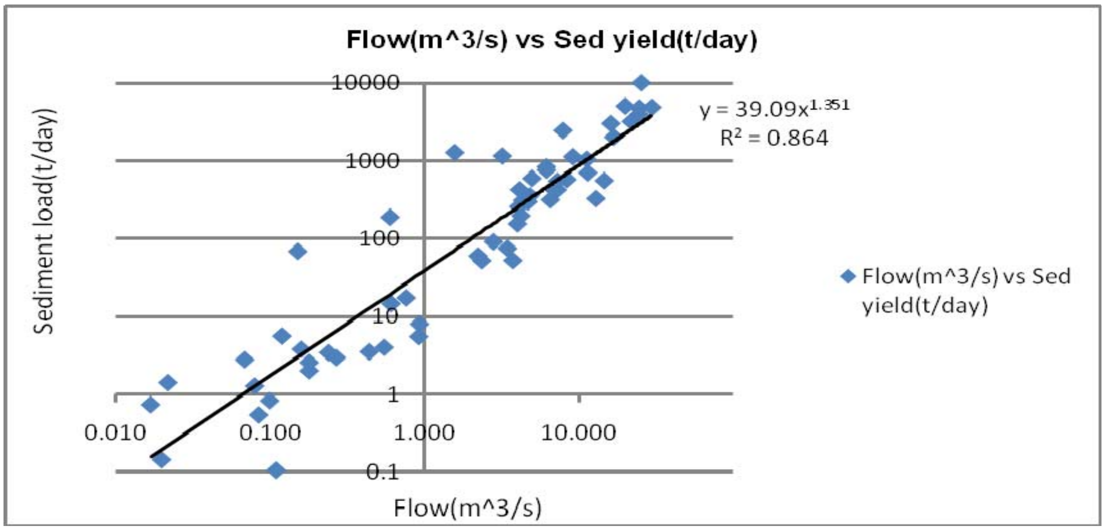

Figure A-13 Sediment rating curve-Station 2030 Teme (Motta)

Table A-14 Flow and Sediment load for rating curve-Suha (Bichena)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1985	8	29	3.950	384	131
1985	9	1	22.950	955	1893
1985	10	2	0.585	88	4
1985	10	5	2.850	223	55
1985	11	13	0.207	50	0.90
1986	4	30	0.041	170	0.60
1986	5	25	0.004	186	0.1
1986	6	29	3.520	603	183
1986	9	13	9.320	1088	876
1986	9	13	8.580	1085	804
1986	9	14	16.510	1848	2636
1986	9	17	5.610	369	179
1986	9	18	3.666	423	134
1986	10	30	0.620	157	8
1986	12	29	0.110	220	2
1987	2	28	0.080	96	0.7
1987	4	17	0.220	280	5

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1987	6	28	0.450	255	10
1987	8	6	7.820	1066	720
1987	8	7	3.850	780	259
1987	9	22	0.510	124	5
1987	9	26	1.380	275	33
1987	10	30	0.240	129	3
1988	5	27	0.312	619	17
1988	6	26	0.230	141	3
1988	7	25	18.440	2554	4069
1988	8	2	11.970	1520	1572
1988	8	9	19.240	2944	4893
1988	8	9	9.070	948	743
1988	8	9	22.690	3987	7815
1988	8	10	18.030	2162	3368
1988	8	10	32.47	12640	35459
1988	8	11	20.3	4386	7693
1988	8	11	22.440	4389	8509
1988	8	11	28.180	12448	30308
1988	8	12	16.710	2520	3638
1988	9	4	27.670	9297	22226
1988	10	30	0.900	84	7
1989	1	10	0.080	1703	12
1989	3	27	0.100	205	2
1989	5	6	0.520	155	7
1992	6	26	0.160	1581	22
1992	7	13	1.220	10205	1076
1994	10	11	0.690	255	15
1995	8	3	13.700	2325	2752
1995	8	5	7.370	688	438
1995	8	6	0.751	272	18
1995	8	11	3.050	683	180

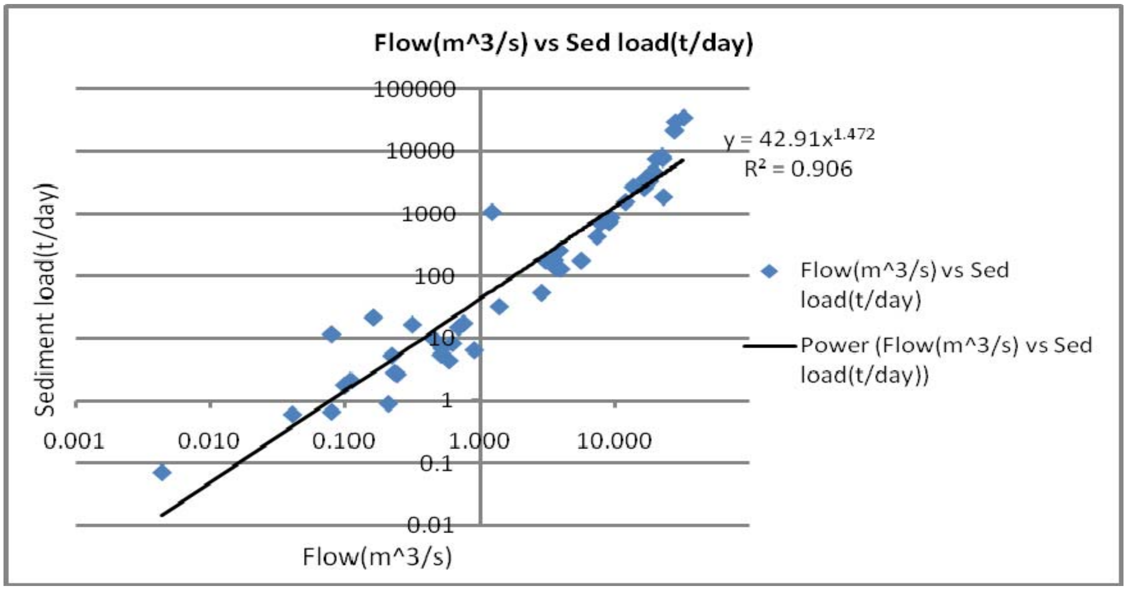

Figure A-14 Sediment rating curve-Station 2031 Suha (Bichena)

Table A-15 Flow and Sediment load for rating curve-Mendel (Tis Abbay)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Ccmg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1987	11	13	0.106	125	1
1988	5	19	0.052	477	2
1988	7	19	1	2354	203
1988	9	7	0.61	107	6
1988	10	14	0.231	84	2
1989	1	3	0.069	341	2
1990	9	7	1.183	528	54
1990	9	10	0.947	339	28
1993	7	20	0.11	802	8
1994	9	22	1.15	548	54

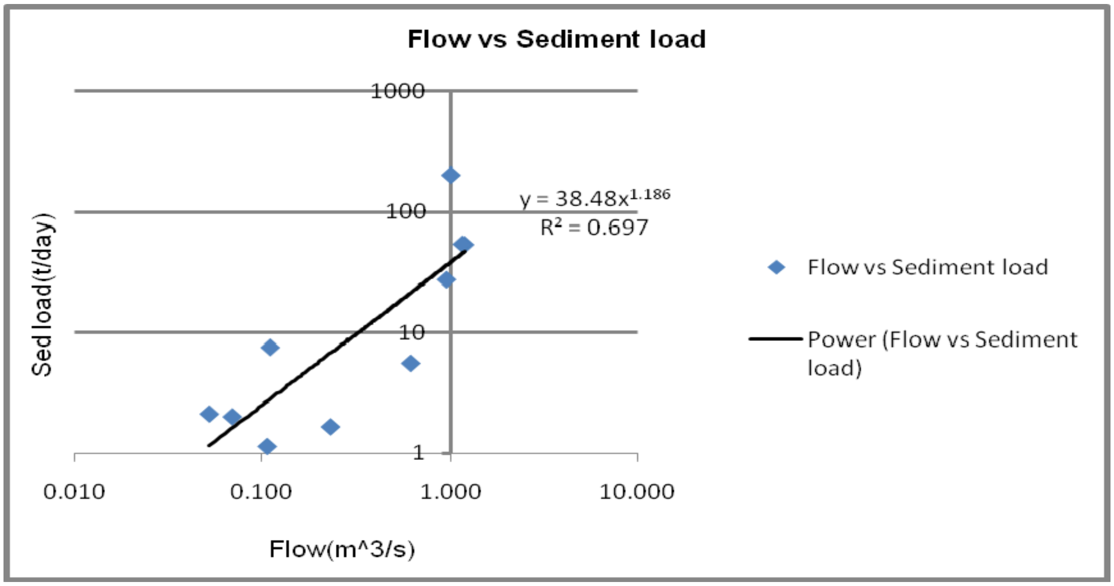

Figure A-15 Sediment rating curve-Station 2036 Mendel (Tis Abbay)

Table A-16 Flow and Sediment load for rating curve-Yeda (Amber)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_s) t/d qs=0.0864*Q*Cc
1988	4	19	0.022	1782	3
1988	5	8	0.022	593	1
1988	6	25	0.06	4083	21
1988	10	28	0.26	236	5
1989	1	9	0.12	551	6
1989	3	27	0.04	822	3
1989	5	2	0.068	956	6
1989	6	20	0.017	1362	2
1989	7	28	0.54	3293	154
1989	8	30	1.25	1796	194
1989	8	30	1.24	1549	166
1989	8	30	1.17	1321	134
1989	8	30	1.45	2334	292
1989	8	30	0.67	1681	97
1989	9	1	0.46	1614	64
1989	9	1	0.36	982	31
1989	9	1	0.32	815	23
1989	9	2	0.44	1486	57
1989	9	2	0.36	1213	38
1989	9	2	0.48	1508	63
1989	9	3	0.28	919	22
1989	9	5	0.27	1382	32
1989	9	6	0.44	1339	51
1989	11	11	0.18	370	6
1992	2	2	0.1	338	3
1993	10	9	1.75	962	145
1994	10	8	1.05	1539	140
1995	8	17	2.126	4631	851
1995	10	5	0.42	543	20

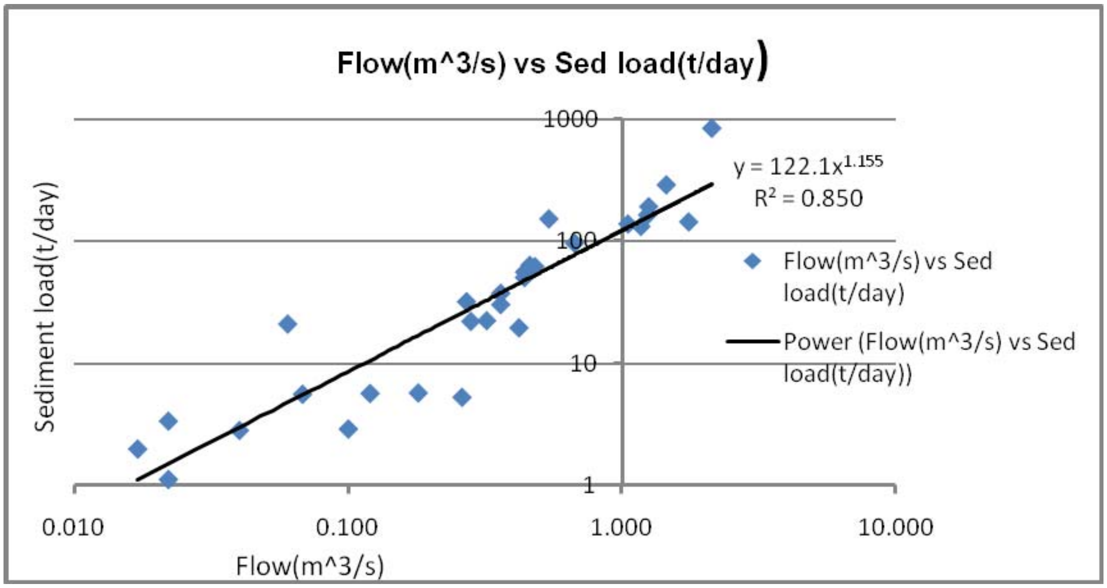

Figure A-16 Sediment rating curve-Station 2038 Yeda (Amber)

Table A-17 Flow and Sediment load for rating curve-Bello (guder)

year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1977	7	15	22.190	13	25
1977	7	21	19.570	45	76
1977	7	29	17.710	10	15
1977	8	6	13.950	13	16
1977	8	11	32.520	23	65
1977	8	16	29.220	30	76
1977	8	25	19.970	17	29
1977	8	31	19.330	10	17
1977	9	8	22.160	15	29
1977	9	14	26.220	47	106
1977	9	22	13.700	10	12
1977	9	29	6.770	23	13
1977	10	5	9.260	13	10
1977	10	13	4.680	10	4
1977	10	21	7.240	10	6
1977	10	27	17.350	17	25
1988	3	29	0.214	22	0.4
1988	6	18	0.595	88	5
1988	11	19	0.601	37	1
1988	12	20	0.294	40	1
1989	1	24	0.286	28	0.7
1989	2	21	0.207	26	0.5
1989	3	26	0.252	22	0.5
1989	4	18	1.252	63	7
1989	5	17	1.307	75	8

year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_s) t/d qs=0.0864*Q*Cc
1990	1	19	0.404	41	1
1990	2	27	0.871	135	10
1990	4	28	0.758	44	3
1990	10	29	0.426	85	3
1991	8	30	0.804	96	7
1994	7	31	22.585	131	255
1995	1	22	0.188	73	1
1995	8	2	30.240	201	526
1996	8	29	0.97	456	38
1996	12	28	0.409	497	17

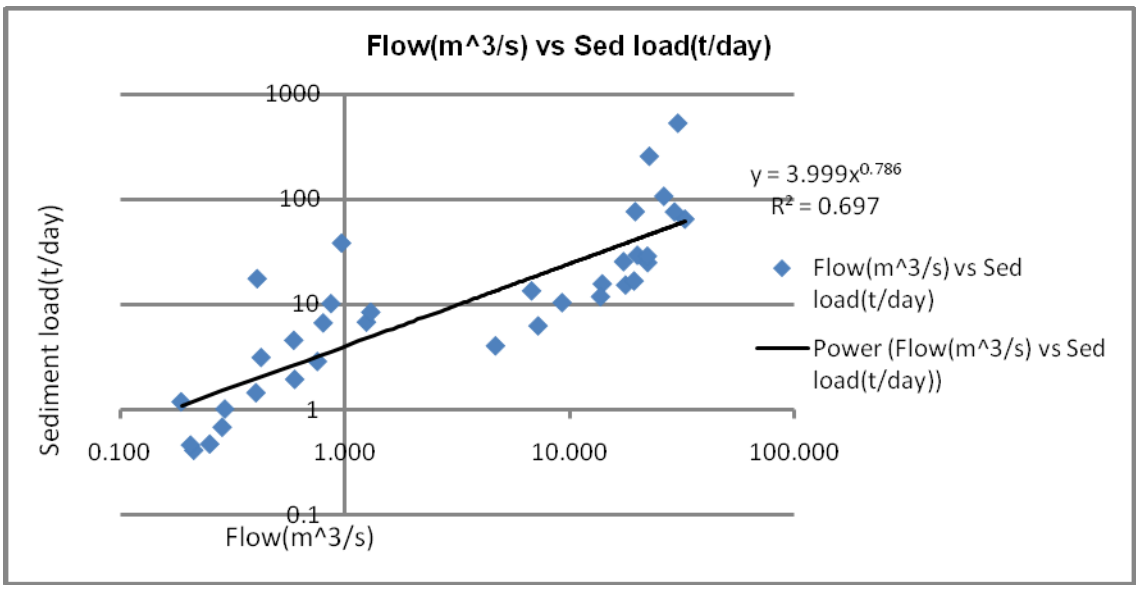

Figure A-17 Sediment rating curve-Station 3001 Bello (Guder)

Table A-18 Flow and Sediment load for rating curve-Guder (Guder)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_s) t/d qs=0.0864*Q*Cc
1968	6	20	1.310	81	9
1968	7	19	17.007	101	148
1968	8	8	67.200	44	253
1968	8	19	52.650	205	932
1968	9	19	67.210	207	1202
1968	10	21	13.741	75	89
1968	11	23	1.009	26	2
1988	12	21	0.623	34	2

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1989	1	24	0.571	39	2
1989	2	20	0.495	39	2
1989	3	26	0.462	23	1
1989	4	19	1.929	524	87
1989	5	16	1.428	66	8
1989	10	30	0.818	43	3
1989	12	14	1.153	40	4
1990	1	18	0.703	135	8
1990	2	17	1.874	152	25
1990	3	23	1.287	49	5
1990	4	11	1.062	116	11
1990	9	8	39.529	90	308
1990	10	10	10.988	77	74
1991	8	25	37.823	95	313
1991	10	28	1.627	103	15
1992	8	31	39.090	112	380
1992	9	23	28.138	137	334
1992	9	31	67.594	159	927
1995	1	23	8.500	107	78
1996	12	28	0.609	113	6

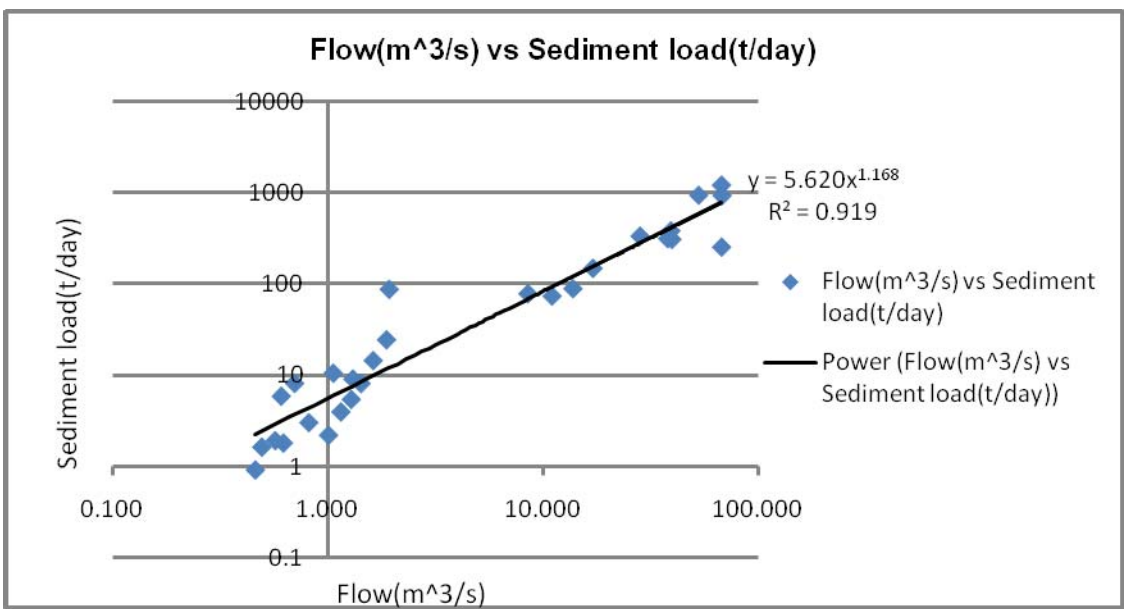

Figure A-18 Sediment rating curve-Station 3005 Guder (Guder)

Table A-19 Flow and Sediment load for rating curve -Gudla (Dembecha)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (Q_S) t/d Qs=0.0864*Q*Cc
1960	9	13	27.590	207	493
1964	9	7	35.600	1578	4855
1968	6	25	41.390	833	2978
1968	7	15	38.400	993	3295
1968	7	22	43.960	1613	6127
1968	7	30	67.340	648	3768
1968	8	7	67.340	357	2077
1968	8	12	41.860	1161	4199
1968	8	14	24.870	874	1879
1968	8	23	26.900	832	1934
1968	9	6	16.220	233	326
1968	9	20	15.930	338	466
1982	7	29	23.210	546	1096
1982	8	25	11.620	151	152
1985	8	17	30.920	336	897
1985	8	18	34.270	1140	3375
1985	8	19	17.770	851	1307
1985	9	25	19.220	103	171
1986	1	2	0.290	273	7
1986	2	23	0.710	280	17
1986	3	18	0.150	393	5
1986	4	25	0.210	180	3
1986	5	23	0.080	273	2
1986	7	17	16.130	690	961
1986	7	19	25.010	551	1191
1986	7	23	33.830	1379	4030
1986	9	5	41.680	5151	18549
1986	9	6	18.600	404	650
1986	10	26	2.610	217	49
1987	1	6	0.310	323	9
1987	2	13	0.180	28	0.4
1987	4	12	0.12	76	1
1987	5	1	0.22	36	0.7
1987	6	24	20.290	403	706
1987	6	27	33.960	1680	4931
1987	8	15	8.860	569	436
1987	9	12	21.030	665	1208
1987	10	6	0.890	536	41
1987	12	27	0.700	103	6
1988	1	28	0.310	113	3
1988	2	15	0.070	136	0.8
1988	6	23	5.100	4146	1827
1988	7	28	5.870	1455	738
1988	9	8	13.880	197	236
1988	10	23	4.950	186	80
1989	1	14	0.260	102	2
1989	1	19	1.080	601	56
1989	2	19	0.160	76	1
1989	5	11	0.122	79	0.8
1989	7	23	28.470	3072	7556

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (Q_S) t/d Qs=0.0864*Q*Cc
1992	2	4	0.300	27	0.7
1993	10	12	5.930	535	274
1995	6	27	37.220	1416	4554
1995	6	27	26.120	420	947
1995	6	28	31.670	978	2677
1995	10	22	1.820	108	17

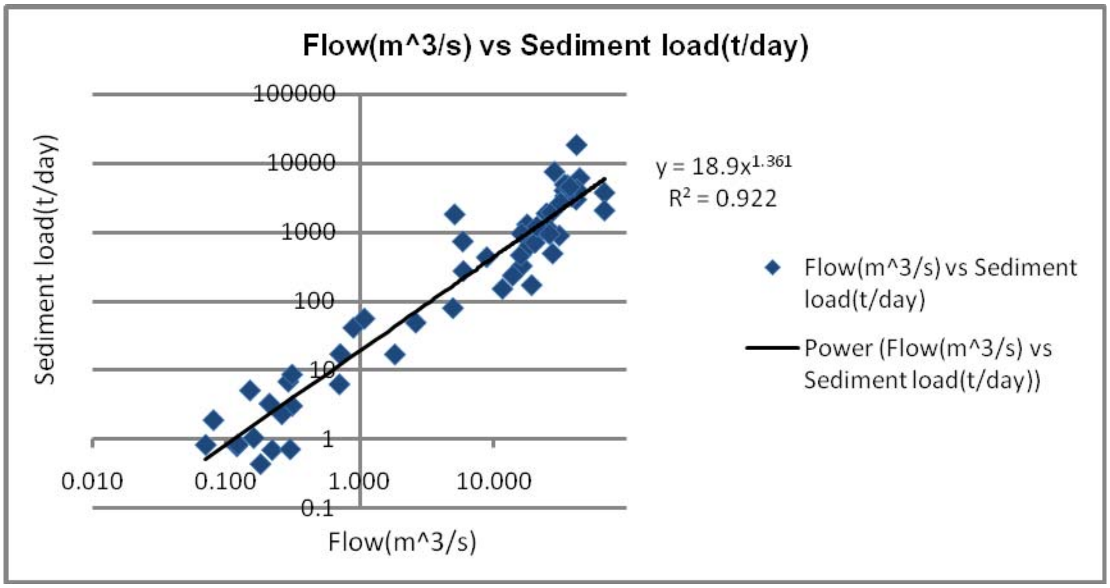

Figure A-19 Sediment rating curve-Station 3012 Gudla (Dembecha)

Table A-20 Flow and Sediment load for rating curve-Temcha (Dembecha)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1968	7	15	37.090	1192	3819
1968	7	22	25.860	1098	2453
1968	8	12	32.010	705	1950
1968	8	27	37.190	934	3000
1968	9	6	13.180	303	345
1968	9	20	25.110	451	979
1969	9	8	23.500	350	711
1985	8	20	52.290	555	2506
1985	8	22	38.240	293	968
1985	9	3	28.810	151	376
1985	9	26	13.070	131	148
1985	10	8	11.040	1560	1489
1985	11	2	3.430	12	4
1986	1	9	0.790	276	19
1986	2	23	0.530	283	13
1986	3	18	0.110	230	2
1986	4	26	0.340	469	14
1986	5	23	0.128	473	5

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1986	7	22	32.720	1014	2868
1986	7	22	35.450	1063	3256
1986	7	23	53.940	1284	5982
1986	9	6	14.940	165	213
1986	10	26	4.240	141	52
1987	1	5	0.450	375	15
1987	4	12	0.179	33	0.5
1987	5	1	0.310	832	22
1987	8	11	34.790	688	2069
1987	8	14	43.630	970	3655
1987	8	15	33.960	903	2650
1987	9	11	48.490	575	2409
1987	10	5	27.030	6142	14345
1987	12	27	0.89	50	4
1988	1	28	0.56	87	4
1988	2	27	0.530	243	11
1988	4	15	0.061	218	1
1988	5	10	0.290	146	4
1988	6	24	4.280	16683	6169
1988	7	28	19.400	625	1048
1988	9	9	16.430	415	589
1988	10	23	8.770	216	163
1989	1	14	0.610	89	5
1989	2	4	0.560	63	3
1989	4	28	5.160	1084	483
1989	4	28	0.240	156	3
1989	5	10	0.404	107	4
1989	6	19	1.800	1005	156
1989	7	12	35.280	1259	3838
1989	11	17	1.770	127	19
1993	10	12	9.650	218	182

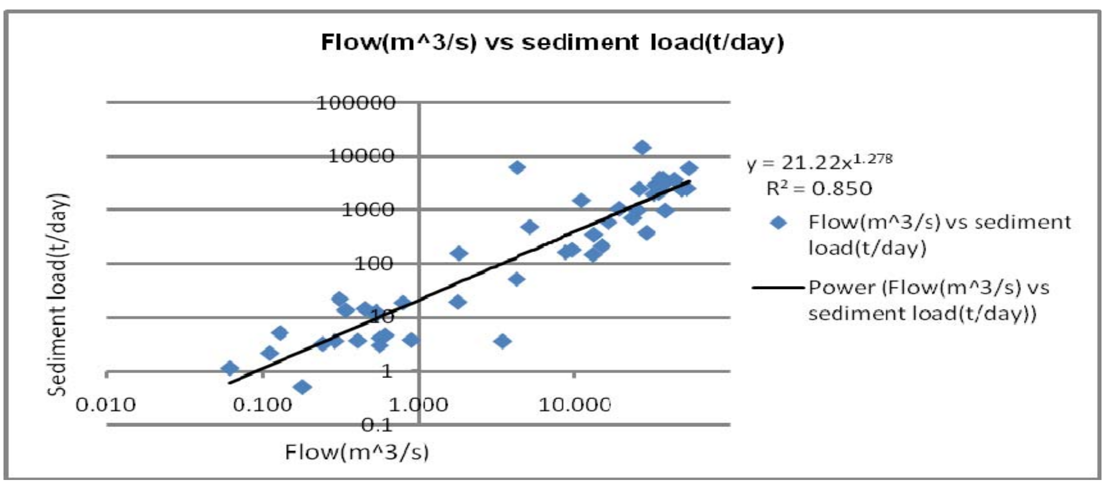

Figure A-20 Sediment rating curve-Station 3014 Temcha (Dembecha)

Table A-21 Flow and Sediment load for rating curve-Neshi (Shambu)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1968	7	1	3.03	669	175
1968	7	11	7.32	125	79
1968	7	22	9.46	153	125
1968	7	29	8.95	111	86
1968	8	5	15.8	541	738
1968	8	12	15.11	581	758
1968	8	19	18.27	933	1473
1968	8	26	17	524	770
1968	9	2	11.82	503	514
1968	9	9	13.1	809	915
1968	9	16	8.75	302	228
1968	9	23	12.11	587	615
1968	10	2	9.41	875	711
1968	10	21	4.04	756	264
1968	10	31	2.25	688	134
1988	3	31	0.112	263	3
1988	6	6	1.96	14	2
1988	10	22	12.332	858	914
1988	11	25	1.25	45	5
1988	12	24	0.769	35	2
1989	1	26	0.445	34	1
1989	2	22	0.39	80	3
1989	3	27	0.467	25	1
1989	4	20	0.419	27	1
1989	5	19	1.155	37	4
1989	6	12	0.711	67	4
1989	12	16	1.855	26	4
1990	1	20	0.62	194	10
1990	2	21	0.436	51	2
1990	3	24	0.281	12	0
1990	4	24	0.305	74	2
1990	10	12	8.811	69	53
1991	8	28	28.052	2048	4964
1991	10	30	1.903	41	7
1995	1	25	0.633	51	3
1995	8	4	12.21	438	462
1996	5	30	1.08	66	6

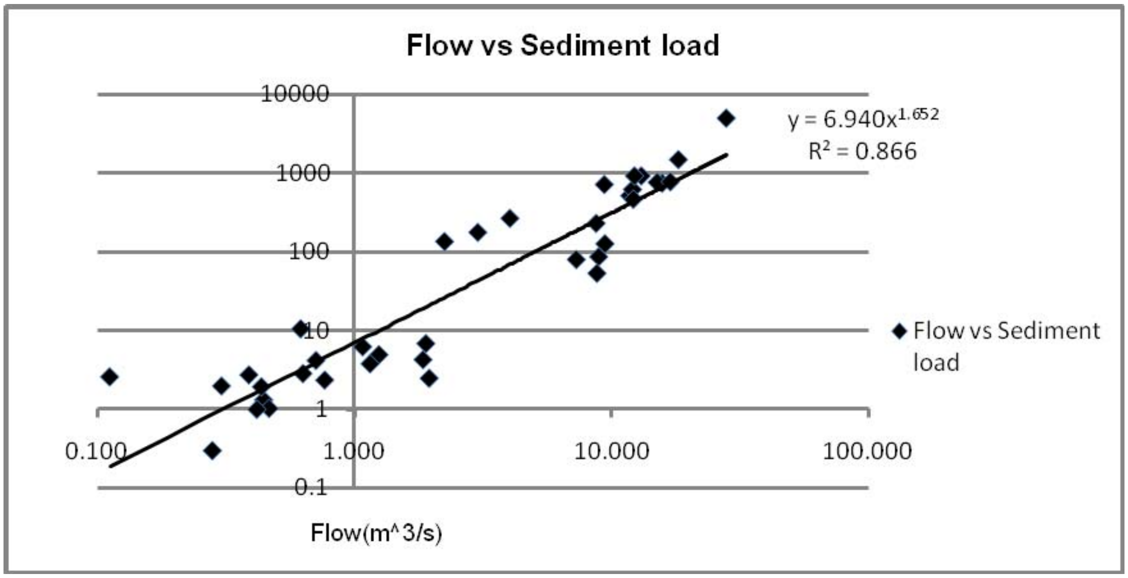

Figure A-21 Sediment rating curve-Station 3026 Neshi (Shambu)

Table A-22 Flow and Sediment load for rating curve-Ardy (Metekel)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment yield (q_S) t/d qs=0.0864*Q*Cc
1977	7	12	15.610	25	34
1977	7	16	22.800	25	49
1977	7	30	16.370	15	21
1977	8	4	12.720	10	11
1977	8	13	24.810	23	49
1977	8	18	18.840	10	16
1977	9	3	27.480	30	71
1984	8	27	19.380	406	680
1984	8	28	21.890	400	757
1984	10	14	7.940	48	33
1985	7	25	44.230	1121	4284
1985	8	7	28.490	530	1306
1985	9	9	67.470	1166	6800
1985	9	18	27.900	1435	3459
1985	9	19	59.910	2200	11388
1985	9	20	21.250	288	530
1985	10	29	4.360	51	19
1985	11	29	1.830	41	7
1986	1	29	0.430	416	15
1986	2	25	0.300	440	11
1986	3	28	0.790	383	26
1986	4	23	0.170	396	6
1986	5	29	0.135	150	2
1986	6	19	2.630	607	138
1986	8	26	32.010	2824	7810
1986	8	27	19.320	364	608

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment yield (q_S) t/d qs=0.0864*Q*Cc
1986	9	25	26.510	906	2076
1986	10	22	10.840	483	452
1987	4	3	0.170	456	6
1987	10	31	1.040	37	3
1988	1	25	0.58	90	4
1988	2	25	0.39	193	6
1988	4	25	0.138	87	1
1988	5	31	0.367	533	17
1988	6	22	9.660	2727	2276
1988	7	31	34.080	677	1993
1988	9	16	17.630	187	286
1988	10	21	14.340	168	208
1989	1	29	0.700	27	2
1989	2	14	0.510	34	2
1989	5	22	2.430	899	189
1993	10	15	10.770	293	273
1994	9	30	10.870	138	129
1995	8	9	23.280	305	614
1995	8	12	40.561	919	3220
1995	8	29	20.610	446	795
1995	9	1	38.410	1856	6160
1995	9	13	70.820	2883	17644
1995	9	20	81.205	2163	15176
1995	9	26	131.150	322	3652
1995	9	30	10.887	161	152
1995	10	2	9.956	246	212
1995	10	7	0.074	215	1
1995	10	13	6.860	198	117

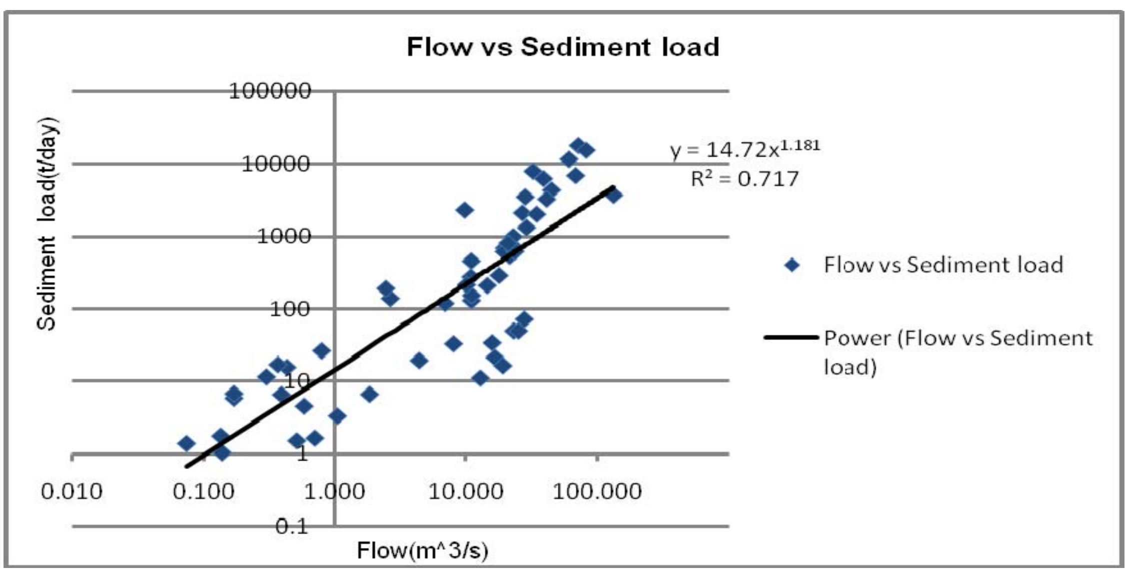

Figure A-22 Sediment rating curve-Station 3029 Ardy (Metekel)

Table A-23 Flow and Sediment load for rating curve-L Fettem (Galibed)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment yield (q_S) t/d qs=0.0864*Q*Cc
1986	4	24	0.45	230	9
1986	4	31	0.44	290	11
1986	5	28	0.48	135	6
1987	2	11	0.78	104	7
1987	4	10	0.55	234	11
1987	12	29	2.21	62	12
1988	1	27	0.83	160	11
1988	2	27	0.86	170	13
1988	6	2	8.862	1371	1050
1989	1	27	1.4	106	13
1989	2	18	0.81	55	4
1989	5	17	1.62	209	29

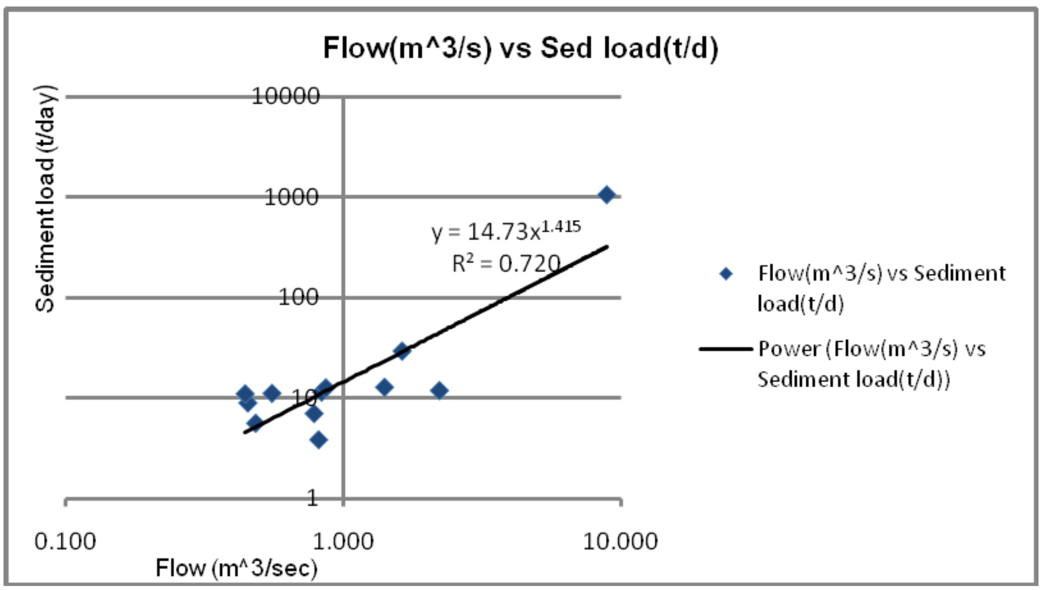

Figure A-23 Sediment rating curve-Station 3036 Lower Fettem (Galibed)

Table A-24 Flow and Sediment load for rating curve-Upper Dedessa (Dembi-Toba)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (Q_S) t/d Qs=0.0864*Q*Cc
1990	3	15	4.16	45	16
1990	3	21	5.41	108	50
1990	7	2	9.14	180	142
1990	9	18	98.5	151	1288
1990	12	22	4.37	84	32
1993	4	12	8.01	65	45
1993	5	16	2.89	93	23
2002	11	4	20.953	75	135
2003	5	30	2.129	132	24
2003	5	31	1.929	169	28
2003	6	2	1.652	153	22
2005	9	15	122.8	245	2594
2005	9	16	100.122	210	1813
2006	7	23	146.4	300	3794

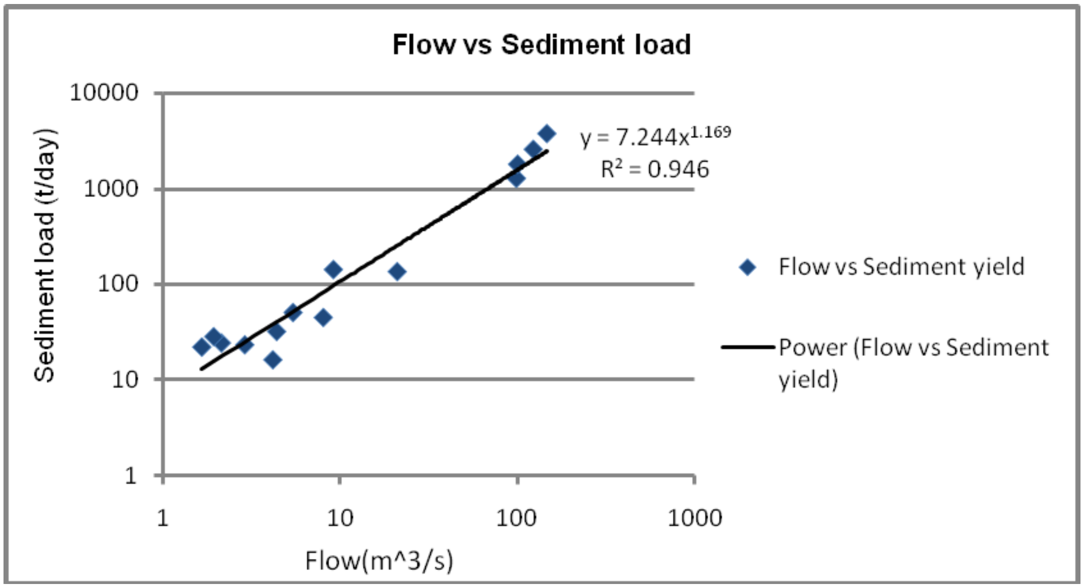

Figure A-24 Sediment rating curve-Station 4014 Upper Deddessa (Dembi-Toba)

Table A-25 Flow and Sediment load for rating curve-Anger (Guttin)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_s) t/d $qs=0.0864*Q*Cc$
1990	2	26	3.53	93	28
1990	4	29	2.486	136	29
1990	7	28	38.539	603	2006
1990	10	21	29.103	154	387
1991	11	2	12.669	109	120
1991	8	31	71.903	224	1392
1992	8	15	75.132	474	3079
1992	9	5	74.902	273	1765
1995	8	7	61.69	275	1467
1995	8	31	50.93	796	3502
1995	9	5	195.18	283	4772
1996	8	7	1.34	1192	138
2006	8	31	49.6	1231	5276
2007	2	1	1.869	340	55

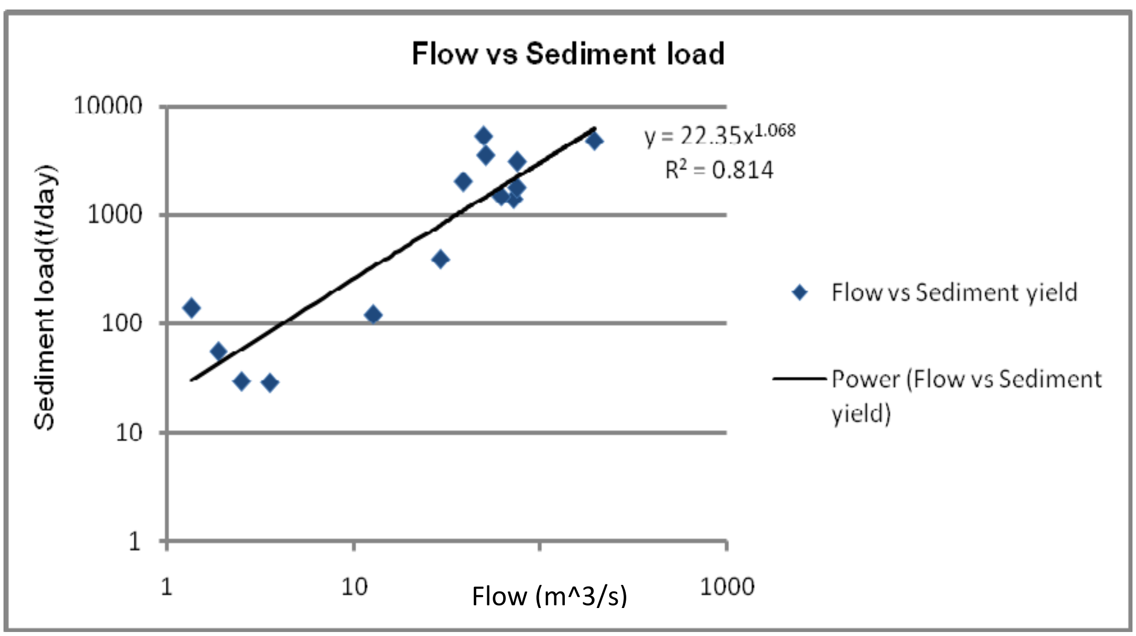

Figure A-25 Sediment rating curve-Station 4007 Anger (Guttin)

Table A-26 10Flow and Sediment load for rating curve-Tato (Gute)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1988	1	26	0.284	92	2
1988	4	3	0.062	118	1
1988	6	20	1.771	457	70
1988	7	22	1.406	283	34
1988	8	3	2.546	2009	442
1988	8	22	3.645	2311	728
1988	8	23	1.994	427	74
1988	8	24	2.09	249	45
1988	8	25	1.877	660	107
1988	8	26	1.787	472	73
1988	8	27	1.777	514	79
1988	8	28	1.545	280	37
1988	8	29	1.617	504	70
1988	8	30	1.665	290	42
1988	10	30	1.119	115	11
1988	11	27	0.492	92	4
1988	12	20	0.114	48	0
1989	1	24	0.135	67	1
1989	1	27	0.134	57	1
1989	2	25	0.9	45	3
1989	3	30	0.071	23	0
1989	4	24	0.233	140	3
1989	5	21	0.222	88	2
1989	6	14	0.661	145	8
1989	9	27	2.436	489	103
1989	12	19	0.492	103	4
1990	1	22	0.166	235	3
1990	2	23	0.07	185	1
1990	3	26	0.146	39	0
1990	4	26	0.166	132	2
1990	6	22	0.518	184	8
1990	7	31	2.213	267	51
1990	10	17	1.108	142	14
1991	9	5	5.364	236	110
1992	8	18	8.459	491	359
1992	9	3	2.046	215	38
1992	9	25	1.819	167	26
1995	1	31	0.099	91	1
1995	8	8	3.044	260	68
1996	6	1	0.293	152	4
1996	8	4	1.15	287	29
1996	9	9	0.64	434	24

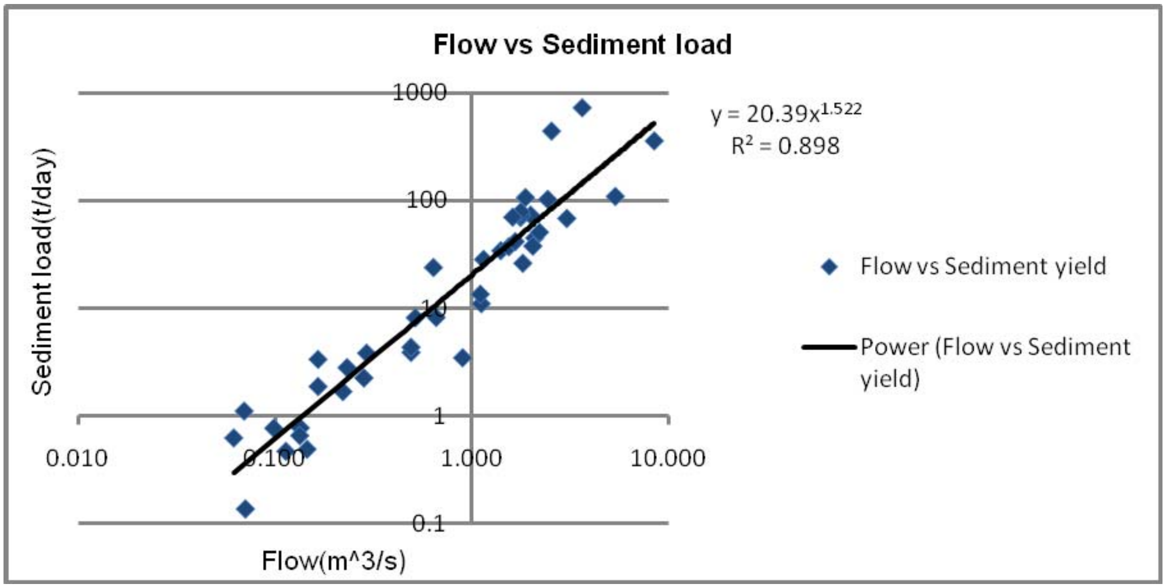

Figure A-26 Sediment rating curve-Station 4010 Tato (Gute)

Table A-27 Flow and Sediment load for rating curve-Haffa (Asossa)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1989	11	19	3.65	95	30
1990	3	27	0.338	65	2
1990	6	22	0.52	181	8
1993	12	25	0.78	96	6
1995	4	10	0.44	91	3
1996	3	5	0.44	74	3
1996	5	20	1.05	122	11

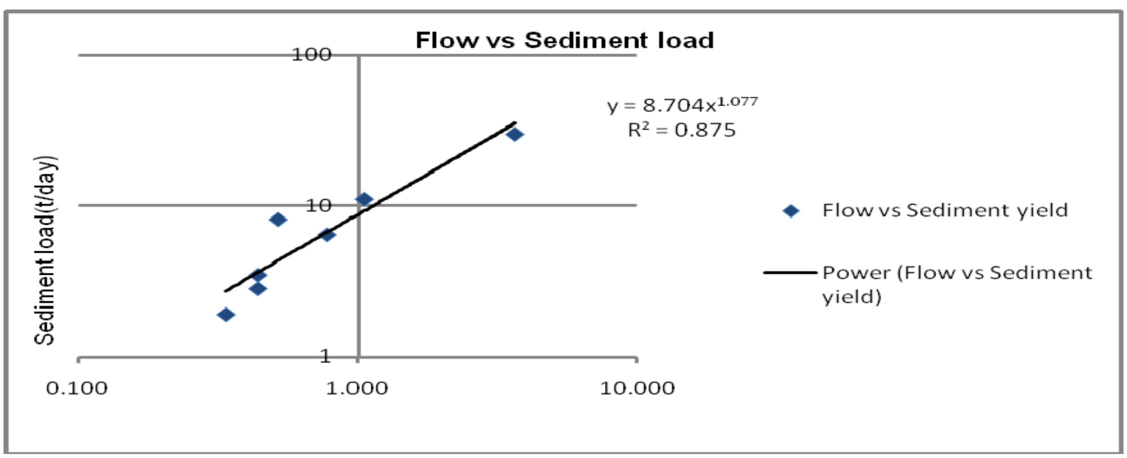

Figure A-27 Sediment rating curve-Station 5005 Haffa (Asossa)

Table A-28 Flow and Sediment load for rating curve-Dilla (Nedjo)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_S) t/d qs=0.0864*Q*Cc
1985	9	24	4.12	1110	395
1986	8	4	10.88	825	775
1986	8	4	1.21	401	42
1988	1	22	3.87	169	56
1988	3	20	0.4	47	2
1988	1	6	13.114	1200	1360
1989	6	21	1.28	64	7
1989	10	30	3.2	726	201
1990	6	18	1.28	404	45
1990	3		0.46	40	2
1994	10	6	1.78	179	28
1995	10	6	0.35	85	3
1995	6	17	0.63	65	4
1995	4	28	2.13	140	26
1995	10	14	1.62	88	12

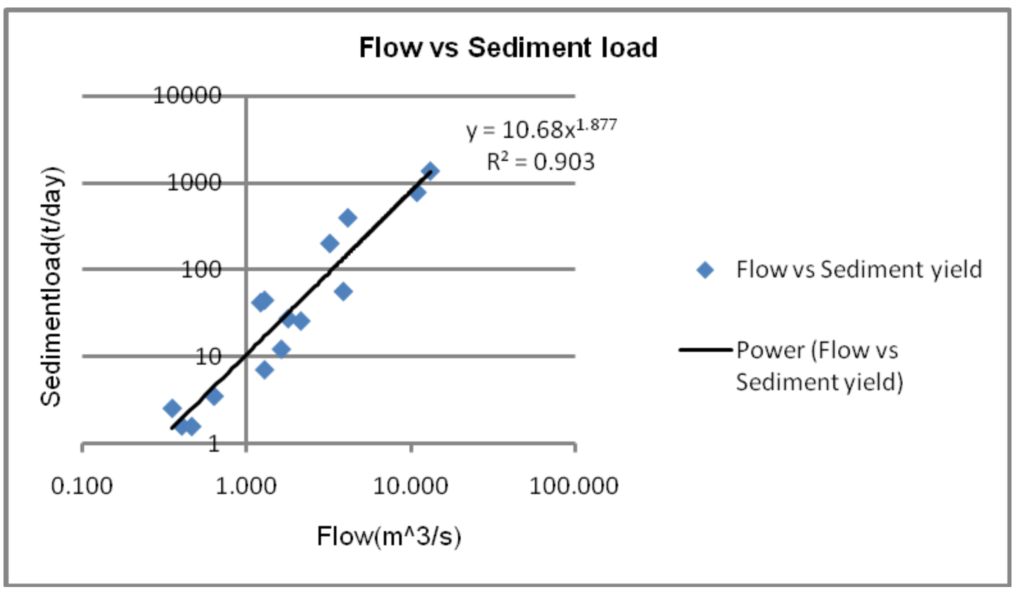

Figure A-28 Sediment rating curve-Station 5009 Dilla (Nedjo)

Table A-29 Flow and Sediment load for rating curve-Main beles (Metekel)

Year	Month	Day	Flow (Q)m^3/s	Sediment Concentration (Cc) mg/l	Daily sediment load (q_s) t/d qs=0.0864*Q*Cc
1994	10	1	64.95	378	2121
1995	9	23	378.66	192	6277
1995	8	26	167.259	889	12850
1995	8	19	373.532	3088	99659
			105.146	562	5110
1995	9	13	141.385	216	2637
1995	10	4	63.647	859	4726
1995	9	1	95.212	1047	8610
1995	10	16	17.235	189	282
2003	9	8	150.22	1034	13418
2003	9	9	146.7	1314	16657

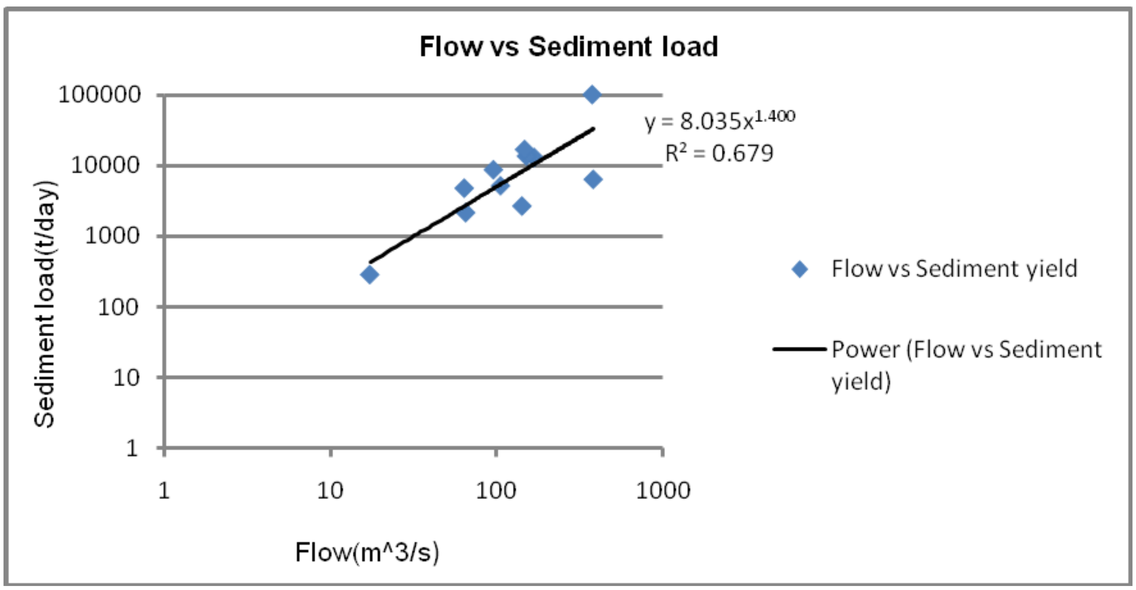

Figure A-29 Sediment rating curve-Station 6005 Main Beles (Metekel)

APPENDIX-B

Table B-1 Sediment yield in ton- Station 1002   Gilgel Abbay (Merawi)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	1912	1609	856	381	393	43043	582551	700619	564486	140658	8427	3793	2048728
1987	1382	759	681	503	13003	142668	653715	859583	563780	170291	23772	6022	2436160
1988	2692	1418	718	366	1662	47386	834417	1281975	763376	224540	22308	5070	3185928
1989	2004	780	984	840	5269	87581	1272693	1585846	647200	104782	10786	5322	3724087
1990	2099	1052	668	396	931	21878	461230	1033110	611995	100920	6412	2378	2243071
1991	1213	559	438	1911	6573	168797	1158104	1425588	928896	90674	9059	3102	3794913
1992	1509	767	528	1890	5671	64052	539961	1237743	705080	317435	47606	8245	2930486
1993	2439	1132	971	2199	10392	230934	1190914	1005334	807635	359857	29459	4882	3646149
1994	1912	936	597	449	5596	215236	722987	1006464	528252	31611	7324	3255	2524618
1995	1138	566	381	426	18290	105477	342318	1317358	605075	36814	7184	2516	2437540
1996	1152	500	3482	2411	36737	300386	1309938	1506765	677680	311631	192220	101385	4444286
1997	819	359	338	318	31875	176219	897687	1216682	539367	186469	67465	8972	3126569
1998	1709	575	371	192	19080	230317	711169	1073856	760909	398384	20431	3344	3220337
1999	1232	428	237	431	8534	169868	896374	1093264	545221	566319	22907	4346	3309162
2000	1086	404	252	1075	4514	132794	731681	1306737	610159	590038	72342	5793	3456875
2001	1305	492	353	354	4057	219378	806544	1283481	599225	84819	12818	2407	3015233
2002	903	316	229	132	152	88138	761106	928925	371599	49269	6994	1541	2209304
2003	507	232	176	62	164	122577	1042611	1103398	957324	67617	7657	1454	3303780
2004	543	211	114	873	186	53173	696968	904163	676245	224775	8467	2207	2567925
2005	672	225	368	162	527	82284	647076	496268	496364	135820	21979	12436	1894181

Annual mean 2975966.57 ton

Catchment area 1664 km^2

Sediment yield 1788.44 ton/ km^2/yr

Table B-2 Sediment yield in ton- Station 1005 Ribb (Addis Zemen)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	90	27	4	9	0	38693	447246	762402	361625	23157	1682	798	1635735
1987	235	93	116	61	4289	6099	22253	205737	51112	2181	594	154	292925
1988	52	40	8	0	154	6484	502317	867186	321918	65735	4538	1084	1769516
1989	869	324	300	323	571	18379	171057	577178	98942	18155	3952	2097	892148
1990	1050	520	304	279	211	1877	215787	434854	320957	25551	4438	3414	1009240
1991	2159	463	311	1256	1212	5047	271348	652875	646627	15675	2502	1246	1600720
1992	232	39	31	3812	1035	2812	364581	1401886	312484	39485	108497	886	2235782
1993	989	298	211	1934	11535	12218	297740	417331	342584	34264	3156	413	1122673
1994	170	19	15	68	1085	34047	568471	917444	404244	2731	484	247	1929026
1995	139	86	93	923	741	3830	245283	620443	188237	2272	900	648	1063594
1996	334	207	494	2379	40116	176964	570694	769048	106664	20768	4615	1392	1693675
1997	535	198	908	323	20945	29398	299585	401112	46100	30452	21877	1920	853352
1998	510	132	114	58	3025	14884	348540	527342	284519	44371	7200	773	1231467
1999	613	255	177	127	196	11578	331585	599746	274773	286504	42049	43723	1591328
2000	13723	246	136	978	683	5608	279800	675519	228178	67853	10841	1587	1285153
2001	605	248	316	243	387	71596	436382	612870	144864	10422	2118	702	1280754
2002	333	111	147	296	47	32470	115749	325487	127690	5109	1140	1168	609748
2003	494	283	386	53	19	14188	298546	527664	290368	23625	7089	4785	1167498
2004	1761	1206	878	2147	1392	9225	242628	409599	98825	13524	3593	1834	786613
2005	1246	640	2400	431	853	44405	314212	465095	251826	33256	9225	5526	1129113

Annual mean 1259002.91 ton

Catchment area 1592 km^2

Sediment yield 790.83 ton/ km^2/yr

Table B-3 Sediment yield in ton- Station 1006 Gumara (Bahir Dar)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	10667	4223	1594	1006	432	152483	1304006	1484757	867078	258104	53266	24300	4161918
1987	2700	1190	765	443	10320	78377	280621	1640665	363299	42700	13428	3941	2438450
1988	1247	553	288	171	411	4135	2830109	2328562	959094	535408	38036	12044	6710057
1989	4194	1493	675	527	1405	69788	1207366	2039626	629813	141729	78254	14240	4189109
1990	5122	1094	665	360	579	3213	580354	2861861	1400942	130077	10719	3625	4998610
1991	1401	492	332	406	1049	138079	1056393	2579189	833034	154293	14972	13849	4793491
1992	6982	3690	9122	1044	4732	6266	380500	2405151	707763	451633	71237	22716	4070837
1993	5961	1845	832	1239	5369	46257	1009209	1899015	1211616	296603	49510	13379	4540832
1994	4894	1836	681	285	1650	142107	1002963	3078241	1552663	119981	23071	11061	5939434
1995	4275	2626	2651	2374	3218	20504	695500	2146745	1132512	150334	83374	56239	4300353
1996	26391	8351	9786	9358	36686	539208	2914745	3258415	1237513	275131	122084	73220	8510889
1997	44018	25700	21818	14537	33224	471928	2050828	2143991	832157	572896	474340	85736	6771173
1999	22404	3262	892	565	890	20259	750062	1135453	458022	594679	57923	32979	3077392
2000	17831	7874	2786	6058	3503	77214	1375865	2585970	478674	417025	59497	16231	5048526
2001	7441	3333	3171	2049	3400	72939	1139575	3124460	568528	63432	18122	9371	5015820
2002	6309	3527	3865	3039	1799	183962	1014096	2161173	825059	57028	22085	15304	4297246
2003	9880	6612	7479	4803	4569	82220	1014882	2572466	2096149	450741	28040	15012	6292854
2004	9628	7102	5704	7030	5225	52656	869521	1274051	479523	124283	28872	16272	2879866
2005	10427	7045	9170	5420	8617	86325	824326	1513962	1639446	350622	33102	18168	4506629

Annual mean 4870709.69 ton

Catchment area 1394 km^2

Sediment yield 3494.05 ton/ km^2/yr

Table B-4 Sediment yield in ton- Station 1007   Megech (Azezo)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	55.1	43.7	34.3	39.9	35.7	2532.5	20785.7	40809.4	11660.0	2544.2	837.3	484.1	79861.9
1987	235.8	87.9	56.9	50.0	895.1	2332.8	4363.1	20096.7	4022.8	1117.8	522.9	155.9	33937.7
1988	64.1	78.7	19.2	11.7	48.7	276.9	27997.2	43045.1	10634.8	4429.1	1650.7	469.2	88725.4
1989	231.3	70.8	129.1	148.8	592.3	2193.1	4667.1	18137.8	4027.9	1977.7	108.4	28.6	32312.8
1990	102.1	42.0	26.0	20.6	100.8	595.8	12445.8	15339.5	7630.3	1123.7	365.0	225.3	38016.9
1991	113.9	70.3	97.8	196.1	85.9	3029.4	4650.4	21995.7	4226.3	1329.7	373.1	148.8	36317.3
1992	85.7	47.1	85.7	388.7	228.8	384.3	8507.7	22177.4	17146.6	2527.2	1225.1	689.0	53493.1
1993	273.5	199.5	220.4	249.5	793.8	3501.2	9746.3	28117.4	15076.8	4673.5	1175.6	268.2	64295.8
1994	286.8	118.7	77.4	69.2	354.6	2516.8	12900.5	47154.7	13441.6	1490.4	799.6	425.1	79635.4
1995	219.7	131.9	132.7	121.8	916.6	3628.7	13385.1	52708.0	6873.4	425.3	128.9	75.9	78748.0
1996	22.3	10.1	8.8	177.3	1628.2	12447.4	17316.1	38648.4	8245.5	2047.2	903.1	435.8	81890.1
1997	262.4	152.1	164.8	160.9	1057.0	6528.1	26145.2	21835.5	4318.8	2926.0	1494.4	465.1	65510.1
1998	177.8	128.5	186.8	167.6	348.3	2131.9	29457.5	65639.7	17332.2	6144.6	1050.6	2006.3	124771.6
1999	1731.6	1263.9	1335.8	1405.8	3132.1	2809.8	13186.8	42534.0	19875.2	11829.7	6290.1	4782.5	110177.4
2000	3873.0	2513.9	2843.9	3981.3	3872.7	5240.0	14019.5	30798.6	13191.0	9424.2	4659.4	3713.9	98131.4
2001	3114.8	2969.2	4578.4	4533.6	5761.9	2546.6	25884.7	51345.7	10118.2	2749.0	1400.1	509.0	115511.1
2002	332.3	170.5	192.5	116.2	259.9	1261.4	20747.5	21245.9	7580.5	2659.4	1993.4	1616.1	58175.5
2003	1269.3	1133.0	1198.0	1034.5	1023.8	6875.6	19071.1	46118.3	12484.4	5029.1	2760.9	2337.0	100335.0
2004	1545.9	1376.0	1355.1	2006.3	1372.1	4047.7	23862.4	40108.2	9481.2	6366.6	3603.7	2980.3	98105.5
2005	2531.9	2101.5	2767.5	2296.7	2432.8	18507.9	16234.1	38433.5	20423.6	8518.7	5024.5	3690.0	122962.6

Annual mean 78045.73 ton

Catchment area 462 km^2

Sediment yield 168.93 ton/ km^2/yr

Table B-5 Sediment yield in ton- Station 2001 Abbay (Kessie)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	332567	193937	177008	268596	147403	1194110	13417712	26637001	11449114	3101076	1158410	559993	58636927
1987	280041	145849	307939	257530	398394	509599	992526	11358520	2996723	1496700	933199	377634	20054653
1988	183356	128576	67992	53502	25704	70988	24157555	75880261	25869226	8307849	2763707	1312624	138821340
1989	741481	350977	351336	445991	165936	195219	5599403	21466041	9584921	3129170	1351523	959447	44341444
1990	392735	227706	171312	162705	79679	62249	4860910	19468233	8918152	2819370	948294	470725	38582070
1992	452813	276784	197091	128163	141061	97384	3445305	34160525	13313640	6348303	2775412	1225348	62561830
1993	569004	265519	160334	971015	829456	776314	19334225	23414976	24846759	7009171	2591020	1144104	81911897
1994	524865	228926	172664	80518	273392	629369	32022958	84394335	30060785	6073603	2618365	747774	157827553
1995	210748	120182	168621	392306	285867	314034	14925889	43127516	13490415	1811226	933181	473017	76253002
1996	257305	143299	360576	483317	1032213	3078393	34424329	75917038	17564894	5505397	2394282	1441656	142602699
1998	942109	503952	971604	780400	1052958	2240042	18800296	26524739	4299638	5674784	3647506	1362045	66800073
1999	1254965	873726	513418	417247	177288	523224	47058226	89173494	22127648	13846694	4680564	2240874	182887368
2000	1288695	810111	247065	817506	388053	375953	21480283	82016813	18162178	11181871	5495019	2128195	144391740
2001	675326	608750	1883896	1824445	1489443	2733147	71304443	89325292	17175759	4823211	2417776	1753618	196015105
2002	2157539	1663176	1614647	1644004	1231881	1930773	14808562	45151431	10675293	2109296	1301259	1193245	85481107
2003	1002088	843929	1126008	1047207	713338	1199775	29252637	61276202	14396464	2746840	1280258	1247339	116132086
2004	1097134	844950	886783	901980	724356	1247842	13555628	44823503	5746531	2714444	1016287	842953	74402390

Annual mean 99276663.75 ton

Catchment area 65784 km^2

Sediment yield 1509.13 ton/ km^2/yr

Table B-6 Sediment yield in ton- Station 2003   Abbay (Bahir Dar)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	46347	30649	22138	13059	7993	6812	20632	73216	206469	212919	116918	68466	825618
1987	44133	27993	21725	12933	10882	12602	18910	66546	135107	133860	87570	54624	626883
1988	37080	23824	17390	10394	7295	7242	29834	251009	492828	429031	225877	114779	1646582
1989	62175	34391	25199	14903	11241	10293	27782	141826	265885	221379	126930	71779	1013782
1990	42824	24372	16217	10013	6840	4773	10268	52656	171913	176256	94733	52450	663314
1992	50939	29880	20213	12069	8416	5799	19901	116199	240386	246399	178334	105771	1034304
1993	55127	29362	21534	13489	9762	13523	48208	137605	361391	342302	201808	108584	1342695
1994	55127	29362	21534	13489	9762	13523	48208	137605	361391	342302	201808	108584	1342695
1995	15888	10281	8751	6308	4901	4732	23929	72174	121508	112448	75252	34667	490840
1996	16706	15458	15466	14731	15708	18065	16142	79999	410990	331741	174355	119087	1228448
1997	75884	52845	78807	68348	66456	65524	46988	98452	140694	173791	163849	111380	1143018
1998	96163	23091	11146	18858	29615	8974	60892	194113	506256	433195	243917	135819	1762038
1999	95935	79257	45257	41593	14932	30515	65271	132359	305397	366427	261965	146399	1585306
2000	95191	59585	22768	55040	12375	4054	71649	176022	335775	341850	245073	128531	1547914
2001	34745	49343	120784	130524	93389	96545	148961	149802	253227	201683	127581	103764	1510347
2002	135583	110283	94270	94174	76141	72782	86025	94944	114125	99554	86610	80610	1145102
2003	71314	60708	68173	58086	49165	44534	55266	64281	70812	63919	67580	74713	748551
2004	74707	65025	67749	47423	42829	41129	43694	57492	44599	46746	43365	41819	616577
2005	39302	45552	55186	60734	70493	66569	94265	68010	44220	48381	64491	62879	720081

Annual mean 1104952.47 ton

Catchment area 15321 km^2

Sediment yield 72.12 ton/ km^2/yr

Table B-7 Sediment yield in ton- Station 2004 Andassa (Bahir Dar)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	925	565	628	503	528	24328	347089	120999	64921	36180	3636	1817	602119
1987	1142	568	412	224	8080	45301	115359	238144	43283	14932	7066	1908	476419
1988	1479	963	496	367	1163	9617	224219	512757	147381	234602	19272	6091	1158406
1989	2646	1460	1143	389	1390	3445	621141	398617	147301	37302	10394	5649	1230877
1990	2755	1456	1008	659	567	2349	153734	663262	196853	51158	10440	5377	1089617
1991	2792	1368	1032	1437	966	94799	753098	762979	782696	68880	17621	8987	2496653
1992	6262	3297	2254	2534	1907	1871	592678	1327305	216533	180807	89100	16611	2441158
1993	5395	2139	1359	1176	3229	29371	359631	426053	223522	77237	19659	7060	1155831
1994	2532	1300	1258	907	2510	23385	268634	541235	204344	21028	9003	4852	1080988
1995	2403	1258	1132	819	1875	12995	381633	561860	211081	19368	7547	3792	1205762
1996	1864	1037	1505	5225	7432	94077	1489118	865259	473286	74881	28450	15452	3057587
1997	6163	5427	4422	1526	42507	29201	182728	219407	65435	190199	17318	3493	767825
1998	1908	906	728	640	22852	234590	749289	771249	364132	378364	32682	15027	2572366
1999	8946	3994	1711	1153	1596	8294	634211	539838	79073	165773	15778	6515	1466882
2000	3246	1525	996	1132	831	6540	76233	2012794	406479	375668	27350	7244	2920039
2001	3321	1535	1036	772	1306	27931	334484	725624	136632	25299	9257	4865	1272061
2002	2722	1324	957	656	675	18504	99811	229732	47934	16701	6423	2841	428281
2003	1525	776	594	412	324	8113	922142	671679	296048	60088	10200	4895	1976796
2004	2250	1246	906	1008	605	2765	245975	362842	99288	37593	6807	3288	764573
2005	1852	983	891	628	622	5997	91673	107616	290114	72092	7022	2949	582440

Annual mean 1437333.9 ton

Catchment area 573 km^2

Sediment yield 2508.44 ton/ km^2/yr

Table B-8 Sediment yield in ton- Station 2007 Beressa (Debre Brehan)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	21.36	26.17	297.89	142.81	60.28	147.74	25063.12	60802.95	14664.63	84.71	49.78	43.30	101404.75
1987	37.18	41.32	66.10	202.39	355.18	80.69	63.40	10763.48	175.47	315.78	59.53	55.53	12216.05
1988	58.96	51.55	77.05	91.88	121.20	127.25	12004.44	154135.76	28251.35	333.38	52.67	44.48	195349.97
1989	43.90	36.62	53.36	103.11	51.61	71.07	4897.07	38768.46	7937.37	104.51	63.41	73.54	52204.03
1990	56.54	69.34	89.64	314.92	97.69	75.72	18579.71	44150.94	66088.18	187.39	37.56	38.43	129786.05
1991	37.48	30.91	38.09	56.31	102.79	151.42	14154.69	162116.76	11148.14	107.60	33.35	30.18	188007.71
1992	32.22	32.66	30.69	36.92	33.19	41.08	6567.13	104841.43	21975.35	181.63	45.13	33.08	133850.51
1993	26.32	37.39	28.83	108.36	2101.34	107.51	120417.88	13508.13	2025.47	6206.71	55.17	36.91	144660.03
1994	33.42	28.20	44.39	52.25	93.13	138.15	65318.73	280481.04	71070.94	100.80	90.66	74.63	417526.33
1995	64.77	56.01	73.65	137.28	141.05	152.31	15682.01	151035.75	31126.44	127.83	115.12	130.42	198842.62
1996	122.57	101.14	275.51	523.43	1550.87	1051.91	87173.24	173564.46	3212.21	260.60	232.02	195.64	268263.60
1997	191.80	162.26	227.90	411.17	317.13	977.34	93507.51	54535.15	341.44	6386.35	464.22	117.25	157639.51
1998	172.05	90.77	103.91	246.08	478.71	263.23	33251.42	148059.85	14386.42	486.42	73.17	48.56	197660.58
1999	38.96	24.08	39.63	28.68	45.37	142.16	54815.84	119771.11	6815.13	1215.46	20.08	7.54	182964.03
2000	6.25	7.71	5.65	11.05	47.47	34.02	9277.11	83986.04	7606.61	1837.67	263.06	6.54	103089.18
2001	17.06	205.75	380.87	112.07	163.39	70.36	62155.41	78724.96	1424.93	0.00	0.00	0.00	143254.80
2002	110.47	94.61	125.62	91.59	122.72	181.65	1975.35	66433.10	11576.79	69.31	43.44	55.92	80880.56
2003	52.06	57.06	42.71	345.34	111.47	187.72	16845.54	22263.84	2642.45	87.45	2.90	8.52	42647.06
2004	2.60	144.72	214.12	275.41	235.64	593.73	11691.40	50832.23	2198.25	135.04	38.05	27.45	66388.63

Annual mean 148244.00 ton

Catchment area 211 km^2

Sediment yield 702.58 ton/ km^2/yr

Table B-9 Sediment yield in ton- Station 2017 Muga (Bichena)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	86.5	51.3	107.8	164.1	69.2	13061.7	36752.3	65121.3	31693.9	3106.1	177.8	110.2	150502.3
1987	53.4	31.8	784.2	525.6	6385.4	9668.2	10298.2	51610.4	2440.2	630.3	163.1	332.9	82923.7
1988	100.7	154.7	23.0	33.6	176.9	211.1	66601.5	168923.1	38036.0	23092.6	669.5	68.1	298090.8
1989	75.8	144.6	2231.0	1534.3	399.1	2308.8	40970.1	59807.0	15671.6	1087.8	63.5	6014.1	130307.7
1990	311.6	692.9	396.5	296.9	400.3	84.2	15003.7	44020.2	18650.6	1621.8	113.1	70.8	81662.4
1991	47.2	20.7	68.5	21.7	44.9	294.8	74370.4	96925.5	20830.5	770.3	291.2	151.4	193837.4
1992	109.9	124.5	70.1	832.8	851.4	232.3	11780.9	59335.8	27836.8	7438.1	468.8	259.8	109341.3
1993	134.0	52.0	28.2	2737.6	4554.4	3791.2	76797.2	40576.4	35551.7	12521.6	495.5	84.9	177324.7
1994	134.0	54.7	75.8	51.5	338.9	1597.4	140458.5	194043.6	42994.2	1439.4	464.4	250.8	381903.1
1995	134.0	68.4	85.1	728.1	624.7	426.1	29358.1	67242.6	16174.4	40835.6	139.6	136.0	155952.7
1997	185.9	80.7	271.2	637.0	737.9	5154.3	51658.3	65275.9	3095.0	19977.3	3694.7	820.8	151589.1
2001	191.6	95.1	448.4	268.4	398.9	9697.4	171808.1	139927.3	21303.9	1902.6	478.2	297.7	346817.7
2002	318.5	104.7	1095.8	937.9	108.4	745.4	31793.7	60420.9	6102.5	592.3	206.7	412.5	102839.4
2003	120.8	197.9	1660.9	1811.9	78.4	1578.7	90901.6	86969.8	32440.0	5251.8	496.6	327.7	221836.2
2004	108.2	56.0	138.3	685.5	334.2	2221.5	78194.1	113528.2	12874.5	10638.4	717.8	508.2	220005.0
2005	108.0	12.7	291.9	112.5	452.3	921.5	76316.9	46745.9	35937.6	2395.2	410.2	180.6	163885.3

Annual mean 185551.18 ton

Catchment area 375 km^2

Sediment yield 494.80 ton/ km^2/yr

Table B-10 Sediment yield in ton- Station 2018 Azuari (Motta)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	114.7	76.0	66.5	90.4	37.1	3808.6	51374.1	24028.6	12725.6	2483.4	260.5	161.3	95226.9
1987	99.0	70.3	184.4	100.1	1486.1	1174.9	9004.1	22252.3	3098.2	306.6	343.0	223.0	38342.0
1988	188.6	235.5	118.9	94.0	112.0	552.0	46845.8	132539.9	14649.8	9400.2	652.8	225.6	205615.0
1989	177.7	180.2	310.3	106.5	332.4	292.8	43567.0	27616.7	19718.6	10309.3	228.3	135.9	102975.7
1990	127.2	98.5	142.3	131.3	95.7	954.5	21025.9	18200.9	1025.2	645.5	407.1	420.7	43274.9
1991	418.7	288.2	362.6	484.4	763.4	1078.0	23500.5	214392.3	21176.2	4251.1	318.0	99.2	267132.7
1992	87.3	84.2	129.9	341.7	591.7	3348.0	97787.7	170893.9	8343.6	35701.2	6226.5	457.2	323992.8
1993	178.7	106.8	186.8	807.8	2014.4	10769.8	98573.7	57906.6	11281.9	3399.9	768.5	253.2	186248.3
1994	120.5	85.5	100.1	90.8	1171.6	8623.2	93997.1	221376.4	5077.2	561.8	393.3	195.1	331792.5
1995	98.1	41.6	74.7	67.7	839.8	1320.3	204628.0	77446.2	7717.8	1843.8	320.7	267.6	294666.1
1996	218.0	108.5	224.7	744.3	2168.8	5255.6	98300.3	115817.4	22776.9	4431.9	1158.8	512.3	251717.6
1997	232.4	87.6	166.9	1409.7	1036.3	7996.2	144844.0	41871.9	11144.4	8209.9	10330.9	1923.7	229253.7
1998	1051.3	428.1	242.8	71.3	73.1	1186.5	64008.6	155552.0	8991.1	107113.4	1569.4	144.8	340432.3
1999	244.8	75.6	9.6	23.4	98.8	1027.1	78310.0	132274.8	19159.3	39361.8	1250.8	322.5	272158.4
2003	156.3	60.6	118.5	92.2	9.8	5692.9	127963.9	105331.3	28983.7	7688.3	475.7	312.6	276885.7
2004	196.1	66.1	38.1	91.1	191.7	1372.4	46584.0	47873.2	10539.2	4303.9	383.8	272.7	111912.5

Annual mean 210726.69 ton

Catchment area 209 km^2

Sediment yield 1008.26 ton/ km^2/yr

Table B-11 Sediment yield in ton- Station 2027 Aleltu (Muke Turi)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	4.3	3.3	106.5	435.4	102.3	550.7	10246.0	22320.6	6032.4	327.8	127.8	40.7	40297.9
1987	27.8	25.8	118.3	287.3	360.2	348.3	1251.9	19145.0	1652.2	108.6	43.5	17.6	23386.4
1988	19.4	31.1	27.1	47.8	25.5	23.9	7774.3	36322.6	8132.7	295.3	42.1	27.8	52769.6
1989	13.4	8.7	10.4	61.5	31.7	9.9	5221.6	26081.6	6887.6	253.5	36.4	29.3	38645.6
1990	14.4	49.0	33.9	87.8	15.4	11.9	3139.9	37281.6	10198.0	241.4	43.1	20.3	51136.9
1991	7.7	18.4	46.1	15.8	11.6	338.8	26453.1	62006.5	5770.1	83.9	39.2	25.3	94816.6
1992	17.8	71.9	27.2	16.2	25.2	8.5	3037.6	18701.6	10797.0	440.6	67.5	57.4	33268.5
1993	37.9	34.5	20.3	101.7	104.3	83.8	17438.2	33444.8	18440.5	527.4	60.2	27.1	70320.5
1994	24.8	4.1	7.8	19.8	7.9	26.6	14415.2	25794.2	8487.7	201.1	51.7	23.2	49064.0
1995	6.5	8.6	26.1	121.2	61.3	43.3	3577.5	25277.2	2536.6	100.2	52.0	37.5	31848.0
1996	38.8	28.4	103.6	55.6	56.5	463.1	20576.2	28195.3	8022.3	226.4	46.6	41.9	57854.9
1997	42.3	26.4	25.9	37.0	25.6	351.5	18487.2	16678.0	505.0	129.6	84.3	52.9	36445.9
1998	50.8	44.3	62.2	36.6	97.1	59.7	14238.8	37165.1	8057.6	862.3	136.2	58.3	60869.0
1999	31.6	19.0	42.2	22.8	7.9	111.2	11338.4	51803.0	4441.0	289.8	66.3	17.3	68190.4
2000	6.2	2.0	0.6	4.7	13.5	12.5	4469.0	34386.1	2134.7	158.9	42.8	22.8	41253.7
2001	14.0	10.1	39.6	42.1	39.6	134.2	19386.2	12704.8	1835.8	75.0	33.1	20.2	34335.1
2002	20.1	12.1	21.5	15.0	6.0	13.7	5390.5	13584.5	1556.8	50.0	24.4	11.0	20705.6

Annual mean 47365.20 ton

Catchment area 447 km^2

Sediment yield 105.96 ton/ km^2/yr

Table B-12 Sediment yield in ton- Station 2028 Robi Jida (Muke Turi)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	0.0	10.4	6.6	19.9	15.9	155.3	9640.7	16867.7	3548.4	36.3	0.4	2.7	30304.3
1987	9.6	4.4	20.1	131.2	23.8	21.1	104.6	8647.6	297.0	28.2	9.5	6.3	9303.3
1988	4.5	4.5	3.4	1.0	0.7	0.3	7313.2	14079.6	6514.6	114.7	13.1	8.7	28058.3
1989	4.9	5.1	1.9	7.6	2.5	0.4	2887.0	17651.8	5634.2	45.1	20.3	17.2	26277.8
1990	7.4	13.8	9.4	7.1	1.0	0.2	1018.3	25861.7	1905.1	109.7	21.5	10.0	28965.3
1991	6.9	4.6	6.2	0.5	0.1	0.2	9649.7	22817.5	4377.6	38.6	11.4	12.3	36925.5
1992	10.8	32.3	6.0	2.5	1.5	0.2	3119.8	19706.0	7084.9	272.3	30.1	18.5	30284.9
1993	11.1	14.7	5.0	45.1	56.4	61.6	13449.2	19639.3	13372.8	501.1	71.0	60.8	47288.2
1994	60.7	26.4	34.7	28.9	15.9	27.0	15730.3	17009.3	5359.5	191.6	74.3	55.4	38614.1
1995	38.1	24.8	23.9	45.3	47.8	10.3	3883.2	17832.0	4308.3	35.2	19.4	16.8	26285.0
1996	20.9	5.0	31.0	18.9	10.3	246.1	14271.4	29542.9	2561.8	77.9	36.9	21.9	46844.9
1997	22.9	8.3	33.6	1.7	0.8	1.9	10291.4	16087.8	949.4	31.9	19.2	12.8	27461.8
1998	10.2	7.6	12.8	0.6	7.2	1.3	13187.7	32942.7	7937.0	986.6	58.0	33.9	55185.8
1999	25.5	7.9	7.0	2.7	18.7	0.9	13494.5	38963.6	5049.1	780.5	77.3	21.5	58449.3
2000	12.1	2.7	0.5	0.5	3.1	2.8	9243.5	20955.2	1070.1	250.6	92.0	183.9	31816.8
2001	31.9	7.7	29.1	11.5	4.1	7.0	22244.3	24018.2	3432.1	42.5	20.9	16.7	49866.1
2002	27.1	5.4	10.4	3.1	0.4	0.8	1785.1	37332.4	3097.9	34.3	15.4	13.2	42325.5
2003	10.5	3.6	0.3	4.7	0.4	35.0	17790.7	36707.4	5966.0	80.6	18.9	17.6	60635.7
2004	11.2	7.4	5.4	17.5	5.2	34.7	10091.5	19349.6	6004.6	140.6	35.6	23.8	35727.0
2005	38.5	8.0	2.2	13.9	886.3	193.4	22245.1	51212.8	11475.4	161.3	50.9	31.6	86319.6

Annual mean 39846.96 ton

Catchment area 762 km^2

Sediment yield 52.29 ton/ km^2/yr

Table B-13 Sediment yield in ton- Station 2030 Teme (Motta)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	75.8	32.2	21.9	40.2	13.3	2347.3	31523.5	11710.9	8219.5	1503.6	98.5	26.0	55612.8
1987	29.1	26.8	39.2	95.0	1428.7	4078.3	8435.2	14076.2	1807.3	722.8	676.3	139.1	31554.1
1988	75.5	70.3	0.0	0.0	17.4	198.6	49035.6	44645.3	4939.3	4617.5	285.4	43.1	103928.1
1989	10.0	3.1	294.0	156.7	231.5	270.0	16214.2	22026.7	6016.1	645.6	61.2	742.9	46672.0
1990	159.8	127.9	36.4	60.0	87.6	470.2	68370.6	528904.1	14451.6	266.4	115.7	58.8	613109.3
1991	9.0	50.7	180.4	104.6	235.4	317.5	124852.0	108362.9	10203.0	80.8	33.3	18.8	244448.4
1992	12.5	40.2	44.4	496.5	824.5	2007.2	8668.5	62606.4	4938.7	5201.7	840.5	256.4	85937.5
1993	312.1	141.7	191.0	1316.9	1045.8	1779.2	45129.9	10380.9	11719.6	2219.9	607.9	195.0	75040.0
1994	129.7	175.0	211.0	177.7	3197.9	3145.0	56411.7	92142.6	11994.2	304.6	180.1	130.3	168199.8
1995	65.0	31.9	75.1	47.7	695.8	332.0	106342.2	19298.3	3401.5	519.6	193.8	168.2	131171.2
1996	224.2	74.6	112.6	474.0	2293.1	5435.4	43694.0	41559.9	12001.1	3017.5	748.8	290.8	109926.1
1997	179.8	44.6	314.0	600.3	493.1	5942.8	30530.7	13626.5	5312.2	7871.0	3739.9	661.5	69316.5
1998	370.6	84.1	174.2	27.8	358.3	5156.5	27053.4	45602.0	8746.6	40767.0	2556.0	249.2	131145.7
1999	188.5	40.4	9.3	8.1	145.9	611.3	29459.4	38524.5	7849.7	9482.4	750.5	180.1	87250.0
2000	196.5	13.7	18.0	593.2	303.9	1074.2	30664.2	32413.1	3972.2	6526.8	2255.2	454.7	78485.7
2001	189.4	71.3	83.9	86.5	169.7	4810.2	48255.9	79167.8	8207.9	1771.5	583.2	143.7	143541.0
2002	125.9	31.0	110.0	83.0	45.0	2032.8	14887.1	30997.0	4911.8	374.1	93.3	106.8	53798.0
2003	47.6	18.3	139.4	47.0	11.2	1946.3	45106.8	25488.9	7364.2	1837.2	181.2	247.9	82436.2

Annual mean 128420.69 ton

Catchment area 156.3 km^2

Sediment yield 821.63 ton/ km^2/yr

Table B-14 Sediment yield in ton- Station 2031 Suha (Bichena)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	745.9	651.5	660.2	540.4	483.9	3351.7	59471.5	135232.4	37526.6	6111.0	1430.1	872.8	247078.0
1987	870.4	432.1	1826.5	887.7	3997.7	6246.0	7690.9	80370.9	3717.9	1701.6	922.4	798.5	109462.6
1988	700.3	981.0	352.0	149.4	53.6	635.0	66741.3	96466.1	42504.0	11898.5	1589.9	782.8	222853.8
1989	471.3	358.3	1691.1	2904.0	1885.9	1132.5	29036.7	54886.9	14270.7	2252.1	914.1	2546.1	112349.5
1990	900.0	1757.6	633.7	458.9	674.9	453.0	21764.2	31467.0	4165.4	2534.9	633.6	556.6	65999.9
1991	455.8	87.3	385.9	245.0	348.8	727.6	37740.2	135491.6	8377.3	1878.2	802.0	637.6	187177.6
1992	624.6	1544.2	585.0	395.5	672.7	493.2	11710.1	97835.3	41366.4	1322.4	487.5	309.1	157345.9
1993	180.5	39.5	5.6	2246.2	449.1	21373.2	69608.3	35777.3	28155.9	4684.8	340.0	72.2	162932.7
1994	37.6	19.0	39.5	10.7	210.3	3108.5	77963.5	89285.9	32262.9	1446.7	263.0	116.6	204764.0
1995	120.3	30.8	50.9	127.0	1684.3	162.9	35275.3	61696.2	19480.4	870.5	174.1	166.0	119838.7
1996	365.4	35.3	240.4	713.8	2555.6	7922.8	62020.9	65280.6	9871.1	760.6	722.3	175.1	150663.9
1997	120.3	42.2	54.0	169.1	533.7	4152.7	50594.6	58896.4	2982.9	19884.2	2184.4	294.8	139909.5
1998	91.7	114.1	121.7	18.4	4094.0	8618.2	64030.4	90651.0	30539.0	34358.2	928.5	217.7	233783.0
1999	187.3	20.0	5.3	3.9	40.1	1285.1	37101.2	54449.1	7975.9	36289.0	695.9	196.8	138249.5
2003	9.9	24.6	2273.2	1645.6	5.0	2758.8	60456.5	67257.2	36698.3	7591.4	114.2	97.0	178931.8
2004	22.6	10.8	14.4	327.0	313.1	295.3	25999.0	42120.4	8551.1	9130.6	158.0	80.9	87023.1

Annual mean 157397.72 ton

Catchment area 359 km^2

Sediment yield 438.43 ton/ km^2/yr

Table B-15 Sediment yield in ton- Station 2036 Mendel (Tis Abbay)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1988	46.3	41.1	40.5	37.8	44.5	64.4	1857.1	3204.0	1662.5	1535.4	280.3	117.4	8931.4
1989	66.3	40.6	47.0	55.9	63.2	106.8	1606.4	1031.3	902.9	708.9	176.4	124.9	4930.7
1990	72.9	59.4	64.1	57.8	59.5	53.0	913.6	2496.4	1027.4	363.1	54.6	25.6	5247.4
1991	12.4	9.9	12.7	17.0	47.9	2711.0	2342.1	1509.0	320.8	262.5	147.9	85.4	7478.6
1993	107.9	68.8	62.2	65.5	86.7	186.7	1356.8	1663.4	1700.2	691.0	193.6	132.2	6315.1
1994	89.3	68.4	66.8	60.9	96.2	126.4	907.1	2899.6	1609.2	252.1	150.3	92.2	6418.7
1995	69.7	54.7	62.1	61.8	77.1	150.4	806.8	1438.5	1361.5	239.7	109.1	58.0	4489.3
1996	50.7	40.2	51.6	83.6	35.4	462.4	3778.6	4951.8	2308.9	437.7	180.7	96.9	12478.7
1997	59.1	39.2	43.1	31.6	105.9	239.8	1071.9	730.3	238.7	309.2	225.0	86.9	3180.7
1998	93.4	76.9	40.3	30.5	217.0	424.4	1449.5	2190.5	1145.3	1155.2	196.5	81.6	7101.0
1999	49.5	31.1	32.5	27.3	32.4	69.6	822.1	1557.6	593.6	2043.5	257.3	81.2	5597.4
2000	37.1	29.7	25.7	42.9	36.9	111.4	208.5	4093.2	495.3	1009.4	245.0	87.9	6423.0
2001	51.4	33.7	34.5	29.3	33.0	131.1	829.5	1199.4	891.0	191.6	72.4	42.1	3539.0
2002	37.2	15.6	26.6	19.6	19.4	68.6	251.7	1394.5	718.6	178.3	22.1	10.4	2762.4
2003	9.8	10.4	9.3	5.2	10.1	362.4	2471.0	3149.8	4776.4	766.1	157.0	66.8	11794.1

Annual mean 6445.82 ton

Catchment area 72 km^2

Sediment yield 89.53 ton/ km^2/yr

Table B-16 Sediment yield in ton- Station 2038 Yeda (Amber)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1989	81.2	46.9	85.7	31.7	53.2	60.5	2970.2	10277.2	1576.0	529.1	434.1	410.8	16556.5
1990	2250.8	1736.1	501.0	359.7	371.3	340.7	1442.0	8436.4	7470.3	2840.8	1224.2	848.1	27821.5
1991	738.4	577.0	506.2	408.9	413.4	586.0	1979.1	5813.7	3820.8	621.4	587.4	576.7	16628.8
1993	245.9	71.6	78.8	76.2	196.6	809.4	6123.2	7595.4	7440.1	3401.5	1699.6	1302.1	29040.4
1994	4468.4	3929.0	4123.7	3428.3	1898.3	4854.4	22294.5	39405.1	28808.2	6477.2	3013.1	2582.0	125282.2
1995	2212.7	1219.2	146.7	115.1	105.6	145.1	6372.0	26183.9	10333.1	1410.5	560.2	804.5	49608.6
1996	505.8	215.9	128.2	140.5	650.8	2874.9	14347.1	26895.3	13921.6	2832.1	1027.9	840.7	64380.9
1997	729.6	528.9	427.2	344.3	636.8	4734.7	16764.9	27197.0	12210.3	5109.9	1599.9	931.3	71214.9
1998	1420.3	713.7	510.6	384.3	564.9	1338.4	27598.0	35748.6	40712.5	37975.1	6339.4	3919.7	157225.5
1999	23946.8	20748.7	21916.5	19834.4	20816.5	27052.1	69847.0	89886.6	67658.9	62860.9	31996.9	27067.4	483632.6
2000	23386.1	20908.7	20846.0	37549.9	22851.2	30725.4	92780.3	96926.5	82579.7	66602.4	38123.1	27514.4	560793.6
2001	673.2	459.6	439.8	415.3	415.4	412.9	2506.8	29826.4	45046.5	20115.2	5683.6	991.9	106986.6
2002	500.6	198.3	219.2	440.9	791.9	14486.8	34628.3	13826.4	3519.9	1995.1	1737.8	1658.8	74003.9

Annual mean 137167.38 ton

Catchment area 125 km^2

Sediment yield 1097.34 ton/ km^2/yr

Table B-17 Sediment yield in ton- Station 3001 Bello (Guder)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1987	50.3	36.8	87.0	79.7	127.3	711.8	1054.0	1389.4	1141.6	384.4	94.4	65.6	5222.2
1988	51.3	53.9	41.4	32.4	40.6	140.6	832.9	1534.2	1380.7	693.1	119.7	60.7	4981.7
1989	46.4	50.3	61.5	156.8	118.7	834.4	802.1	1082.6	1213.5	485.7	117.6	71.1	5040.8
1990	59.4	81.2	98.1	73.6	162.6	682.7	1105.5	1573.2	1348.4	429.7	80.9	51.4	5746.7
1991	42.8	36.4	47.0	28.2	39.7	89.5	591.2	1209.2	861.3	187.7	54.9	46.2	3234.0
1992	45.2	64.3	40.8	46.7	112.0	418.1	1212.9	1435.1	1088.1	577.8	116.8	61.7	5219.6
1993	43.9	43.7	42.3	132.5	241.0	907.8	1026.3	1702.8	1324.5	507.7	205.6	69.2	6247.4
1994	46.6	32.0	45.7	33.5	60.9	298.8	1082.8	1086.9	983.0	170.0	80.2	64.1	3984.4
1995	55.6	48.0	53.2	71.7	93.7	154.8	665.6	1165.2	903.9	224.6	83.4	71.9	3591.7
1996	54.1	30.3	103.6	107.3	316.6	1148.5	1372.7	1606.5	1199.7	430.3	102.2	69.2	6541.0
1997	66.5	38.4	42.2	65.2	74.1	543.9	1380.3	1249.2	833.2	447.9	269.3	134.4	5144.7
1998	91.8	51.7	69.2	38.0	65.1	327.3	1406.2	1488.3	1318.9	1063.2	157.7	64.8	6142.2
1999	52.9	35.1	40.1	32.1	57.7	306.1	1109.5	1525.2	1178.1	963.2	130.2	61.4	5491.7
2000	46.1	32.7	31.8	48.4	98.6	280.9	817.3	1384.7	1269.5	899.1	252.6	94.5	5256.2
2001	54.7	42.5	88.1	77.1	162.2	1026.1	1272.3	1156.5	1105.5	575.4	112.3	60.2	5733.0
2002	55.9	36.8	45.1	45.4	37.8	251.2	1176.8	1212.2	864.1	149.7	52.4	50.4	3977.8
2003	43.7	33.2	49.8	57.1	31.5	104.2	849.3	1388.4	1185.3	351.9	62.8	52.3	4209.4
2004	46.5	34.3	36.8	47.0	36.4	137.1	747.2	1244.4	1351.8	673.2	80.4	57.0	4492.3

Annual mean 5014.26 ton

Catchment area 290 km^2

Sediment yield 17.29 ton/ km^2/yr

Table B-18 Sediment yield in ton- Station 3005 Guder (Guder)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	83.6	101.7	124.4	147.9	106.1	2796.8	10991.6	12019.9	11250.9	4226.4	328.2	116.5	42294.0
1987	78.1	61.2	216.1	225.1	382.5	4341.7	10439.1	14531.0	8685.9	1652.3	253.6	132.9	40999.5
1988	89.8	114.8	53.6	43.3	73.5	420.2	5955.8	17557.4	11712.2	3297.6	353.8	133.7	39805.7
1989	94.4	104.7	136.3	367.2	299.8	5476.3	14097.5	14470.2	11268.1	1544.4	296.5	256.8	48412.1
1990	114.8	215.9	346.9	226.7	447.1	4711.9	15767.5	18302.8	14358.9	2987.6	242.1	128.8	57851.0
1991	104.7	90.9	148.4	63.7	126.9	413.2	4011.0	17853.6	10771.9	903.1	160.9	122.0	34770.2
1992	150.7	196.3	137.7	97.5	408.9	3807.0	16253.7	19592.5	12882.4	2608.9	424.2	201.0	56760.9
1993	138.0	122.1	75.6	233.3	585.8	9447.4	12537.7	16753.5	14996.2	2880.2	1222.7	257.7	59250.3
1994	149.3	90.5	138.5	99.9	221.3	1413.5	12400.7	13588.2	9835.6	890.1	233.7	137.2	39198.3
1995	99.0	74.9	73.9	179.3	276.6	664.2	5942.0	14825.5	8954.2	955.3	210.7	146.2	32401.8
1996	159.3	80.4	551.9	425.4	1719.7	8895.8	12926.7	15343.8	7797.9	2613.5	388.5	189.8	51092.6
1997	183.7	96.1	96.9	286.2	251.9	2853.4	11533.7	11920.3	5077.3	2299.4	795.9	442.7	35837.4
1998	249.6	116.4	242.6	74.9	174.8	1721.1	10336.7	15221.3	10240.4	6758.5	651.8	187.6	45975.7
1999	134.1	61.7	72.9	46.0	295.7	2844.7	10639.5	14752.0	9934.0	7069.3	654.4	257.8	46762.3
2000	168.0	103.0	88.2	269.5	420.9	2430.7	6319.2	13449.3	14954.8	6597.8	1393.7	217.5	46412.5
2001	216.3	127.4	506.4	360.7	721.6	8509.7	13468.7	11940.4	9474.8	3193.0	492.2	217.2	49228.3
2002	198.1	114.7	133.8	233.4	346.8	1487.8	11174.3	10934.4	6335.4	935.8	208.2	169.9	32272.7
2003	152.4	104.8	253.1	290.6	111.6	885.0	9436.5	13386.0	10476.9	2052.0	269.1	188.9	37607.0
2004	148.1	96.3	115.2	266.9	200.9	1109.4	7426.5	11933.8	10878.7	4760.5	269.3	142.7	37348.4
2005	123.1	41.3	131.8	206.0	463.5	1885.4	9379.6	12866.7	8721.3	3089.8	333.8	116.0	37358.4

Annual mean 43581.96 ton

Catchment area 524 km^2

Sediment yield 83.17 ton/ km^2/yr

Table B-19 Sediment yield in ton- Station 3012 Gudla (Dembecha)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	95.1	37.1	68.2	69.1	73.8	7215.2	106561.5	50604.3	34912.0	8534.4	675.3	247.4	209093.4
1987	107.1	47.5	104.9	56.0	6686.8	36787.8	91439.5	93301.4	34848.1	4856.1	1081.4	622.1	269938.7
1988	189.2	76.8	43.3	25.9	64.8	4820.3	184351.5	144727.2	29329.6	14671.2	1574.2	300.6	380174.5
1989	74.4	24.5	61.6	76.2	624.0	996.7	53302.7	76486.9	31087.1	5658.8	769.2	735.5	169897.5
1990	280.9	102.0	59.0	50.9	86.9	1250.3	36936.6	52541.9	29595.6	4563.3	325.7	103.3	125896.4
1991	44.0	14.9	19.8	24.9	246.2	39193.6	166989.7	128520.3	67335.3	8303.0	857.1	246.0	411794.9
1992	67.2	33.5	105.8	5938.6	780.7	32855.6	108995.2	154135.8	83222.4	26280.1	651.8	420.6	413487.4
1996	365.5	32.4	1688.0	1397.4	8496.2	39476.7	111673.1	99241.1	20539.7	5397.2	836.3	305.3	289448.7
1998	350.0	69.9	469.1	52.3	937.0	33184.5	92551.2	111865.3	54740.9	40267.4	2198.5	375.2	337061.4
1999	323.6	102.0	43.8	34.8	728.2	17907.1	68223.3	68350.7	38684.1	47731.1	2193.2	568.8	244890.7
2000	256.3	70.2	33.6	354.6	450.7	31640.7	76162.4	57387.0	49072.1	44411.2	4727.3	790.3	265356.4
2001	255.1	115.6	418.4	75.8	555.4	14538.4	64245.4	81970.1	19895.5	5572.9	1511.5	549.6	189703.7
2002	478.4	85.7	106.0	93.9	61.4	21797.2	106557.4	91824.9	31336.5	2522.9	751.2	1092.5	256708.0
2003	216.9	59.0	277.7	55.4	13.5	15529.4	99846.3	97823.6	51535.8	9771.3	115.2	48.1	275292.4

Annual mean 274196.01 ton

Catchment area 242 km^2

Sediment yield 1133.04 ton/ km^2/yr

Table B-20 Sediment yield in ton- Station 3014 Temcha (Dembecha)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	129.5	40.3	42.4	46.6	243.8	4101.5	45547.8	23210.0	21783.5	7024.0	1097.9	544.2	103811.5
1987	165.7	52.9	131.3	86.8	2165.9	18352.9	43577.5	48640.1	21510.4	3561.8	924.6	716.0	139885.7
1988	122.0	55.0	22.1	1.1	4.2	2746.4	57595.5	75214.3	19006.9	12801.3	1972.7	466.0	170007.5
1989	178.2	121.7	247.9	272.4	838.3	2335.1	28094.7	42334.6	30443.5	7729.1	1665.6	1380.3	115641.4
1990	493.1	271.7	200.7	117.3	309.8	708.2	15035.5	42075.0	24584.8	8630.1	1046.2	329.8	93802.2
1991	139.8	75.6	59.4	40.5	1334.2	10475.8	45127.2	47370.4	27529.2	4074.1	1114.2	647.5	137988.1
1992	274.3	168.1	247.3	596.7	767.8	10291.6	33645.0	58523.6	36347.2	21444.0	6268.9	2514.4	171088.9
1993	1244.5	514.6	339.5	524.4	1481.8	14623.7	43050.6	59573.0	44436.8	15053.5	2920.7	560.3	184323.3
1994	266.6	100.6	97.4	101.9	1973.7	22748.5	34148.6	62745.8	34425.4	3561.6	2016.8	733.4	162920.2
1995	181.6	98.5	335.5	614.1	2966.5	7543.2	32358.5	41263.4	27382.9	4277.7	1355.8	662.4	119040.1
1996	898.9	375.0	951.1	1337.6	5268.0	21556.2	54827.5	52185.9	20561.6	6300.1	1770.9	1067.9	167100.6
1997	608.5	399.5	730.0	1161.9	3393.9	9040.6	27490.3	41953.5	20600.3	14953.6	12861.2	4208.0	137401.2
1998	1676.8	657.8	1416.1	335.2	2085.7	13266.9	49265.0	51376.1	31918.3	21821.9	2005.1	509.3	176334.1
1999	628.3	293.0	592.1	619.6	824.2	8652.0	38834.8	44307.3	21019.2	24334.6	1745.1	114.1	141964.1
2003	17.5	0.8	1040.6	919.2	851.5	20979.2	48093.9	77737.4	89035.1	44927.9	3299.1	912.5	287814.8
2004	204.1	432.9	546.4	683.4	608.3	1467.5	5669.0	25874.6	19310.8	5077.9	1590.0	360.1	61824.9

Annual mean 148184.29 ton

Catchment area 406 km^2

Sediment yield 364.99 ton/ km^2/yr

Table B-21 Sediment yield in ton- Station 3026 Neshi (Shambu)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986.0	699	288	900	1730	2433	2550	8507	19658	13310	2518	202	70	52865
1987.0	6	0	0	0	3213	33125	64455	145451	48679	11396	0	0	306326
1988.0	0	0	0	0	0	5091	63850	108793	24728	10105	734	109	213410
1989.0	83	51	37	113	177	759	56052	101803	61055	16108	262	767	237268
1990.0	256	78	39	34	52	171	91217	59216	30459	8036	541	126	190225
1991.0	68	44	34	38	84	166	16980	39515	42678	1149	183	58	101000
1992.0	86	48	29	86	129	870	2510	8406	39487	40053	4028	618	96352
1993.0	215	82	44	99	160	2158	30045	147727	106537	26639	1202	198	315107
1994.0	126	65	51	29	294	867	3844	32455	31737	2623	257	106	72453
1995.0	52	35	39	28	199	154	3497	32152	8049	2747	184	77	47212
1996.0	74	30	16	27	286	659	25810	40764	18215	5395	421	147	91841
1997.0	60	33	27	44	87	4303	40036	82441	31516	6052	1396	232	166228
1998.0	86	30	25	13	91	374	11790	38024	29878	28712	2766	235	112024
1999.0	125	33	14	13	175	3150	30830	102833	109521	105313	1486	240	353733
2000.0	106	43	26	44	99	324	5983	19309	28873	17670	2134	365	74976
2001.0	114	41	36	35	56	554	13685	81083	35681	4850	346	96	136576
2002.0	67	27	24	71	21	414	20635	65504	22143	1519	121	68	110613
2003.0	34	11	20	7	0	415	6802	79775	103873	29310	167	67	220481
2004.0	22	8	2	6	2	1163	36851	53146	33025	14867	544	93	139726
2005.0	15115	10951	17153	16812	17015	38460	327143	174489	141345	67394	22401	15701	863980

Annual mean 195119.84 ton

Catchment area 322 km^2

Sediment yield 605.96 ton/ km^2/yr

Table B-22 Sediment yield in ton- Station 3029 Ardy (Metekel)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1987	189.8	89.0	29.6	36.1	214.5	6836.4	11881.7	21522.4	18138.5	12468.4	2833.8	677.1	74917.2
1988	299.4	130.2	61.7	19.2	234.1	5445.1	15546.5	18924.7	17803.3	11200.8	2090.7	638.2	72393.9
1989	260.0	57.7	15.2	24.7	724.3	4053.6	20068.5	24478.6	23745.6	8704.2	1886.7	638.3	84657.5
1990	299.2	164.2	105.1	44.2	95.0	760.3	6424.5	18438.1	16451.0	6664.3	908.7	327.3	50681.9
1991	149.2	36.7	9.6	0.1	199.9	4722.7	13362.3	15018.5	19025.9	7390.4	1696.2	539.8	62151.4
1992	300.1	145.8	79.1	94.8	228.1	3151.0	8973.6	16273.4	12684.9	9393.5	2536.7	1034.5	54895.4
1993	353.4	164.9	95.7	108.5	344.1	7567.8	17122.0	20874.1	22331.6	9146.9	3450.3	696.5	82255.6
1994	314.0	124.6	69.8	52.8	270.4	3270.5	10167.9	22445.9	14994.2	5011.4	1513.6	576.6	58811.7
1995	220.5	106.7	82.9	62.7	222.4	2467.5	10199.3	23401.3	18079.3	5555.6	1123.9	423.7	61945.9
1996	194.8	85.6	77.8	120.1	1142.5	4964.7	26918.1	36361.7	27435.4	11828.4	762.3	342.5	110233.8
1997	541.5	350.1	330.2	359.0	1713.7	8806.8	16750.2	21153.9	17502.1	11480.2	6537.3	1550.2	87075.2
1998	647.3	360.3	266.2	259.4	734.2	6711.6	12668.9	16864.8	14743.0	9275.6	2579.7	1000.1	66111.3
1999	701.1	371.1	102.1	92.9	1218.1	10803.9	21007.0	23847.5	16010.5	17532.6	2159.6	636.8	94483.2
2000	314.5	153.2	241.8	441.6	1328.1	14616.4	21042.4	22163.0	17371.8	14290.6	5913.3	1304.7	99181.3
2001	571.9	245.6	186.6	204.0	930.2	10615.6	9460.7	18971.6	29112.3	8461.2	2362.3	871.7	81993.7
2003	508.2	317.1	238.3	182.4	195.5	7001.2	32661.2	23117.7	32143.5	15190.7	1502.2	799.6	113857.6
2004	481.3	299.2	226.6	205.4	351.0	3127.6	21703.1	48614.8	45718.0	35147.7	17277.1	10849.0	184000.9

Annual mean 84685.15 ton

Catchment area 209 km^2

Sediment yield 405.19 ton/ km^2/yr

Table B-23 Sediment yield in ton- Station 3036 Lower Fettem (Metekel)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	864.5	478.1	437.4	329.9	165.6	10321.8	26294.3	196848.6	78700.4	26654.7	2981.7	511.3	344588.3
1987	417.5	336.4	298.2	387.9	2211.4	20262.8	88003.2	97435.8	54839.2	68935.6	7640.3	2336.0	343104.4
1988	1017.5	440.5	317.4	237.2	1019.9	16248.4	91420.6	208253.6	105715.4	57444.2	5450.2	1850.6	489415.5
1989	1167.9	616.0	614.7	796.1	1906.1	13665.9	293568.8	250952.3	134575.4	25475.6	4685.0	2554.8	730578.6
1990	1115.6	691.6	496.6	376.3	1065.7	2055.2	96148.3	221629.6	101836.6	24166.4	2856.2	1019.0	453457.0
1992	715.6	442.2	396.4	972.6	3165.2	17028.5	103326.0	201824.6	180223.3	67066.9	11571.8	3590.2	590323.3
1993	1306.0	883.4	612.4	1567.3	2001.0	24253.4	114533.4	301617.1	237260.4	79013.6	19409.7	1322.4	783780.0
1994	642.2	676.2	488.0	847.1	1900.2	15220.8	145782.2	346118.3	117026.8	10977.4	4055.8	1742.1	645477.2
1995	616.7	442.2	581.7	511.2	1172.5	15082.2	149663.4	226934.7	150829.4	8775.1	2455.6	1552.9	558617.7
1996	615.2	304.9	419.0	1302.8	7550.5	22945.2	97090.8	119536.7	92404.9	22001.7	3513.8	1379.3	369064.8
1998	922.8	315.8	269.7	570.2	1246.0	15425.9	116774.9	192066.3	97059.2	87546.8	8361.2	1925.6	522484.3
1999	1197.1	586.3	280.1	339.9	4124.8	46984.8	93569.7	157716.9	78630.2	157304.2	13565.8	3633.4	557933.2
2000	1286.2	525.6	259.5	1069.8	3007.5	25774.8	139792.1	164126.2	69791.1	96592.6	21483.5	3514.7	527223.7
2001	1183.5	478.1	437.4	647.5	4445.1	34599.1	81637.5	255646.9	97880.7	26983.0	8702.0	2359.7	515000.5
2002	1118.8	491.8	427.9	445.7	506.5	24040.1	146136.2	216981.4	91771.6	14082.4	5931.2	1286.4	503220.0
2003	532.0	338.5	524.4	158.2	9.8	3267.2	111471.9	151953.9	132366.0	17279.4	3042.5	1077.0	422020.8

Annual mean 522268.09 ton

Catchment area 757 km^2

Sediment yield 689.92 ton/ km^2/yr

Table B-24 Sediment yield in ton- Station 4014 Upper Dedessa (Dembi)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	874.4	530.6	1030.5	879.7	995.3	8615.2	48005.6	34575.9	56715.2	9992.1	2779.6	1239.9	166233.8
1988	2074.9	1800.6	1371.7	638.0	2967.6	26269.2	38344.3	77062.0	100280.6	135575.9	2717.9	1262.4	390364.9
1989	877.2	705.6	419.7	1258.9	869.6	4126.4	28865.6	45923.0	51279.3	13241.8	3133.9	1570.9	152271.9
1990	2143.3	13757.5	12319.2	2799.1	1034.2	8455.8	45662.0	118134.6	70526.2	21000.8	2565.6	978.5	299376.8
1991	714.7	663.6	650.2	1382.0	3731.7	11383.8	57466.7	107068.5	49804.6	23162.8	1495.4	909.9	258434.0
1994	1590.4	1519.4	1934.3	2770.6	4967.7	18174.6	50972.3	73961.1	53753.9	8455.6	3325.0	1875.1	223299.9
1995	1424.5	1335.2	1929.4	2968.1	6685.0	13308.5	32801.7	49989.3	63186.0	15878.8	4202.2	4399.1	198107.7
1996	1424.5	1335.2	1929.4	2968.1	6663.7	13293.3	32882.7	50086.1	63186.0	15878.8	4202.2	4399.1	198249.0
1997	2531.2	1553.4	2809.1	3878.6	7959.8	23653.8	38891.0	65480.9	35981.3	50098.7	32961.1	7958.8	273757.7
1998	3517.0	1531.9	2424.3	1405.8	4025.0	17617.5	49993.5	82295.4	56510.9	62883.4	14973.7	2520.4	299698.9
1999	1426.7	649.7	846.0	1008.8	7878.5	24949.3	43969.9	44294.0	38282.9	57002.4	6833.1	2125.9	229267.2
2000	1074.3	534.6	415.6	1069.3	5633.9	19038.2	54304.9	58046.2	44133.2	36857.4	12592.8	2623.0	236323.5
2001	1386.0	1024.9	1223.2	1651.0	8101.8	41301.5	62695.4	60945.8	56698.5	37900.5	8635.9	2712.7	284277.1
2002	1969.5	689.9	641.8	951.0	643.3	9390.2	33397.3	46927.6	34319.6	9959.7	3515.9	1680.0	144085.8
2003	734.3	369.8	974.4	3123.8	666.9	9232.5	43350.6	39718.3	62360.0	12642.7	2422.0	1054.1	176649.5

Annual mean 235359.85 ton

Catchment area 1806 km^2

Sediment yield 130.32 ton/ km^2/yr

Table B-25 Sediment yield in ton- Station 4007 Anger (Guttin)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1987	8403.1	3980.9	4781.0	2627.4	6660.1	16235.5	26498.6	35634.4	24439.8	14718.4	7675.3	4911.3	156566.0
1988	3081.9	2148.1	1543.2	576.9	1423.6	7306.7	33956.0	65180.7	67000.1	40485.2	12834.5	6663.8	242200.5
1989	4347.1	2543.4	2843.1	2506.7	3032.4	7388.3	28545.8	51456.4	57337.8	34204.8	9865.1	7292.4	211363.2
1990	4928.4	3242.4	2540.6	2081.3	2892.3	5017.6	16094.3	74675.1	58298.7	27302.6	9263.0	6027.4	212363.7
1991	1869.4	685.1	2307.4	3140.1	3589.6	23687.6	26431.5	53548.9	47689.1	16143.2	8076.4	6199.8	193368.2
1994	7253.1	5192.6	4381.1	3498.2	8165.2	14989.9	46752.8	92322.6	70077.5	16050.7	12244.9	8935.4	289863.8
1995	6381.3	4226.6	4021.1	4191.4	5973.5	7809.0	16672.7	53250.7	41748.5	23298.4	9406.5	6576.2	183556.0
1996	5044.3	3041.3	3512.5	2833.9	7393.0	21054.3	66147.2	86024.8	67137.9	33419.0	12230.7	8938.3	316777.2
1997	6229.0	4229.3	4578.9	10187.7	28941.2	48243.0	74898.8	42973.0	18200.6	10658.3	7496.4	7298.3	263934.5
1998	7255.0	4783.6	4640.1	3212.3	5986.0	8376.8	45418.9	92564.6	91605.9	75450.2	26461.5	14595.1	380350.0
1999	12619.1	6808.5	5451.0	4549.2	8499.2	11774.9	31903.2	54212.3	50662.1	88716.3	24225.0	13345.7	312766.7
2000	9078.3	5981.8	4894.2	5692.0	8140.4	12872.1	26510.7	51501.4	45000.3	49797.1	17854.5	11032.0	248354.6
2001	7696.9	5129.7	4643.7	3655.6	6555.2	11697.4	26504.2	58928.9	61044.8	23603.7	12213.2	8774.0	230447.4
2002	6742.8	4162.4	3671.9	2770.6	2095.5	12575.5	30654.6	40946.9	40504.0	16528.6	7841.1	5858.5	174352.4

Annual mean 244018.88 ton

Catchment area 3742 km^2

Sediment yield 65.21 ton/ km^2/yr

Table B-26 Sediment yield in ton- Station 4010 Tato (Gute)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1996	134.55	65.52	104.24	108.48	172.61	1787.48	4455.45	3255.25	2465.15	1225.03	269.66	185.61	14229.04
1997	111.59	64.73	76.58	102.85	135.58	265.28	695.72	1159.78	467.48	337.87	306.69	181.50	3905.64
1998	102.54	54.64	67.49	51.16	101.55	514.42	1445.48	2271.00	2866.95	1369.41	302.17	101.89	9248.68
1999	65.12	32.71	28.91	27.39	120.17	136.79	863.26	604.70	518.60	1198.55	248.14	96.70	3941.03
2000	55.22	30.16	22.33	50.76	63.13	671.93	719.42	2472.78	1081.02	684.16	323.50	353.37	6527.79
2001	610.63	426.64	42.89	55.32	79.38	283.55	408.14	2161.94	9965.58	2348.96	1578.22	213.63	18174.87
2002	60.34	34.19	35.03	48.52	28.52	62.55	576.98	481.92	339.32	149.89	64.60	53.92	1935.80
2003	30.42	19.13	38.48	39.77	11.99	174.19	2543.39	2871.28	1168.17	156.31	61.39	59.65	7174.19
2004	33.71	13.82	13.59	15.12	108.27	162.30	1521.99	1180.00	287.19	124.55	66.77	47.01	3574.32
2005	26.09	6.74	15.26	13.77	26.54	2086.06	647.10	1551.88	2746.88	551.36	268.29	88.21	8028.19

Annual mean 7673.96 ton

Catchment area 42.5 km^2

Sediment yield 180.56 ton/ km^2/yr

Table B-27 Sediment yield in ton- Station 5005 Haffa (Asossa)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	218.5	137.5	120.9	110.2	112.5	197.3	150.2	263.8	240.5	270.8	134.5	123.6	2080.2
1987	115.0	88.1	97.5	88.2	149.3	270.2	272.0	470.1	649.8	590.6	288.7	158.9	3238.6
1988	109.1	118.4	103.4	85.3	106.4	459.2	411.5	615.5	694.5	770.6	581.9	340.9	4396.7
1990	358.6	190.1	109.7	73.4	85.3	114.3	252.2	645.0	777.3	520.2	263.5	134.6	3524.3
1991	77.8	44.0	31.3	257.9	655.8	683.0	1088.7	988.4	906.4	642.9	374.2	145.9	5896.3
1992	16.8	0.1	0.2	140.9	283.8	264.8	797.9	1004.0	785.4	744.7	405.8	210.2	4654.6
1994	157.1	92.1	62.6	54.0	138.6	159.7	449.3	544.0	813.9	676.5	362.5	178.8	3688.9
1995	108.4	63.7	73.3	35.1	174.3	282.2	677.8	1130.4	1142.6	916.9	312.6	151.6	5068.9
1996	81.2	40.1	165.5	80.7	253.1	901.3	956.4	1096.2	1746.1	1318.5	544.2	295.8	7479.1
1997	182.8	95.9	68.2	84.2	256.9	766.2	817.4	874.2	1315.1	912.1	715.1	333.3	6421.4
1998	195.3	110.1	84.2	60.9	220.6	283.7	274.5	748.5	1422.4	1446.6	866.9	397.2	6110.8
1999	226.9	128.6	87.6	75.7	261.0	330.3	612.6	1375.1	1552.4	2049.3	1006.5	510.6	8216.6
2000	272.4	146.9	94.7	92.4	213.5	681.1	949.5	1126.4	1446.5	1562.4	1081.4	559.4	8226.4
2001	297.5	160.3	112.1	89.5	107.7	297.2	428.2	751.1	1288.7	1725.8	966.0	494.1	6718.3
2002	262.7	141.7	100.9	67.5	76.8	229.5	1019.9	1016.5	1360.3	1009.8	499.9	250.5	6035.9
2003	149.9	85.4	62.5	45.9	113.3	395.1	238.0	400.1	848.1	571.1	258.7	143.2	3311.3

Annual mean 5316.77 ton

Catchment area 194 km^2

Sediment yield 27.41 ton/ km^2/yr

Table B-28 Sediment yield in ton- Station 5009 Dilla (Nedjo)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	129.8	80.0	69.3	49.0	34.3	598.3	582.6	1710.8	2960.4	501.4	187.3	108.2	7011.2
1994	3069.2	2047.3	1823.4	1697.0	5154.3	6044.1	13131.6	16782.3	13394.3	6305.1	4449.3	3162.5	77060.3
1995	140.4	89.5	90.5	67.0	140.1	507.9	1671.1	14776.6	20257.8	1176.8	392.7	241.2	39551.4
1996	162.4	90.8	91.3	69.0	590.3	49424.6	3306.4	30835.6	8945.1	1172.3	419.1	252.6	95359.5
1997	161.4	86.7	80.4	59.8	103.3	588.3	2728.1	18848.9	1529.0	1330.6	709.7	281.7	26508.0
1998	170.7	90.9	58.9	44.1	714.5	306.7	7410.4	23735.6	5602.2	2367.3	786.9	356.1	41644.4
1999	245.2	142.0	653.9	69.2	6949.8	2005.2	9531.8	33044.4	9962.6	4215.1	707.4	336.2	67862.6
2000	201.7	118.4	87.1	205.5	559.1	25121.6	65264.3	11656.4	4546.9	10449.1	949.9	431.5	119591.4
2001	145.1	82.4	53.6	45.1	3707.9	3566.8	10117.4	11759.3	15298.0	945.7	215.9	120.3	46057.4
2002	77.5	39.4	29.5	21.9	97.2	22020.9	31006.3	24283.6	14334.6	838.1	307.9	180.3	93237.3

Annual mean 61388.34 ton

Catchment area 69 km^2

Sediment yield 889.69 ton/ km^2/yr

Table B-29 Sediment yield in ton- Station 6005 Main Beles (Metekel)

year/month	January	February	March	April	May	June	July	August	September	October	November	December	year
1986	1006	55	45	8	2	5400	323844	247209	230225	23641	2549	258	834243
1987	47	156	99	23	2164	27610	95107	378488	117478	176183	29249	2162	828765
1988	379	143	99	17	113	7277	1017956	1125689	712691	96651	10405	2149	2973571
1989	818	329	182	103	1114	6845	239766	542969	298536	92753	10234	2404	1196053
1990	968	386	207	59	40	1273	183906	706923	188128	38193	3711	583	1124378
1991	377	95	1414	5303	14642	45904	252379	335178	431670	32007	4631	4097	1127697
1992	1577	444	180	169	521	2872	64415	503715	265398	186826	14563	2843	1043525
1993	3101	5257	173	115	2086	76758	242919	545075	450417	119602	12760	1878	1460142
1994	647	221	92	34	261	9440	122890	440783	281143	31407	3999	1184	892102
1995	359	127	103	42	2459	50996	245330	502306	171761	29870	2704	911	1006968
1996	323	119	114	72	1746	25262	123222	1000675	347972	69410	5614	1712	1576241
1997	4407	2502	1874	1251	4525	32931	245334	393336	188041	277623	68706	10912	1231442
1998	4403	1953	1247	498	1682	39187	411584	784675	480717	269946	33533	10857	2040282
1999	5235	2354	1735	1309	10979	51827	228401	693839	228744	220104	28528	10712	1483768
2000	5546	2954	1872	2092	8206	47762	207144	828711	242785	306285	46049	13243	1712648
2001	6985	4013	3123	1272	3770	79904	360180	1084342	365366	265756	50069	13024	2237804
2002	6777	3452	2436	1373	879	24247	166643	358197	245984	63896	12699	4943	891526
2003	2865	1842	1360	578	191	48651	437691	806032	517518	182190	23164	6803	2028884
2004	3422	2334	1583	1425	1744	52167	597815	624055	324573	162980	16319	6714	1795129

Annual mean 1446587.84 ton

Catchment area 3431 km^2

Sediment yield 421.62 ton/ km^2/yr

APPENDIX-C

Table C-1 Monthly Rainfall (mm)-Station Merawi

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1986	0.0	4.5	4.5	19.4	22.0	359.5	523.1	179.9	353.5	64.7	28.4	0.0	1559.5
1987	0.0	0.0	19.0	15.2	320.9	314.7	332.5	307.5	165.8	64.3	0.8	0.0	1540.7
1988	11.2	20.3	1.7	0.0	153.3	366.9	503.3	283.4	187.8	182.1	23.3	0.2	1733.5
1989	0.0	0.0	46.5	49.1	163.0	211.5	374.9	375.8	149.2	104.7	12.1	17.1	1503.9
1990	2.6	0.0	23.4	2.5	49.8	209.1	474.8	573.5	228.6	113.0	17.0	0.0	1694.3
1991	0.3	0.0	7.7	131.6	79.0	337.9	609.5	425.8	331.6	131.1	16.0	25.8	2096.3
1992	0.0	0.0	3.3	107.4	59.3	273.3	463.9	373.1	171.2	108.0	21.0	0.0	1580.5
1995	0.0	2.0	15.6	37.3	187.1	291.9	345.1	279.0	158.7	48.6	6.4	29.6	1401.3
2005	0.0	2.7	52.0	0.0	107.3	214.6	445.7	285.3	296.5	109.6	0.0	0.0	1513.7
Monthly Mean	1.6	3.3	19.3	40.3	126.9	286.6	452.5	342.6	227.0	102.9	13.9	8.1	1624.9

Annual mean 1625 mm

Table C-2 Monthly Rainfall (mm)-Station Addis Zemen

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1995	0	3.4	17.2	0.0	91.3	91.4	292.7	312.4	58.6	2.3	0.0	2.3	871.6
1996	0	0.0	14.8	21.7	82.4	421.1	219.5	262.3	106.4	12.6	23.0	0.0	1163.8
1997	0	0.0	4.7	26.2	1.7	118.3	337.0	49.4	33.7	56.9	5.0	0.0	632.9
1998	0	0.0	0.0	11.1	32.4	106.8	325.5	187.0	19.9	1.2	0.0	0.0	683.9
1999	0	1.2	11.0	21.0	113.0	127.6	409.7	349.1	156.1	107.0	0.0	0.0	1295.7
2000	0		0.0	71.5	19.8	166.1	598.7	512.2	150.2	51.6	14.0	0.0	1584.1
2001	0	0.0	0.0	15.6	71.2	200.3	147.5	212.2	36.2	14.0	0.0	0.0	697.0
2002	0	0.0	22.4	0.0	13.0	270.3	424.1	459.7	150.9	2.0	0.0	0.0	1342.4
2003	0	1.0	7.0	27.0	0.0	182.2	481.3	338.5	183.9	7.9	0.0	0.0	1228.8
2004	0	7.5	0.0	50.5	20.0	121.5	421.9	316.8	135.8	47.2	44.6	0.0	1165.8
2005	0	0.0	50.0	17.5	36.9	162.2	397.8	319.3	248.7	0.0	2.0	0.0	1234.4
Monthly Mean	0.0	1.3	11.6	23.8	43.8	178.9	368.7	301.7	116.4	27.5	8.1	0.2	1082.0

Annual mean 1082 mm

Table C-3 Monthly Rainfall (mm)-Station Bahir Dar

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1986	0	0.3	5.1	17	9.4	212.4	410.7	273	170.8	116	0	0	1214.3
1987	0	0.1	0.8	8.3	198	234.5	208.1	302	133.3	97.2	9.3	0	1191.6
1988	1.2	27	0	0	31.7	164.9	467.3	274	192.2	114	31	8.8	1311.2
1989	0	0	7.9	9.8	123	169.6	412.4	513	269.2	76	16.4	3.3	1600.6
1990	4.6	6.3	1	20	15.9	83.6	559.5	463	224.2	40	0	0	1418.2
1991	0	0.1	7	22	82.6	173.1	557.2	368	227.5	101	0.9	0	1539.1
1992	0	0	4.3	64	49.9	114.4	290.5	447	154.1	210	65.3	0	1398.6
1993	5.5	0	12	27	106	207.8	476.5	363	252	115	18.9	0	1584.2
1994	0	0.8	0	22	104	190.3	314.1	272	145.6	19.2	3.7	5.6	1076.5
1995	0	4.1	8.4	19	76.5	261.4	233.5	260	106.2	20.5	8.4	4.7	1002.4
1996	0	0.7	28	49	99.2	261.6	295.2	359	211.9	48.4	26.7	0	1380.0
1997	0	0	19	29	238	121.7	233.5	218	179.7	146	23.4	10.1	1217.5
1998	0	0	19	0.6	108	196.5	384.1	433	240.6	115	1.1	0	1497.6
1999	9	0	0	8.1	50.5	130.9	393.6	486	196.3	197	3	0	1474.4
2000	0	0	0.3	90	61.2	153.7	314.2	517	225.8	173	27.8	0	1563.8
2001	0	0	1	23	54.8	257.3	380.6	522	142.5	86.7	2.5	12.5	1482.7
2002	0	1.2	8.2	16	2	437.2	465	405	154.9	17.8	0.5	1	1508.7
2003	0	0	0.3	0	1.2	239.2	616.2	451	709.4	74.2	5.2	5.7	2102.5
2004	8.7	21	5.1	39	7.3	144.3	503.3	295	232	89.9	7.4	0	1352.2
2005	0.7	9	86	9.9	74.6	188.8	533.3	248	278	52.8	7.4	0	1487.6
Monthly Mean	1.5	3.5	10.7	23.7	74.6	197.2	402.4	373.4	222.3	95.4	12.9	2.6	1420.2

Annual mean 1420 mm

Table C-4 Monthly Rainfall (mm)-Station Gonder

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1986	0.0	0.0	6.9	33.3	10.5	159.0	322.7	278.1	85.7	79.3	20.2	3.2	998.9
1987	12.8	0.0	2.1	36.5	210.6	207.5	232.6	195.2	125.1	90.6	17.4	3.7	1134.1
1988	0.0	32.6	0.0	12.2	62.2	190.5	306.6	304.1	92.1	83.3	7.7	0.7	1092
1989	0.0	1.4	38.7	32.4	59.7	206.4	269.1	279.7	108.1	34.5	7.0	11.9	1048.9
1990	4.2	0.0	6.5	29.7	18.0	59.4	361.1	235.2	129.4	1.4	1.2	0.0	846.1
1992	0.0	0.0	2.7	51.7	80.7	86.8	249.5	218.2	117.6	79.6	11.9	21.6	920.3
1993	0.0	3.5	30.8	78.5	104.2	166.6	305.4	201.9	136.6	86.7	16.5	0.5	1131.2
1994	0.0	1.0	0.0	7.8	84.5	156.0	289.4	265.9	125.0	37.9	20.0	2.8	990.3
1995	0.0	0.0	34.5	23.9	99.3	105.9	283.0	307.4	91.8	11.9	0.9	19.8	978.4
1996	0.0	4.4	22.2	83.6	183.8	194.7	249.3	290.0	74.8	67.7	23.2	0.4	1194.1
1997	0.0	1.8	28.2	42.8	124.2	184.8	239.7	230.4	33.1	200.3	40.2	13.7	1139.2
1998	0.0	0.0	10.0	3.7	88.5	284.9	383.0	487.9	125.7	126.4	4.8	0.0	1514.9
1999	35.5	0.0	0.0	42.0	127.1	146.4	444.8	400.6	211.5	337.8	11.3	52.6	1809.6
2000	0.0	1.4	3.9	73.2	60.7	364.3	451.4	368.6	166.6	268.7	1.9	0.0	1760.7
2001	0.0	0.9	0.5	35.6	79.7	394.2	568.9	481.6	118.2	145.4	16.0	0.0	1841.0
2002	3.2	4.3	12.0	16.6	87.1	197.4	312.7	255.6	76.8	45.2	5.8	4.2	1020.9
2003	0.0	22.1	11.1	0.0	37.9	244.2	318.0	280.7	134.9	21.3	0.0	5.7	1075.9
2004	1.6	3.7	5.3	37.6	1.4	181.4	378.6	312.3	112.4	67.6	23.0	0.0	1124.9
Monthly Mean	3.2	4.3	12.0	35.6	84.5	196.1	331.4	299.6	114.7	99.2	12.7	7.8	1201.2

Annual mean 1201 mm

Table C-5 Monthly Rainfall (mm)-Station Dejen

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1990	3	17.4	109	57.9	87.1	124.3	348	304.9	215	20	0	0	1287
1991	2.7	4.4	8.8	11.6	37.1	199	277	343.6	175	18.5	0	10.9	1088
1992	40.4	32.9	30.6	77.5	69.5	154.3	185	230.2	186	98.6	27.2	0	1133
1993	8.8	11.7	35.7	172	121	171.3	284	239.7	212	123	0	0	1378
1994	0	0	59.7	14.2	117	96.9	402	364	259	0	1.4	0	1314
1995	0	0	15.2	56.3	87.4	120.8	330	388	193	6	4.7	39.1	1240.1
1996	5.2	2.3	86.5	140	196	152.7	492	356.8	98.3	18.3	31.8	7.2	1586.1
1997	54.8	0	95.9	173	96.1	310.9	376	335	53.6	201	199	13.9	1909.2
1998	0.4	13	62.1	3.6	188	166.7	384	472.1	193	255	0	0	1738.0
1999	4.9	0	0	28.8	87.1	161	637	595.3	129	296	2.1	5.5	1946.9
2000	0	0	0	178	102	156.9	492	558.8	288	159	65.8	3.2	2003.2
2001	0	9	121	87.5	83.7	298	645	361.5	134	101	2.2	6.2	1849.5
2002	60.9	12.3	77.2	55.1	20.2	168	483	422.5	201	0	0	8.6	1508.7
2003	0	36	139	10.2	3.3	123.9	273	283.3	193	0	16.1	9.9	1087.3
2004	6.5	16.9	46	56.4	12.5	108.7	269	249.6	92.6	116	19.6	0	993.6
Monthly Mean	12.5	10.4	59.1	74.8	87.1	167.6	391.8	367.0	174.8	94.1	24.6	7.0	1470.8

Annual mean 1471 mm

Table C-6 Monthly Rainfall (mm)-Station Debre Brehan

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1995	0.0	28.5	19.1	68.4	26.5	23.3	327.5	233.8	60.4	5.1	0.0	1.7	794.3
1996	20.7	2.8	75.4	9.7	129.2	138.0	336.4	252.5	24.3	0.0	3.0	0.0	992.0
1997	29.5	4.0	41.2	82.4	25.9	95.1	272.1	200.6	34.8	89.1	3.9	3.1	881.7
1998	26.7	13.2	14.9	49.3	43.0	13.5	337.3	289.0	70.6	5.2	0.0	0.0	862.7
1999	0.0	0.0	26.5	2.8	11.8	48.9	362.4	365.1	52.4	59.6	1.4	0.0	930.9
2000	0.0	0.0	25.9	47.3	37.1	46.6	352.4	317.5	105.2	28.5	18.8	6.8	986.1
2001	0.0	33.8	70.5	18.8	64.6	34.9	406.3	260.4	32.2	4.1	0.0	3.4	929.0
2002	18.1	28.0	60.6	46.1	18.4	28.4	214.4	295.8	109.1	3.1	0.0	8.4	830.4
2003	15.6	36.3	60.2	85.7	3.8	93.5	334.1	288.7	74.2	0.0	0.0	7.4	999.5
2004	24.4	9.7	29.7	113.3	5.6	99.7	334.7	327.8	78.9	14.1	11.8	0.0	1049.7
Monthly Mean	13.5	15.6	42.4	52.4	36.6	62.2	327.8	283.1	64.2	20.9	3.9	3.1	925.6

Annual mean 926 mm

Table C-7 Monthly Rainfall (mm)-Station Bichena

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1986	0	24.6	61.2	45.6	20.5	99.5	178	111.5	122	99.1	0	15.4	777.8
1987	2.1	9.3	89.5	43.1	116	69.3	135	253.4	53.1	45.9	15.4	11.5	843
1988	15.9	66.5	0	28.2	10.5	105	656	182	219	48.8	0	0	1332
1989	11.3	2.8	75.2	87.8	29.5	62.8	172	197	93.3	3	0	101	835.9
1990	1.7	36.5	51.0	48.6	48.2	27.7	171.3	123.0	81.0	2.0	6.5	0.0	597.5
1993	1.3	19.3	50.6	74.2	136.7	50.7	190.9	113.4	89.6	47.1	6.5	0.0	780.3
1994	1	24.9	14.1	23.3	47.3	48.2	283.2	244.1	80.2	0.2	0.6	0.0	767.1
1995	0.3	10.2	28.4	33.0	105.2	37.3	234.2	305.0	66.3	6.0	4.2	34.6	864.7
1996	25.6	0.0	63.6	137.4	84.3	154.9	191.9	184.2	74.8	0.0	15.1	0.0	931.8
1997	0	0.0	54.7	0.0	51.3	127.3	223.1	105.7	147.3	151.3	51.0	0.0	911.7
1998	0	0.0	35.5	10.3	144.2	126.5	305.4	362.1	92.0	147.2	12.0	0.0	1235
1999	0	0.0	0.0	26.8	11.7	69.1	252.0	179.2	28.0	136.5	0.0	3.2	706.5
2000	0	0.0	3.0	114.3	36.4	71.0	373.6	394.8	126.8	107.1	62.5	36.0	1326
2001	0	24.0	84.8	24.9	81.2	107.3	310.3	362.7	76.3	19.5	0.0	5.0	1096
2002	3.9	6.8	80.2	4.3	0.0	41.9	252.8	205.2	34.5	0.0	0.0	0.0	629.6
2003	15	68.0	101.9	7.2	3.0	98.2	252.3	227.8	94.9	34.2	19.4	12.9	934.8
2004	7.8	6.3	23.4	68.0	7.6	46.0	252.3	286.8	71.6	87.7	5.4	12.4	875.3
Monthly Mean	5.1	17.6	48.1	45.7	54.9	79.0	260.8	225.8	91.3	55.0	11.7	13.6	908.5

Annual mean 909 mm

Table C-8 Monthly Rainfall (mm)-Station Motta

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1992	0	2.3	13.4	67.7	62.3	73.3	184.1	324	77.2	123	56.4	32.5	1016
1993	3	13	36.7	124	143	77.5	343.4	146	201	118	12	0	1218
1994	0	0	10.3	32.3	103	103	312.3	301	150	37.1	29.7	7.9	1087
1995	0.0	7.0	9.0	22.0	77.8	60.2	355.2	238.0	104.5	70.3	4.1	22.2	970.3
1996	0.3	2.1	66.4	61.4	203.7	110.6	310.9	365.7	164.0	58.4	70.5	9.2	1423
1997	0.4	0.0	54.4	58.7	139.9	176.5	272.0	184.4	164.3	188.2	43.0	3.3	1285
1998	5.7	1.0	18.2	34.4	119.6	93.4	363.4	368.5	170.7	198.8	49.2	0.9	1424
1999	18.8	0.0	0.0	22.6	52.9	109.9	300.4	372.6	157.2	202.7	5.5	26.5	1269
2000	0.0	0.0	7.6	111.5	8.0	38.4	243.1	257.8	148.2	209.8	63.0	8.9	1096
2001	0.0	15.3	106.2	28.5	69.6	137.5	443.1	326.1	144.3	143.7	37.2	3.6	1455
2002	10.8	0.3	30.8	93.0	26.8	127.9	300.7	288.6	186.1	60.9	7.0	9.3	1142
2003	0.0	11.4	33.6	8.5	8.8	76.5	339.8	354.1	265.3	52.3	14.7	0.3	1165
2004	0.0	7.4	7.0	59.0	14.2	142.0	203.0	269.2	181.3	134.9	23.9	0.0	1042
2005	3.8	4.5	50.7	27.9	20.3	138.5	261.3	226.2	204.5	195.6	61.4	0	1195
Monthly Mean	3.1	4.6	31.7	53.7	75.0	104.7	302.3	287.3	165.6	128.1	34.1	8.9	1199.2

Annual mean 1199 mm

Table C-9 Monthly Rainfall (mm)-Station Muke Turi

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1995	0	25.5	40.1	95.9	36.4	32.8	298	298	107	0	0	17.2	951.2
1996	67.6	8.9	37.3	44.4	134	163	213	315	88.2	0	6.8	1.4	1079
1997	17.8	0	66.6	32.9	25.5	110	272	255	24.1	94.7	14.4	7.7	920.1
1998	7	39.3	41.6	14.2	99	56	312	200	122	66	3.1	0	960.2
1999	9.4	0	10	13	10.5	57.8	287	368	41.2	44.5	0	1.5	843.1
2000	0	0	14.6	84.1	45.1	50.1	238	278	177	103	67.8	0	1058
2001	0	36.1	118	18	94.5	112	339	205	98.2	9.4	9	9.9	1050
2002	50.2	21.4	64.7	27.8	41.3	84.2	243	230	78.4	0	0	40.2	881.4
2003	35.6	24	66.3	50.4	11	110	369	312	142	0	0	19	1139
2004	34.1	6.4	34.8	80.3	12.3	121	252	267	124	24.6	0	2.1	958.8
2005	33.7	0	77.1	45.4	118	83.5	246	285	135	0	0	0	1024
Monthly Mean	23.2	14.7	51.9	46.0	57.1	89.1	279.0	273.9	103.3	31.1	9.2	9.0	987.6

Annual mean 988 mm

Table C-10 Monthly Rainfall (mm)-Station Tis Abbay

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1986	1.6	0	0	9.6	50.9	150	298	242	141	28.4	13.3	0	934.2
1987	0	0	3.6	19.5	167	184	217	127	71.9	120	0	0	909.7
1988	2.4	14.1	0	0	54	130	432	223	141	118	0	13	1127.2
1989	0.3	0	5.4	16.7	38.8	142	410	296	242	174	7.4	0	1331.6
1990	2.2	0	2.9	0	45.7	95.6	298	448	145	115	0.1	1	1152.7
1992	0	0	0	24	55	68	105	393	420	159	163	47	1433.3
1995	0	0	13.5	23.1	94	169	447	328	18.8	0	29.5	5.6	1128.2
1998	0	0	3.8	8.8	153	247	309	255	118	123	0	0	1218.1
1999	7.8	0	1.3	3.1	36.2	141	441	744	156	115	8.9	0	1653.9
2000	0	0	0	93.2	29.9	209	314	410	144	250	17.8	0	1468
2001	0	0	3.7	0	38.3	104	260	239	150	85	0	5.8	886.3
2002	0	0	12.1	20.4	10.7	205	242	310	142	0	2.1	0	943.7
2004	0	0	0	20.6	38.4	172	329	205	288	203	11.4	0	1268.3
Monthly Mean	1.1	1.1	3.6	18.4	62.4	155.1	315.4	324.7	167.5	114.6	19.5	5.6	1188.9

Annual mean 1189 mm

Table C-11 Monthly Rainfall (mm)-Station Debre Markos

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1986	0.0	30.3	10.3	93.9	28.2	193	268	268	133	53.1	0.0	0.0	1078
1987	0.0	25.6	108	53.1	188	179	218	196	126	86.5	6.1	16	1202
1988	14.4	60.2	0.7	52.3	31.7	174	296	334	261	95.4	1.5	0.0	1321
1989	6.5	22.8	142	91.0	23.0	163	355	331	204	10.4	7.7	85.9	1443
1990	4.8	13.3	52.1	70.2	32.9	149	333	353	276	11.3	20.8	0	1317
1991	8.8	3.8	46	69	92	114	221	312	168	50.8	32.5	51	1169
1992	142	23.5	19.9	124	83.1	145	165	308	169	94.6	71.7	5.5	1350
1993	8.0	27.4	37.8	121	198	210	305	263	322	150	5.5	0.0	1647
1994	9.3	5.0	35.5	42.7	140	148	281	301	218	7.4	13.2	0.5	1201
1995	0.0	1.0	20.3	90.4	147	126	246	345	151	14.4	12.4	95.5	1250
1996	27.6	4.6	74.1	108	228	292	252	361	152	33.1	35.2	23.2	1590
1997	14.3	0.0	29.6	97.5	119	151	287	339	206	184	85.0	23.5	1535
1998	2.9	2.2	21.0	4.4	152.4	86.0	203.2	252.6	270.7	200.8	6.9	0.0	1203
1999	72.6	0.0	2.8	43.2	46.8	180.7	252.0	340.3	164.3	209.5	2.5	28.3	1343
2000	0.0	0.0	2.9	110.5	29.5	174.9	281.7	211.1	270.7	265.9	32.7	12.3	1392
2001	0.0	3.7	58.1	101.2	129.6	154.7	365.1	322.3	170.3	66.9	0.0	2.2	1374
2002	57.0	0.0	92.2	75.2	11.2	155.9	276.3	335.9	234.6	3.9	2.2	61.5	1306
2003	3.6	57.4	69.6	19.2	5.3	212.0	205.5	351.6	256.8	10.7	0.3	18.8	1211
2004	4.1	7.6	14.4	180.1	19.8	195.0	292.6	317.7	205.2	87.5	37.7	22.4	1384
Monthly Mean	19.8	15.2	44.1	81.4	89.7	168.5	268.6	307.4	208.4	86.1	19.7	23.5	1332.3

Annual mean 1332 mm

Table C-12 Monthly Rainfall (mm)-Station Guder

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1995	2.3	17.3	43.4	108	170	117	301	310	144	8.4	4.6	46.9	1272
1996	15.8	25.5	304	213	319	273	358	413	91.4	0	26.3	5.9	2046
1997	28.4	0	45.8	254	148	398	244	361	56.2	123	141	6.7	1806
1998	54	22.5	94.7	14.8	119	189	247	126	89.5	104	0.1	0	1061
1999	46.5	3.9	10.3	14.1	196	335	271	158	110	176	0	0	1322
2000	0	0	26.9	80.9	153	242	268	307	215	61	92	15	1462
2001	31.4	36.7	121	71.4	205	199	260	265	147	0.7	7.1	2.9	1347
2002	37	23.2	48.4	55.5	97.8	276	253	70.7	73.2	0	0	25.5	959.9
2003	46.2	52.6	70.5	254	18.5	219	185	249	200	2.4	21.6	21.5	1341
2004	44.9	10.4	53.1	199	18.2	228	306	332	257	25	0	4.9	1478
Monthly Mean	30.7	19.2	81.8	126.4	144.5	247.8	269.2	259.3	138.3	50.1	29.3	12.9	1409.4

Annual mean 1409 mm

Table C-13 Monthly Rainfall (mm)-Station Dembecha

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1991	5.7	8.7	13.8	8.7	41.8	258	351	142	120	106	17.9	1.4	1074.9
1992	19.1	10	50.1	28.4	88.2	221	279	262	157	171	24.4	25.5	1334.7
1993	1.6	3.3	52.3	119	125	216	306	268	278	146	101	0	1614.6
1994	0	0	28.3	16.7	136	330	398	277	178	25.7	52.3	0	1442.1
1995	0	0	5.5	158	125	242	277	273	137	12.9	27.2	35.6	1292.4
1996	18.5	7	81	72	191	381	494	143	75.9	14	70.5	4.9	1552.6
1997	4.1	0	48.2	81.6	195	254	230	274	266	171	88.4	16.5	1628.7
1998	10.4	0.9	63.6	0	92.7	246	338	358	190	164	23	0	1487.6
1999	45.1	0	0	34.3	87.8	153	371	266	314	226	33.8	9.6	1541.1
2000	2.8	0	0	69.2	23.3	212	207	196	280	206	140	8.2	1344.8
2001	0	11.3	125	50.1	207	128	221	367	177	104	29	20	1439.4
2002	25.6	7.3	57.4	13.7	11.7	199	263	274	116	21.9	0	72.3	1062
2003	0	14.3	47.1	21.1	4	249	370	273	226	111	4.8	5.8	1325.2
2004	2	2	28.5	84.5	21.7	211	317	188	159	56	55.3	0	1123.8
Monthly Mean	9.6	4.6	42.9	54.1	96.5	235.5	315.8	254.3	191.0	109.7	47.7	14.3	1376.0

Annual mean 1376 mm

Table C-14 Monthly Rainfall (mm)-Station Neshi

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1995	0	32.4	49.3	66	187	180	241	293	240	28	11	16	1342.3
1996	36.6	5.3	77	83.7	295	182	355	266	199	8.2	72	14	1594.5
1997	3.1	2.5	60.3	113	236	281	336	296	154	237	84	7.5	1809.3
1998	12	11.6	47.3	30.1	88.8	270	264	233	223	189	3.4	0	1370.7
1999	29.2	0	0.5	36.2	220	304	189	250	241	256	2.5	16	1544
2000	6.3	0	3.3	115	147	228	295	280	195	141	36	36	1483.5
2001	0	12	107	54.6	217	175	324	198	145	77.4	31	9.5	1350.9
2002	11.9	13.5	97.9	57	149	243	545	361	198	23.8	4.5	24	1727.7
2003	6.5	33.4	66.3	7.4	1.4	351	248	248	326	3.8	35	16	1343.2
2004	12.2	5.4	18	96.9	125	271	315	239	243	135	20	18	1498.1
Monthly Mean	11.8	11.6	52.7	66.0	166.6	248.5	311.2	266.4	216.2	110.0	29.9	15.6	1506.4

Annual mean 1506 mm

Table C-15 Monthly Rainfall (mm)-Station Chagni

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1986	0	0	0	9.8	17.5	299.9	239.8	302.5	234.8	177.6	21.6	0	1304
1987	13.6	0	0	0	0	202.1	284.3	373.4	292.4	0	0	0.3	1166
1988	3.1	42.4	2.3	0	145.6	394.7	344.1	325.2	323.8	219.5	22.4	0.3	1823
1989	0	0	17	35.5	219.1	248.4	395.7	373.5	266.6	161.5	5.1	7.2	1730
1990	17.5	0	11	0.1	65.2	165.3	388.2	483.2	283.8	169.6	6	0	1590
1998	0	0	0	0	142.9	359.9	299.7	246	261.2	392.5	44.2	6.2	1753
1999	1.5	0	0	24.9	260.9	336.5	234.3	391.7	235.1	228.0	30.7	15.2	1759
2000	0	0	1.8	122.1	155.7	286.5	334.8	360.2	322.2	316.5	47.7	3.0	1951
2001	0	0	1.3	20.1	210.1	349.0	264.2	233.3	251.6	267.8	25.4	8.1	1631
2002	1.2	0	4.6	38.3	29.3	258	300.1	345.9	215.2	199.5	15	1.2	1408
2003	0	13.5	16	0	89.2	404.5	357.7	323.2	281.6	86.6	17.9	2.5	1593
2004	0	0.5	6.4	77.7	67.5	293.6	350.2	334.7	410.5	102.2	54	17	1714
2005	0	0.4	56	3.1	184.8	336.2	319.6	251.2	317.1	220.5	27.6	0	1716
Monthly Mean	2.8	4.4	8.9	25.5	122.1	302.7	316.4	334.2	284.3	195.5	24.4	4.7	1625.9

Annual mean 1626 mm

Table C-16 Monthly Rainfall (mm)-Station Nekemt

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1987	0.0	4.5	178.2	86.0	182.8	475.0	398.2	316.8	267.1	126.1	29.4	0.0	2064.1
1990	5.9	2.3	84.4	25.0	119.3	333.5	408.6	479.4	311.9	78.0	41.5	2.9	1892.7
1993	1.3	35.8	38.6	211.6	257.7	567.0	443.1	479.1	238.1	190.3	15.0	0.0	2477.6
1994	4.0	3.5	69.9	62.6	383.7	357.2	469.1	430.9	186.7	55.9	64.9	1.6	2090
1995	0.0	4.3	66.7	65.6	207.0	385.2	388.7	484.0	306.0	87.6	50.5	13.3	2058.9
1996	40.3	4.3	104.0	143.1	292.3	391.9	563.5	344.3	272.0	97.0	45.2	23.0	2320.9
1997	13.5	0.9	68.1	244.2	256.3	406.1	445.8	226.6	156.1	229.1	137.1	6.2	2190
1998	10.1	0.0	52.1	40.9	275.8	549.8	486.6	347.7	432.5	291.6	48.6	11.7	2547.4
1999	42.4	2.4	0.6	94.8	382.0	331.1	194.9	250.9	238.2	338.7	23.8	8.9	1908.7
2000	0.3	0.0	2.9	107.2	224.9	509.3	332.2	540.9	240.8	138.8	19.2	19.7	2136.2
2001	0.0	26.4	50.8	83.6	240.8	349.6	336.2	352.4	267.4	168.8	16.0	48.3	1940.3
2002	24.9	21.1	74.3	106.2	77.4	376.8	427.3	260.3	186.9	117.6	0.2	33.0	1706
2003	0.3	47.5	54.9	21.3	55.1	422.9	429.7	439.0	312.9	18.9	25.5	9.5	1837.5
2004	7.2	6.9	12.7	76.6	206.3	293.9	409.9	433.0	248.9	71.9	20.2	11.9	1799.4
Monthly Mean	10.7	11.4	61.3	97.8	225.8	410.7	409.6	384.7	261.8	143.6	38.4	13.6	2069.3

Annual mean 2069 mm

Table C-17 Monthly Rainfall (mm)-Station Dembi

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1995	8.9	22	29.4	80	92.1	41	35.9	38.4	55	30	33	40	505.6
1996	60.8	19	129	128	290	295	342	222	219	108	36	1.8	1849.7
1997	74.3	7.6	69.6	228	253	237	248	227	255	329	45	7.6	1980.9
1998	2	0	62.7	73.8	261	213	268	280	227	185	36	0	1607.2
1999	43.5	0	8.1	99.3	222	248	348	271	272	291	0	51	1853.2
2000	16.5	0.8	9.8	107	239	315	345	438	452	277	38	24	2260.4
2001	31.4	57	199	205	377	512	456	607	647	563	0	53	3705.7
2002	148	14	267	173	132	548	401	308	315	66.1	7.9	24	2404.4
2003	10.7	86	108	213	222	316	320	158	204	54.7	22	29	1744
2004	39	13	22.5	67.5	132	230	106	197	207	116	34	11	1173
Monthly Mean	43.5	21.9	90.4	137.4	221.7	295.4	286.9	274.5	285.4	201.9	25.1	24.2	1908.4

Annual mean 1908 mm

Table C-18 Monthly Rainfall (mm)-Station Asossa

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1986	0.0	0.0	25.6	35.9	54.4	160.1	171.5	218.0	82.0	158.7	5.7	0.0	911.9
1987	0.0	0.0	5.7	37.5	205.1	185.1	177.7	201.3	115.4	96.2	3.9	0.0	1027.9
1988	0.0	0.0	11.7	39.7	83.5	294.9	196.2	191.4	171.8	187.0	5.7	0.0	1181.9
1989	0.0	0.1	19.8	23.5	170.3	200.9	247.4	258.7	270.7	91.6	1.8	0.6	1285.4
1994	0.0	0.1	19.8	39.7	130.0	152.5	258.9	170.6	142.2	106.3	16.1	0.0	1036.2
1995	0.0	0.0	75.2	28.7	244.1	200.9	107.7	220.2	147.6	99.5	0.0	0.6	1124.5
2000	0.0	1.3	0.0	83.5	442.5	465.0	324.0	314.0	342.3	287.0	59.5	0.0	2319.1
Monthly Mean	0.0	0.2	22.5	41.2	190.0	237.1	211.9	224.9	181.7	146.6	13.2	0.2	1269.6

Annual mean 1270 mm

Table C-19 Monthly Rainfall (mm)-Station Nedjo

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1987	0.0	0.0	98.1	11.5	323.5	280.9	286.0	222.8	217.0	128.6	30.6	0.0	1599
1988	3.1	19.5	45.9	0.0	184.1	403.8	459.7	285.7	347.1	140.6	6.9	0.3	1897
1990	2.6	1.2	26.5	7.0	130.7	264.8	380.8	370.0	308.6	79.2	1.8	0.2	1573
1992	2.8	0.0	20.8	77.5	227.7	281.5	229.6	251.7	272.5	182.8	39.0	3.7	1590
1993	3.8	6.2	28.1	81.2	106.6	390.0	323.0	503.4	286.8	106.8	23.2	0.0	1859
1994	2.0	0.0	5.5	101.8	254.2	203.8	319.7	222.1	220.1	79.7	74.2	1.3	1484
1995	0	0	69.5	123	149	336	280.4	332	325	31.8	1.6	6.7	1654
1996	1.9	0	60.8	39.1	240	198	206.2	169	192	49.9	28	0	1185
1998	0.5	0	0.2	56.6	217	312	187.3	288	357	148	13	0	1579
1999	0	0	0	41.8	320	281	253.4	307	241	245	25	3.7	1717
2000	0	0	0.2	102	189	282	241.3	179	184	132	19	0	1328
2001	0	0	9.4	35.4	151	201	238.7	231	178	83	0	35	1161
2002	1.7	0	12.9	24.5	77.4	312	367.1	283	264	92.2	3.6	4.8	1443
2003	0	18.4	7.2	11.4	67.4	325	329.4	299	397	48.2	37	0	1539
2004	28.6	5.4	13	30.9	197	258	364.7	347	236	82.5	33	0	1597
Monthly Mean	3.1	3.4	26.5	49.6	188.8	288.6	297.8	285.9	268.4	108.7	22.4	3.7	1546.9

Annual mean 1547 mm

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I**, Jemal Hangie Tuffa** declare that I am the sole author of this thesis and it is my own original work and that it has not been presented and will not be presented to any other university for a similar or any other degree award.

Jemal Hangie **Signature: ---------------------------**

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Date of submission ……………………………