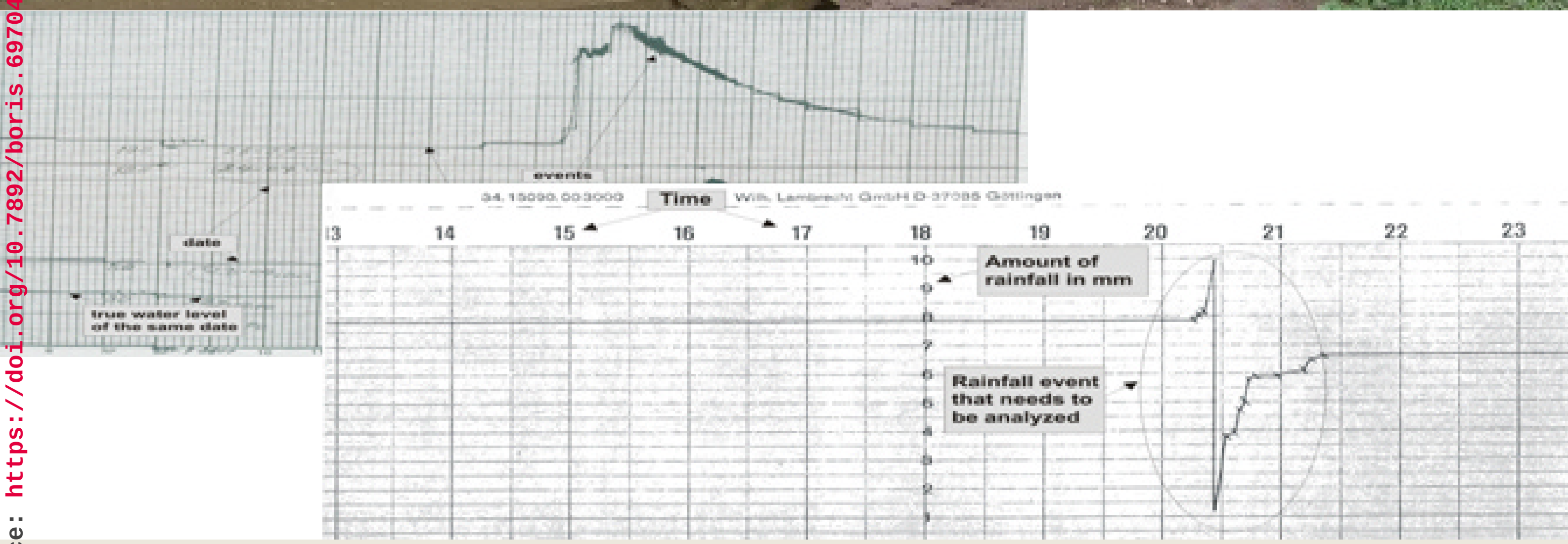
Afdeyu Research Sub-Station

Hydrometeorological Data Analysis 1984–2007

Selamawit Tesfay
Salem Beyene
Goitom Zewengel
Henok Iyassu
Robiel Okbagabriel

2009



source: https://doi.org/10.7892/boris.69704 | downloaded: 13.3.2017

Afdeyu Research Sub-Station

Hydrometeorological Data Analysis 1984-2007

Citation:
Tesfay Selamawit, Beyene Salem, Zewengel Goitom, Iyassu Henok, Okbagabriel Robiel: Afdeyu Research Sub-Station Hydrometeorological Data Analysis 1984-2007. 60 pp. SLM Eritrea; National Agricultural Research Institute (NARI), and Ministry of Agriculture, Eritrea; Syngenta Foundation for Sustainable Agriculture (SFSA), and Centre for Development and Environment (CDE), University of Bern.

Publisher:
Centre for Development and Environment (CDE), University of Bern, and National Agricultural Research Institute (NARI), Bern 2010

Printed by:
Varicolor AG, Bern.

Copyright:
Sustainable Land Management Programme (SLM) Eritrea, and NARI.

Layout:
Selamawit Tesfay

Photos front cover:
Selamawit Tesfay

Copies of this report can be obtained from:

National Agricultural Research Institute (NARI)
P.O.Box 4627
Asmara, Eritrea

Sustainable Land Management Programme (SLM) Eritrea
Centre for Development and Environment (CDE)
University of Bern
Hallerstrasse 10
CH-3012 Bern, Switzerland
www.cde.unibe.ch
info@cde.unibe.ch

Table of Contents

Table of Contents iii
1 INTRODUCTION 1
1.1 Back ground 1
1.2 OBJECTIVES OF THE RESEARCH PROGRAM 2
2 The Current Report 2
2.1 Objective of the report 2
2.2 Overview of Afdeyu Database (AFBASE) 2
2.3 OVERALL DATA PROCESSING PATHWAYS 4
3 METHODOLOGIES 5
3.1 Analysis of the rainfall chart rolls 5
3.2 Analysis of the river record shee ts 6
3.3 Data interpretation 9
4 RESULTS AND DISCUSSION 10
4.1 Rainfall 10
4.1.1 Amount and pattern of Rainfall 10
4.1.2 Comparing rainfall data from different devices 14
4.1.3 Intensity and Erosivity of Rainfall 16
4.2 Temperature 18
4.2.1 Air Temperature 18
4.2.2 Soil Surface Temperature 20
4.3 Soil loss, discharge and surface runoff 23
4.3.1 Annual and monthly soil loss and surface runoff 23
4.3.2 Hydrometric results of the catchment 35
4.4 Catchment Land Use (Cropping pattern or Land use mapping) 43
5 Summary Results 45
6 REFERENCES 46
7 Appendix: Land use 1999, 2002 - 2007 47

Tables and Figures

Tables

Table 2.1 List of parameters measured or monitored at Afdeyu 2
Table 2.2 Afdeyu hydrometreorological data status 3
Table 3.1 Example of the rainfall analysis 6
Table 3.2 Summary report of available climatic records 9
Table 4.1 Total rainfall amount, number of rainy days, and number of erosive storms 14
Table 4.2 Monthly and annual air temperature 1986-2007 19
Table 4.3 Monthly and annual soil surface temperature 1989 - 2007 22
Table 4.4 Test Plots and Experimental Plots data range 23
Table 4.5 Annual rainfall, erosivity, runoff and soil loss on test plots (1986-2007) 24
Table 4.6 Mean monthly rainfall, erosivity, runoff and soil loss on test plots (1986 -2007) with the exception of TP4 (1986-2001) and PTP5 (1999-2002). 28
Table 4.7 Annual rainfall, erosivity, runoff and soil loss on experimental plots (1987 -2001) 31
Table 4.8 Ranking of the different soil conservation measures in different years, showing the effects of a certain SWC structure on erosion. If two absolute amounts were similar, the same rank was set. 33
Table 4.9 Mean monthly rainfall, erosivity, runoff and soil loss on experimental plots (1987-2001) .. 34
Table 4.10 Total annual values of the most relevant hydrological parameters (1984 -2003) 37
Table 4.12 Mean monthly values of the most relevant hydrological parameters (1984 -2003) 39
Table 4.13 Land use in percentage total cultivated in 1999 and 2002 -2007 43

Figures

Figure 3.1 Example of a chart roll; Section of 17-8-1999 5
Figure 3.2 River record sheet 7
Figure 4.1 Annual rainfall distribution of 1984 - 1991 11
Figure 4.2 Annual rainfall distribution of 1994 - 2007 11
Figure 4.3 Annual rainfall amount 1984 - 2007 12
Figure 4.4 Monthly rainfall distribution 12
Figure 4.5 Number of rainy days 13
Figure 4.6 Plot comparing the rainfall amount from DRRD and Autometeorological station 15
Figure 4.7 Plot comparing the rainfall amount from DRRD and Autometeorlogical station 15
Figure 4.8 Mean monthly erosivity and mean monthly rainfall 16
Figure 4.9 Annual erosivity and rainfall (1984 -2002) 17
Figure 4.10 Monthly rainfall versus erosivity from autometeorological station in 2007 17
Figure 4.11 Comparing maximum, minimum and mean air temperature value for analog and digital thermometer readings, 2005. 18
Figure 4.12 Average monthly maximum, mean and minimum air temperature (1986 -2007) 19
Figure 4.13 Comparing maximum, minimum and mean soil surface temperature value for analog and digital thermometers 20
Figure 4.14 Average monthly maximum, mean and minimum soil surface temperature (1989 -2007) 21
Figure 4.15 Monthly mean rainfall and air temperatu re 22
Figure 4.16 Annual test plot results: rainfall vs runoff (1986-2007) and erosivity vs soil loss (1986 - 2002) 26
Figure 4.17 Annual test plot results: Runoff vs soil loss (1986 -2007) 27
Figure 4.18 Monthly mean test plot graphs 29
Figure 4.19 Graphs showing relationship between runoff and soil loss on test plots 30
Figure 4.20 Annual Soil loss on experimental plots (1988 – 2001) 32
Figure 4.21 Annual runoff on experimental plots (1988 – 2001) 32
Figure 4.22 Monthly mean soil loss on experimental plots (1998 – 2001) 34
Figure 4.23 Mean monthly runoff on experimental plots (1988 – 2001) 35
Figure 4.24 Annual rainfall, discharge and sediment load. 36
Figure 4.25 Plot of annual values of rainfall vs river discharge and discharge vs sediment load (1984 - 2007) 38
Figure 4.26 Monthly mean rainfall Vs Catcment Disharge (1984 – 2003) 40
Figure 4.27 40
Figure 4.28 Mean monthly Catcment discharge Vs Sediment loss (1984 - 2003) 41
Figure 4.29 Drainge ratio vs Sediment Concentration (1984 – 2003) 41
Figure 4.30 Mean monthly sediment load vs Sediment concentration (1984 -2003) 42
Figure 4.31 Comparison of Soil loss and runoff at the different measurement levels. 42
Figure 4.32 Land use in % of total cultivated area in 1999 and 2002 -2007 44

Forward

The main objective of this paper is to present the analysed results of the different hydrometeorological parameterds measured at Afdeyu research station and update the overall database. The data has been analysed from 1984- 1998 and a book was published as “Long term monitoring of Soil Erosion and Soil and Water Conservation in Afdeyu, Eritrea (1984-1998)”. As the Afdeyu research station is permanent and the collection of hydrometeorological data is continuous, raw data collection has continued until the present. To go further with the documentation the hydrometeorological data has been encoded, analysed and interpreted until 2007 and included in this report. The results and interpretations found were more all the same like the previous results presented in the book and some published materials.

In addition to the presentations and illustrations of the hydrometeorological data presented in chapter 4, a review of the background information of the station, the procedures of data collection, encoding and analysis has been included in the first part of this report and can be used as a reference.

1 INTRODUCTION

Soil and Water conservation has a long history in Eritrea. Farming has been going on for thousands of years, and traditional conservation measures have evolved at the local level. In the past, massive physical soil conservation structures were constructed and millions of tree seedlings planted. But the success of these measures was limited due to poor management and little follow-up. (Bein *et. al.,* 2002)

In Eritrea, farming is the dominant sector of the economy, and the rural population is increasing by over 3% per annum. Soil erosion is recognized as a serious problem affecting most areas of the country. The extent of soil erosion and the effect of selected physical conservation structures have been studied by different people. The results of those different research studies have been examined and carried out at Afdeyu soil conservation research station. The station is unique in the sense that it is, at present, the only site that provides field based data on erosion and soil conservation. The station cannot present results, which are representative of Eritrea as a whole, but it nevertheless gives an indication of the magnitude of the erosion problem in the highland areas and the effects of conservation measures and techniques. (Bissrat and Kohler, 1999)

1.1 Back ground

Afdeyu is located 20 km north-west of Asmara, in the Maekel zoba, Serejaka sub-zoba, about 2 km east of the road from Asmara to keren. Altitudinal range of the catchment is 2300-2460 m above sea level and the catchment size is 177 hectares. According to agro-climatic classification of Eritrea, the catchment is located in the *kebesa* zone, also known as dry *Weyna Dega* (Hurni, 1990; Hurni, 1986). The climatic conditions are semi-arid, mean daily air temperature is about 17^{o}C, and mean annual rainfall about 450 mm. High variability of rainfall, occurrence of erratic heavy rainfalls of short duration and high intensity are typical in the catchment. Soils of the catchment are mainly Cambisols with a loamy texture, developed on metamorphic volcanic material of Proterozoic age. High land use pressure and a deficit in fertilizer led to nutrient decline during the long time of land use. Erosion by water reduced soil depth and subsequently also soil fertility. Rain fed subsistence- oriented mixed-farming with ox-drawn ploughing and livestock-keeping is the traditional as well as the actual farming system. Main crops are barley and wheat, covering about 60% of the total arable land. (Stillhardt *et al.*, 2002). Small areas along the river bed are used for irrigation farming to produce vegetables like onions, tomatoes, and potatoes. Demographic data shows that land use pressure in the area is very high.

Afdeyu research station is one of seven research stations of the soil Conservation Research Programme (SCRP), which were established in the early 80ies in different agro-ecological belts of the East African high lands. It was established in 1984. Two research assistants were trained and recruited. Two test plots and two micro plots of different slopes and land use cover, river gauge station and climatic station (rainfall and temperature) were set up. Thus the station started measuring data on temperature, rainfall, runoff and soil loss from test plots, micro plots and river gauge station. Another two test plots and two micro plots were set up towards the end of the 1984 and four experimental plots were set up in 1988. All the test plots, micro plots and experimental plots were set up on farmers' fields under farmers' conditions.

1.2 OBJECTIVES OF THE RESEARCH PROGRAM

As stated by Thomas, *et al.* (1999) the main objective of the soil conservation research program is to support soil conservation efforts by monitoring soil erosion and relevant factors of influence, developing appropriate soil and water conservation measures; and building local and international capacity in this field of research.

In addition, the soil conservation research program implemented at Afdeyu aims to provide information for the following purposes:

- To establish guidelines for planners and implementers of soil conservation programs and initiatives,
- To advise policy and decision makers on soil conservation and conservation related issues of sustainable land management.
- To provide training education and in matters relating to soil erosion and conservation.
- To sensitize the general public via the mass media about the problem of soil erosion and the need for soil conservation.

2 The Current Report

2.1 Objective of the report

- To sustain the objectives of the soil research program, by analyzing and interpreting the data collected in Afdeyu research sub-station from 1999 – 2007.

2.2 Overview of Afdeyu Database (AFBASE)

The main parameters measured / monitored are rainfall, temperature, evaporation, sunlight duration, runoff and sediment load. In addition ground water monitoring, photomonitoring of erosion hotspots, assessment of current erosion damage (ACED) and land cover map are measured or monitored in the station. The parameters measured since the establishment of the research station and their availability is shown in Table 2.1 and Table 2.2 respectively. Methods of measurement are explained in "Long term monitoring of Soil Erosion and Soil and Water Conservation in Afdeyu, Eritrea (1984-1998)" and a review has been included in this report.

Table 2.1 List of parameters measured or monitored at Afdeyu

	Field/ Analysis Form	Measurement location		Parameter	
PLRE	Rainfall Analysis	PL	Pluviograph	RE	Rainfall /Erosivity
XYSR	Plot Data, Field Record and Laboratory Analysis	XY	Plot (TP[1], EP[2], MP[3])	SR	Soil Loss/ Runoff
RSSL	River Sample Record and Analysis	RS	River Station	SL	Soil Loss
RSRD	River Discharge Analysis	RS	River Station	RD	River Discharge
DRRD	Raingauge Record	DR	Daily Raingauge	RD	Rainfall Distribution
INRI	Daily Rainfall Inclination Record	IN	Inclinometer	RI	Rainfall Inclination
CSCD	Climatic Data Record	CS	Climatic Station	CD	Climatic Data
RSWH	Daily Water Height of RiverStationRecord	RS	River Station	WH	Water Height
CAVC	Weekly Vegetation Cover Estimation	CA	Catchment	VC	Vegetation Cover
CAHA	Harvesting Samples	CA	Catchment	HA	Harvesting

data being used by the TESTMAIN program for further analysis

[1] TP: Testplot

[2] EP: Experimental Plot

[3] MP: Microplot------ not functioning

Table 2.2 Afdeyu hydrometreorological data status

Year	PLRE	XYSR	RSSL	RSRD	DRRD	INRI
1984	PD	?	PD	PD	?	X
1985	PD	?	PD	PD	?	X
1986	SD	SD	SD	SD	SD	SD
1987	SD	SD	SD	SD	SD	SD
1988	PD	PD	PD	?	?	PD
1989	PD	PD	PD	PD	?	PD
1990	PD	PD	PD	PD	?	PD
1991	PD	?	?	?	?	PD
1992	X	X	X	X	X	X
1993	X	X	X	X	X	X
1994	PD	PD	?	PD	?	PD
1995	PD	PD	?	PD	PD	PD
1996	PD	PD	?	PD	?	PD
1997	PD	PD	?	PD	?	PD
1998	PD	PD	?	PD	?	PD
1999	SD	SD	SD	SD	X	SD
2000	SD	SD	SD	SD	X	SD
2001	SD	SD	SD	SD	X	SD
2002	SD	SD	SD	SD	SD	SD
2003	SD	SD	SD	SD	SD	X
2004	X	SD	SD	SD**(**poor quality data**)***	SD	X
2005	X	SD	SD	SD**(**poor quality data**)***	SD	X
2006	X	PD	PD	PD	PD	X
2007	X	PD	PD	PD	PD	X

X**=** no data
PD= primary data table in the database
SD= secondary data table in the database
?= data should be available, also in digital form.
* The river gauge had problems in data recording.

Assessment of current erosion damage (ACED)

To assess current erosion damage, rill erosion features are searched after rainfall event, the depth, and length and width measurements of the rill are taken and photos are also taken.

Photo monitoring

To see the progress of gully formation or piping 17 hot spots of gully and piping are identified and photos are taken both before and after rainy season and are documented.

Growth observation

Growth observation is taken from none fixed fields of farmers, from the time of germination to the time of ripening (drying) to see growth pattern.

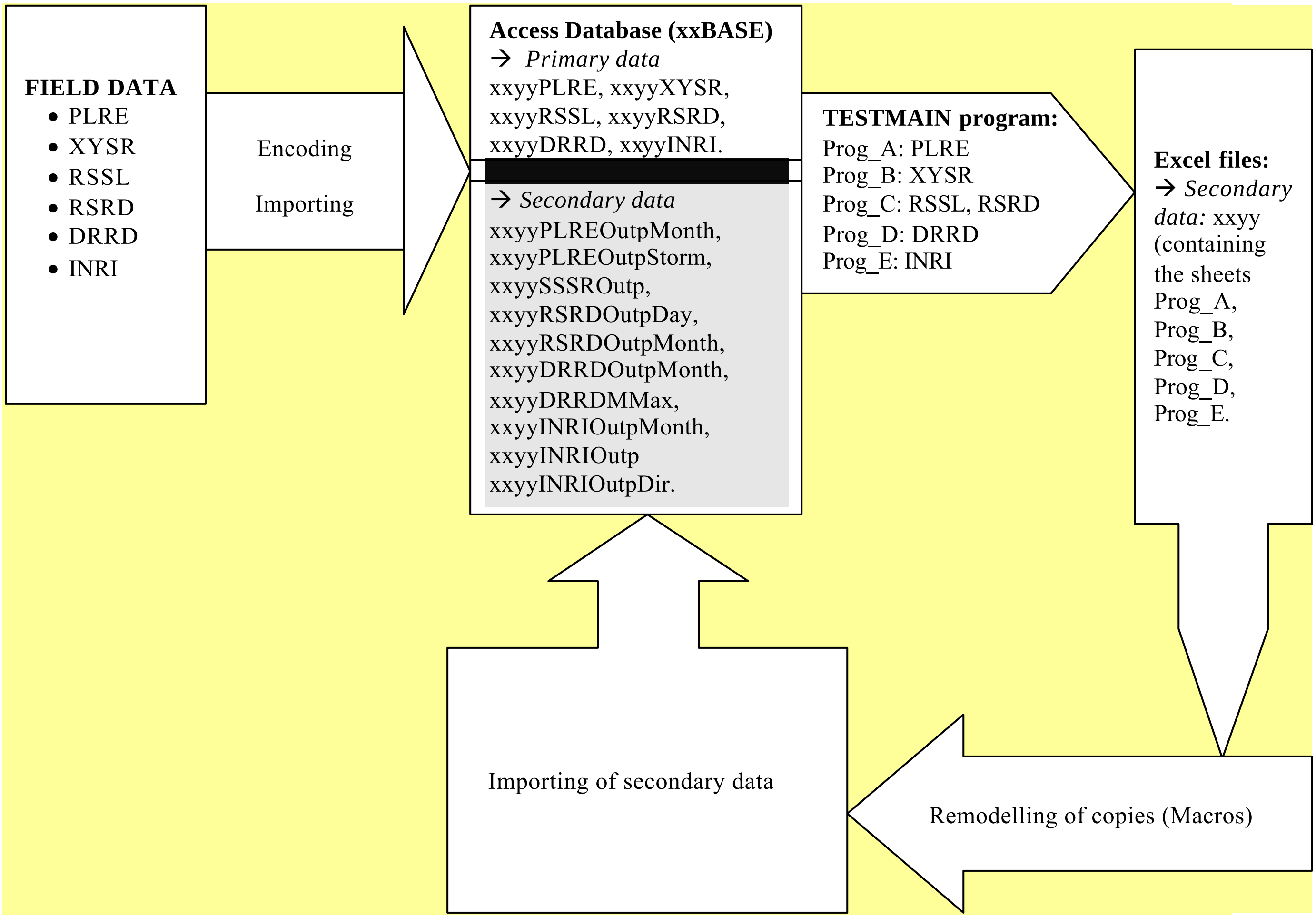
Harvesting samples

Samples of most varieties are taken from the farmers' fields during harvest time to estimate annual biomass and grain production. There are fixed and none fixed fields where the samples are taken and they are indicated in the map. The fixed sampling fields are representatives of low, medium and high production fields. Thus annual production (tons/ha) from the randomly selected field and the fixed fields is collected.

Cropping pattern

Cropping pattern of Afdeyu mapped once in a year and incorporated in to the satellite image (map).

2.3 OVERALL DATA PROCESSING PATHWAYS



3 METHODOLOGIES

Basically, there are two different types of raw data:

1. Data that can be entered directly into the entry masks such as the plot data (XYSR), iver sample record and analysis (RSSL), daily rain gauge record (DRRD), and the daily rainfall inclination record (INRI).
2. Data that first has to be analyzed before it can be entered into the computer, like the pluviograph rainfall charts (PLRE) and the river discharge plots (RSRD).

The data that does not need any further analysis can be encoded right away. The other data, the chart rolls of the rainfall and the river record sheets, needs to be analyzed and put into the required form before it is analyzed. In order to analyze the data, different tools such as a pencil and a translucent setsquare are needed.

3.1 Analysis of the rainfall chart rolls

The pluviometer is recording the amount of rainfall on a chart roll. A needle draws the course of the rainfall events on this chart roll. Each month has one chart roll. The date of change of the chart roll means that the records on this chart roll are from the preceding month. For example, if the date is the 1st of July, the chart roll is from June.
In order to be able to calculate the intensity and the erosivity of rainfall event with the help of TESTMAIN, the chart roll needs to be analyzed and the data transferred onto the PLRE form.
The layout of the chart roll consists of the following items (see figure 3.1).

- **Horizontal**:
  → Time is written above the chart roll lines (24 hours). Each vertical line represents 30 minutes interval. When measuring with a translucent setsquare, each millimeter represents 3 minutes interval.
  → Below the chart roll lines are the dates
- **Vertical**: the numbers 0 to 10 is the amount in mm. Each line represents 0.1 mm.

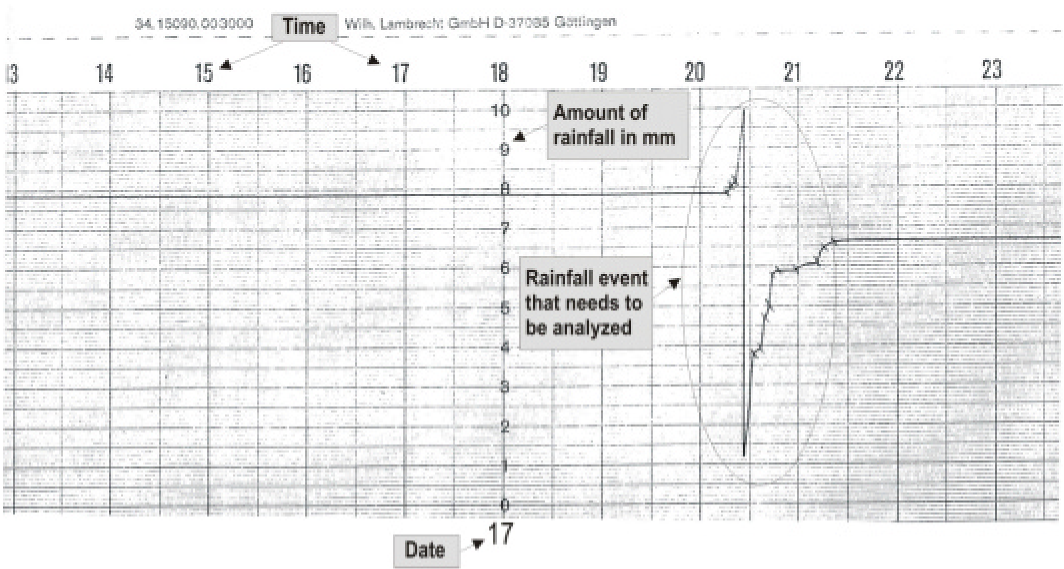


Figure 3.1 Example of a chart roll; Section of 17-8-1999

When analyzing the chart roll, first the line drawn by the pluviometer (= amount of rainfall) is divided into intervals with equal gradients. Like this, the corresponding amount of rainfall is obtained for each time interval, which indicates the intensity. The more the rain during a time interval, the steeper the curve is.
After dividing the curve into equal gradient intervals, reading and calculating can be started. This means the PLRE form with *date*, *start* time, *and end* time and *amount* of rainfall is filled. (See Figure 3.1 and table 3.2 for clarification).

1. For instance, in the picture above, the first *start* time is after 20h. When measuring from 20h, 5 mm is measured; because 1 mm = 3 minutes. The first *start* time is at 20.15h and the *end* time is at 6 mm → 20.18h.
2. In a next step, the amount of rainfall is recorded by counting the vertical lines. 1 line = 0.1 mm of rain.
3. The process is continued until the whole event is analyzed.
4. The sharp drop down in the rainfall curve is not a negative rainfall event. This is resulted when the instrument quickly empties itself after it is filled up with water.

Table 3.1 Example of the rainfall analysis

Date	Start	End	Amount (mm)
17.8.1999	20.15	20.18	0.1
17.8.1999	20.18	20.21	0.1
17.8.1999	20.21	20.32	4.5
17.8.1999	20.32	20.36	0.1
17.8.1999	20.36	20.39	0.8
17.8.1999	20.39	20.42	0.3
17.8.1999	20.42	20.44	0.8
17.8.1999	20.44	20.48	0.1
17.8.1999	20.57	21.12	0.2
17.8.1999	21.12	21.15	0.4
17.8.1999	21.15	21.21	0.1

For an event going on until the next day, the two days are clearly defined, otherwise the TESTMAIN program cannot read the input tables even if they have the same gradient: e.g. *end* time 23.59, *start* time 0.00.
The PLRE form is not a continuous recording form such as the river record sheets; it is only filled in with event data.

3.2 Analysis of the river record sheets

The analysis of the river record sheets is similar to the rainfall analysis. The analysis is performed in the same way as the rainfall analysis with two exceptions:

- **If samples have been taken**: the analysis of the river record is different because of the sample times and its corresponding water heights. 10 minutes samples are taken as soon as the water turns brown. There is usually a swift to a 30 minutes sampling time when the water level is decreasing. These sample times are the fix points in the RSRD form.

- **If no samples have been taken**: in order to know the water height between the *start* and the *end* time, the corresponding *true water level* of the *start* and *end* time is added and divided by two (since the average true water level value in between the *start* and *end* time is needed).

To analyze the river record sheets, three different forms are used.

- Daily water height of river station record (RSWH): shows for each day the true water level around 8h;
- River sample record and analysis (RSSL): shows the sampling date and time as well as the true water level of the sampling time;
- River discharge analysis (RSRD): needs to be filled in; and the river record sheets.

In order to save paper, the river record sheets are usually not changed every day (see figure 3.2). The writer pen of the record sheet is shifted up so that it doesn't coincide with the record of the day before. This will be done as many times until the sheet is full and a new one must be put into the river gauge. The date is specified for the corresponding line, which represents the true water level.
Time is marked at the bottom of the record sheet in the horizontal direction. Each thick line represents a full hour while the thinner lines represent 10-minute intervals.
The true water level (cm) is listed in the vertical direction where each line represents a 2 cm interval.

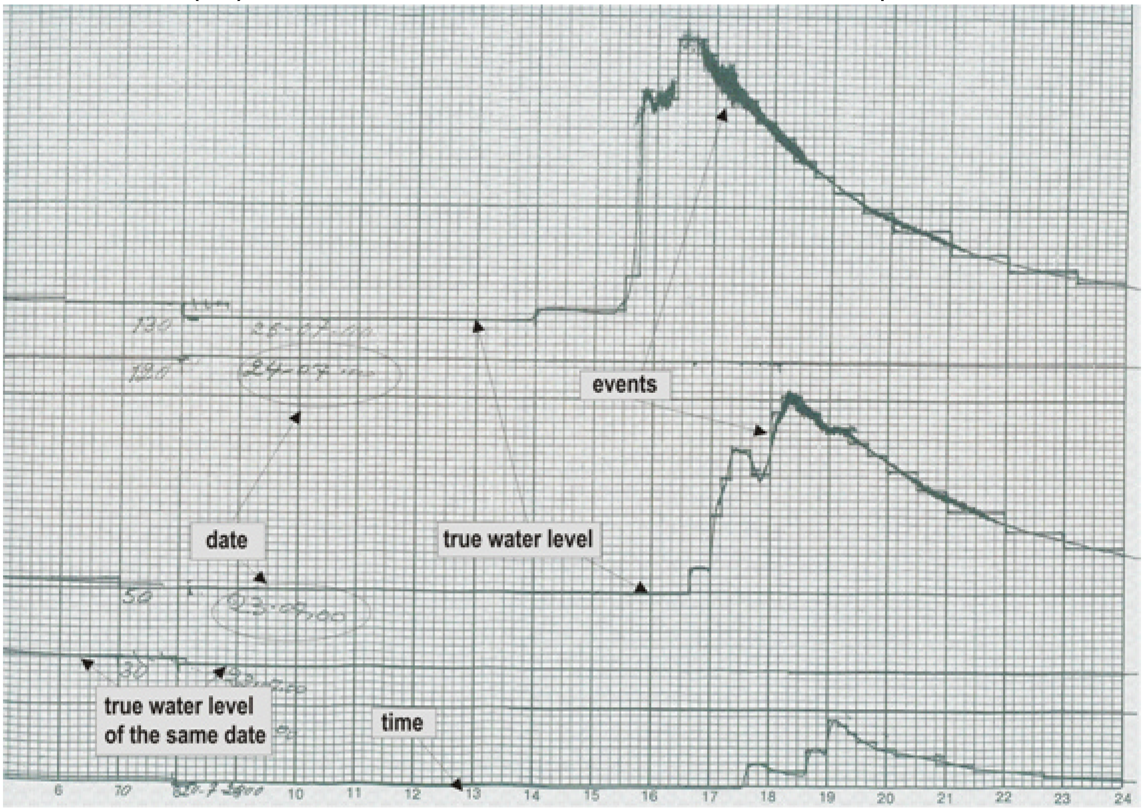


Figure 3.2 River record sheet

Different procedures have been followed for different cases.

For cases with no event and no samples taken,

1. If there is no event and the true water level stays on the same level, the value for the respective date is looked up from the RSWH form and value entered for the whole day; e.g. *date* 22-7-2000, *start* 0.00, *end* 23.59, *true water level* 2 cm.
2. If there is a small event but no samples, analysis of that event is made as for the rainfall (intervals of the same gradients). Because the average value is needed, the water level at the *start* time and at the *end* time is taken and averaged.

For cases with an event and samples taken as for example on the 23rd of July 2000,

1. Marks were made on the river record sheets for the times when samples have been taken (the sampling time and the true water levels were looked up from the RSSL form). The sampling time must be in the middle of the start and end time. So, if for example the 10-minutes sampling time is at 17.15h, the start time must be at 17.10h and the end time at 17.20h. The true water level is the one of the sampling time from the RSSL form (17.15h). Next sampling time will be 10 minutes later, at 17.25h. The corresponding start time is at 17.20h and the end time at 17.30h. Again, the true water level is the one of the sampling time from the RSSL form. It goes on like this until there is a swift to the 30 minutes sampling interval.
2. If the sampling interval is 30 minutes, for example after 17.25h the next sampling time is at 17.55h, shift to a 30 minutes interval is made in the analysis. This sampling time must be in the middle again: for a 30 minutes interval, the start time must be 15 minutes before the sampling time, means at 17.40h and the end time at 18.10h. The true water level is the one of the sampling time (17.55h) from the RSSL form.
3. Because of the change from 10 to 30 minutes sampling interval, a gap of 10 minutes between 17.30h and 17.40h is observed. In order to fill this gap as well as the other gaps of the curve not yet covered by sampling times, average value of the corresponding true water level of the start and end time is taken.
4. When there are no sampling times recorded any more, analysis of the remaining part of the graph is made by dividing it into intervals of equal gradients. Then the average water level of the corresponding start and end time is taken.

There is continuous information for the analysis of the river record sheets, i.e. the corresponding RSRD forms for every minute during the whole year is filled. It doesn't matter if there was an event or not. For each date, there must be a separate entry, otherwise the TESTMAIN program is not calculating. Additionally, the program can't read any time >23.59. If an event goes on until the next day, the days are clearly divided and analysis for each day is made separately even if they have the same gradient. E.g. end 23.59, start 0.00! If samples have been taken at 23.55, make a start time at 23.50 and end time at 23.59 and proceed with start time 0.00.

3.3 *Data interpretation*

Here are the major points for interpreting the data. Mostly the ideas are from the long term monitoring report for consistency.

1. **Rainfall**
   - Amount (monthly and annual amount of rainfall) and pattern of rainfall (the pattern of rainfall between the months of the year and over the years)
   - Intensity and erosivity of rainfall
2. **Soil loss and runoff**
   - **Soil loss and surface runoff (test and experimental plots)**
     - Effect of different soil conservation measures
     - The different erosion processes in relation to the diverse factors like topography (slope gradient, slope length), soil condition (soil type, vegetation cover, soil moisture and infiltration) and rainfall (amount and intensity).
     - Comparing the results of test and experimental plots in order to observe different erosion processes.
     - Comparing annual and monthly values for observing dynamics of erosion in relation to rainfall amount.

   - **River discharge and sediment yield / Hydrometric results of the catchment:**
     - Effect of land use pressure for causing runoff and soil loss
     - Discharge variability in relation to different factors
     - Sediment concentration in relation to soil plough condition and cover
     - Relation between rainfall, runoff and total sediment load
     - Effect of farming methods
3. **Temperature** (monthly and annual air and soil surface temperature of the area)
4. **Auto met data:** Describe the data of all the parameters

Available Climatic records

Table 3.2 Summary report of available climatic records

Parameter	Method	Years with data
Rainfall	PLRE	1984 - 2002
	DRRD	2002 - 2006
	INRI	1986 - 2006
Temperature	Air temperature	1986 - 2006
	Soil temperature	1986 - 2006

In addition, the following points for data interpretation were included.

- Percentage (i.e. in which month the highest percentage of rainfall, runoff, sediment load, discharge, and sediment yield is observed.)
- Highest change (maximum increase or decrease) per month or per year
- Difference
- Approximate ratio
- Proportion (max, min)
- Trend / pattern
- Interval / data range
- Temporal variation (start and end of rainfall event)
- Rainfall distribution
- Risk of dry and wet spells

Additional information about the data interpretation can be referred from the Long term monitoring report (page 27-29).

4 RESULTS AND DISCUSSION

4.1 Rainfall

4.1.1 Amount and pattern of Rainfall

Rainfall is the determining parameter as it influences the discharge and surface runoff of an area depending on the interaction of environmental factors like the soil type, slope of the catchment and vegetation cover of the area) and human activities (deforestation, land use changes and unrestricted agricultural practices).

Starting date: Rainfall data collection started since 1984.
Data quality:

- Data of 1984 is incomplete as the station was established around mid of the year, but it is estimated that more than 90% of the rainfall of the year was recorded.
- Data for 1992 – 1993 is missing
- From 2003 onwards, daily rainguage data is used since PLRE data only exists until 2002.

Data type: PLRE (up to 2002), DRRD (from 2002) and rainfall from automatic weather station (from 2006).

Over all, the main results can be summarized as follows:

- Mean number of rainfall days per year: 54
- Minimum number of rainfall days per year: 24 (1990)
- Maximum number of rainfall days per year: 73 (2001)
- Mean number of rainfall days with erosive storm events per year: 11.7 (definition of erosive storms: the minimum amount of rainfall must be 12.5 mm; one event must be separated from the next or the previous by at least 6 hours). This value only refers to the years 1984-2002. From 2003 onwards, the erosive storms cannot be found since daily rainguage recording, DRRD data, is used instead of PLRE.
- Minimum number of rainfall days with erosive storm events per year: 7 (1984 and 1991)
- Maximum number of rainfall days with erosive storm events per year: 19 (1995)
- Mean annual amount of rainfall: 468.7 mm
- Minimum annual amount of rainfall: 244.1 mm (1990)
- Maximum annual amount of rainfall: 689.9 mm (2006)
- Mean minimum amount of rainfall per month: 0 mm (Dec)
- Mean maximum amount of rainfall per month 156.8 mm (August)
- Maximum amount of rainfall during a single event: 98.2 mm in 2000, (which is about 46.5 % of the monthly total and 20.7% of the annual rainfall values).

Generally, Afdeyu shows bimodal rainfall distribution picking in May and August, with lower values in the period from November to April and in June.
The average annual rainfall of the 22 years is 468.7 mm. For comparison purpose, the data years are divided in two; after 1991 there are changes in political and institutional conditions and as a result 1992 -1993 data doesn't exist.
The average annual rainfall 1984 - 1991 is 362.1mm and that of 1994-2007 is 529.7 mm, showing a difference of 167.6 mm. There is only one year with annual rainfall amount less than 400 (367.6mm (DRRD), 298.8mm (PLRE) in 2002) from 1994 onwards. On the other hand the annual rainfall of the years 1984-1991 is below 400mm except in two years (425mm in 1986 and 582mm in 1988). The same trend is also shown for the monthly mean values. The monthly mean values before 1991 are lower in most cases, especially in July and August where more than 50% of the annual rainfall falls,

than those after 1994. Mean monthly rainfall of July and August for the years 1984-1991 is less than 100 mm (89mm), but more than 100mm (168.4mm) for 1994 and beyond.

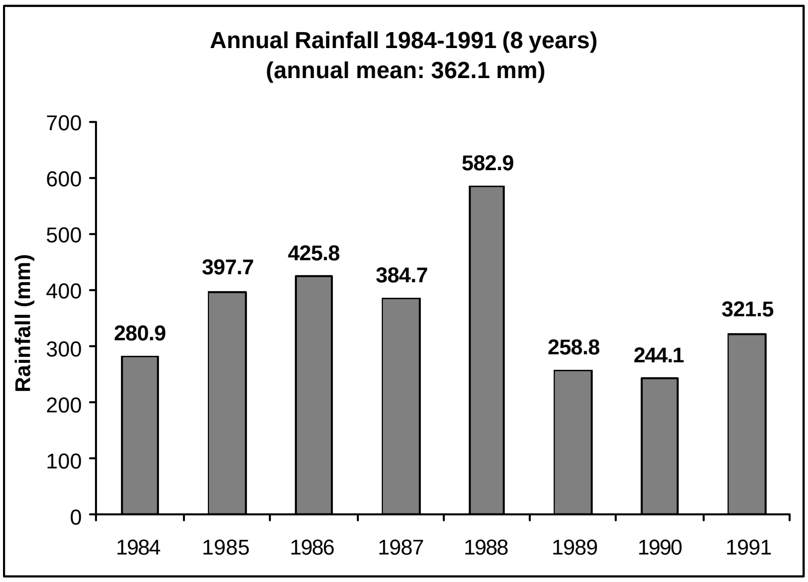


Figure 4.1 Annual rainfall distribution of 1984- 1991

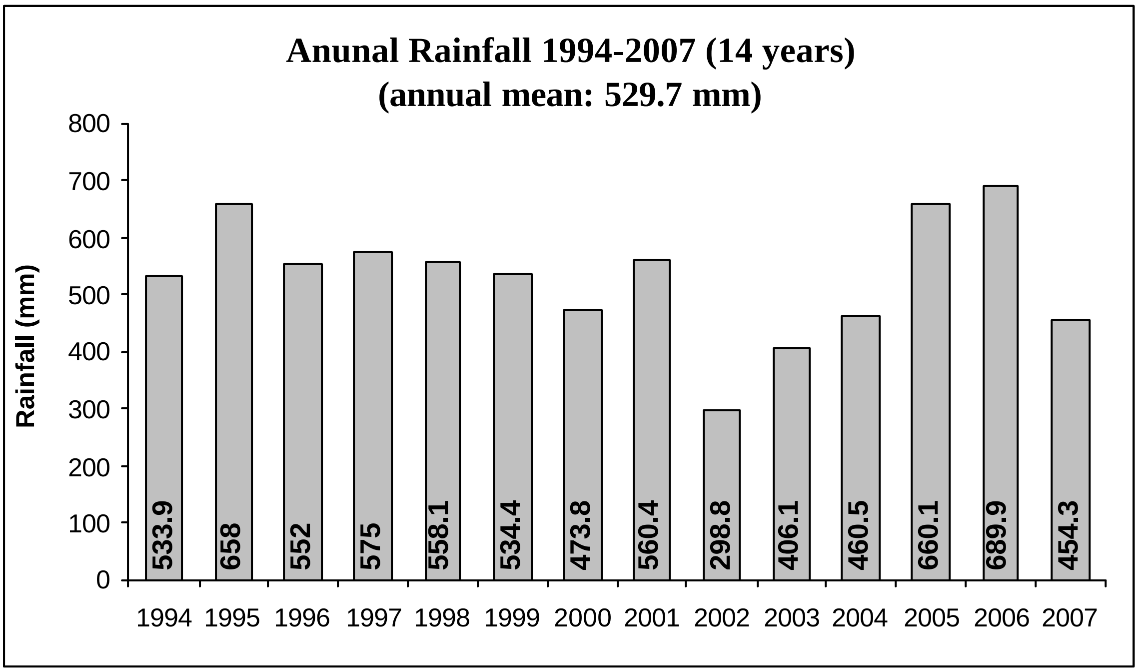


Figure 4.2 Annual rainfall distribution of 1994 - 2007

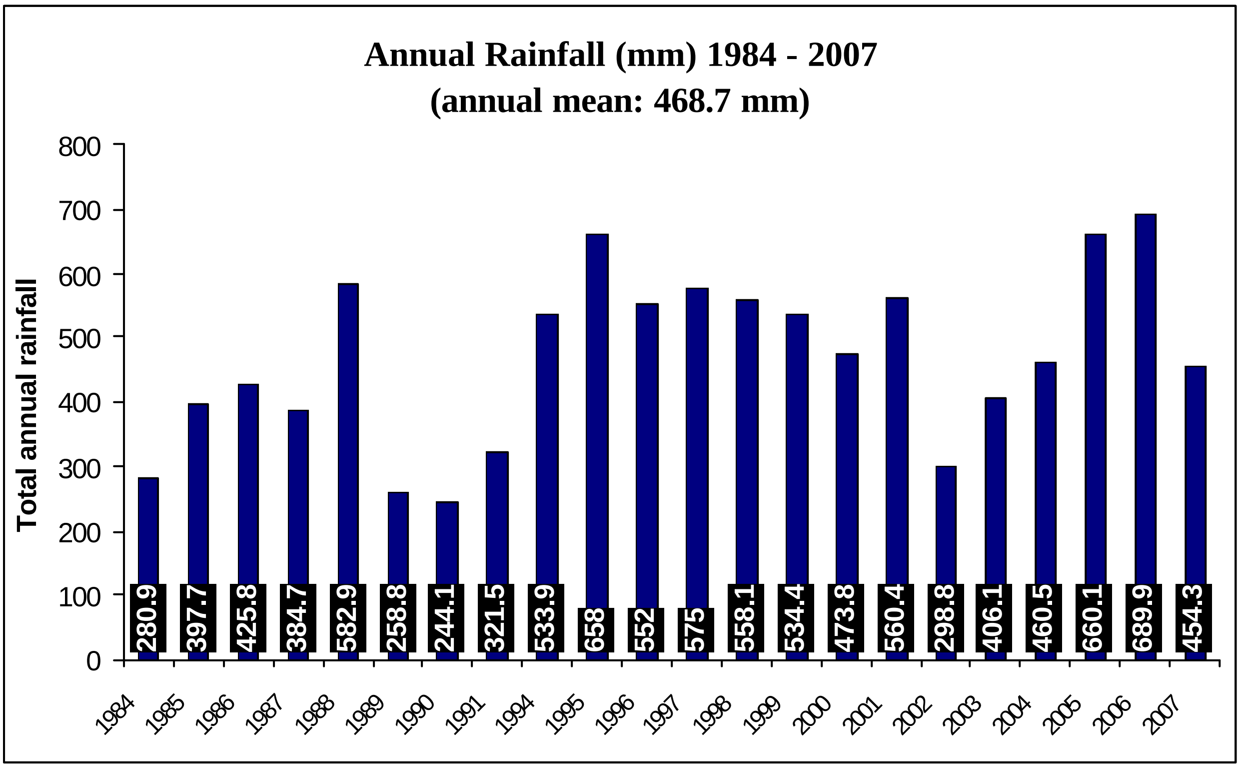


Figure 4.3 Annual rainfall amount 1984 - 2007

N.B. 2003-2007 data was taken from DRRD.

The general pattern of rainfall is demonstrated in the following figure 4.4 which shows bimodal rainfall picking in May and August).

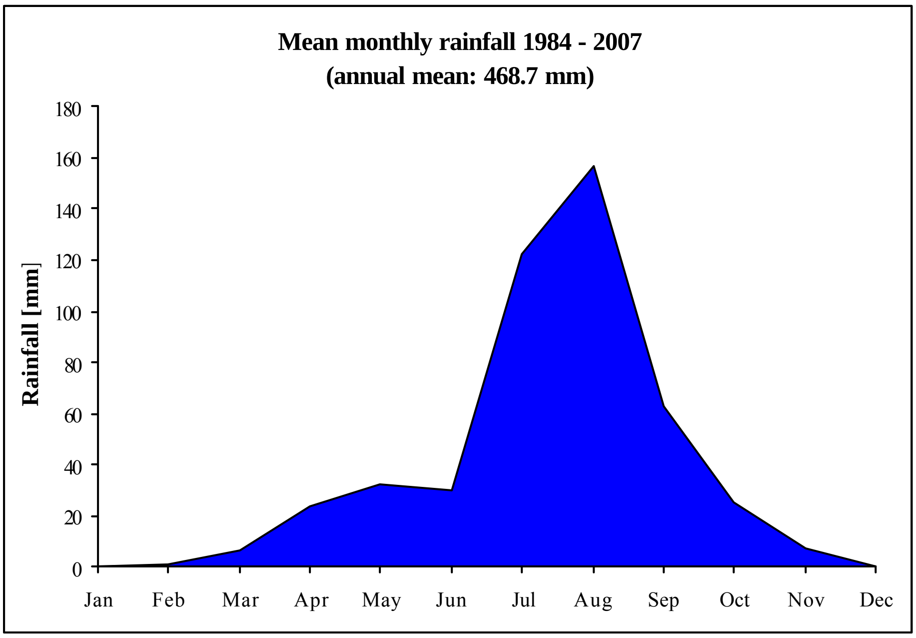


Figure 4.4 Monthly rainfall distribution

As can be seen from Figure 4.4, about 59 % of the total annual rainfall falls in July and August (26% in July and 33.5% in August).
Bearing in mind the number of rainy days also gives an indication about change in the trend of rainfall. The maximum number of rainy days is observed in 2001 while the minimum is in 1990.
Table 4.1 shows the number of rainy days for 1984-2007. For simplicity, graph has been plotted to compare the number of rainy days before and after 1991 with average of 45 (12.33 %) and 60.6 (16.59%) days, respectively. This indicates that there is a general increase in rainfall amount and number of rainy days from 1994 – 2007 as compared to the data of 1984-1991.

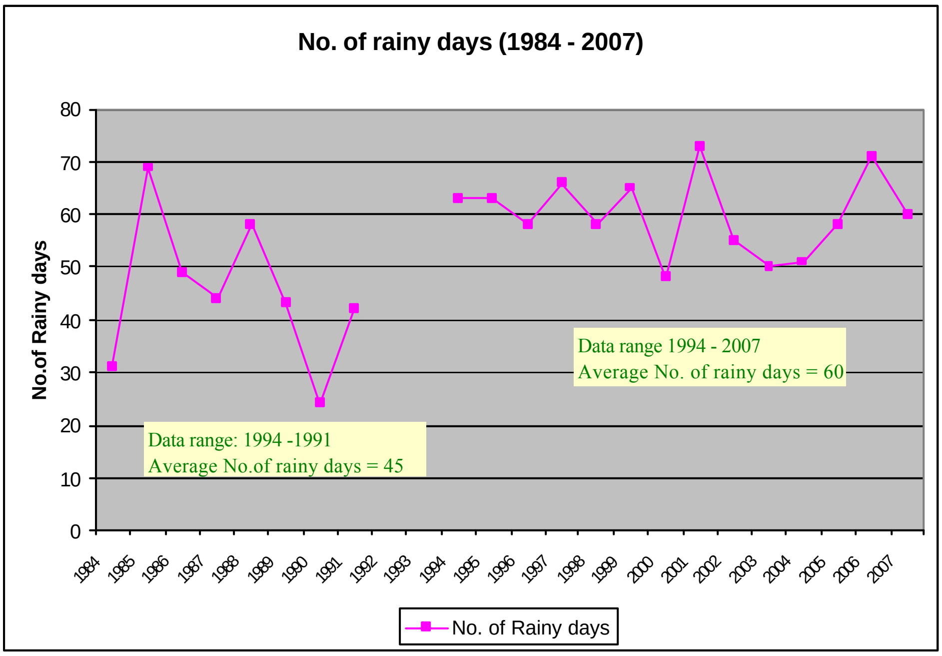


Figure 4.5 Number of rainy days

Table 4.1 Total rainfall amount, number of rainy days, and number of erosive storms

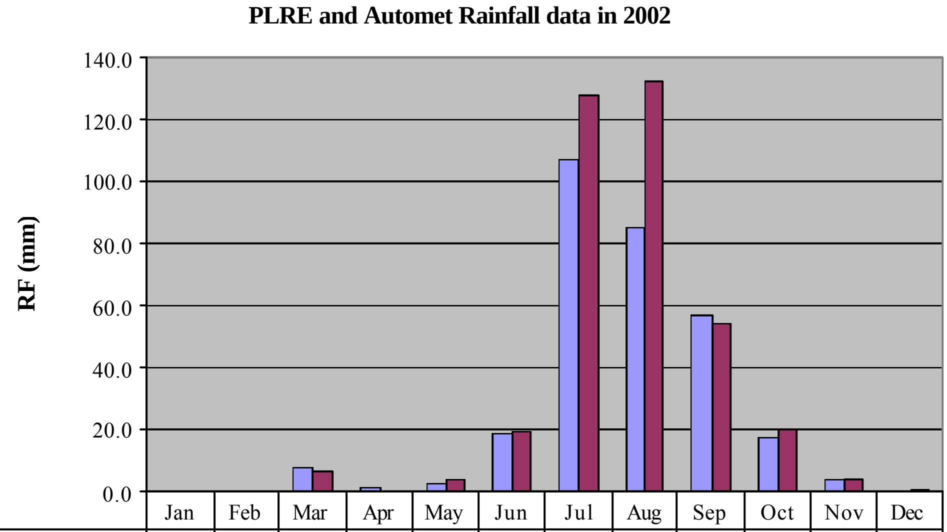
Year	Annual Total Rainfall	RF Days	RF events with >12.5mm (Erosive storms)
1984	280.9	31	7
1985	397.7	69	10
1986	425.8	49	9
1987	384.7	44	10
1988	582.9	58	13
1989	258.8	43	8
1990	244.1	24	8
1991	321.5	42	7
1994	533.9	63	14
1995	658.0	63	19
1996	552.0	58	15
1997	575.0	66	16
1998	558.1	58	15
1999	534.4	65	14
2000	473.8	57	10
2001	560.4	73	16
2002	298.8	55	11
2003	406.1	50	8
2004	460.5	51	11
2005	660.1	58	17
2006	689.9	71	17
2007	454.3	60	12
Mean	**477.93**	**54.67**	**12.24**
Max	**689.9**	**73**	**19**
Min	**244.1**	**24**	**7**

N.B. Erosive storms for 2003-2007 are taken from the daily data.

4.1.2 Comparing rainfall data from different devices

PLRE and DRRD data

The PLRE data is no more available as of 2003, but here comparison will be given to see the difference. Year 2002 is the only one with rainfall records from both PLRE and DRRD. Overall, data from the daily rain gauge (DRRD) is elevated by 68.8mm with maximum difference in August.

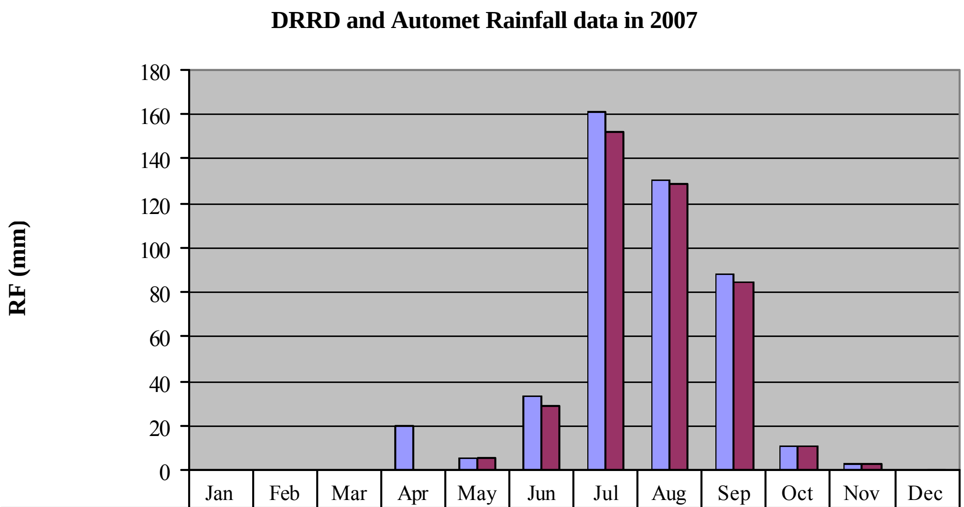


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RF from PLRE	0.0	0.0	7.5	0.8	2.6	18.4	106.6	85.3	57.0	17.0	3.5	0.1
RF from DRRD	0.0	0.0	6.5	0	3.5	19	128	132.5	54	19.5	4.2	0.4

Figure 4.6 Plot comparing the rainfall amount from DRRD and Autometeorological station

Daily rain gauge (DRRD) and Auto-met data

Daily rainfall recordings from the auto-met station have slight variation with values from the manually recoded daily rain gauge. It is higher by 36.3mm and the maximum variation is observed in April. Since the 2006 and 2008 data is incomplete, 2007 data will only be used to show the difference. This year data of the auto-met will also be used as PLRE to calculate the respective runoff and soil loss values from plots using TestMain program.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RF from DRRD	0.0	0.0	0.0	20.2	5.3	33.5	161.7	131.0	88.5	11.0	3.1	0.0
RF from Automet	0.0	0.0	0.0	0.0	5.9	29.7	152.9	129.5	84.8	11.2	3.5	0.5

Figure 4.7 Plot comparing the rainfall amount from DRRD and Autometeorlogical station

4.1.3 Intensity and Erosivity of Rainfall

Erosivity of rainfall determines the energy of the rain to cause erosion which is expressed by its intensity. The intensity of the rainfall is expressed as the amount of rainfall per length of time in which it occurs. Generally, high rainfall intensity is observed during storms of short duration and vice versa.

The following three graphs illustrate the relationship between erosivity and rainfall. Both erosivity and rainfall amount have bimodal distribution, i.e., peaking in May and July / August. This indicates that the higher the amount of rainfall the higher the erosivity and thus there will be more risk of erosion.

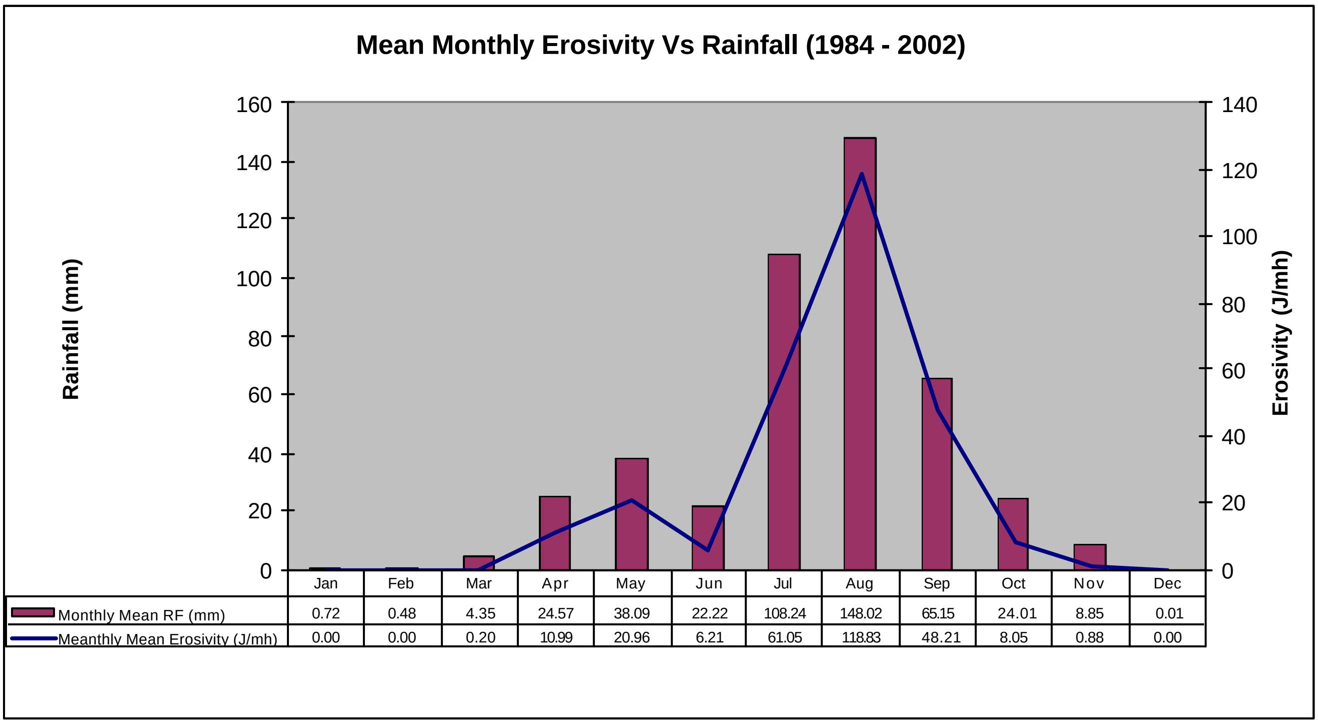


Figure 4.8 Mean monthly erosivity and mean monthly rainfall

N.B. data is only taken up to 2002 because there is no PLRE data and thus the intensity of each storm cannot be calculated.

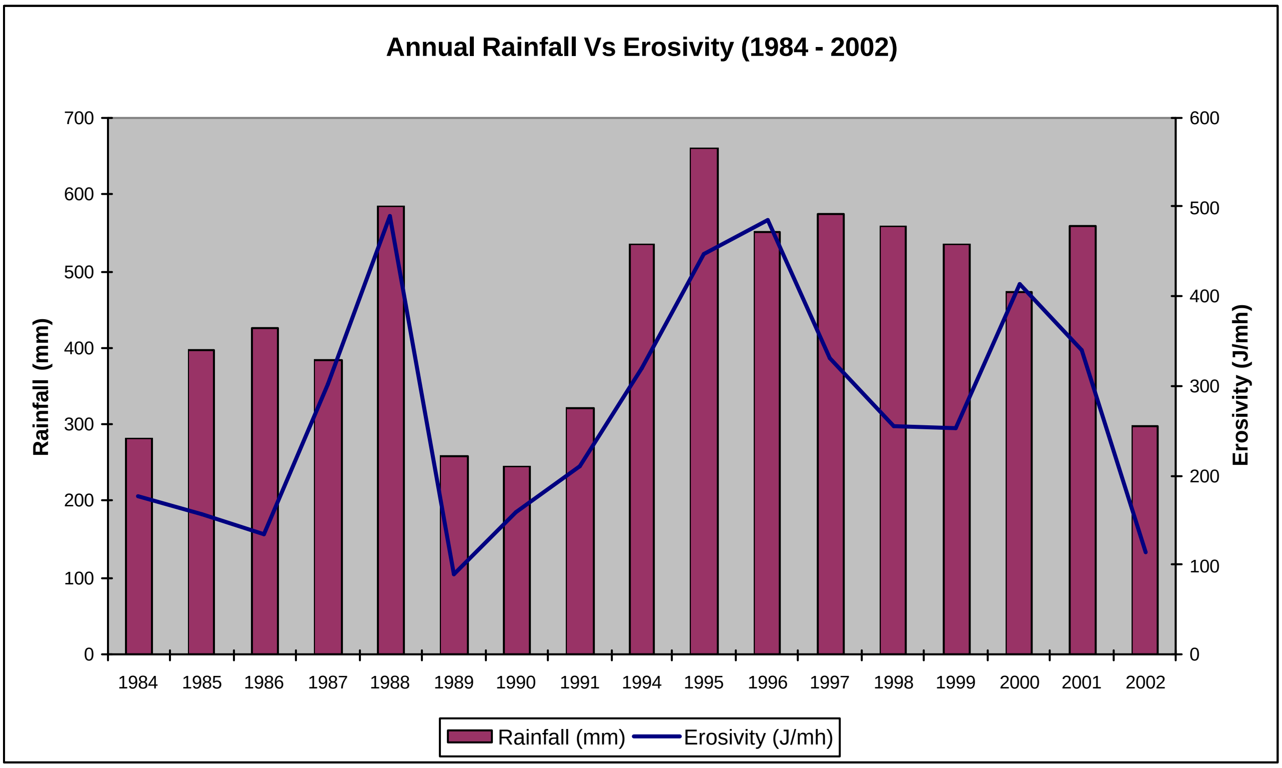
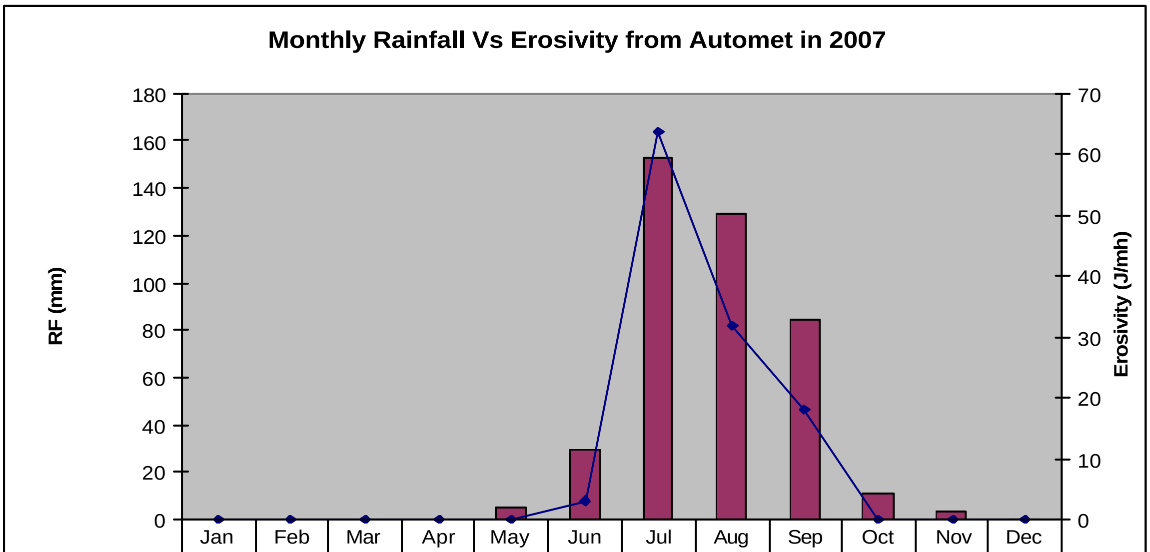


Figure 4.9 Annual erosivity and rainfall (1984-2002)

Starting from 2006 rainfall intensity can be calculated using the data from the auto meteorological station by adding the consecutive rainfall events and taking the respective time ranges. In this section 2007 data will only be used to show the erosivity value calculated using the program TestMain as it is includes data for all months throughout the year.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RF	0.0	0.0	0.0	0.0	5.9	29.7	152.9	129.5	84.8	11.2	3.5	0.5
Erosivity	0.0	0.0	0.0	0.0	0.0	3.2	63.6	32.0	18.0	0.0	0.0	0.0

Figure 4.10 Monthly rainfall versus erosivity from autometeorological station in 2007

4.2 Temperature

4.2.1 Air Temperature

Temperature was recorded initially using analog thermometer. Digital thermometer was set up as of 2002. The following figure demonstrates the similarity in trend between the analog and digital thermometer data for 2005. As the temperature readings both from the analog and digital thermometers showed same trend, the analog reading is presented through out this report because analog data is available for all the years.

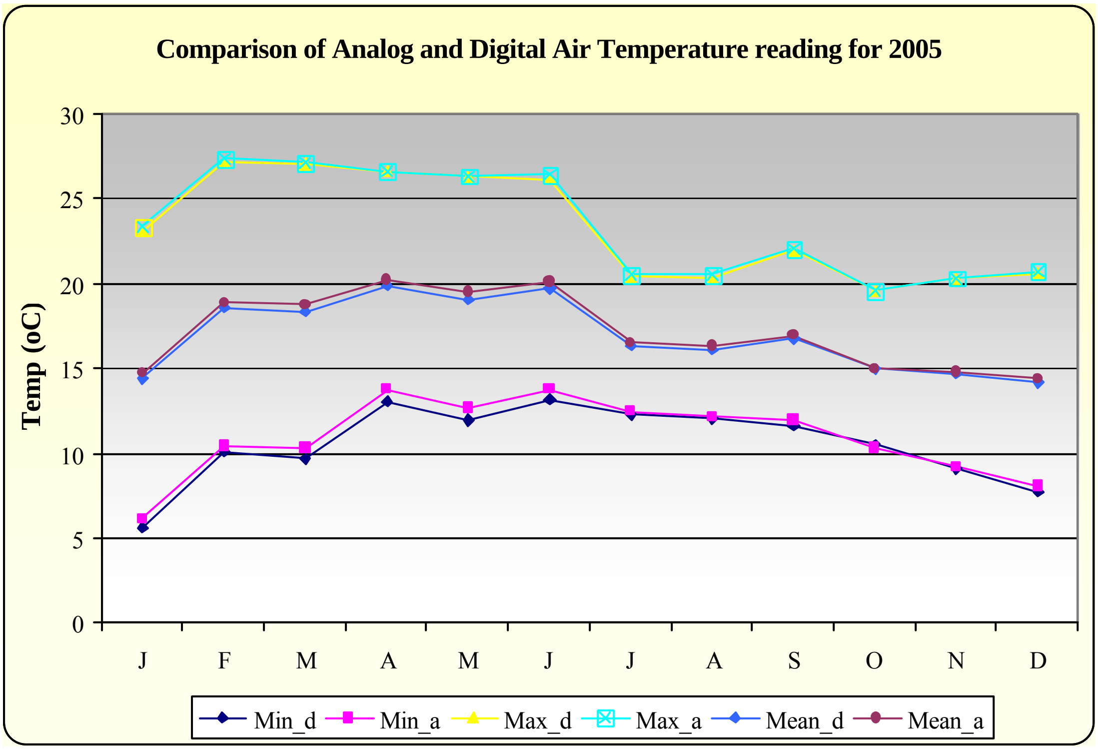


Figure 4.11 Comparing maximum, minimum and mean air temperature value for analog and digital thermometer readings, 2005.

Main results of measurement are:

- Daily minimum air temperature ranges from 0 ^{0}C (in Jan 2003) to 18 ^{0}C (in Apr 2002) with the mean monthly minimum value of 10.9 ^{0}C.
- Daily maximum air temperature ranges from 14 ^{0}C (in Aug 2003) to 32 ^{0}C (in Apr and May of 2001 & 2002) with the mean monthly maximum value of 23.7 ^{0}C.
- Annual minimum air temperature 16.4 ^{0}C in 2006
- Annual maximum air temperature 20.2 ^{0}C in 1986
- Annual mean air temperature 17.4 ^{0}C

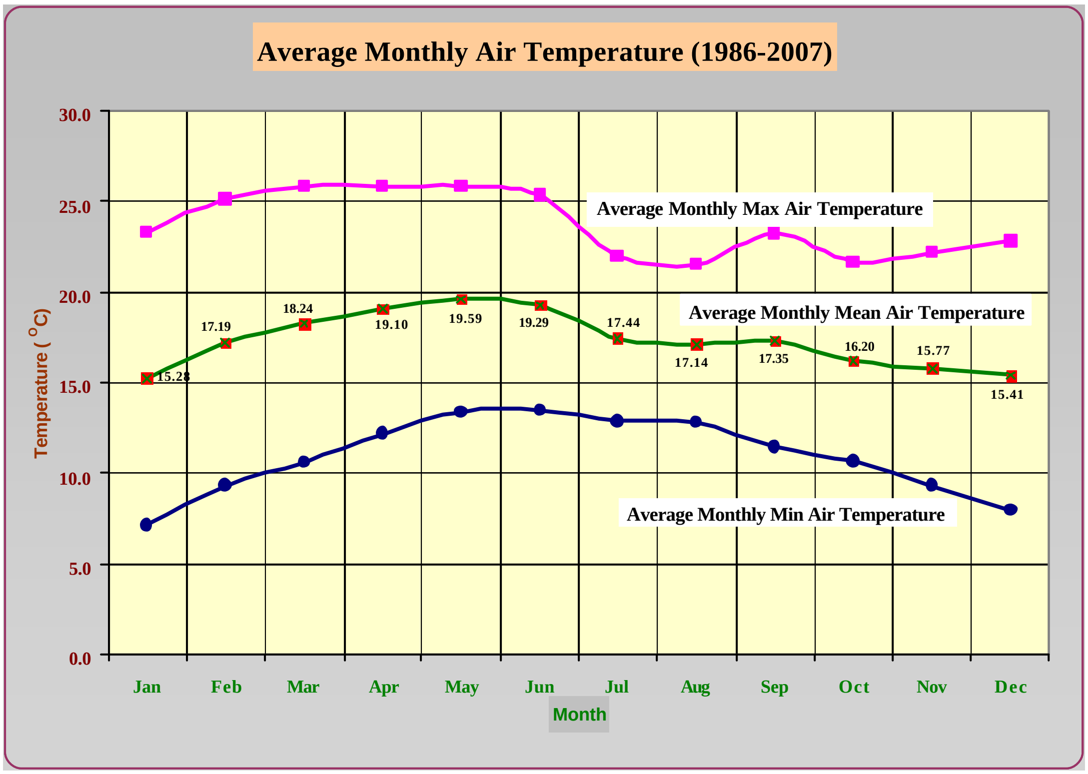


Figure 4.12 Average monthly maximum, mean and minimum air temperature (1986-2007)

N.B. No data available for 1992 and 1993.

Table 4.2 Monthly and annual air temperature 1986-2007

Month	Monthly minimum	Monthly maximum	Monthly mean
Jan	7.1	23.4	15.3
Feb	9.3	25.2	17.2
Mar	10.6	25.9	18.2
Apr	12.2	25.9	19.1
May	13.4	25.9	19.6
Jun	13.5	25.4	19.3
Jul	12.9	22.0	17.4
Aug	12.8	21.5	17.1
Sep	11.4	23.3	17.4
Oct	10.7	21.7	16.2
Nov	9.3	22.2	15.8
Dec	8.0	22.8	15.4

Year	Annual mean	Year	Annual mean
1986	20.2	**2001**	17.6
1987	18.8	**2002**	17.6
1988	16.8	**2003**	17.7
1989	16.5	**2004**	17.5
1990	17.2	**2005**	17.2
1991	17.0	**2006**	16.4
1994	16.7	**2007**	16.5
1995	16.9		
1996	16.9		
1997	17.0		
1998	17.1		
1999	17.2		
2000	18.3		

The mean monthly air temperature ranges from 15.3 °C in January to 19.6 °C in May.

4.2.2 Soil Surface Temperature

Like air temperature, soil surface temperature was also recorded using analog and digital thermometers. The following figure demonstrates the similarity in trend between the two taking 2003 data.

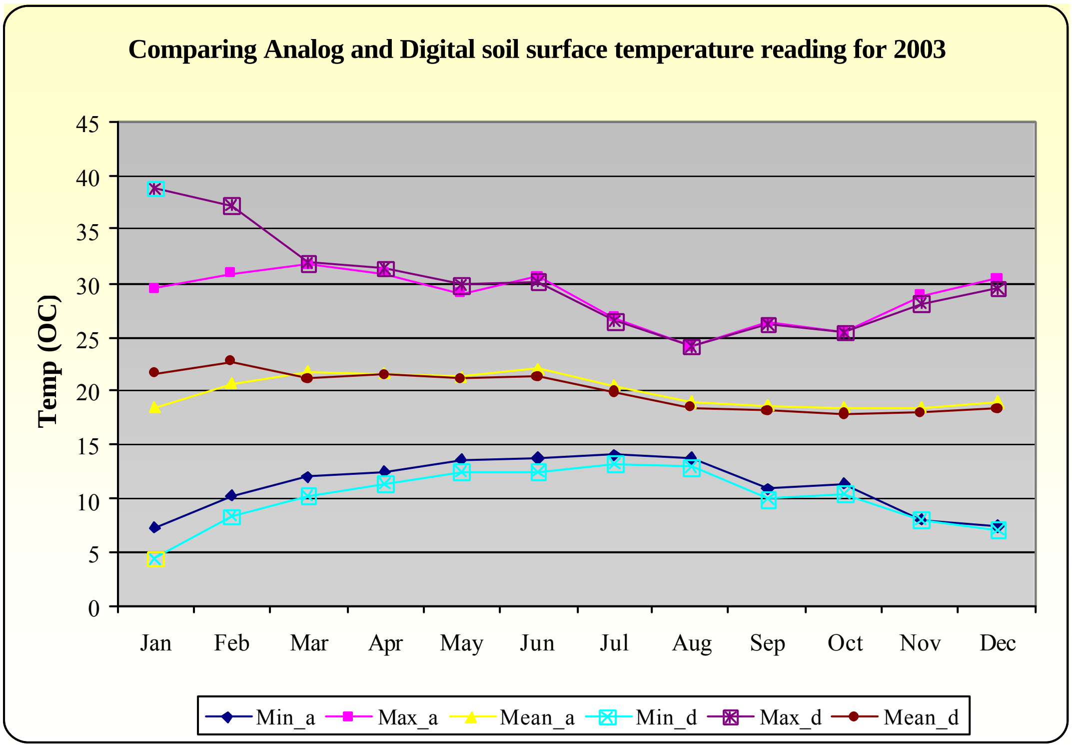


Figure 4.13 Comparing maximum, minimum and mean soil surface temperature value for analog and digital thermometers

As it can be seen from the above figure, there is slight variation between the analog and digital thermometer readings for soil surface temperature taking 2003 as a sample year. But in this report the analog reading is used as it represents for all years.

Main results of measurement are:

- Daily minimum soil surface temperature ranges from 0 ^{0}C (in Jan 2005) to 19 ^{0}C (in Apr & Sep 1999 and Jun 2000).
- Daily maximum soil surface temperature ranges from 9 ^{0}C (in Oct 2005) to 49 ^{0}C (in Dec 2001).
- Annual minimum soil surface temperature 18.2 ^{0}C in 1989 and 2006
- Annual maximum soil surface temperature 23.7 ^{0}C in 2001
- Annual mean soil surface temperature 20.3 ^{0}C

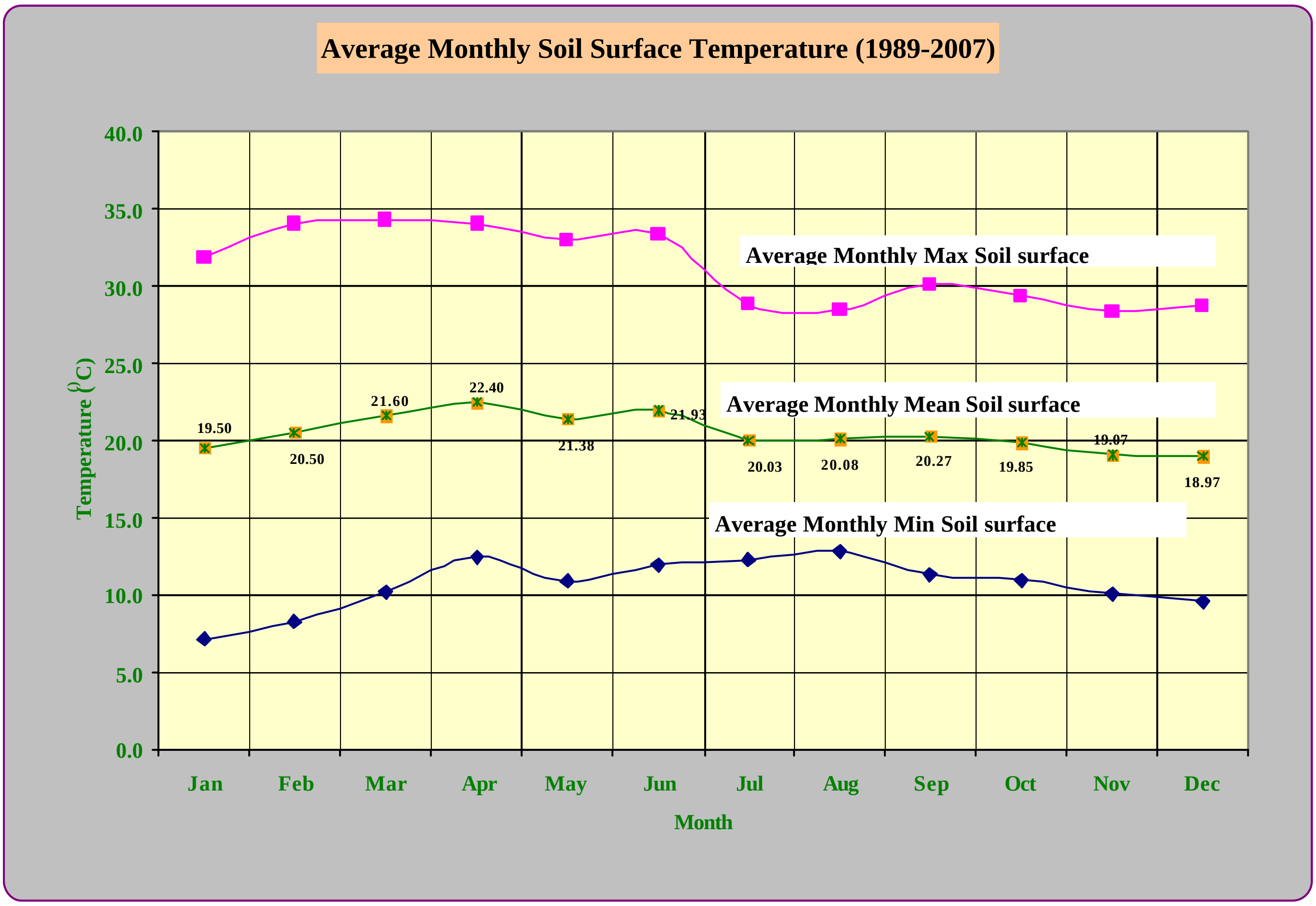


Figure 4.14 Average monthly maximum, mean and minimum soil surface temperature (1989-2007)

N.B. No data for 1992 and 1993)

As it can be seen from Table 4.3, the mean monthly soil surface temperature ranges from 19 °C in December to 22.4 °C in April.

Table 4.3 Monthly and annual soil surface temperature 1989 - 2007

Month	Monthly minimum	Monthly maximum	Monthly mean
Jan	7.1	31.8	19.5
Feb	8.30	34.0	20.5
Mar	10.2	34.3	21.6
Apr	12.4	34.0	22.4
May	10.9	33.0	21.4
Jun	11.9	33.3	21.9
Jul	12.3	28.8	20.0
Aug	12.8	28.5	20.1
Sep	11.3	30.1	20.3
Oct	11.0	29.3	19.8
Nov	10.1	28.3	19.1
Dec	9.6	28.7	19.0

Year	Annual mean	Year	Annual mean
1989	18.2	2004	19.2
1990	20.2	2005	19.0
1991	20.4	2006	18.2
1994	22.7	2007	18.5
1995	21.8		
1996	21.0		
1997	20.6		
1998	19.0		
1999	20.7		
2000	21.2		
2001	23.7		
2002	21.2		
2003	20.0		

Figure 4.15 demonstrates the relationship between rainfall and temperature. As it can be seen from the figure, in July and August there is high rainfall while the temperature is lower in these months and keeps on increasing when rainfall is lower. This indicates that rainfall and temperature have inverse relationship among each other.

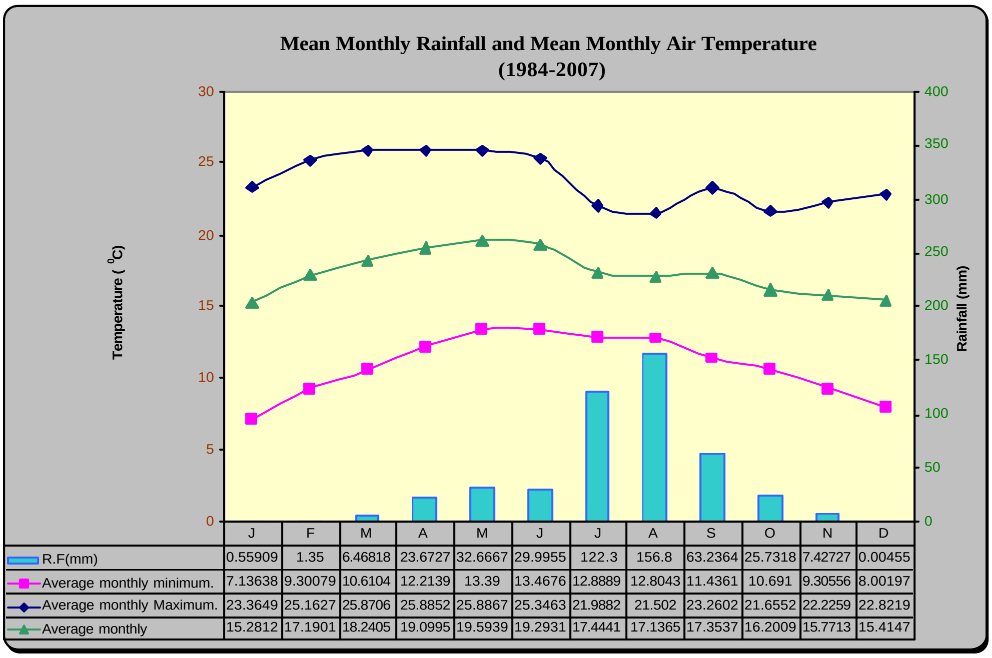


Figure 4.15 Monthly mean rainfall and air temperature

4.3 Soil loss, discharge and surface runoff

As stated in Brigitta et al., (2002) surface flow (runoff, river discharge) and eroded material (soil loss, suspended sediment yield) are two of the main variables continuously monitored in Afdeyu research station. They are measured in four different scales:

- Microplots (1988-1990)
- Test plots (1984- present, with some exceptions)
- Experimental plots (1988- 2001)
- Research catchment level (river gauging station) (1984-present)

Table 4.4 Test Plots and Experimental Plots data range

Parameter	Method		Years with data
Soil loss and runoff	Test plot	TP1-TP3	1986-present
		TP4	1986-2001
		TP5	1999-present
	Experimental plot	EP1-EP4	1987-2001
		EP5	1987-1990

Note:

- No data for 1991-1993 for both test and experimental plots.
- No TP data for 1995
- No EP data after 2001.
- EP5 and TP5 are excluded from the analysis as the existing data is only for few years.

4.3.1 Annual and monthly soil loss and surface runoff

The relationship between rainfall erosivity and soil loss from each of the test plots and experimental plots as well as the discharge and sediment yield over the whole catchment is explained in this section.

A. Test plot results

The runoff and soil loss is measured from small plots situated on farmers' land (test plots) with different slopes and land use practices. The test plots give information about the condition of the runoff and soils lost from the farmers' fields.

In 1984, four test plots (TP) were established in Afdeyu where soil loss and runoff were measured in plot tanks. Soil type for all plots according to Bosshart (1997) is Cambisol, other sources characterize it as Lixisol. The following conditions are represented on the four test plots:

TP 1: 31 % slope and the vegetation cover is grass
TP 2: 2 % slope and the plot is covered with annual crops
TP 3: 10 % slope and the plot is covered with annual crops
TP 4: 65 % slope and the plot is partly covered with rock outcrops and bare soil, partly with grass
TP5: 10% slope and the plot is covered with annual crops

The amount of runoff and soil loss depends on the slope percentage and cover type. The recent analysis revealed that TP2, TP3 and TP5 are under permanent crop rotation and values indicate that the mean soil loss is higher in the steeper slopes, i.e TP3 and TP5 with a slope of 10% and compared to TP2 with a slope of 2%. Measurements from TP4 have been discontinued at the end of 2001 because the plot was very eroded covered mainly with rock.

Annual values

			TP1		TP2		TP3		TP4		TP5	
Year	**Rainfall (mm)**	**Erosivity (J/mh)**	**Runoff (mm)**	**Soil Loss (t/ha)**	**Runoff (mm)**	**Soil Loss (t/ha)**	**Runoff (mm)**	**Soil Loss (t/ha)**	**Runoff (mm)**	**Soil Loss (t/ha)**	**Runoff (mm)**	**Soil Lo (t/ha)**
1984	280.9	177.76										
1985	397.7	154.85										
1986	425.8	134.36	240.63	19.56			190.31	28.98	176.70	39.57		
1987	384.7	302.70	188.83	38.90			165.89	18.71	150.82	29.71		
1988	582.9	490.98	381.35	44.96	322.36	61.75	305.13	26.74	184.67	17.53		
1989	258.8	89.22	42.59	2.72	7.95	0.44	55.59	5.21	40.52	5.08		
1990	244.1	159.74	80.20	7.41	45.07	4.14	86.94	6.37	70.27	15.01		
1991	321.5	210.65										
1994	533.9	319.94	182.61	3.62	245.78	8.98	408.16	20.16	263.61	10.03		
1995	658.0	448.32										
1996	552.0	486.07	208.90	9.65	272.14	12.14	240.17	23.38	180.25	12.50		
1997	575.0	331.69	131.58	4.56	100.02	6.56	239.03	18.63	260.61	12.24		
1998	558.1	255.55	117.43	2.43	104.72	4.87	194.96	17.16	163.70	12.10		
1999	534.4	251.67	125.73	19.55	66.90	4.05	110.29	10.61	146.46	18.19	64.29	7.02
2000	473.80	413.92	132.47	2.38	146.93	30.35	339.92	31.79	151.42	12.15	268.25	24.53
2001	560.4	339.37	98.27	0.69	109.83	5.45	390.58	46.38	249.70	21.69	390.46	35.88
2002	298.8	114.52	28.49	0.00	89.13	8.16	242.33	29.81			183.21	14.59
2003	406.1		147.36	8.67	124.56	8.92	72.59	3.54			71.97	3.96
2004	460.5		227.13	43.51	286.29	52.85	224.28	35.17			135.81	12.68
2005	660.1		260.65	15.08	173.89	10.12	445.44	35.27			497.32	38.72
2006	689.9		205.62	12.85	127.15	4.49	345.74	26.56			369.75	33.70
2007	454.3		104.96	6.45	56.06	3.98	164.81	10.39			163.24	10.30
Mean	**468.7**	**275.37**	**161.38**	**13.50**	**142.42**	**14.20**	**234.56**	**21.94**	**169.89**	**17.15**	**238.25**	**20.15**
SD	**133.8**	**130.61**	**85.72**	**14.60**	**93.09**	**18.15**	**117.88**	**11.82**	**68.56**	**9.44**	**152.29**	**13.29**
Median	**467.2**	**255.55**	**139.92**	**8.04**	**117.20**	**7.36**	**231.66**	**21.77**	**170.20**	**13.76**	**183.21**	**14.59**

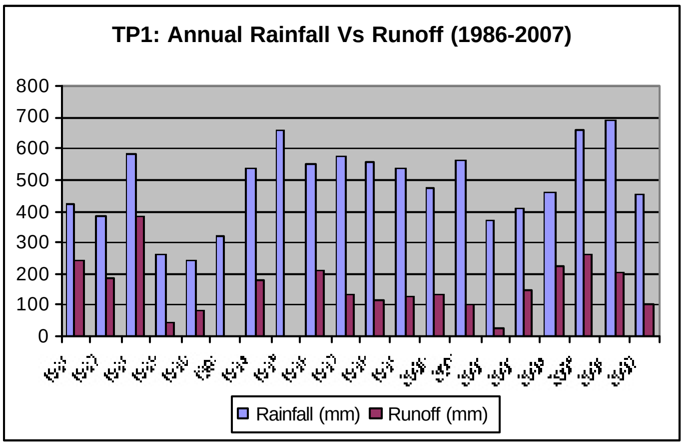
Table 4.5 Annual rainfall, erosivity, runoff and soil loss on test plots (1986-2007)

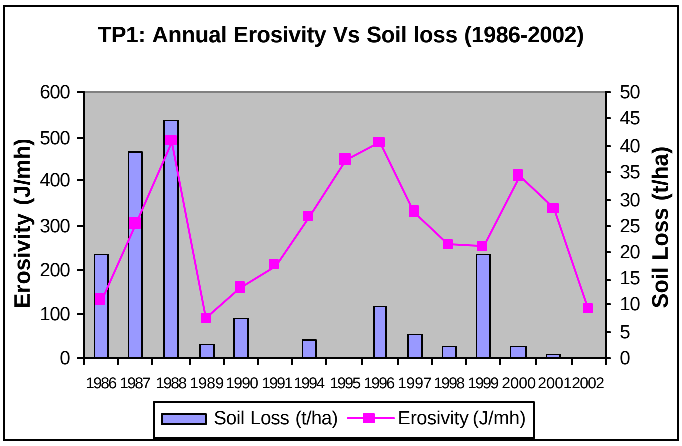
Notes:

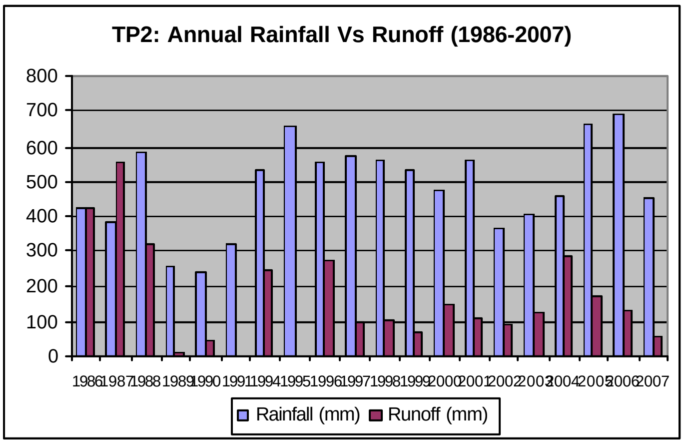
- 1986 and 1987 TP2 runoff was higher than rainfall. Thus it is not included in the table
- For 2003 - 2007 there is no PLRE data, thus erosivity value cannot be calculated
- No data for 1991-1993
- No TP data for 1995.

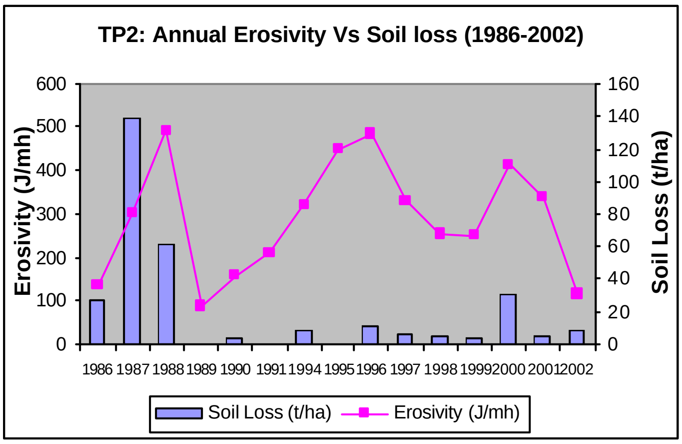
The following graphs indicate the annual variation on test plots.

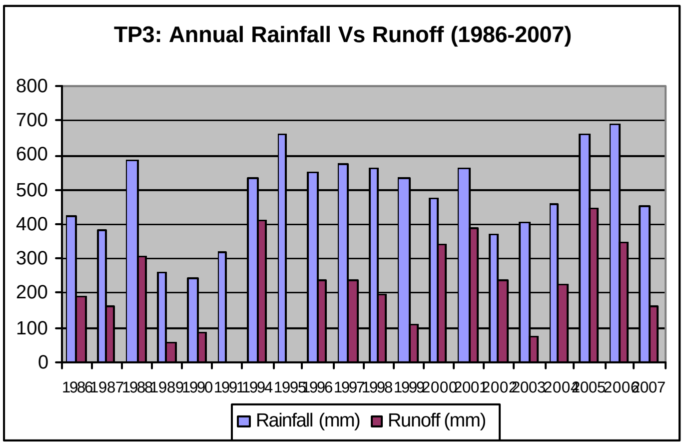
N.B. The erosivity vs. soil loss plots are only made till 2002 for the reason that erosivity data only exists up to 2002, and for TP4 up to 2001 for the soil loss value is zero in 2002.

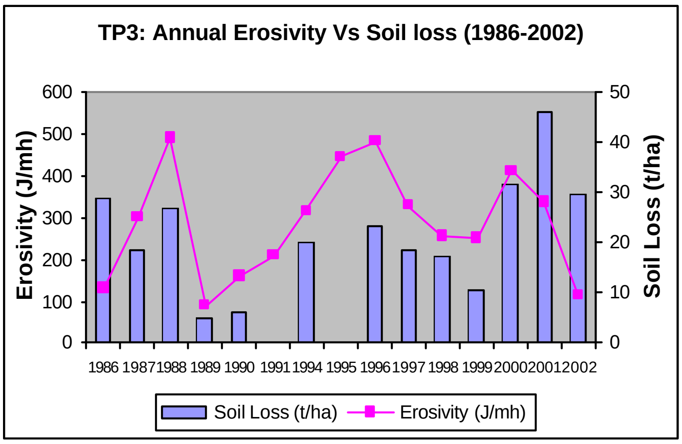

TP1: Annual Rainfall Vs Runoff (1986-2007)
800
700
600
500
400
300
200
100
0
Rainfall (mm)
Runoff (mm)


TP1: Annual Erosivity Vs Soil loss (1986-2002)
Erosivity (J/mh)
Soil Loss (t/ha)
600
500
400
300
200
100
0
50
45
40
35
30
25
20
15
10
5
0
1986 1987 1988 1989 1990 1991 1994 1995 1996 1997 1998 1999 2000 2001 2002
Soil Loss (t/ha)
Erosivity (J/mh)


TP2: Annual Rainfall Vs Runoff (1986-2007)
800
700
600
500
400
300
200
100
0
1986 1987 1988 1989 1990 1991 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007
Rainfall (mm)
Runoff (mm)


TP2: Annual Erosivity Vs Soil loss (1986-2002)
Erosivity (J/mh)
Soil Loss (t/ha)
600
500
400
300
200
100
0
160
140
120
100
80
60
40
20
0
1986 1987 1988 1989 1990 1991 1994 1995 1996 1997 1998 1999 2000 2001 2002
Soil Loss (t/ha)
Erosivity (J/mh)


TP3: Annual Rainfall Vs Runoff (1986-2007)
800
700
600
500
400
300
200
100
0
1986 1987 1988 1989 1990 1991 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007
Rainfall (mm)
Runoff (mm)


TP3: Annual Erosivity Vs Soil loss (1986-2002)
Erosivity (J/mh)
Soil Loss (t/ha)
600
500
400
300
200
100
0
50
40
30
20
10
0
1986 1987 1988 1989 1990 1991 1994 1995 1996 1997 1998 1999 2000 2001 2002
Soil Loss (t/ha)
Erosivity (J/mh)

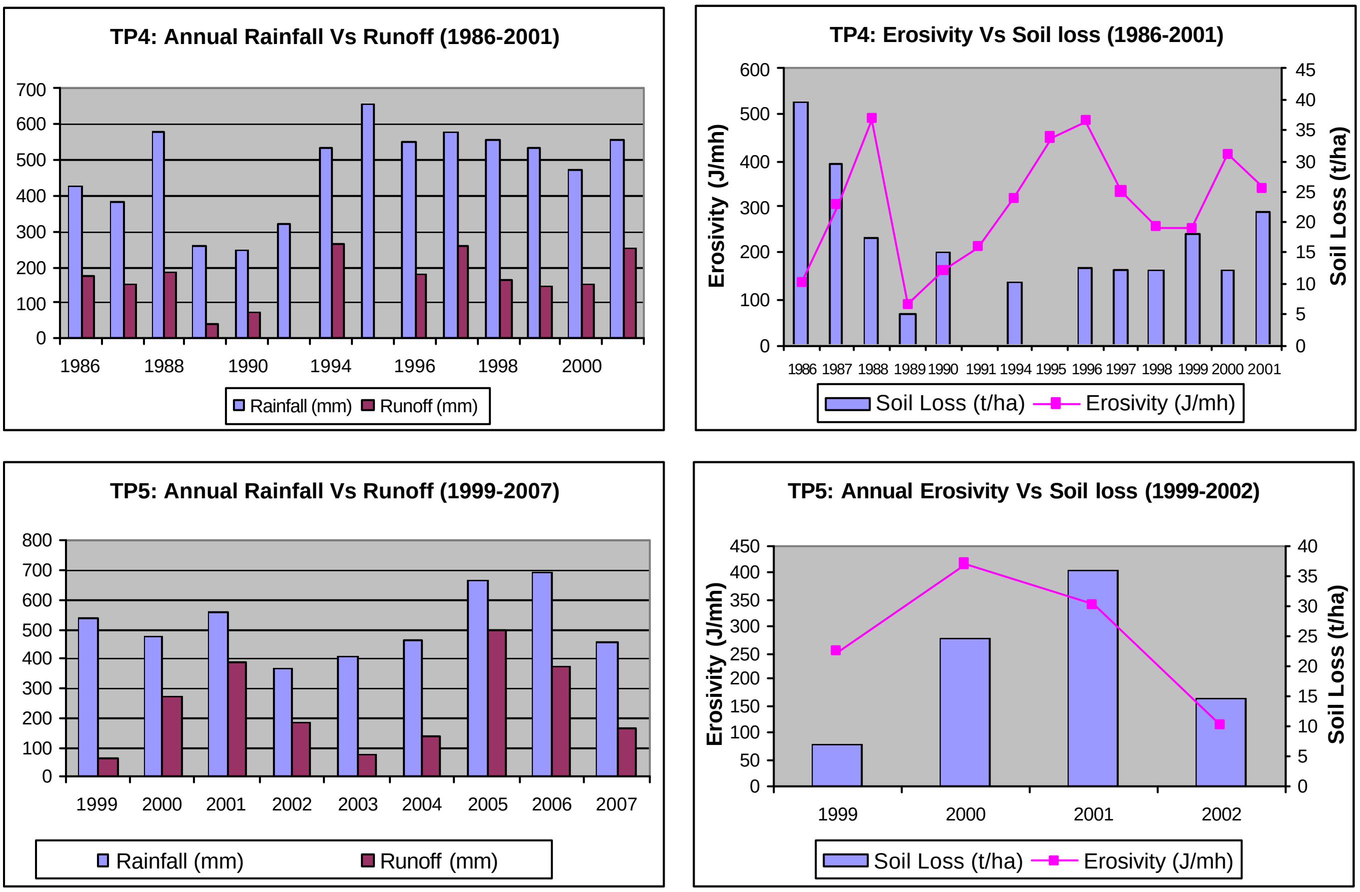


Figure 4.16 Annual test plot results: rainfall vs runoff (1986-2007) and erosivity vs soil loss (1986-2002)

Notes are the same as the preceding table.

Here are also plots showing annual relationship between runoff and soil loss on test plots

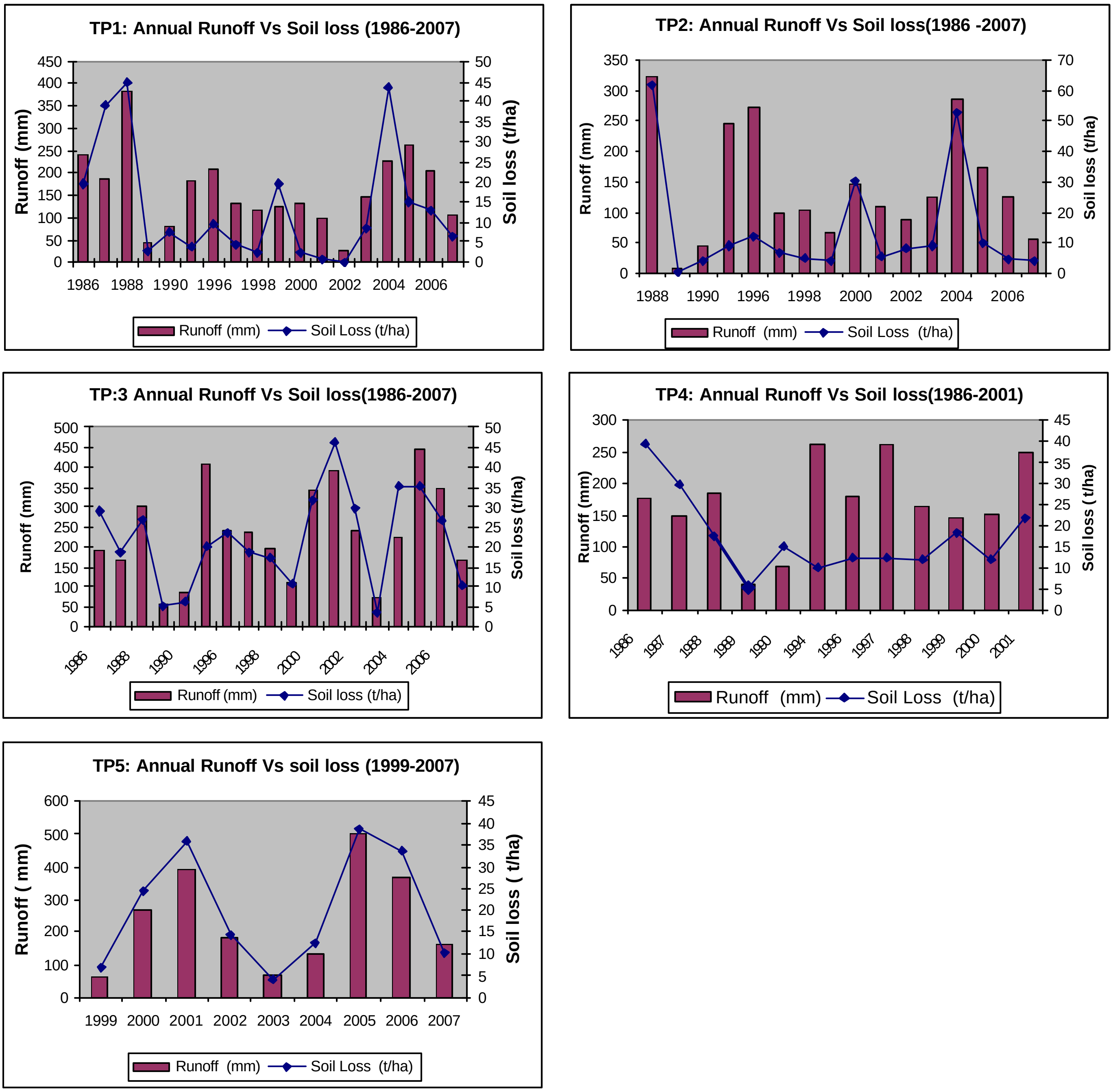


Figure 4.17 Annual test plot results: Runoff vs soil loss (1986-2007)

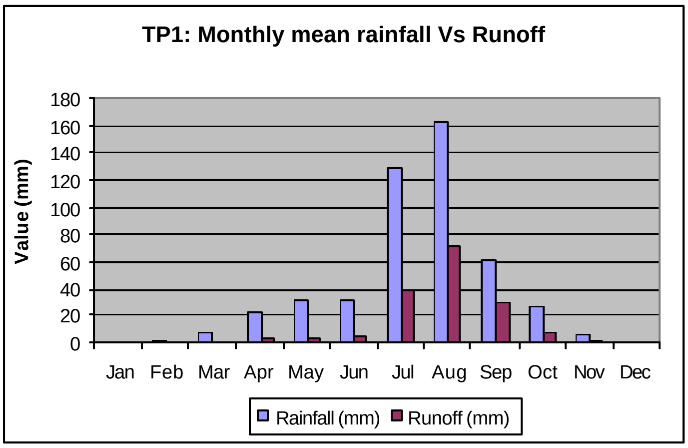
Monthly variation on Test plots
The monthly mean runoff of the test plots increases as the rainfall increases. Thus the highest runoff occurred in the month of August when the highest mean rainfall was recorded.

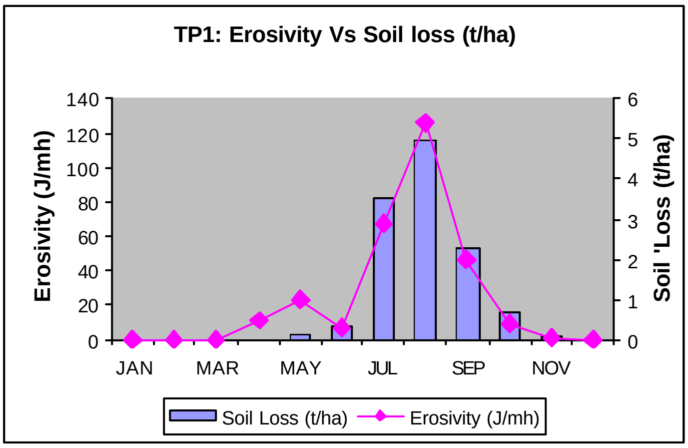
Table 4.6 Mean monthly rainfall, erosivity, runoff and soil loss on test plots (1986-2007) with the exception of TP4 (1986-2001) and PTP5 (1999-2002).

			TP1		TP2		TP3		TP4		TP5	
Month	Rainfall (mm)	Erosivity (J/mh)	Runoff (mm)	Soil Loss (t/ha)	Runoff (mm)	Soil Loss (t/ha)	Runoff (mm)	Soil Loss (t/ha)	Runoff (mm)	Soil Loss (t/ha)	Runoff (mm)	Soil Lo (t/ha
Jan	0.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.55	0.00	0.06	0.00	0.23	0.02	0.05	0.00	0.00	0.00	0.28	0.00
Mar	4.93	0.22	0.16	0.01	0.00	0.00	0.25	0.02	0.09	0.00	0.00	0.00
Apr	22.92	10.80	3.25	0.15	3.98	0.33	7.55	0.85	0.89	0.13	11.52	0.98
May	36.81	22.75	3.69	0.12	1.56	0.12	6.93	0.69	4.82	0.34	4.09	0.34
Jun	23.58	7.04	5.30	0.23	8.78	0.78	11.03	1.12	7.37	0.88	4.27	0.35
Jul	119.47	67.64	39.52	4.95	39.71	4.88	54.17	6.15	35.35	5.01	70.63	8.26
Aug	159.09	125.67	70.97	5.21	88.51	8.50	107.00	9.75	85.37	6.74	106.01	8.33
Sep	62.46	45.96	29.35	2.02	21.05	1.18	35.02	1.81	27.48	2.53	32.23	1.18
Oct	25.59	9.13	7.53	0.75	16.88	6.07	11.39	1.54	7.08	1.28	9.22	0.71
Nov	7.92	0.69	1.55	0.05	0.24	0.00	1.17	0.02	1.43	0.24	0.00	0.00
Dec	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: The monthly rainfall and erosivity values were only taken for 1986 – 2002, i.e. until the time in which there was PLRE data.

The following graphs indicate the monthly test plots' rainfall, runoff, and soil loss variations. It is clear from the graphs that show the relationship of erosivity and soil loss, on all the test plots soil loss is low during April and May despite the erosive rains. Soil loss shows a very sharp increase during the months of July and August as the runoff increases.





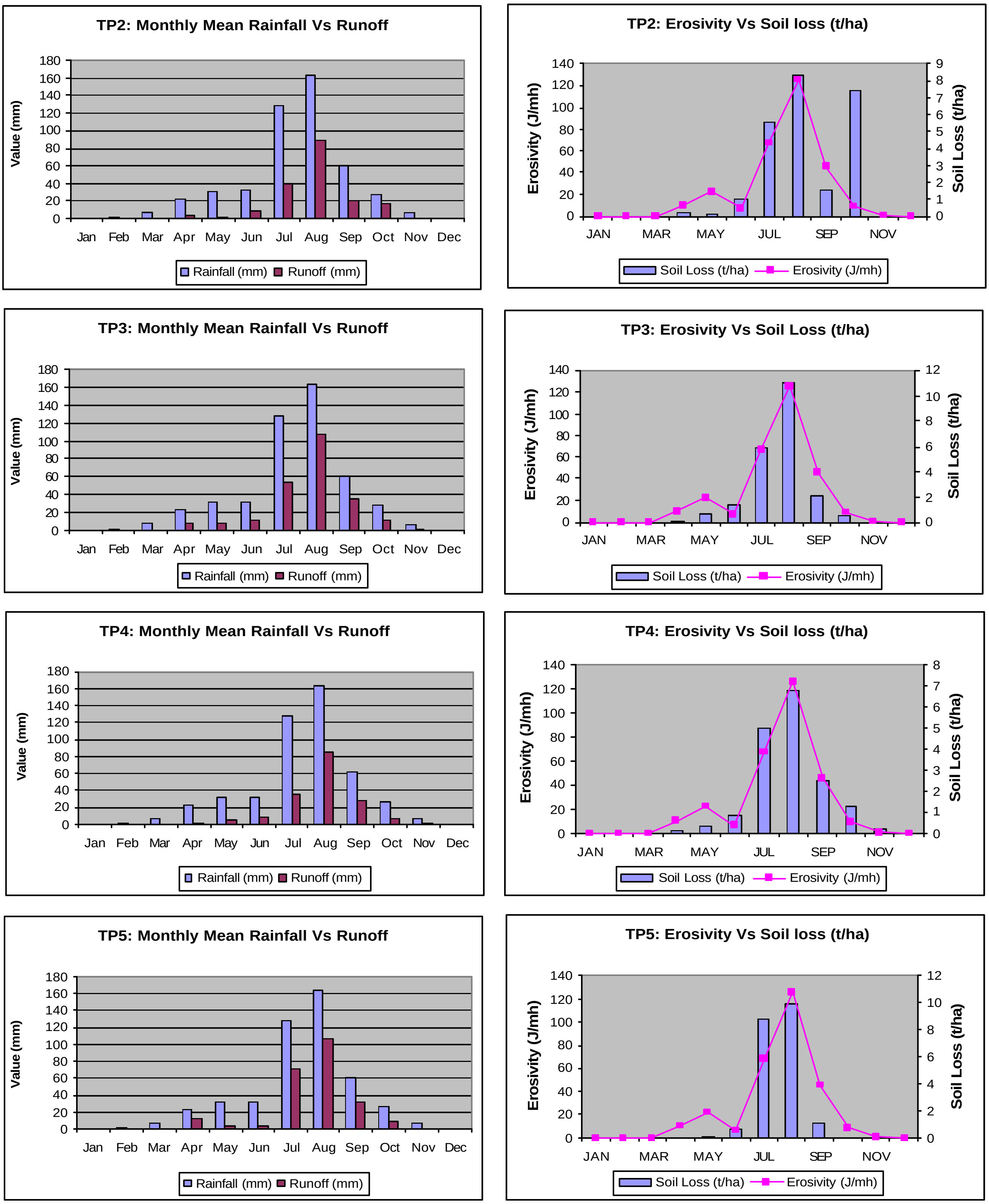


Figure 4.18 Monthly mean test plot graphs

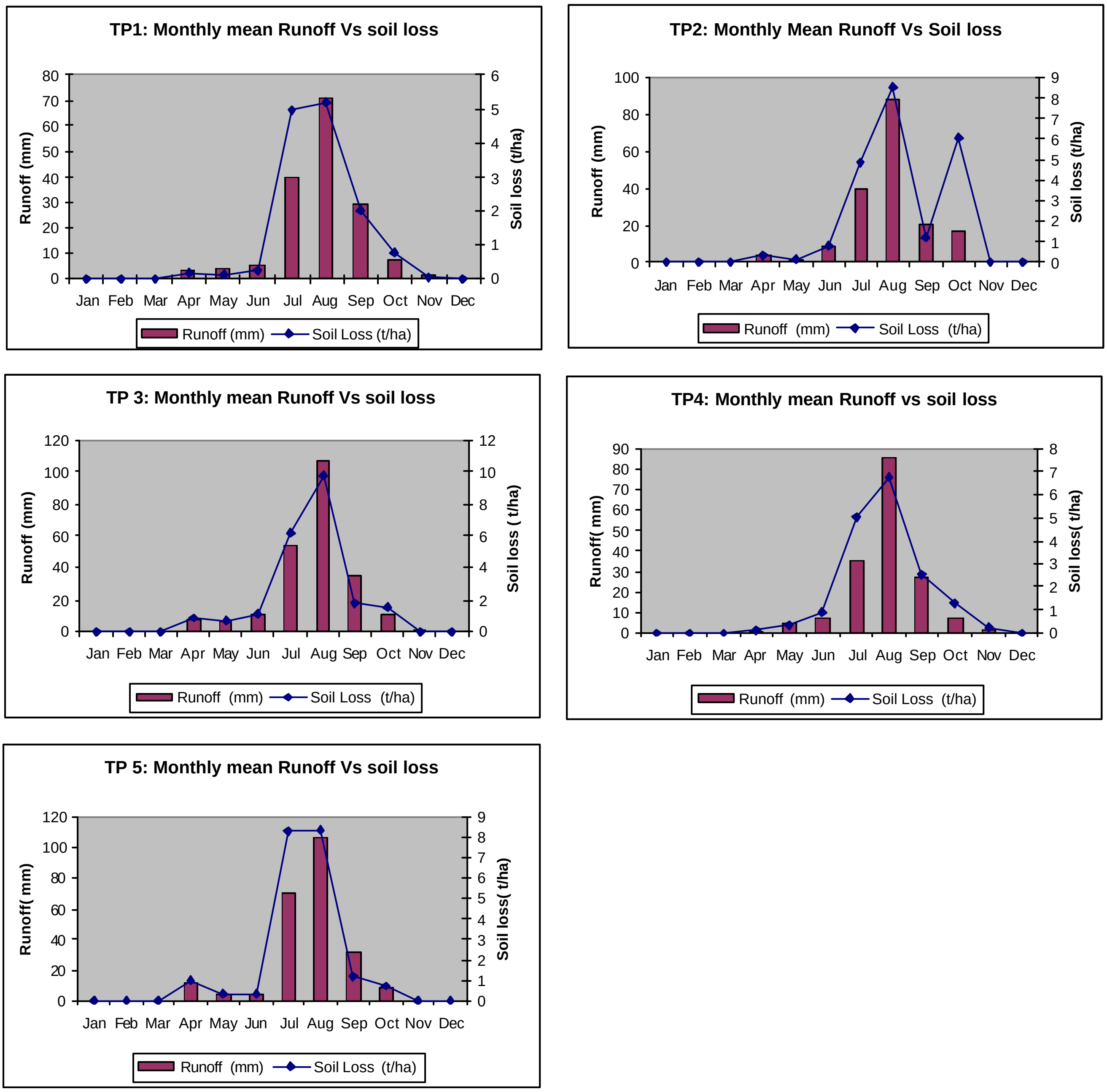


Figure 4.19 Graphs showing relationship between runoff and soil loss on test plots

Figure 4.19 shows that soil loss reaches its peak during the month of August in all the test plots. In TP1 and TP5 the amount of soil lost was also higher in the month of July. The highest soil loss i.e., around 10 tonnes per hectare was observed in TP3 with a slope of 10%.

B. Experimental plot results

The aim of building experimental plots was to compare the impact of different soil conservation measures on soil erosion and production.

Five experimental plots were built in 1988. The measurement of the fifth plot is not included in the following analysis because of its different size. The four experimental plots are situated next to each other on Cambisol/Lixisol on a slope of 31 %. Graded structures were not tested in Afdeyu because water needs to be harvested. On experimental plots the following soil conservation structures were tested versus a control plot (EP1) with no conservation structures:

- Level bund (EP2)
- Level Fanya Juu (EP3)
- Level double ditch (EP4)

Annual values

Table 4.7 Annual rainfall, erosivity, runoff and soil loss on experimental plots (1987-2001)

			EP1		EP2		EP3		EP4		EP5	
Year	Rainfall (mm)	Erosivity (J/mh)	Runoff (mm)	Soil Loss (t/ha)	Runoff (mm)	Soil Loss (t/ha)	Runoff (mm)	Soil Loss (t/ha)	Runoff (mm)	Soil Loss (t/ha)	Runoff (mm)	Soil Loss (t/ha)
1987	384.70	302.70	14.96	16.50	63.29	85.53	65.13	44.53	90.15	60.66	91.37	110.33
1988	582.90	490.98	436.77	70.81	359.28	114.25	229.53	39.04	176.20	20.94	247.01	23.80
1989	258.80	89.22	37.28	3.57	34.27	3.20	10.37	0.65	7.13	0.24	5.48	0.00
1990	244.10	159.74	65.67	10.35	90.72	8.64	15.74	1.49	8.13	0.35	7.64	0.23
1991	321.50	210.65										
1994	533.90	319.94	254.56	10.67	40.72	0.06	23.21	0.03	30.81	0.04		
1995	658.00	448.32	248.42	87.55	148.37	21.90	106.36	5.52	108.75	6.95		
1996	552.00	486.07			189.02	24.12	70.17	2.96	92.63	4.43		
1997	575.00	331.69	257.33	58.45	84.56	5.96	24.75	0.33	21.96	0.00		
1998	558.10	255.55	251.28	66.17	90.53	3.75	64.15	2.38	57.97	1.80		
1999	534.40	251.67	255.07	17.21	147.59	10.25	212.51	11.27	135.18	7.19		
2000	473.80	413.92	258.68	79.42	100.94	15.19	83.60	14.98	53.02	5.73		
2001	560.40	339.37	372.73	109.44	187.18	22.87	80.38	6.44	58.37	0.90		
Mean	**479.8**	**315.37**	**222.98**	**48.19**	**128.04**	**26.31**	**82.16**	**10.80**	**70.03**	**9.10**	**87.88**	**33.59**
SD	**133.5**	**123.27**	**132.88**	**37.43**	**89.20**	**35.82**	**71.60**	**15.22**	**52.34**	**17.27**	**113.38**	**52.36**
Median	**534.4**	**319.94**	**254.56**	**58.45**	**95.83**	**12.72**	**67.65**	**4.24**	**58.17**	**3.12**	**49.51**	**12.02**

Note:

- No data for 1991-1993.
- No EP data from 2002 onwards
- In 1996 runoff value of EP1 is higher than rainfall, thus it was excluded during data analysis.

The following graphs indicate the absolute and relative annual runoff and soil loss variation on experimental plots (1988-2001). The results of 1988-1998 were presented in Stillhardt *et al*., 2002. Thus the current report includes the results of 1999-2001.

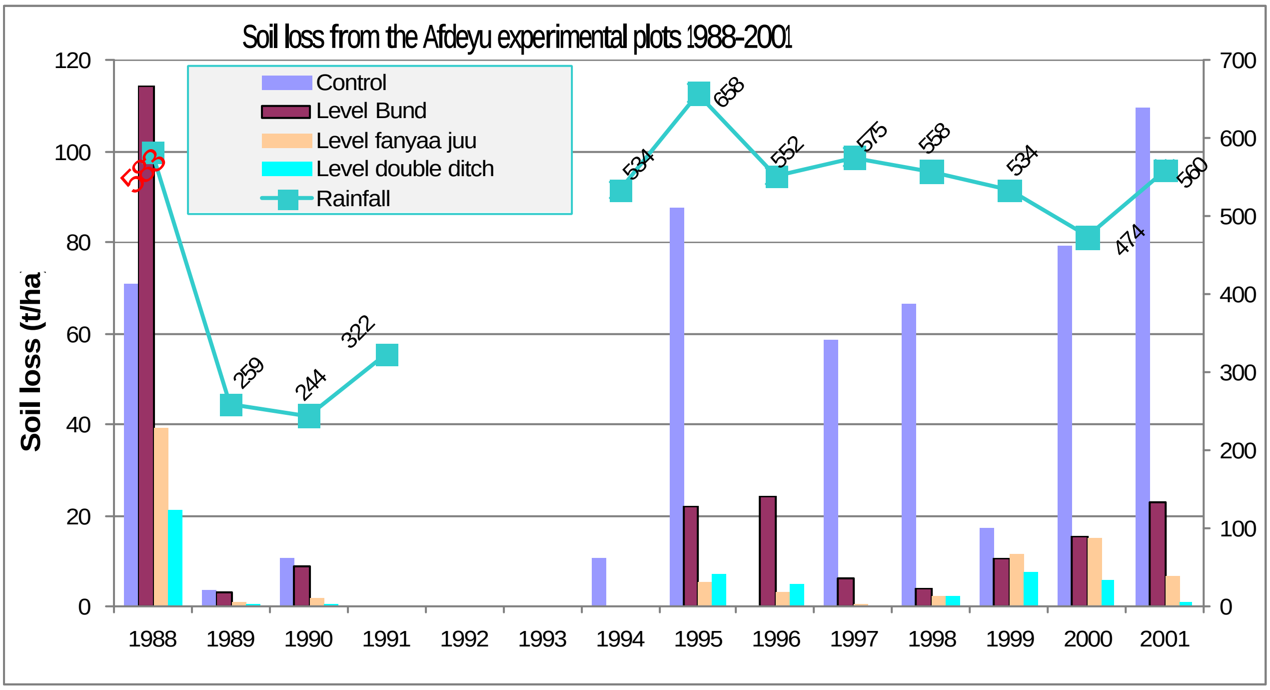


Figure 4.20 Annual Soil loss on experimental plots (1988 – 2001)

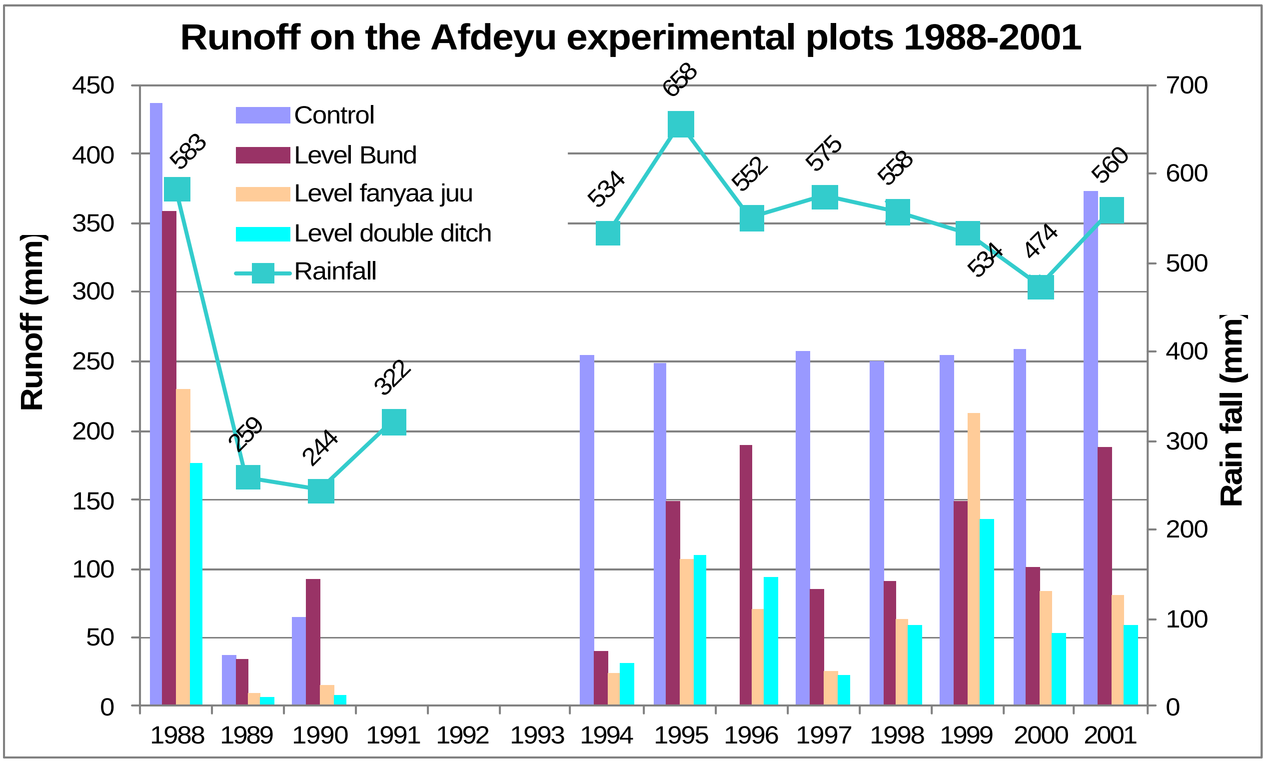


Figure 4.21 Annual runoff on experimental plots (1988 – 2001)

Table 4.8 Ranking of the different soil conservation measures in different years, showing the effects of a certain SWC structure on erosion. If two absolute amounts were similar, the same rank was set.

Year	**Control plot**		**Level bund**		**Level Fanya Juu**		**Level double ditch**	
	Soil loss	**Runoff**	**Soil loss**	**Runoff**	**Soil loss**	**Runoff**	**Soil loss**	**Runoff**
1989	3	3	4	4	2	2	1	1
21990	3	3	4	4	1	1	2	2
1994	4	4	1	3	1	2	1	1
1995	4	4	3	3	1	1	2	2
1996	4	4	3	3	1	1	2	2
1997	4	4	3	3	2	1	1	1
1998	4	4	3	3	2	2	1	1
1999	4	4	2	2	3	3	1	1
2000	4	4	2	3	2	2	1	1
2001	4	4	3	3	2	2	1	1
Total	**38**	**38**	**28**	**31**	**17**	**18**	**13**	**13**
Rank	**4**	**4**	**3**	**3**	**2**	**2**	**1**	**1**

Generally, the control plot shows the highest values of runoff and soil loss. Only during the two dry years 1989 and 1990 the loss from the plot with level bund was higher than that from the control plot. But the total amount is very small and the difference between the results of the two plots is negligible.

As it was presented in Kohler et al., (1999) and Stillhardt et al., (2002) the current result shows that in the environment of Afdeyu level bund is less effective than the other two measures. Compared with the control plot level bund also reduces soil loss and runoff, but compared with the other two measures level bund is less effective. Level double ditch reduce soil loss and runoff to a smaller amount (reaching a total of 13 points for soil loss as well as for runoff). The second effective measure was found to be level Fanya juu with a total of 17 points for soil loss and 18 points for runoff. There differences in between the two measures is not much and was not even visible on the individually scaled double mass curves done in 2002. Taking into consideration that the loss of cultivable area under *Fanya Juu* is 17 %, and under double ditch 24 % (Semere Zaid, 1998), *Fanya Juu* seems to be more promising, at least from a technical point of view. It is important to note that one bund occupy only 14 % of the cultivated area.

Monthly variation on Experimental plots

Table 4.9 Mean monthly rainfall, erosivity, runoff and soil loss on experimental plots (1987-2001)

			EP1		EP2		EP3		EP4		EP5	
Month	Rainfall (mm)	Erosivity (J/mh)	Runoff (mm)	Soil Loss (t/ha)	Runoff (mm)	Soil Loss (t/ha)	Runoff (mm)	Soil Loss (t/ha)	Runoff (mm)	Soil Loss (t/ha)	Runoff (mm)	Soil Lo (t/ha
Jan	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	5.11	0.26	0.14	0.01	0.17	0.02	0.03	0.00	0.02	0.00	0.00	0.00
Apr	25.58	11.77	2.51	0.26	0.61	0.03	0.19	0.00	0.45	0.00	0.09	0.00
May	39.79	22.74	20.46	5.88	11.52	1.59	6.13	0.32	5.32	0.49	0.08	0.00
Jun	20.59	6.33	10.35	0.83	2.10	0.07	0.85	0.02	0.89	0.00	0.19	0.00
Jul	120.42	71.69	64.38	15.08	26.16	8.16	15.84	3.09	13.03	1.92	13.39	2.72
Aug	173.38	140.96	133.96	32.08	55.23	6.83	36.30	2.86	25.92	1.20	21.40	1.14
Sep	59.87	50.28	41.21	4.91	25.89	2.42	16.99	0.80	16.56	0.43	29.76	2.15
Oct	26.99	10.53	4.61	1.75	6.27	7.20	5.78	3.71	7.80	5.06	22.96	27.5
Nov	6.51	0.80	0.45	0.04	0.09	0.00	0.06	0.00	0.04	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 4.22 and 4.23 show that the trend of monthly mean soil loss and runoff from experimental plots are similar to that of test plots and river gauge data. Soil loss reaches its highest level during August. It is observed that soil loss and runoff from the control plot was highest through out the rainy season except for the month of October that additional storm based analysis is required in the future.

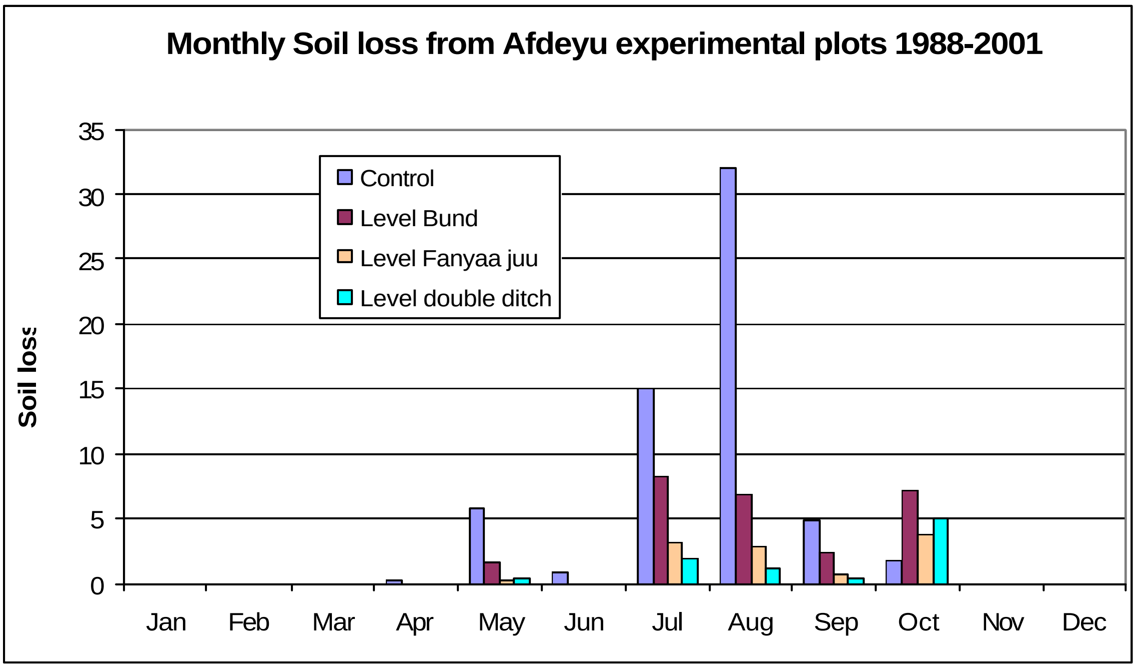


Figure 4.22 Monthly mean soil loss on experimental plots (1998 – 2001)

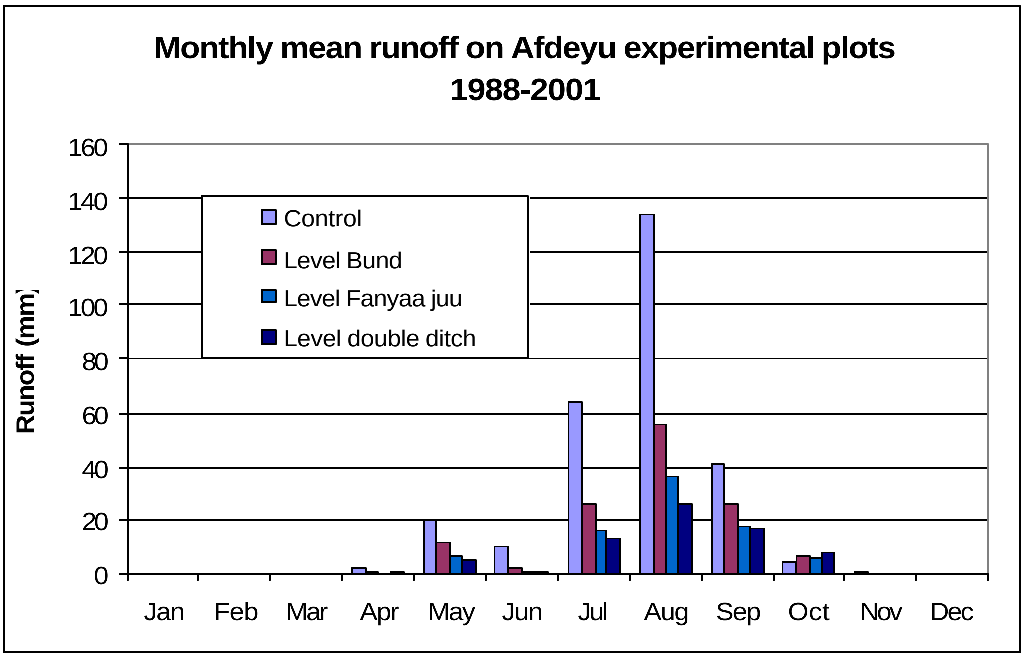


Figure 4.23 Mean monthly runoff on experimental plots (1988 – 2001)

4.3.2 Hydrometric results of the catchment

Hydrometric Station Results of the Mayketin hydrological catchment has been surveyed by Robert Burtscher in 2000. According to Burtscher the total size of the catchment is 185.0 ha, but small parts of the catchment drain along the road. This water reaches the riverbed below the measurement station and the respective area has therefore to be excluded when calculations are made. The size of the "active" catchment is then 177.2 ha. Based on the volume of the dam (broken on 07 September 1986 after intensive rainfalls), diverse SCRP measurements (rainfall amount and intensity, evaporation. discharge) and the determination of the water level – discharge - relation by Bosshart (1997), Burtscher (2000) improved the equations to calculate catchment runoff, especially for events with high runoff.

The results presented below are all based on the research results of Burtscher and might differ from the ones presented in Bosshart (1997). The improved equations to determine runoff are the following:

$Y = 0.03 * X^{2.371}$ for $0 < X = 42$ cm

$Y = 0.001 * X^{3.28}$ for $42 < X = 56.5$ cm

$Y = 0.25 * X^{2.22} – (20 * X – 250)$ for $56.5 < X = 190$ cm

(Y = flow [l/s], X = water level [m])

These equations were used to calculate runoff until 2003. In 2004 the river gauge has been reconstructed again and river discharge from 2004 onwards will be calculated after the river gauge is caliblrated.

When studying the following figures and tables one has to have in mind, that samples for calculating sediment load were only collected when water was visually classified as "brown". This results in an underestimation of the total sediment loss of about 10 – 20 % because it needs a certain density of suspended sediments to make the load visible (brown) because for small events no samples were taken.

The catchment discharge for the years 1985 – 1990 is analyzed on the basis of automatic river gauge protocols. For the years 1994 – 1998 only the hand taken sample records were available. Compared to the records of the gauging stations the manually taken sample records are about 10 % lower.

Annual Values of the Catchment Hydrological Parameters

Figure 4.21 and Table 4.10 present the annual totals of rainfall, catchment runoff and sediment load. It is evident to state that a high total amount of rainfall cause also high runoff and a higher amount of total annual sediment loss. But this may not be the case all the time that further explanations can be found only when single events are studied, including rainfall intensity, plant cover density, soil moisture, crop type, area under fallow, time span since last rainfall, etc.

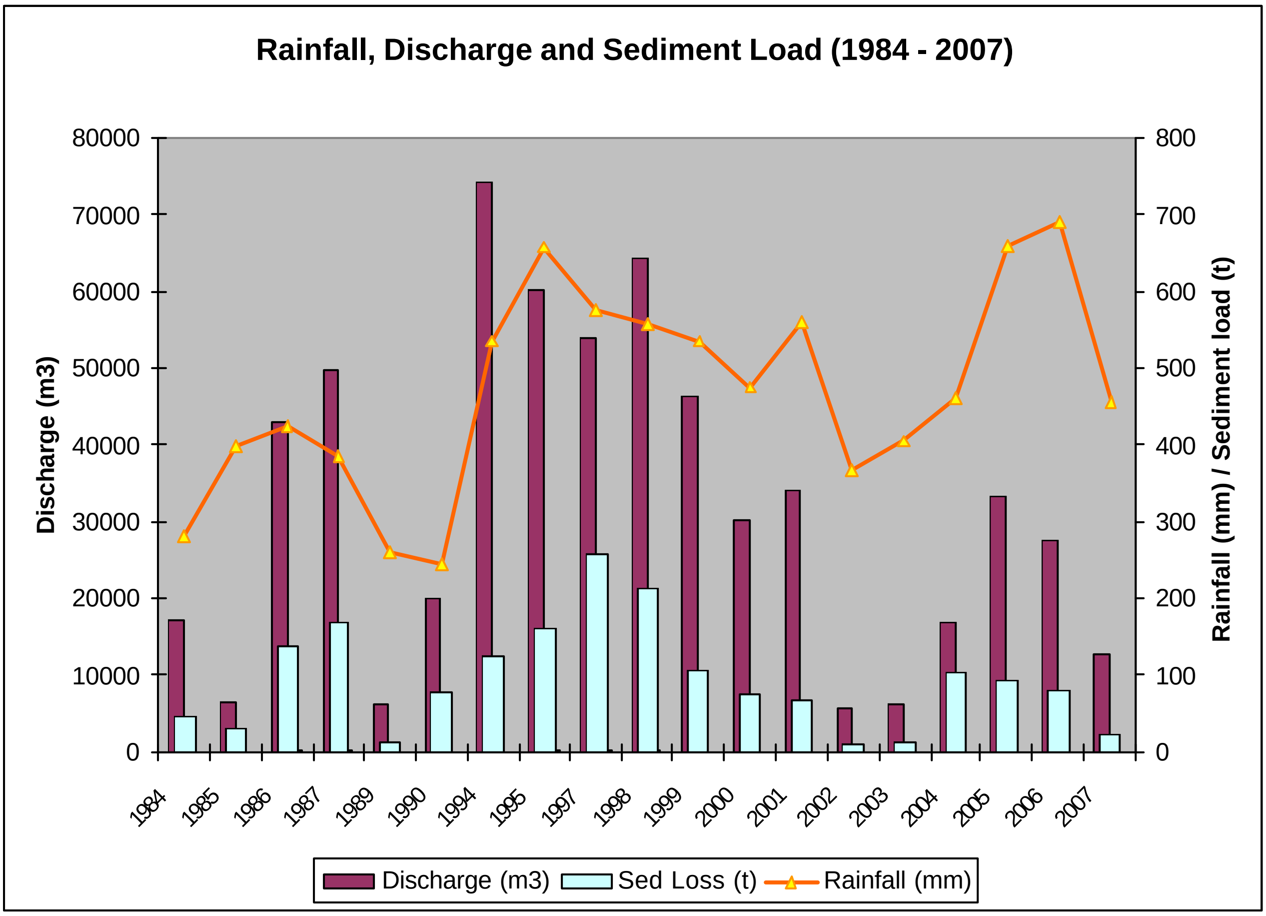


Figure 4.24 Annual rainfall, discharge and sediment load.

Table 4.10 Total annual values of the most relevant hydrological parameters (1984-2003)

Year	Total Annual RF(mm)	Total Annual Discharge (m^3)	Total Annual Drainage ratio(%)	Total Annual Sed load (t)	Total Annual Sed concentration (g/l)
1984	280.9	17,211	3.3	45.4	2.6
1985	397.7	6,532	0.9	31.1	4.8
1986	425.8	43,059	5.5	137.7	3.2
1987	384.7	49,738	7.0	168.5	3.4
1988 *	582.9	138,751	12.9	885.8	6.4
1989	258.8	6,182	1.3	12.6	2.0
1990	244.1	20,040	4.4	76.3	3.8
1994	533.9	74,188	7.5	124.2	1.7
1995	658	60,250	4.9	160.7	2.7
1996 *	552	122,795	12.0	759.1	6.2
1997	575	54,084	5.1	258.4	4.8
1998	558.1	64,203	6.2	212.1	3.3
1999	534.4	46138.81	4.7	106.2	2.3
2000	473.8	30235.62	3.4	75.4	2.5
2001	560.4	34,075	3.3	67.8	2.0
2002	298.8	5,829	1.1	11.2	1.9
2003	406.1	6,180	0.8	13.0	2.1

Note: For 1988 and 1996 RSRD data not available, thus no change is made to correct the previous values.

Here follows the graphical representation of the annual relationships among different hydrological parameters.

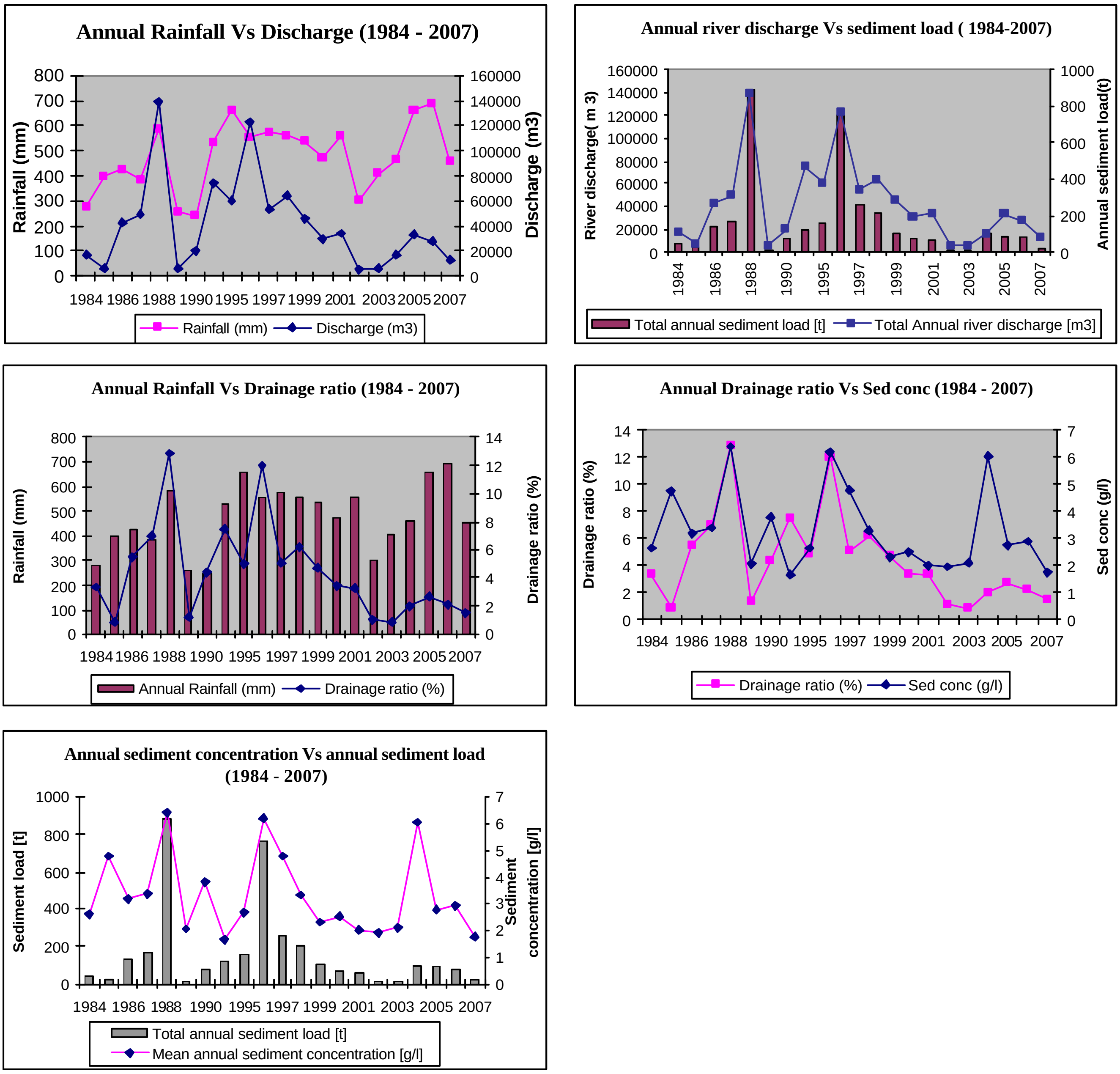


Figure 4.25 Plot of annual values of rainfall vs river discharge and discharge vs sediment load (1984-2007)

Mean Monthly Values of Catchment Hydrological Parameters

Mean monthly values of the most relevant hydrological parameters are given in Table 4.11. Looking into the data of Afdeyu, high runoff and soil loss is observed in August. This is because more rainfall amount is recorded around July and August. But since the soil is dry at the start of the rainy season, most of the rainfall seeps into the soil during the early rainfall periods causing no or low erosion amount. But later, as the area received more and more rain, it gets saturated and overland flow occurs causing more runoff and soil loss from the area.

Table 4.11 Mean monthly values of the most relevant hydrological parameters (1984-2003)

Month	Mean Monthly RF(mm)	Mean Monthly Discharge (m^3)	Mean Monthly Drainage ratio(%)	Mean Monthly Sed loss (t)	Mean Monthly Sed concentration (g/l)
Jan	0.56	0.31	0.03	0.00	0.00
Feb	1.35	1.57	0.06	0.00	1.51
Mar	6.47	0.02	0.00	0.00	0.00
Apr	23.67	598.26	1.37	1.58	2.63
May	32.67	1257.38	2.08	8.48	6.75
Jun	30.00	1059.21	1.91	7.16	6.76
Jul	122.27	6059.73	2.68	25.19	4.16
Aug	156.82	16356.41	5.64	39.15	2.39
Sep	63.24	5219.60	4.46	8.10	1.55
Oct	25.73	1286.45	2.70	4.47	3.47
Nov	7.43	154.90	1.13	0.43	2.80
Dec	0.00	18.01	214.18	0.00	0.00

N.B. Drainage ratio value of December is very high due to exaggerated amount of discharge in 2001. In Dec 2001, the RSRD chart shows a plot of water level but no rainfall is recorded in that month. Thus, it is not included in the graph.

Mean monthly Rainfall vs Discharge

It can be seen that during the small rainfall season in spring when soils are dry and freshly ploughed, a smaller percentage of the rainfall leaves the catchment compared to the situation in August, when the total amount of rainfall is high and soil moisture content is higher than in spring.

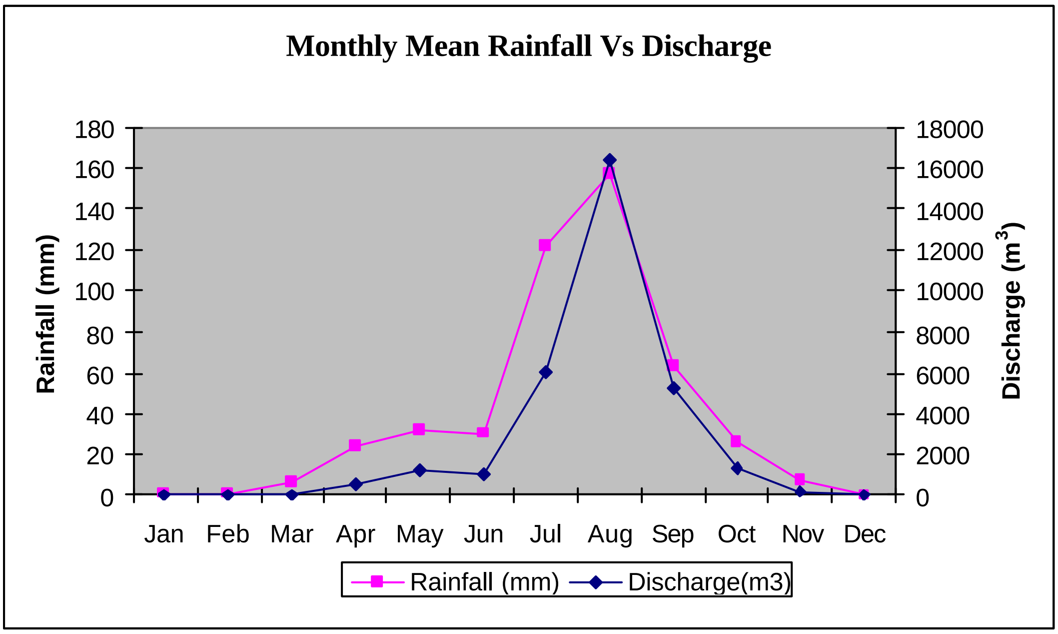


Figure 4.26 Monthly mean rainfall Vs Catcment Disharge (1984 – 2003)

Mean monthly Rainfall Vs Discharge ratio

The discharge expressed as percentage of water leaving the catchment after a rainfall event is known as drainage ratio. For single events the variability is very high, again because numerous other factors influence the catchment runoff.

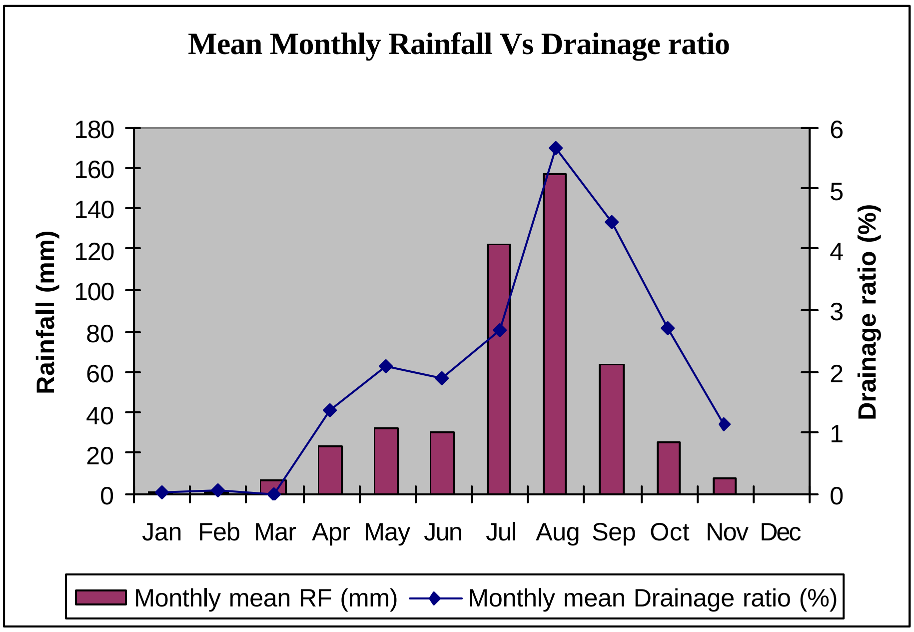


Figure 4.27 Mean monthly Discharge vs Sediment load (1984 – 2003)

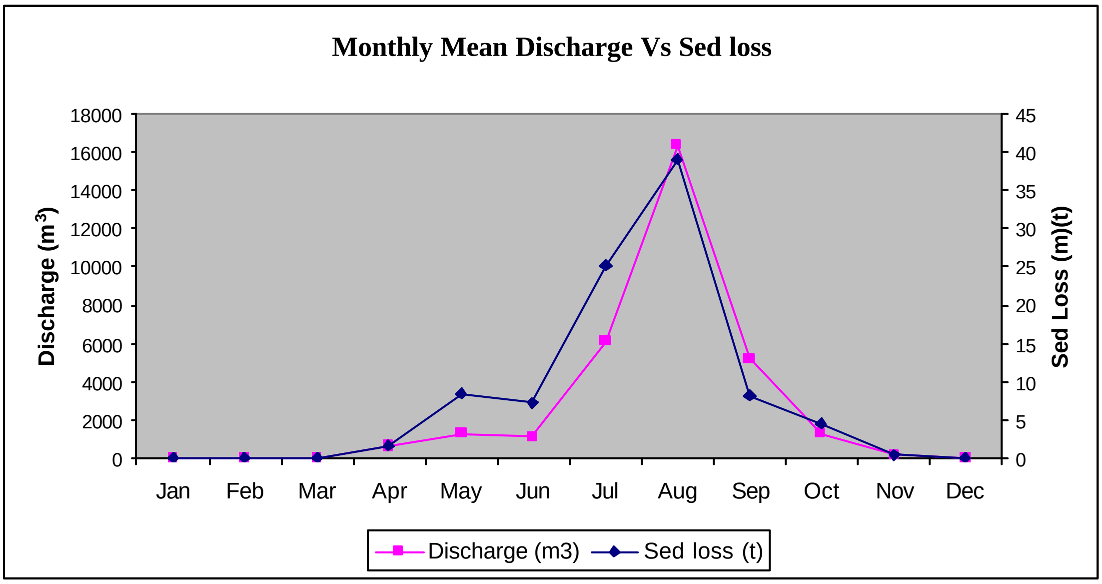


Figure 4.28 Mean monthly Catcment discharge Vs Sediment loss (1984- 2003)

Drainage ratio Vs Sediment concentration

A comparison of the mean monthly sediment concentration (gram sediment per litre runoff) with the drainage ratio shows, that in the beginning of the rainfall season, when soils are freshly ploughed and plant cover is weak, sediment concentration is high and discharge ratio low (high water demand of dry soils, generally low rainfall intensity). For the main rainfall season the picture of drainage ratio follows the picture of the rainfall amounts, but with increasing plant density the sediment concentration decreases.

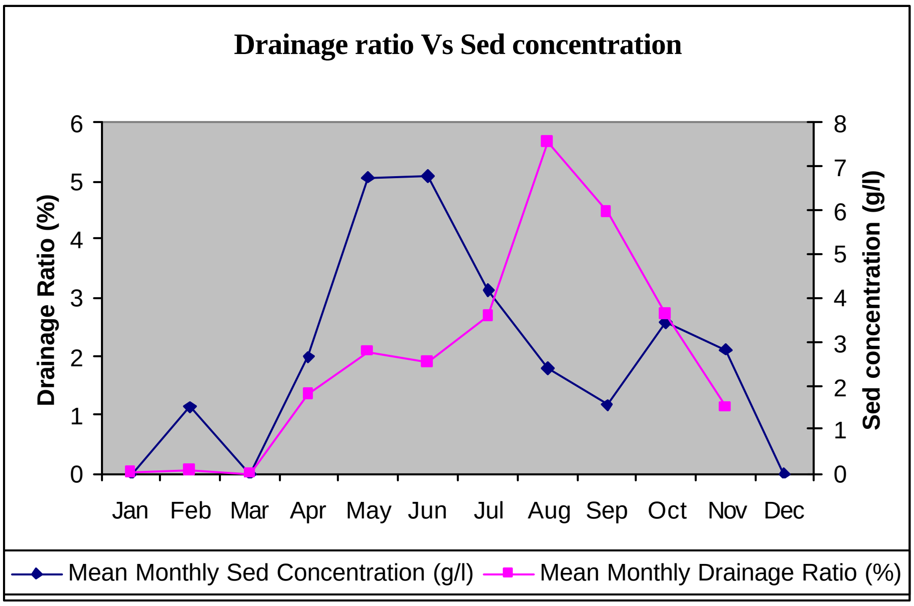


Figure 4.29 Drainge ratio vs Sediment Concentration (1984 – 2003)

Mean monthly sediment loss vs sediment concentration

The sediment loss in tons from the catchement is highest during July and August. While the highest sediment concentration (g/l) was recorded in May and June when the soils are freshly ploughed and the land is almost bare without any vegetation cover.

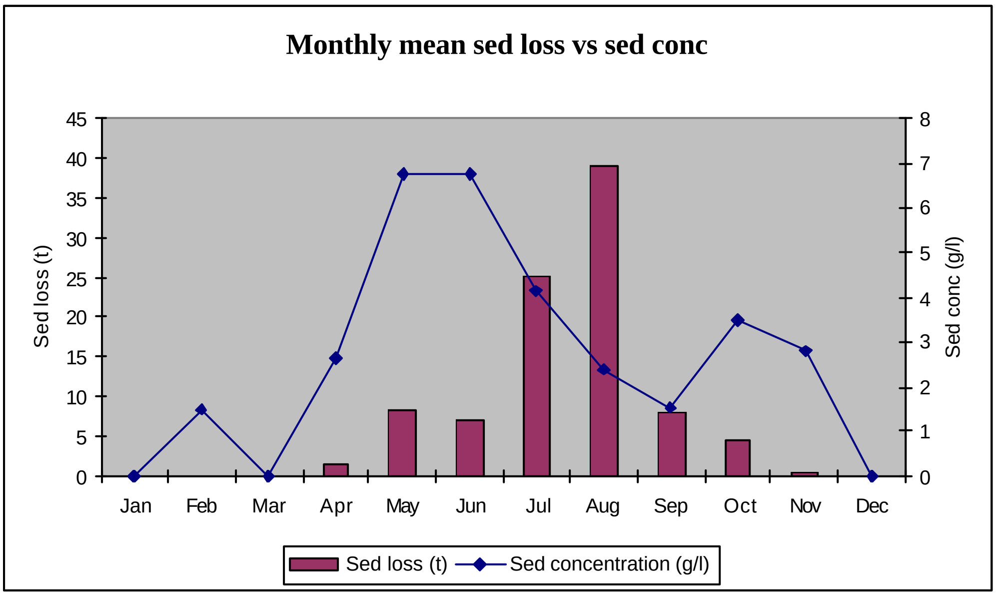


Figure 4.30 Mean monthly sediment load vs Sediment concentration (1984-2003)

Soil loss and runoff at different plot levels

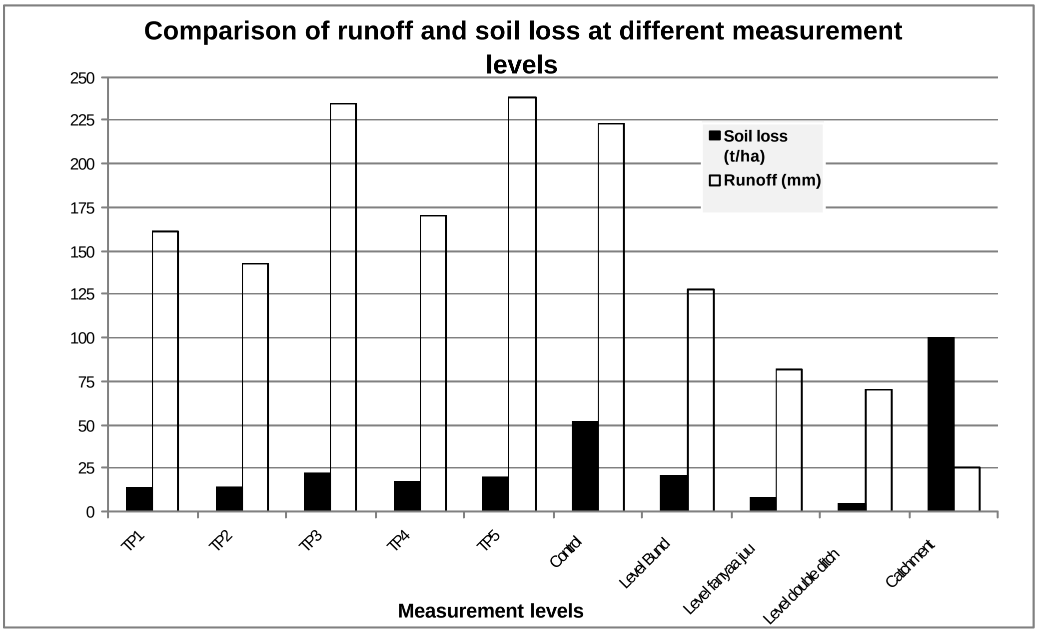


Figure 4.31 Comparison of Soil loss and runoff at the different measurement levels.

4.4 Catchment Land Use (Cropping pattern or Land use mapping)

Cropping pattern or land use is one of the parameters that is measured or assessed annually at Afdeyu research station. Cropping pattern of Afdeyu is mapped once in a year and incorporated in to the satellite image (map) as a sketch map. The satellite sketch map from the field is scanned, digitized and converted into a digital GIS data format starting from 2003. Before 2003 the cropping pattern assessment was done manually and the area coverage of crops grown was estimated based on simple sketch maps that were not georeferenced.

In the publication, "Long-term monitoring of soil erosion and soil and water conservation in Afdeyu, Eritrea (1984-1998)" prepared by Brigitta *et al.* (2002), the land use and crop production of the research catchment have been assessed and reported from 1984- 1998. As a continuation of the data collection and database updating sketch maps showing the cropping pattern of the cathment has been collected for the years 1999 and 2002 manually. Starting from 2003 the land cover mapping has been automated and is being carried out using satellite image maps and digital GIS shape files have been produced for the years 2003 to 2007. These series of digital coverages (Appendix 1) allow someone to assess or conduct any kind of research showing the effect of land cover on the measured parameters like sediment load, amount of runoff or discharge, etc., at a catchment level.

Table 4.12 Land use in percentage total cultivated in 1999 and 2002-2007

	Cereals	***Pulses***	***Oil***	***Grass***	***Fallow***	***Woodland***	***Settlement***	***Different***
1999	63.22	5.72	0.78	6.9	13.69	0.98	5.37	3.33
2002	28.95	2.71	2.11	4.98	50.55	-	6.68	3.99
2003	67.56	2.10	1.00	3.37	11.84	4.71	5.72	3.7
2004	67.83	2.95	1.05	5.42	5.73	7.88	5.65	3.49
2005	65.82	4.3	2.69	5.41	0.21	12.96	5.82	2.79
2006	19.27	1.56	0.51	2.31	65.16	2.11	6.67	2.41
2007	66.42	2.47	0.15	8.22	11.54	3.30	6.25	1.65
Average	**54.15**	**3.12**	**1.18**	**5.23**	**22.67**	**5.32**	**6.02**	**3.05**

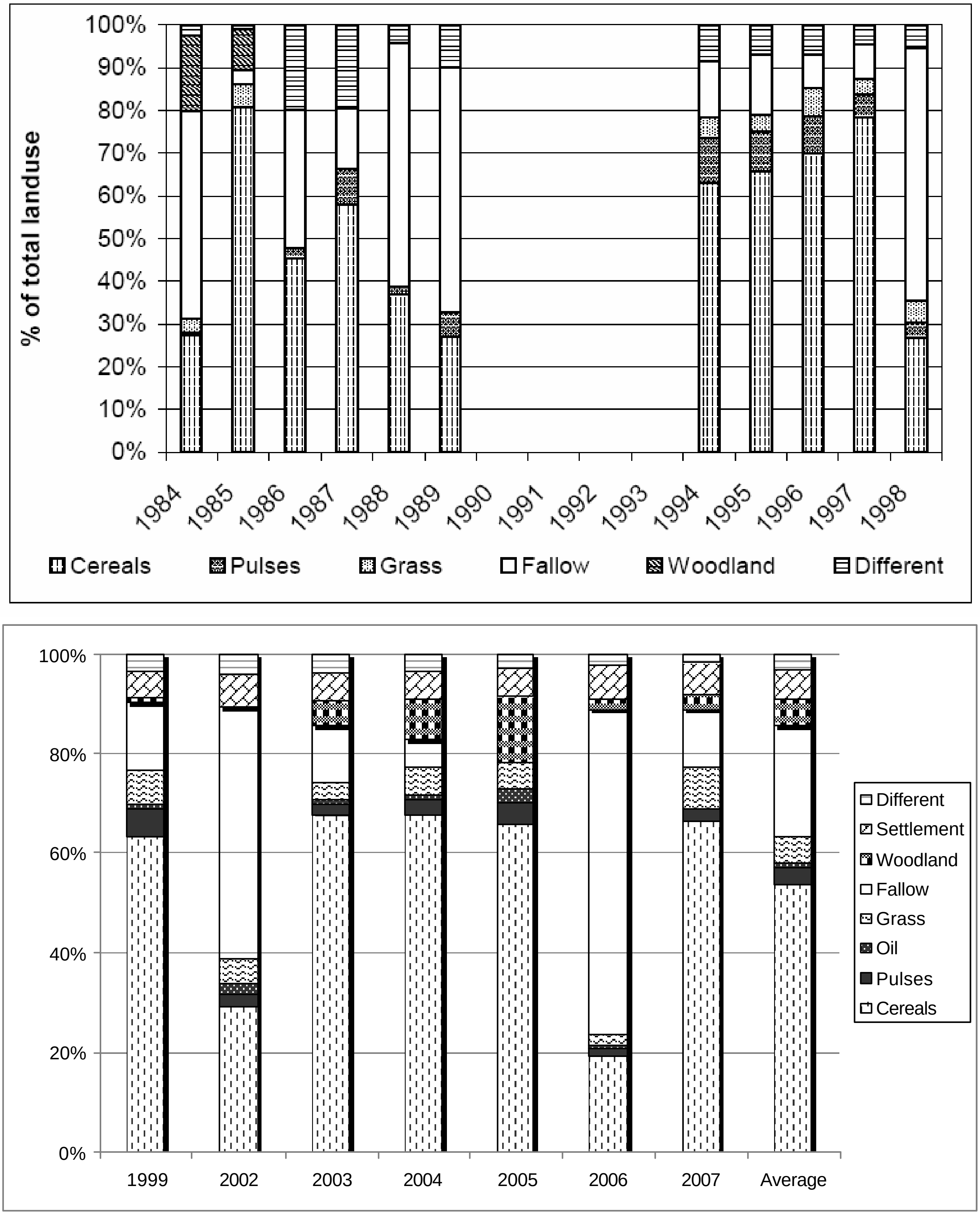


Figure 4.32 Land use in % of total cultivated a rea in 1999 and 2002 -2007

The crop yield and biomass production data is being analysed this year.

5 Summary Results

- The average annual rainfall of the 22 years is 468.7 mm. For comparison purpose, the data years are divided in two before and after 1991. After 1991 there were changes in political and institutional conditions and as a result 1992 -1993 data doesn't exist. The average annual rainfall 1984 - 1991 is 362.1mm and that of 1994-2007 is 529.7 mm, showing a difference of 167.6 mm. This indicates that there is a general increase in rainfall both in amount and number of rainy days after 1991. Generally, Afdeyu shows bimodal rainfall distribution picking in May and August, with lower values in the period from November to April and in June. About 59 % of the total annual rainfall falls in July and August (26% in July and 33.5% in August).

- Annual mean air temperature of Afdeyu is 17.4 ^{0}C. with annual minimum of 16.4 ^{0}C in 2006 and maximum of 20.2 ^{0}C in 1986. Annual minimum soil surface temperature reachesd18.2 ^{0}C in 1989 and 2006 while the annual maximum soil surface temperature was 23.7 ^{0}C in 2001and annual mean soil surface temperature of 20.3 ^{0}C.

- Generally, high rainfall intensity is observed during storms of short duration and vice versa. Looking into the data of Afdeyu, high runoff and soil loss is observed in August. This is because more rainfall amount is recorded around July and August. But since the soil is dry at the start of the rainy season, most of the rainfall seeps into the soil during the early rainfall periods causing no or low erosion amount. But later, as the area received more and more rain, it gets saturated and overland flow occurs causing more runoff and soil loss from the area.

- As it was presented in Kohler et al., (1999) and Stillhardt et al., (2002) the current result shows that in the environment of Afdeyu level bund is less effective than the other two measures. Compared with the control plot level bund also reduces soil loss and runoff, but compared with the other two measures level bund is less effective. Level double ditch reduce soil loss and runoff to a smaller amount (reaching a total of 13 points for soil loss as well as for runoff). The second effective measure was found to be level Fanya juu with a total of 17 points for soil loss and 18 points for runoff. There differences in between the two measures is not much and was not even visible on the individually scaled double mass curves done in 2002. Taking into consideration that the loss of cultivable area under *Fanya Juu* is 17 %, and under double ditch 24 % (Semere Zaid, 1998), *Fanya Juu* seems to be more promising, at least from a technical point of view. It is important to note that one bund occupy only 14 % of the cultivated area.

- Sediment load varies greatly from one year to the other, as they are linked to discharge.

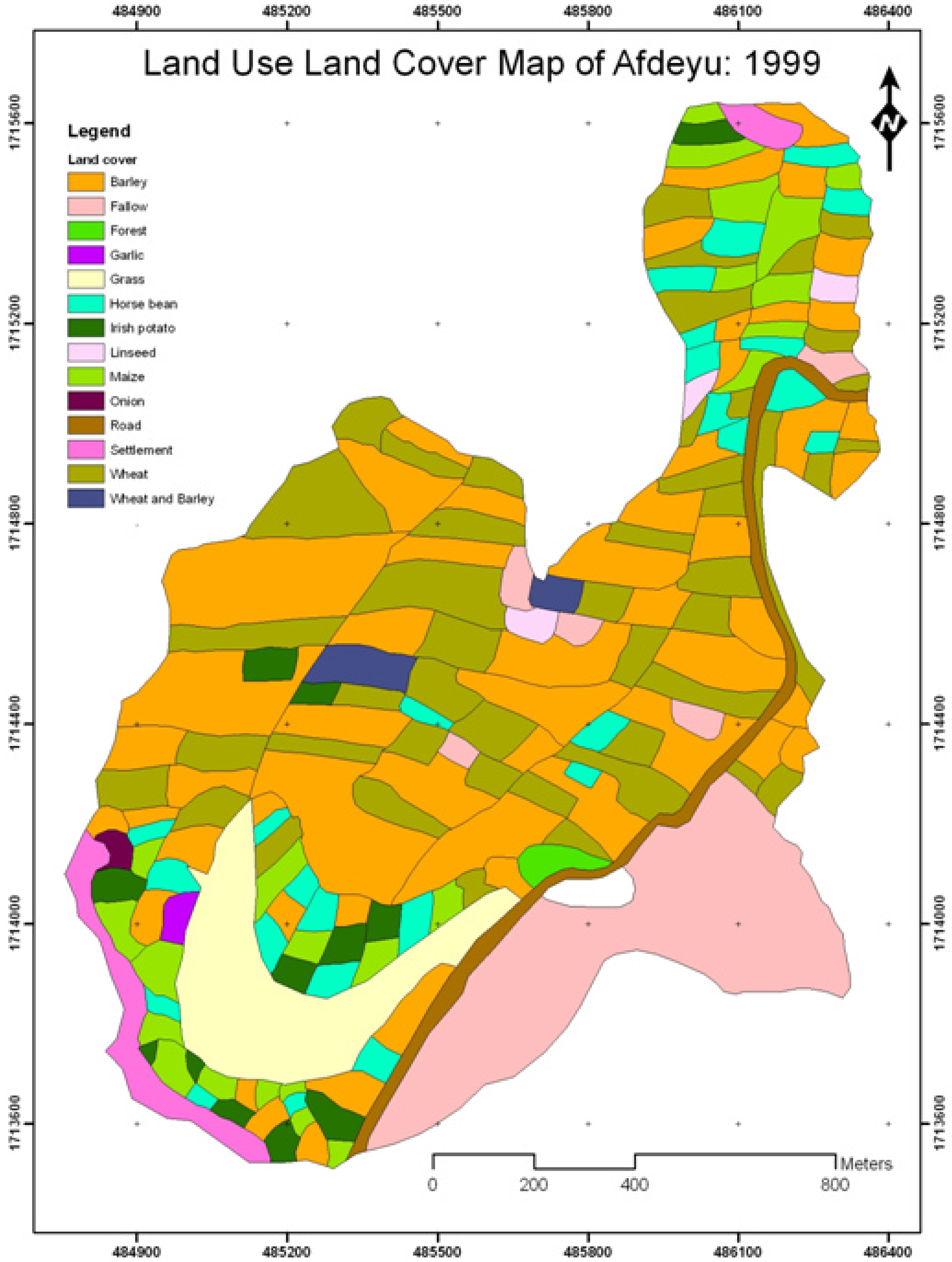
WAY FOREWORD

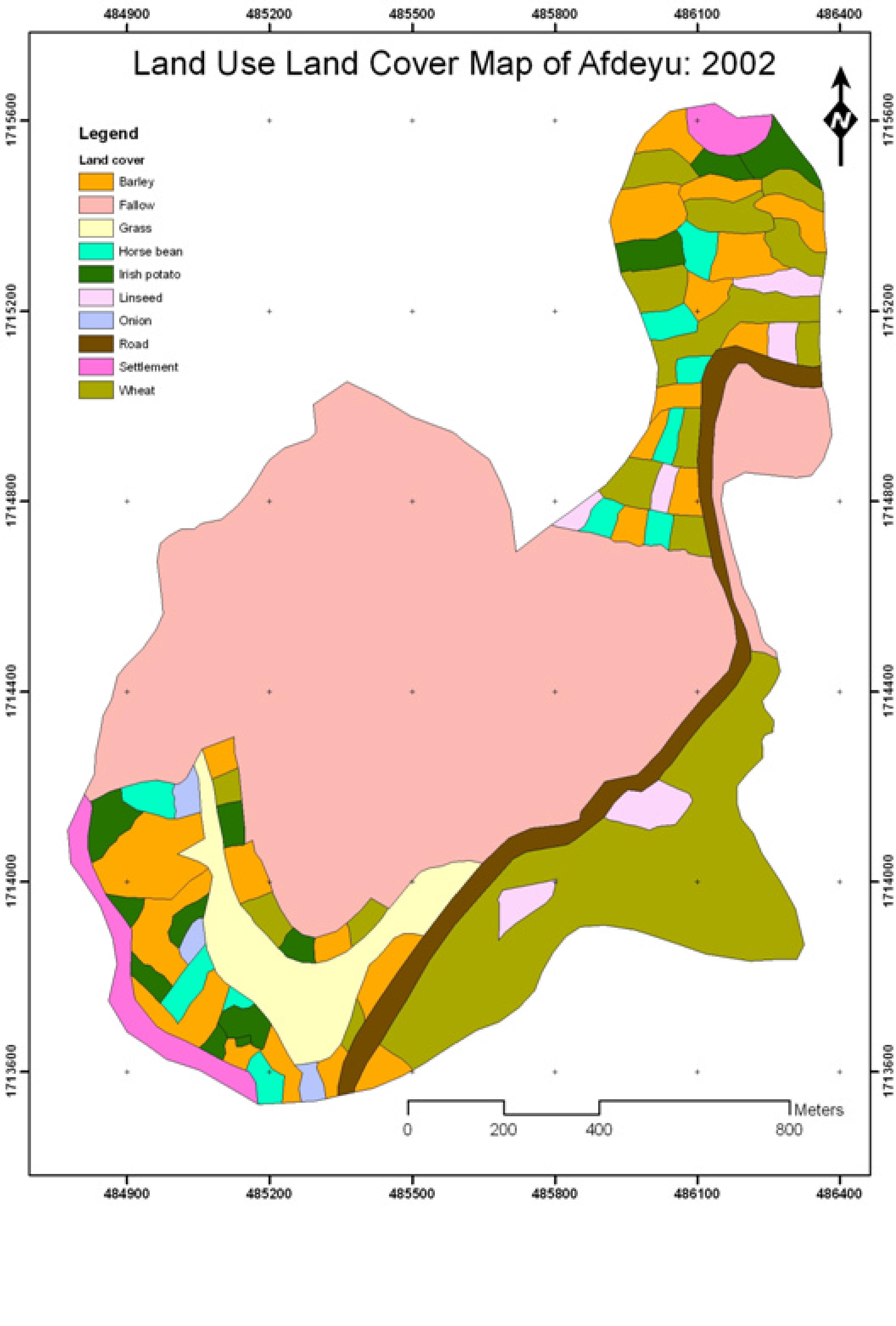
The SCRP has compiled a wealth of first-hand data on different hydrometeorological parameters; this is unique in the African context. The current progress report is provisional and needs to be modified and be done in a comprehensive way. The interpretation made sofar is very preliminary and further stormwise analysis is required. Inaddition to the data analysed and reported sofar harvest samples, growth observation and accessment of current erosion damage are being collected annually, seasonally, biweekly or stormbased. These data can be analysed and correlated with the soil loss and runoff measured from the test plot and the river gauge station.

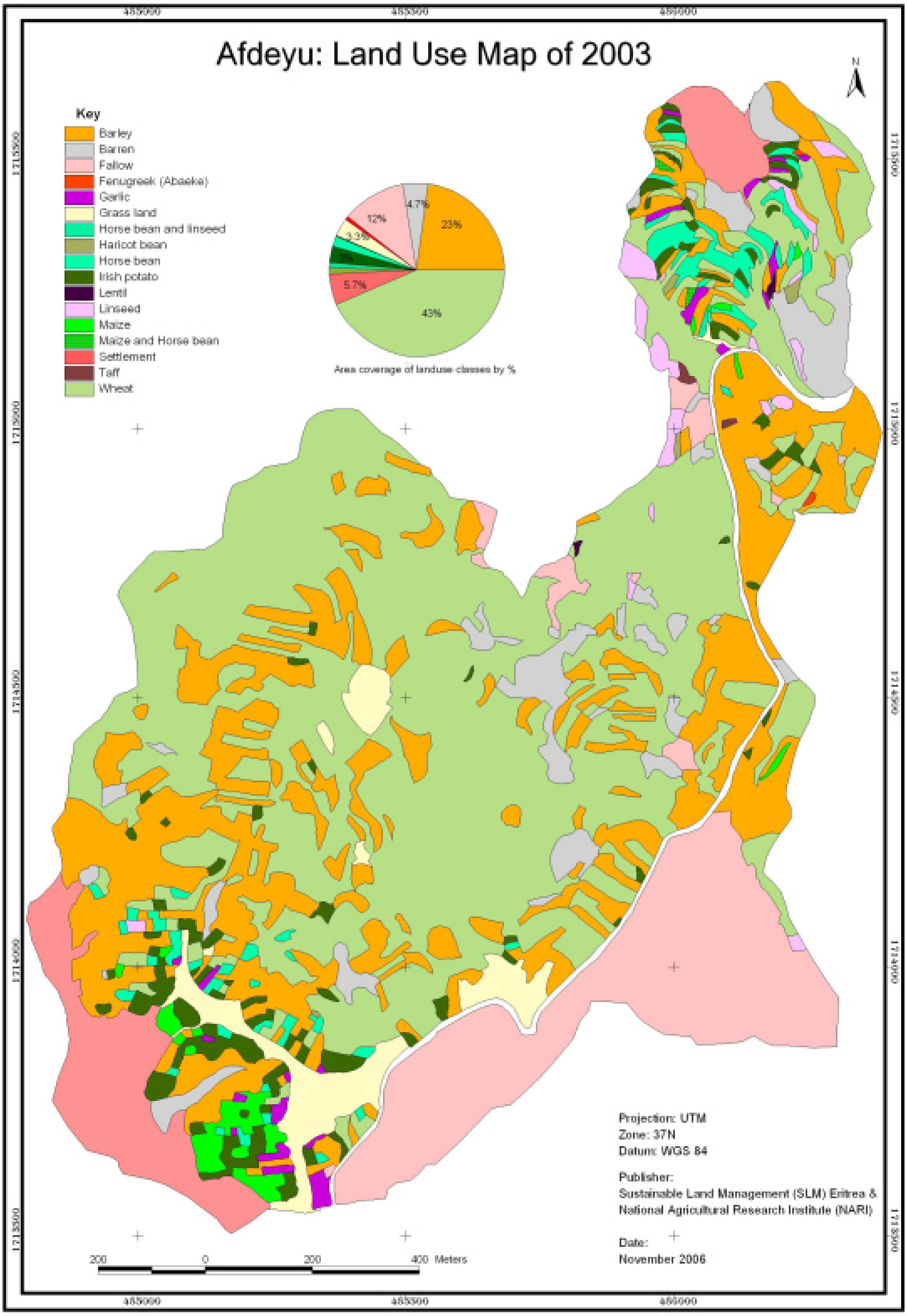
6 REFERENCES

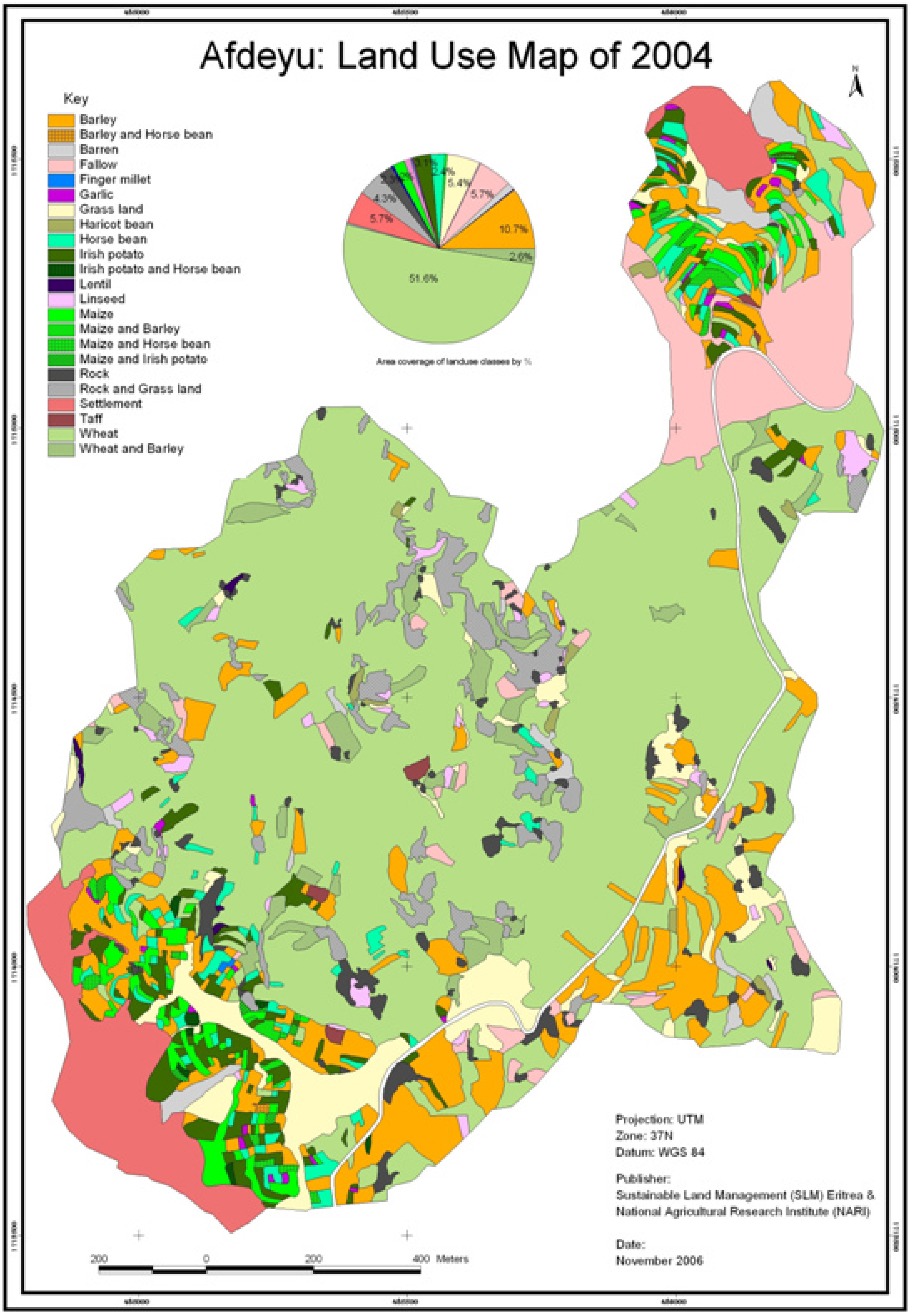
1) Afdeyu research station Activity list RA`s and Check list hand outs.
2) Bissrat, G. and Thomas Kohler. 1999. *Soil and water conservation and management in Eritrea .*Association of Eritrean in Agricultural Sciences(AEAS) & Center for development and environment (CDE), university of Berne, Switzerland.
3) Bein E. and et al. 2002.*Soil and water conservation manual for Eritrea.* RELMA, Nairobi, Kenya.
4) Glenn O. Schwab… et al.1993. *Soil and Water conservation Engineering,* forth edition. United States of America.
5) Hurni H. 1990. Degradation and Conservation of Soil Resources. In: African Mountains and Highlands. Problems and Perspectives. African Mountain Association. Missouri and Bern.
6) Hurni H. 1986. Soil Conservation. Guidelines for Development Agents. SCRP Bern and Addis Abeba
7) Manual for Data Preparation, Analysis and Interpretation of Data compiled at the Research Stations, July 2004, Version 1, University of Berne, Institute of Geography CDE – Centre for Development and Environment, Steigerhubelstrasse 3, 3008 Berne/ Switzerland.
8) Stillhardt, B., Karl Herweg, and Hans Hurni. 2002. *Long- term monitoring of soil erosion and soil and water conservation in Afdeyu, Eritrea (1984- 1998).* Center for development and environment (CDE), university of Berne, Switzerland.

7 Appendix: Land use 1999, 2002 - 2007

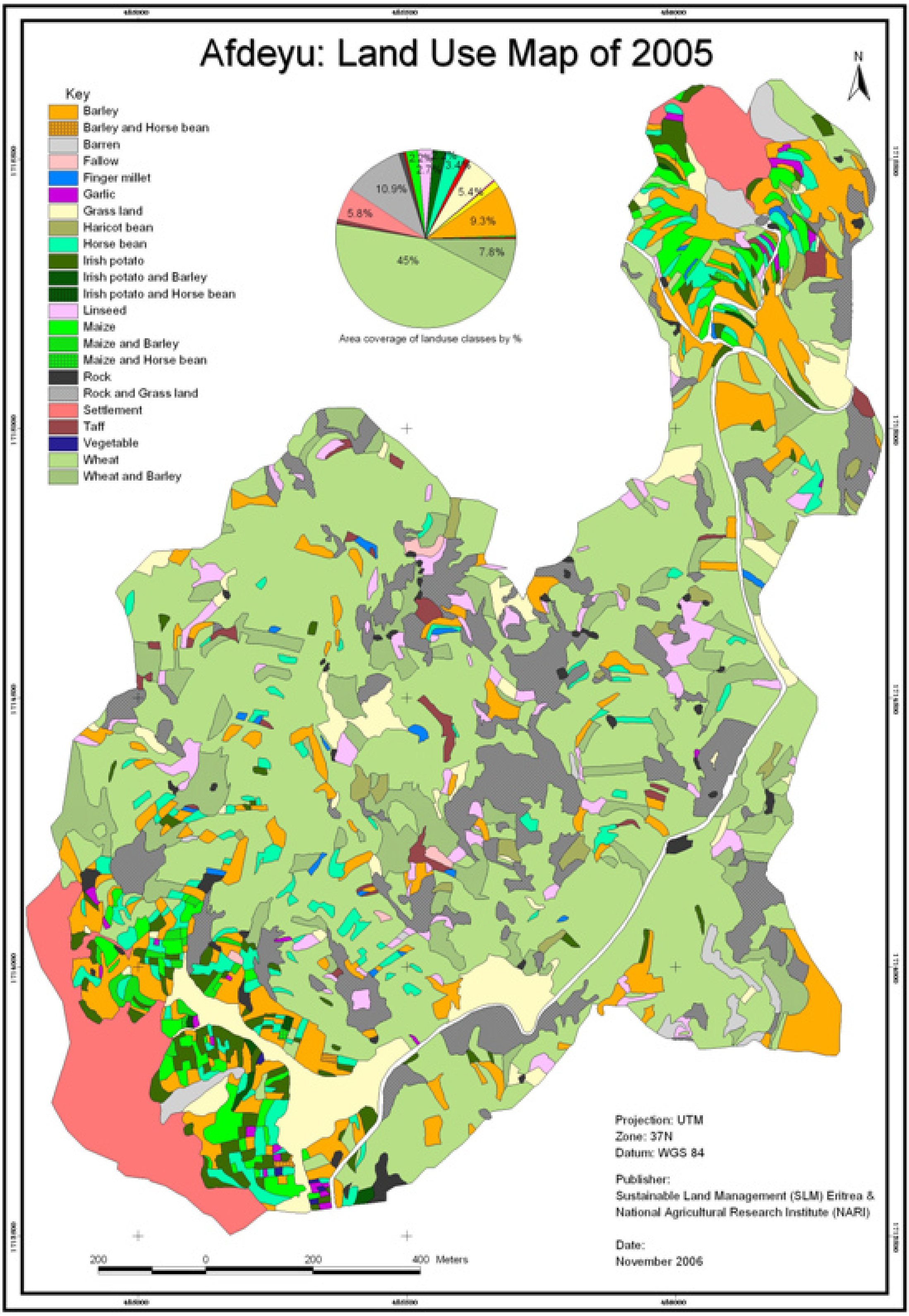



Land Use Land Cover Map of Afdeyu: 2002
Legend
Land cover
Barley
Fallow
Grass
Horse bean
Irish potato
Linseed
Onion
Road
Settlement
Wheat
N
484900
485200
485500
485800
486100
486400
1715600
1715200
1714800
1714400
1714000
1713600
0
200
400
800
Meters

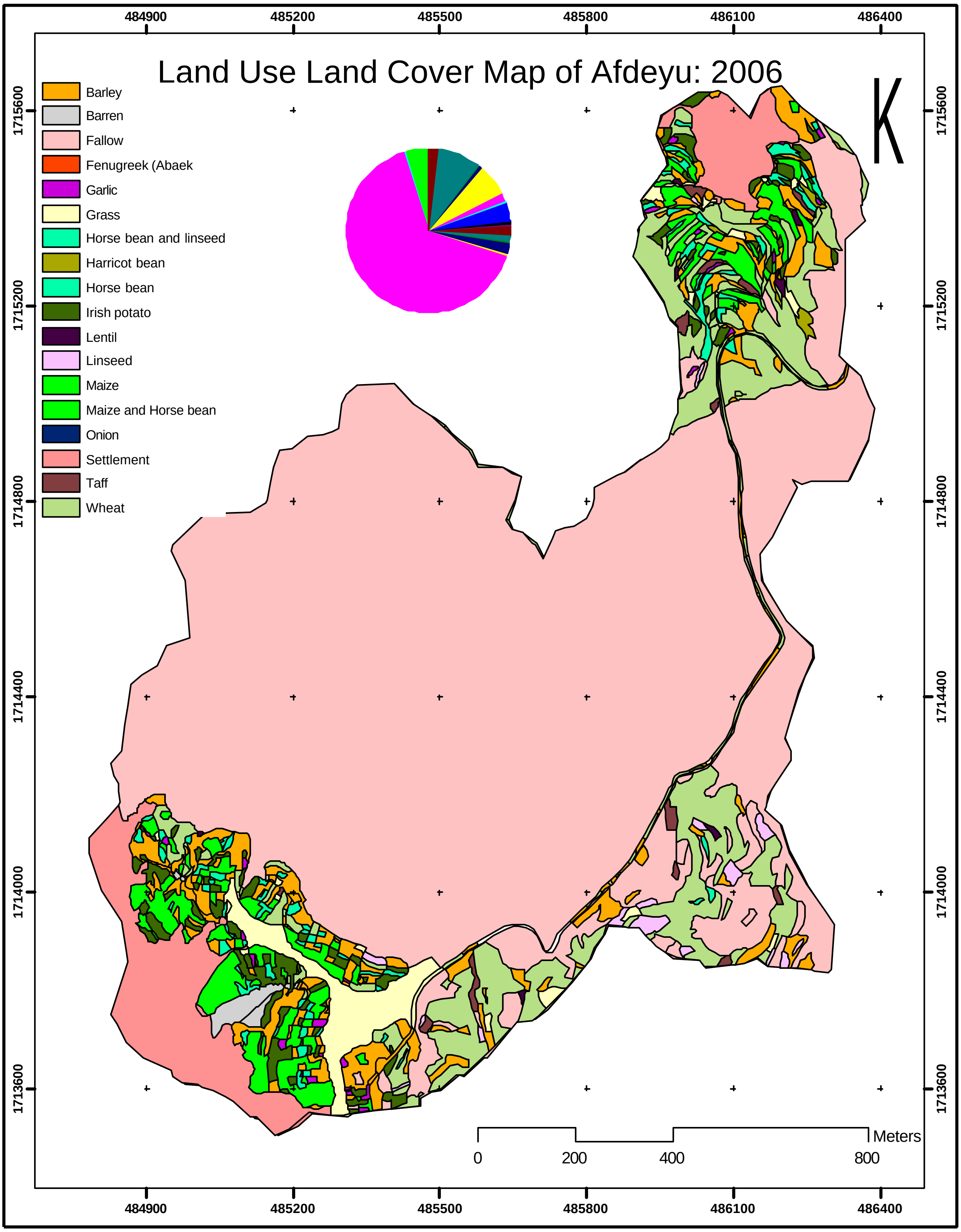

Afdeyu: Land Use Map of 2003
N
Key
Barley
Barren
Fallow
Fenugreek (Abaeke)
Garlic
Grass land
Horse bean and linseed
Haricot bean
Horse bean
Irish potato
Lentil
Linseed
Maize
Maize and Horse bean
Settlement
Taff
Wheat
4.7%
12%
23%
3.3%
5.7%
43%
Area coverage of landuse classes by %
Projection: UTM
Zone: 37N
Datum: WGS 84
Publisher:
Sustainable Land Management (SLM) Eritrea &
National Agricultural Research Institute (NARI)
Date:
November 2006
200 0 200 400 Meters



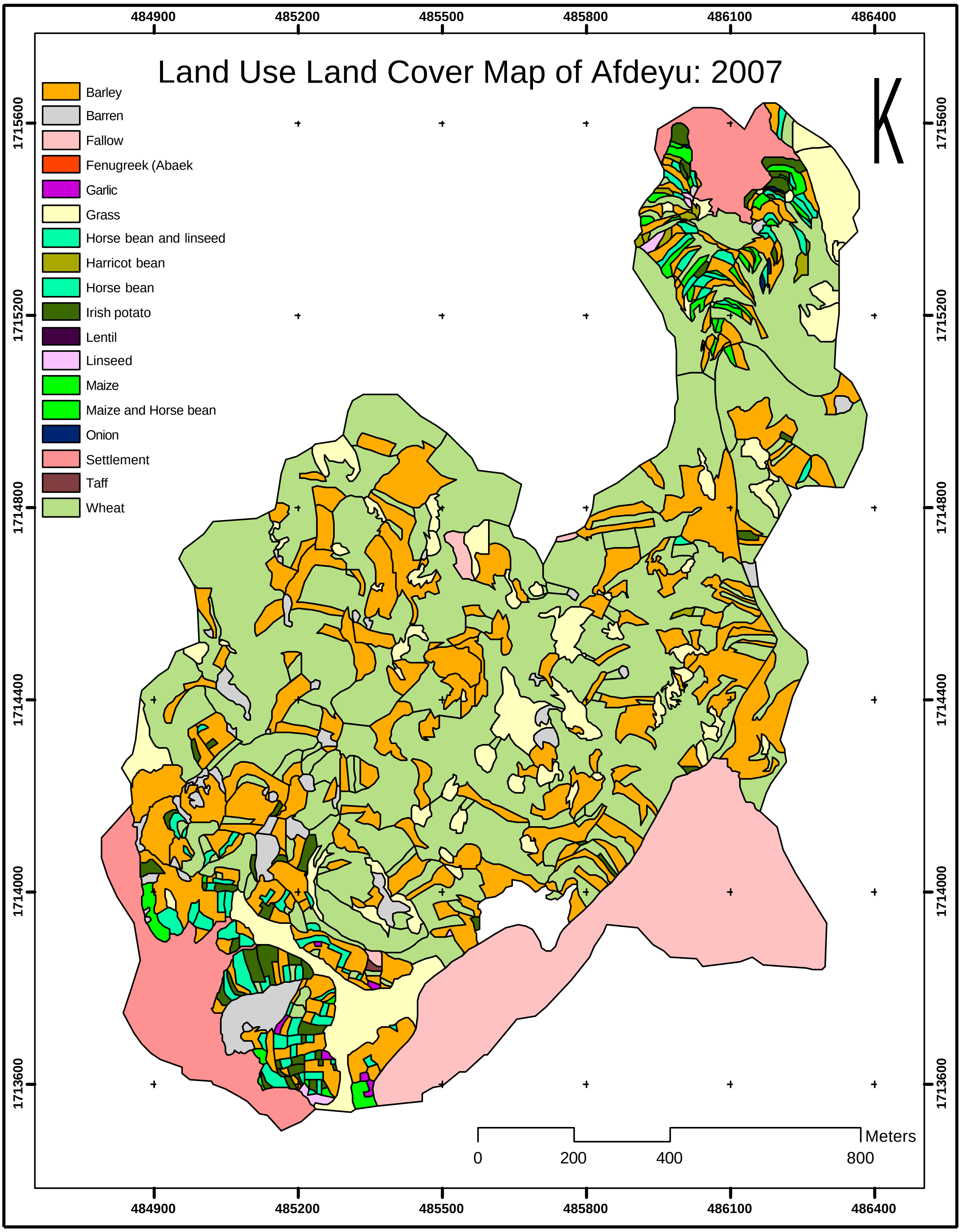
Afdeyu: Land Use Map of 2004
Key
Barley
Barley and Horse bean
Barren
Fallow
Finger millet
Garlic
Grass land
Haricot bean
Horse bean
Irish potato
Irish potato and Horse bean
Lentil
Linseed
Maize
Maize and Barley
Maize and Horse bean
Maize and Irish potato
Rock
Rock and Grass land
Settlement
Taff
Wheat
Wheat and Barley
5.4%
5.7%
10.7%
2.6%
51.6%
5.7%
4.3%
Area coverage of landuse classes by %
Projection: UTM
Zone: 37N
Datum: WGS 84
Publisher:
Sustainable Land Management (SLM) Eritrea &
National Agricultural Research Institute (NARI)
Date:
November 2006
200
0
200
400 Meters



Afdeyu: Land Use Map of 2005
N
Key
Barley
Barley and Horse bean
Barren
Fallow
Finger millet
Garlic
Grass land
Haricot bean
Horse bean
Irish potato
Irish potato and Barley
Irish potato and Horse bean
Linseed
Maize
Maize and Barley
Maize and Horse bean
Rock
Rock and Grass land
Settlement
Taff
Vegetable
Wheat
Wheat and Barley
10.9%
3.4%
5.4%
5.8%
9.3%
7.8%
45%
Area coverage of landuse classes by %
Projection: UTM
Zone: 37N
Datum: WGS 84
Publisher:
Sustainable Land Management (SLM) Eritrea &
National Agricultural Research Institute (NARI)
Date:
November 2006
200
0
200
400 Meters



Land Use Land Cover Map of Afdeyu: 2006
Barley
Barren
Fallow
Fenugreek (Abaek
Garlic
Grass
Horse bean and linseed
Harricot bean
Horse bean
Irish potato
Lentil
Linseed
Maize
Maize and Horse bean
Onion
Settlement
Taff
Wheat
484900
485200
485500
485800
486100
486400
1715600
1715200
1714800
1714400
1714000
1713600
0
200
400
800
Meters



Land Use Land Cover Map of Afdeyu: 2007
Barley
Barren
Fallow
Fenugreek (Abaek
Garlic
Grass
Horse bean and linseed
Harricot bean
Horse bean
Irish potato
Lentil
Linseed
Maize
Maize and Horse bean
Onion
Settlement
Taff
Wheat
484900
485200
485500
485800
486100
486400
1715600
1715200
1714800
1714400
1714000
1713600
0
200
400
800
Meters

Previous SLM Reports

Report 1	A Baseline Survey for Sustainable Development of the Deki Lefay Community, Eritrea (1998)
Report 2	Tradition in Transition – Aspects of Rural Livelihoods in the Eritrean Highlands. A survey for sustainable development of the Adi Behnuna community, Eritrea (2001)
Report 3	Long-term Monitoring of Soil Erosion and Soil and Water Conservation in Afdeyu, Eritrea 1984-1998 (2002)
Report 4	Small-scale Micro Irrigation in Eritrea. A feasibility study of affordable micro irrigation technology in Eritrea (2003). Available as a CDRom.
Report 5	Amadir. Livelihood and Resource Management in an Eritrean Highland Community. A development baseline (2005)
Report 6	Land Management in the Central Highlands of Eritrea. A participatory appraisal of conservation measures and soils (2006)
Report 7	Farmers' appraisal of pearl millet varieties in Eritrea I (2006)
Report 8	Farmers' appraisal of pearl millet varieties in Eritrea II (2007)
Report 9	Calibration of River Gauge at Afdeyu Station, Eritrea (2010)
Report 10	Afdeyu Research Sub-Station Hydrometeorological Data Analysis 1984-2007 (2009)

Other reports related to SLM

Soil and Water Conservation and Management in Eritrea. Current Status and Trends. Published by AEAS (Association of Eritreans in Agricultural Sciences) jointly with SLM (1999)

Irrigation Development in Eritrea: Potentials and Constraints. Proceedings of the Workshop of the Association of Eritreans in Agricultural Sciences (AEAS) and the Eastern and Southern Africa Partnership Programme (ESAPP) (2005)

Innovative Agricultural Approaches of Promoting Food Security in Eritrea: Trends, Challenges and Opportunities for Growth. Proceedings of the Workshop of the Association of Eritreans in Agricultural Sciences (AEAS), 2-3 March 2006, Asmara, Eritrea. (2007)

An Appraisal of the Current Status and the Potential of Surface Water in Upper Anseba Catchment, Eritrea. Ministry of Agriculture, SLM Eritrea, and ESAPP, Syngenta Foundation for Sustainable Agriculture, and Centre for Development and Environment (CDE), University of Bern. (2009)

syngenta foundation for sustainable agriculture

THE STATE OF ERITREA
MINISTRY OF AGRICULTURE
National Agricultural Research Institute

cde centre for development and environment