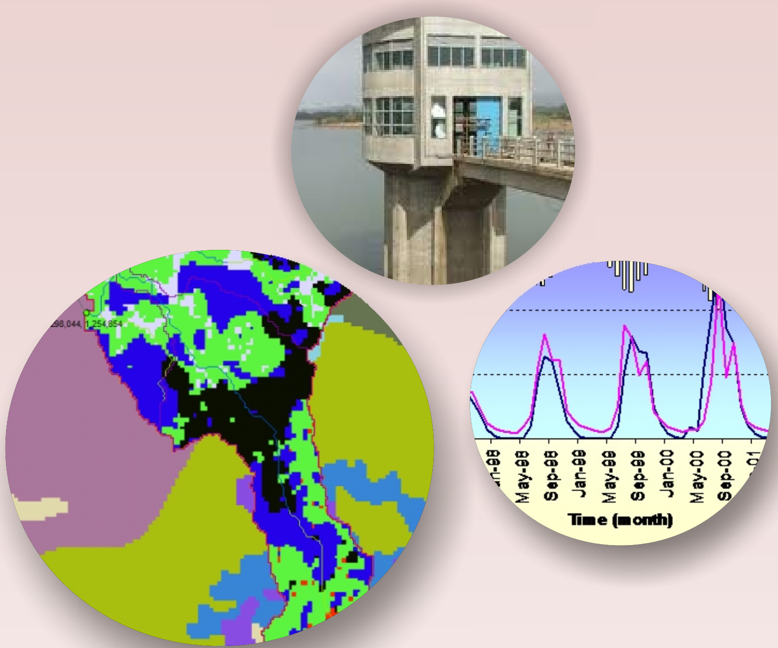
Nile Basin Capacity Building Network

2010



Effect Of Land Use/Land Cover Management on Koga Reservoir Sedimentation

NBCBN-RE

2010

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Project Title
Knowledge Networks for the Nile Basin
"Using the innovative potential of Knowledge Networks and CoP's in strengthening human and institutional research capacity in the Nile region"
Implementing Leading Institute
UNESCO-IHE Institute for Water Education, Delft, The Netherlands (UNESCO-IHE)
Partner Institutes
Nine selected Universities and Institutions from Nile Basin Countries.
Project Secretariat Office
NBCBN-SEC office, Hydraulics Research Institute – Cairo - Egypt
Beneficiaries
Water Sector Professionals and Institutions in the Nile Basin Countries

Short Description

The idea of establishing a Knowledge Network in the Nile region emerged after encouraging experiences with the first Regional Training Centre on River Engineering in Cairo since 1996. In January 2002 more than 50 representatives from all ten Nile basin countries signed the Cairo Declaration at the end of a kick-off workshop was held in Cairo. This declaration in which the main principles of the network were laid down marked the official start of the Nile Basin Capacity Building Network in River Engineering (NBCBN-RE) as an open network of national and regional capacity building institutions and professional sector organizations.

NBCBN is represented in the Nile basin countries through its nine nodes existing in Egypt, Sudan, Ethiopia, Tanzania, Uganda, Kenya, Rwanda, Burundi and D. R. Congo. The network includes six research clusters working on different research themes namely: Hydropower, Environmental Aspects, GIS and Modelling, River Morphology, flood Management, and River structures.

The remarkable contribution and impact of the network on both local and regional levels in the basin countries created the opportunity for the network to continue its mission for a second phase. The second phase was launched in Cairo in 2007 under the initiative of; Knowledge Networks for the Nile Basin. New capacity building activities including knowledge sharing and dissemination tools, specialised training courses and new collaborative research activities were initiated. The different new research modalities adopted by the network in its second phase include; (i) regional cluster research, (ii) integrated research, (iii) local action research and (iv) Multidisciplinary research.

By involving professionals, knowledge institutes and sector organisations from all Nile Basin countries, the network succeeded to create a solid passage from potential conflict to co-operation potential and confidence building between riparian states. More than 500 water professionals representing different disciplines of the water sector and coming from various governmental and private sector institutions selected to join NBCBN to enhance and build their capacities in order to be linked to the available career opportunities. In the last ten years the network succeeded to have both regional and international recognition, and to be the most successful and sustainable capacity building provider in the Nile Basin.

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FOREWORD

This report is one of the final outputs of the research activities under the second phase of the Nile Basin Capacity Building Network (NBCBN). The network was established with a main objective to build and strengthen the capacities of the Nile basin water professionals in the field of River Engineering. The first phase was officially launched in 2002. After this launch the network has become one of the most active groupings in generating and disseminating water related knowledge within the Nile region. At the moment it involves more than 500 water professionals who have teamed up in nine national networks (In-country network nodes) under the theme of "Knowledge Networks for the Nile Basin". The main platform for capacity building adopted by NBCBN is "Collaborative Research" on both regional and local levels. The main aim of collaborative research is to strengthen the individual research capabilities of water professionals through collaboration at cluster/group level on a well-defined specialized research theme within the field of River and Hydraulic Engineering.

This research project was developed under the "Cluster Research Modality". This research modality is activated through implementation of research proposals and topics under the NBCBN research clusters: Hydropower Development, Environmental Aspects of River Engineering, GIS and Modelling Applications in River Engineering, River Morphology, flood Management, and River structures.

This report is considered a joint achievement through collaboration and sincere commitment of all the research teams involved with participation of water professionals from all the Nile Basin countries, the Research Coordinators and the Scientific Advisors. Consequently the NBCBN Network Secretariat and Management Team would like to thank all members who contributed to the implementation of these research projects and the development of these valuable outputs.

Special thanks are due to UNESCO-IHE Project Team and NBCBN-Secretariat office staff for their contribution and effort done in the follow up and development of the different research projects activities.

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The researchers are highly indebted to NBCBN-SEC which made it possible to carry out this research. The research focused on the application of SWAT on Koga Watershed. This watershed drains to Koga reservoir which is expected to irrigate 7000 hectares of land. It is a newly built dam/reservoir. Land use/land cover changes are hypothesised to affect the sedimentation rate of the reservoir. It was attempted in the Koga Watershed Model to simulate two scenarios where the forest cover was removed and replaced by pasture land. However, for this case no significant changes were observed. This first attempt of a model could be used as a useful tool to track the land use/land cover changes and/or related issues like water quality.

The research did not include field data collection. However, Koga watershed management project is currently underway by the Ministry of Water Resources. As field data is made available, this model could be rerun for validation.

The research has focused on the effect of land use land cover change on reservoir siltation. Koga Reservoir siltation and/or sedimentation will occur unless a corresponding and appropriate upland watershed management interventions are carried out in time. The reservoir useful time might be shorter than the design period due to siltation which is a slow and gradual process. The watershed management intervention include among others a land use/land cover change which will effect a reduced sheet and gully erosion due to overland flow.

The research question was that if the settlers in the upland catchment try to change the land use/land cover during the service life of the reservoir, then the sediment yield will also vary. But the extent of variation from the base case is not clearly known and hence it is to be estimated. The base case for the land use/land cover is obtained from the baseline maps. In here, it was attempted to change the land use/land cover for two cases. SWAT model is deployed as a watershed model to investigate the problem of land use/land cover changes.

In the first scenario, FRSE (Forest ever green) and FRST (Forest mixed) are changed by SHRB (shrub land). In this case, there was no change in sediment yield in the channel. In the second scenario, the FRSE (Forest ever green) and FRST (Forest mixed) are changed by Dry land, crop land pasture. In this case, the sediment yield in the channel decreased on average by 3 metric tonnes per day.

Since it is expected that the forest covers might be removed in search of land, it was only attempted to change the forest cover. However, the forest cover covers only 8 percent of the total catchment. Hence, it is concluded that the removal of the forest shall have no effect on the siltation of Koga reservoir.

MoWR	Ministry of Water Resources
SWAT	Solid and Water Assessment Tool
CO-SAERAR	Commission for Sustainable Agriculture and Environmental Rehabilitation for Amhara Region

1
INTRODUCTION

Artificial lakes created by dams are used to store water for irrigation, water supply, recreation and other purpose when needed. The construction of dam water storage changes dramatically the hydrodynamics of the river with direct consequences on the river morphology, habitat and ecology of the whole river system. One major change with direct consequences on the river system is the formation sediments storage at the head of the reservoir to form delta deposition. Suspended sediments are further transported by density currents through the old river channel in reaching at the end the dam section

The project area is cultivated for one rainy season per year and the agricultural production is highly dependent on the amount and duration of the rainfall. Realizing the problem, the construction of dams for irrigation has been a priority for the Government for the last decade to be self sufficiency for food. Due to this, some micro earth dams are constructed by Commission for Sustainable Agriculture and Environmental Rehabilitation for Amhara Region (CO-SAERAR) for irrigation purpose. But most of them are not functional as planned due to sedimentation problem. This is mainly due to insufficient and less reliable sediment yield data, which have been collected for the projects. Such data are, however, crucial when designing new reservoirs.

Koga irrigation and watershed management project contribute towards poverty reduction among smallholders through improvement in food security in the Region in particular, and the country as a whole, consistent with the government's policies of sustainable environment and agricultural development. The reservoir has a capacity to impound a total volume of 83.1 million cubic meter of water for irrigation of 6,500ha command area. The project improves rain fed agriculture, forestry, livestock, water and soil conservation, and sanitation for 22,000 ha of catchment area.

Koga River is located in the Blue Nile Basin. In recent years, an irrigation project is implemented through diverting water from this river. A reservoir, Koga Reservoir, is constructed for this purpose. The size of command area is estimated at 7000 ha. The livelihood of the small scale land holders in the area depends on the water harvested in this reservoir. Hence, it is timely to investigate if Koga reservoir looses its water storage capacity through time through siltation because of human intervention in the Koga catchment.

1.1 SWAT Model Development

The main aim of this research is to simulate, calibrate and validate the SWAT model in order to extract and visualize the sediment yield in the catchment. To do so the following general steps were followed, namely,

1. data collection
2. Model setup.
3. model simulation, calibration and validation
4. Result analysis.

1.2 Literature Review

1.2.1 General

Modeling and simulation are of scientific methods developed to provide customized solutions through identifying a variety of processes within a system to through mathematical models incorporated into versatile software tools.

The rainfall-runoff-transport process is a component of the hydrologic and hydraulic modeling system; therefore, it is a valid approach to develop either 'detailed models" serving a wide range of modeling requirement, or "parsimonious models" meeting a specific requirement. Since rainfall data is generally in abundance as compared to runoff data, the attempt has always been to convert rainfall to runoff. The runoff data shall be used as an agent for the transport of sediment in various forms on catchment surface, in rivers and/or lakes. Hence, the runoff data provide input to the various transport models and river/lake morphological models.

1.2.2 Previous Studies

Lake Tana sub-basin is one of the growth corridors identified to accelerate overall development in Ethiopia. Currently, irrigation projects are underway which will serve the farmers increase their productivity. This is possible through planting of high-value cash crops since sufficient water will be made available from the newly designed reservoirs. Irrigation dams on Megech, Ribb, Koga, Jemma, Gilgelaby and Gumera rivers serve the purpose of irrigating land in the order of thousands of hectares.

The hydrology of these reservoirs have been studied the detail of which serves the project objectives. No single detailed rainfall-runoff model have been found found out in the project documents. Flood modelling has been carried out by depolying HEC-HMS. The sedimentation rate has been computed using empirical formulas.

Gilgelabbay basin, the basin in which the Koga Subbasin is located, has not been explored in detail yet. Gragne (2007) conducted modelling on the Gilgelabay basin. The model performance result, in particular, the coefficient of determination obtained was 0.79 and 0.84 during calibration and validation for the gauging station at Gilgelabbay river, and 0.63 and 0.62 for Koga subcatchment. Deginet (2008) also conducted in the catchment using TOPMODEL. The model was applied to simulate outflows from the catchment and to predict spatial and temporal soil moisture dynamics and variable source areas in space and time. Digital elevation models (DEMs) of grid cell sizes from 30m to 500m have been also used to test the effect of DEM grid cell size variation in the derived topographic index and hydrologic simulations. The model is found to perform satisfactorily with Nash-Sutcliff efficiency of 78% for the 90m resolution DEM. He found out that grid size affects the distribution of topographic index significantly averaging effects on lower values and by increasing mean values as the DEM resolution gets coarser. This effect on the topographic index is also found to propagate in the hydrologic simulations and model efficiency. For the range of DEM grid sizes used for the study (60m to 500m), model efficiency was found to degrade slightly (1.83%) when DEM grid cell size increases from 60m to 500m by using the same calibrated parameters. Internal model predictions, such as overland flow component of the total runoff, the percentage of predicted variable source areas, have also been shown to be affected significantly. Larger grid cell sizes have been found to exaggerate the overland flow component of the total runoff. When the DEM grid cell size increases from 60m to 500m, the percentage of overland flow component of the total runoff increases from 9 to 22.9%. Increase in grid size also has been shown to increase the percentage of predicted variable source areas. While DEM grid size was increased from 60m to 500m the percentage of variable source areas predicted to be fully saturated was found to increase from 5.77% to 27.33% s respectively at the peak flow rate.

Conway (1997) studied a grid – based water balance which requires limited data input, few parameters, and runs on a monthly time step in the upper Blue Nile. Conway calibrated his model to run over a 37 year period (1953 – 1987) and validated to simulate subcatchment runoff and historical variations in the basin. He produced 74% correlation factor between observed and simulated annual flows over 76 years with mean error of 14%. This model was used to investigate the sensitivity of runoff to changes in rainfall and potential evapotranspiration. None of these authors dealt with sediment delivery estimation. Hence, this research addresses this missing task in sufficient detail.

1.3 Reservoir Sedimentation Prediction

The engineering interest in reservoir sedimentation is primarily concerned with three physical aspects: total volume of trapped sediment, spatial distribution of deposit volume and sediment load carried by flow releases including its particle size distribution. The volume of deposit represents the loss of storage capacity which reduces the efficiency of a reservoir to regulate flow. The distribution of deposits determines the relative impact of trapped sediment on the usable storage as well as the prospect of flushing it.

Methods used to predict various aspects of reservoir sedimentation can be broadly classified in to two: *empirical methods* and *mathematical models*. Empirical methods can be methods based on trap efficiency and methods based on sediment distribution whereas the mathematical models solve the governing equations of transport and momentum.

.Empirical methods are based on observation and field measurements made on reservoirs. These methods are simple, low precision and accuracy, limited application, require less data; but can be useful for preliminary estimation purposes or helpful in the feasibility design stage of reservoirs.

The watershed modelling attempt here serves to present a sound basis for land use/land cover planning. Previously, modeling the reservoirs has been carried out using zero dimensional, one dimensional, two dimensional and three dimensional models by various authors (Mulatu(2007), Gebrewubet (2005), Campos (2001), Gessesse and Gebrewubet (2007). However, these models respond to the bed material transport rather than the washload which is estimated using SWAT. The washload is expected to influence the suspended load in such a way that the fall velocity, turbulence parameters, concentration profiles are affected. Hence, through coupling SWAT with reservoir sedimentation modelling , these influecnes could be dealt with. Gessesse and Gebrewubet (2007) have made such an attempt through coupling SWAT and CCHE1D.

2
BACKGROUND

2.1 Koga Catchment

The Koga River is a tributary of the Gilgel Abay River in the headwaters of the Blue Nile catchment. The Gilgel Abay flows into Lake Tana. The Koga catchment can be divided into a narrow steep upper catchment draining the flanks of the Mount Adama range, and the remainder on a relatively flat plateau sloping gently northwestwards. The source of the Koga River is close to Wezem, at an altitude of about 3 200 m. The river is 64 km long, flowing into the Gilgel Abay River after it crosses the Debre Markos - Bahir Dar road, downstream of the town of Wetet Abay, at an altitude of 1 985 m (Mott MacDonald, 2005).

The location of the Koga Dam and Koga Reservoir are shown in Figure 1.0. The nearby hydrometric stations and the potential command area are also shown in the same figure. The Koga catchment has a catchment area of 165 km^2.

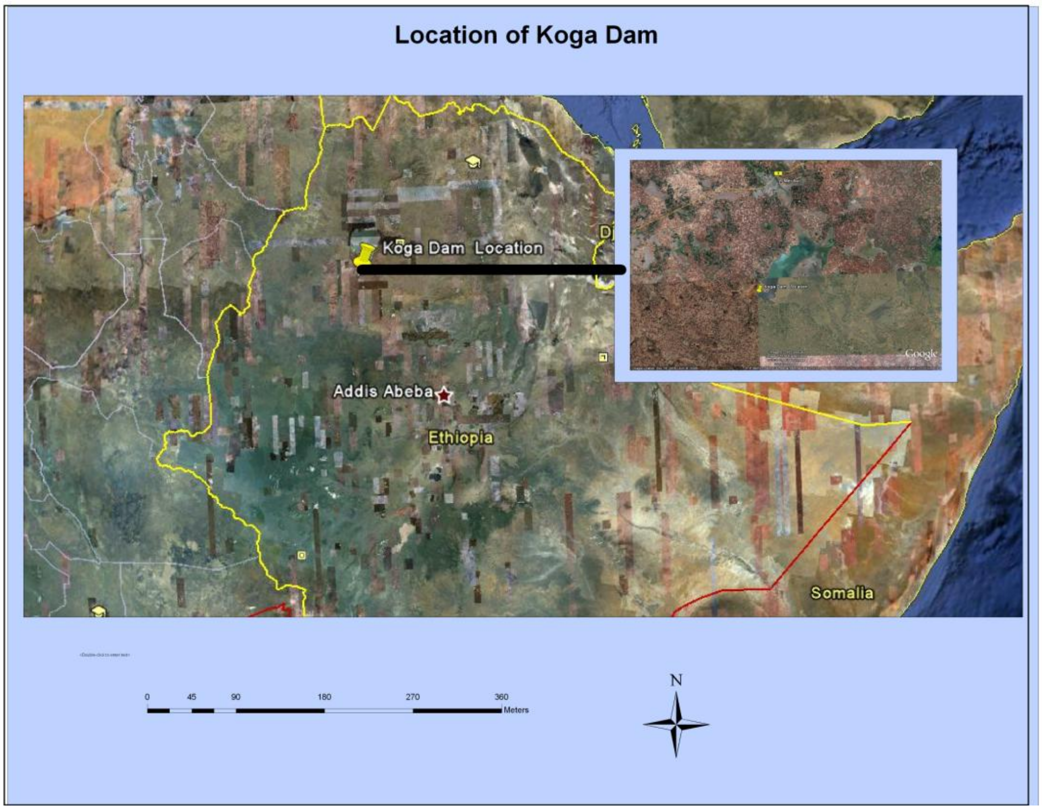

Figure 1: Koga Dam/Reservoir Location Map

2.2 Climate Characteristics

2.2.1 Meteorological Network and Data

Bahir Dar, 35 km to the north east of the project area on the edge of Lake Tana, is the only synoptic station. Daily rainfall is also available for Merawi. There are no stations in the upper portion of the catchment. The stations are run by the National Meteorological Services Agency (NMSA).

The Merawi meteorological station (37^0 09' E and $11^0$25' N) is located adjacent to the project irrigation area, at an altitude of about 2020 m. Available data is limited to the period from 1981 to 1995, covering daily rainfall, and average monthly minimum and maximum temperatures. The station has not operated since the beginning of 1996. Even within the period of record there are a number of gaps.

The Bahir Dar meteorological station (formerly 37^0 21' E and 11^0 36' N, but currently $37^0$25' E and $11^0$36'N) records continuous rainfall, minimum and maximum temperatures, wind speed, sunshine hours, relative humidity, and evaporation.

The key climate characteristics are summarised in Table 1 for Bahir Dar and Table 2 for Merawi. Records of daily rainfall at Bahir Dar start in 1961, although there are two years (1989 and 1990) with missing data, as well as other shorter gaps in the record. The monthly rainfall record is more complete, but it is not clear how the monthly totals have been derived for those periods when there is an incomplete daily record. The 1-hour rainfall intensity is available with the period of 1971 – 1999, although there are also some gaps in this record.

Table 1: Summary of Key Climatic Characteristics for Bahir Dar

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean monthly rainfall (mm)[(1)]	2.6	1.8	7.9	24.2	83.9	187.2	424.3	393.1	198.0	93.4	19.6	3.2	1 439.2
80% probable rainfall (mm)[(1)]	0	0	0	0.6	20.3	121.7	314.2	272.0	147.2	33.9	0.9	0	
Daily maximum rainfall (mm)	16	16.6	32.5	52.8	116	94.8	133	200	70.4	88.5	38.8	15	200
Number of rainy days (> 10 mm)	0	0	0	1	2	6	15	13	6	3	1	0	48
Mean monthly maximum temperature (°C)	26.5	27.9	29.4	29.8	28.7	26.5	23.9	23.8	25.1	26.2	26.3	26.1	26.7
Mean monthly minimum temperature (°C)	7.3	8.9	11.8	13.0	14.2	13.8	13.7	13.4	12.7	12.3	10.2	7.8	11.6
Average monthly temperature (°C)	16.9	18.4	20.6	21.4	21.5	20.2	18.8	18.6	18.9	19.3	18.3	17.0	19.1
Mean monthly wind speed (km/day)[(2)]	121	121	147	156	138	130	104	95	95	104	112	104	119
Mean monthly relative humidity (%)	59	52	49	49	59	72	81	82	78	71	66	62	65
Mean daily sunshine duration (hrs)	9.6	9.6	9	9.2	8.2	7	5.1	4.8	6.7	8.7	9.5	9.6	8.1
Evaporation (mm) (Piche Evaporimeter)	170	189	254	255	208	130	73	67	79	121	137	151	1 832

Table 2: Summary of Key Climatic Features for Merawi

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean Monthly Rainfall (mm)	3.1	2.5	16.6	40.6	132.1	280.4	421.3	357.8	219.2	89.1	16.7	9.3	1 588.8
80% Probable Rainfall (mm)	0	0	3.3	2.5	49.8	209	333	283	159	48.6	0.8	0	
Daily Maximum Rainfall (mm)	14.2	6.9	29.6	74.6	51	87.9	83.3	83.6	98	38	28.4	28.6	98
Number of Rainy Days (> 10 mm)	0	0	1	2	5	10	16	14	9	3	1	1	62
Mean Monthly Maximum Temperature (°C)	28.7	29.5	30.6	30.3	29.2	26.3	23.9	24.0	25.1	26.2	27.5	27.9	27.4
Mean Monthly Minimum Temperature (°C)	7.2	8.4	11.1	12.1	12.9	13.1	12.9	12.8	12.1	11.1	9.0	6.8	10.8
Average Monthly Temperature (°C)	17.9	19.0	20.8	21.2	21.0	19.7	18.4	18.4	18.6	18.7	18.3	17.4	19.1

2.2.2 Long Term Rainfall

The mean annual rainfall at Bahir Dar for 1960 to 2002 is 1 439 mm. The mean annual rainfall for Merawi is 1 589 mm for the period of record (1981 to 1995).

The rainfall in the area has uni-modal characteristics with one rainy and one dry season. The rainy season extends from May to October and dry season from November to April. A high concentration of rainfall occurs in July and August.

95% of the annual rainfall occurs in the wet season months of May to October. The Inter-Tropical Convergence Zone (ITCZ), a low-pressure zone at the meeting point between the dry northeasterly and moist southwesterly winds, is the major rainfall mechanism in the area. The monthly variation of rainfall is in accordance of the movement of the ITCZ. In July and August, when the ITCZ is to the north of the project area, rainfall is at a maximum. The coefficient of variation of Bahir Dar rainfall indicates relative consistency (low variability) for June to September.

The variability is greater in May and October, corresponding to the entrance and exit periods of ITCZ. For the period of common record Merawi rainfall is about 5.7% higher than Bahir Dar rainfall.

Figure 2 provides a comparison of the average monthly rainfalls for Bahir Dar and Merawi. The figure also shows the average monthly Koga River flows, expressed as depth over the catchment.

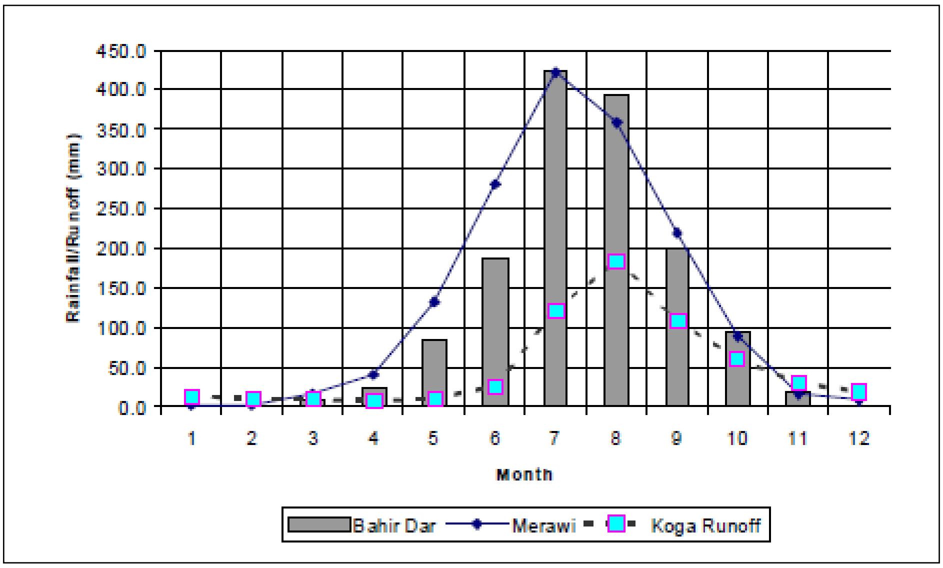

Figure 2: Comparison of Bahir Dar and Merawi Rainfall and Koga River Flows

Source: Koga Irrigation and Watershed Management Project (Mott Macdonald)

2.3 Koga River Flows

2.3.1 Hydrometric Network and Data

There are two river gauges in the Koga catchment, that at Wetet Abay (37^0 02’ E and 11^0 22’ N) has been in place since 1959, the second at the proposed dam site (37^0 08’ E and 11^0 20’ N) was installed in August 2003. The gauges are maintained by the MoWR Hydrology Department.

2.3.2 Wetet Abay Guaging Station

The gauging station is situated in a reach with a rocky bed. Hydraulic control is provided by a bar about 10 m downstream, at least for the low to medium flow range. Bankfull water level is at a stage of 2.0 m. The station is equipped with staff gauges, an automatic water level recorder (AWLR) and stilling well, and a cableway. The staff gauges cover a range 0-4 m and are read twice daily at 0600 and 1800. The AWLR is a SEBA model with one month clock and 6-month chart. As shown in Figure 3 the current meter measurements fall into two distinct groups, due to a shift in zero level after a significant flood in 1981 which led to the station being moved.

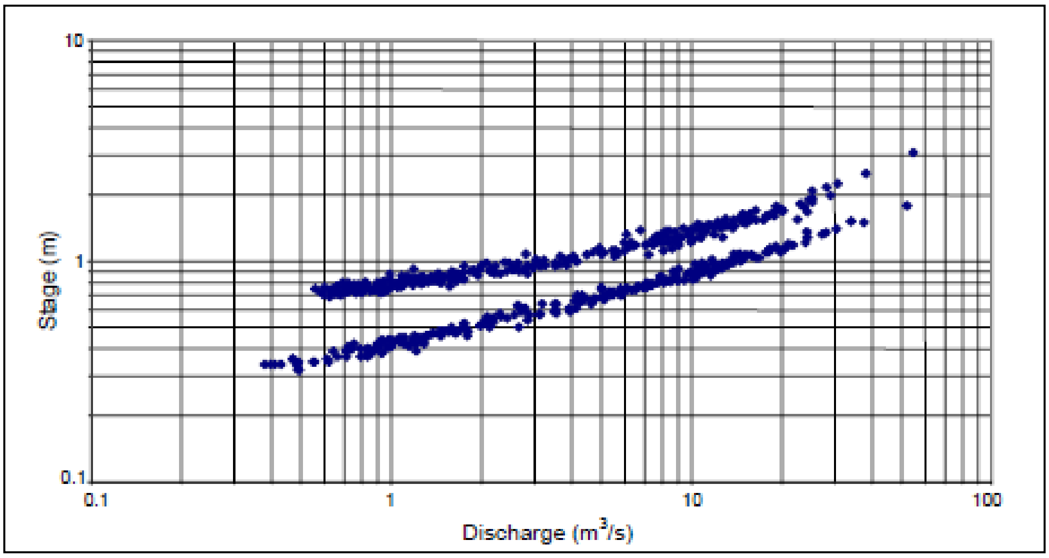

Figure 3: Koga at Wetet Abay - Discharge Measurement

Source: Koga Irrigation and Watershed Management Project (Mott Macdonald)

2.3.3 Dam Site Gauging Station

The MoWR has installed a gauging station at the dam site in July 2003. A flow rating curve has been established using 28 current meter measurements. The flow rating curve is shown in Figure (4) below.

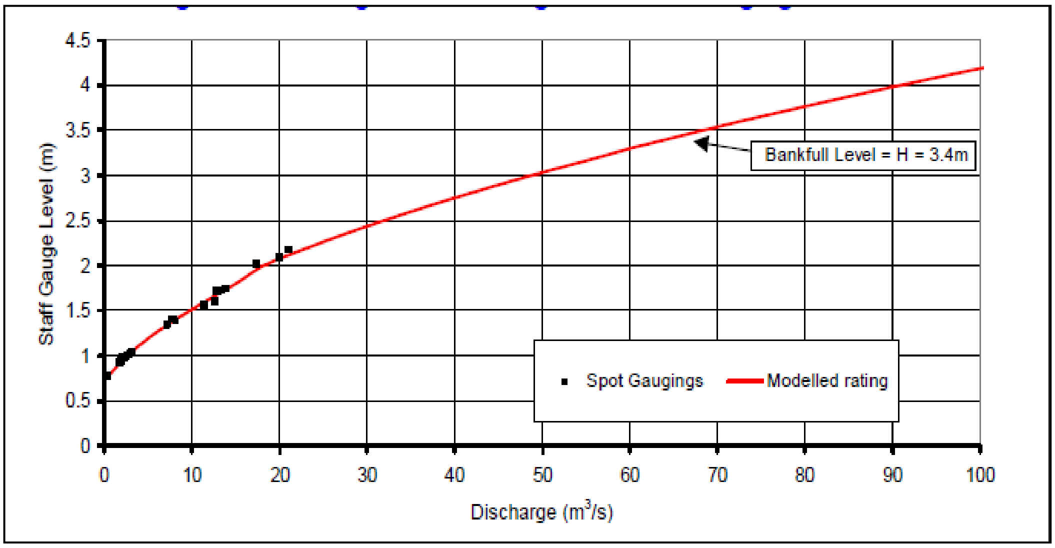

Figure 4: Rating curge at the Dam Site

Source: Koga Irrigation and Watershed Management Project (Mott Macdonald)

3
DATA COLLECTION

SWAT model by its nature require intensive data such as soil data, land use/ Land cover data, digital elevation model (DEM), meteorological and hydrological data as an input to simulate the runoff. Each of these input data are described below.

3.1 Meteorological Data

The meteorological data required were: daily precipitation, daily maximum and minimum air temperature, daily solar radiation, daily wind speed, and daily relative humidity. If any of these data was not available, which is very likely, SWAT can generate data using a weather generator. To do so, monthly statistical values were needed to be generated from the daily ones. Daily precipitation and temperature data were available for each of the subbasins. The rest of the required data will have to be generated from monthly data supplied to SWAT.

- Precipitation and temperature: the daily precipitation and temperature for each subbasin were prepared in text format (one for each gauge).
- Solar radiation, relative humidity and wind speed data were available only for the principal stations, Bahirdar and Dangila. These data for the rest of the stations were generated by SWAT. Moreover, these data were required when the Penman-Monteith equation is used to evaluate potential evapotranspiration.
- Weather simulation data. These data consist of monthly average values of all the parameters required by SWAT in order to generate daily values.

All the above data were collected from Ethiopian National Meteorological Agency for the period from 1995 to 2005.

3.2 Hydrological data

The Koga river flow data which was used for calibrating the SWAT model were collected from Ministry of Water Resource, Hydrology department for the period from 1995 to 2005. The time resolution of the flow data was daily. The flow is generated from a rating curve developed for the stations and staff gauge readings were converted to flow rate. It is the responsibility of the MoWR to process this conversion.

3.3 Digital Elevation Model

The Digital Elevation Model (DEM) is any digital representation of a topographic surface and it is specifically made available in a form of a raster or regular grid of spot heights. It is the basic input of the SWAT hydrologic model. The Koga watershed was delineated and river networks were generated based on the DEM. The DEM used for this study is obtained from MoWR and it has a horizontal resolution of 90 meters. The source of the DEM is SRTM. The associated error in elevation is discussed elsewhere.

Elevation of the study area ranges from 1908 m.a.s.l. to 2998 m.a.s.l. The lowest elevation is found at the outlet of the catchment and the higher elevation is found in the area where Rivers originate. Elevation variation for catchments is shown in the figure 5.

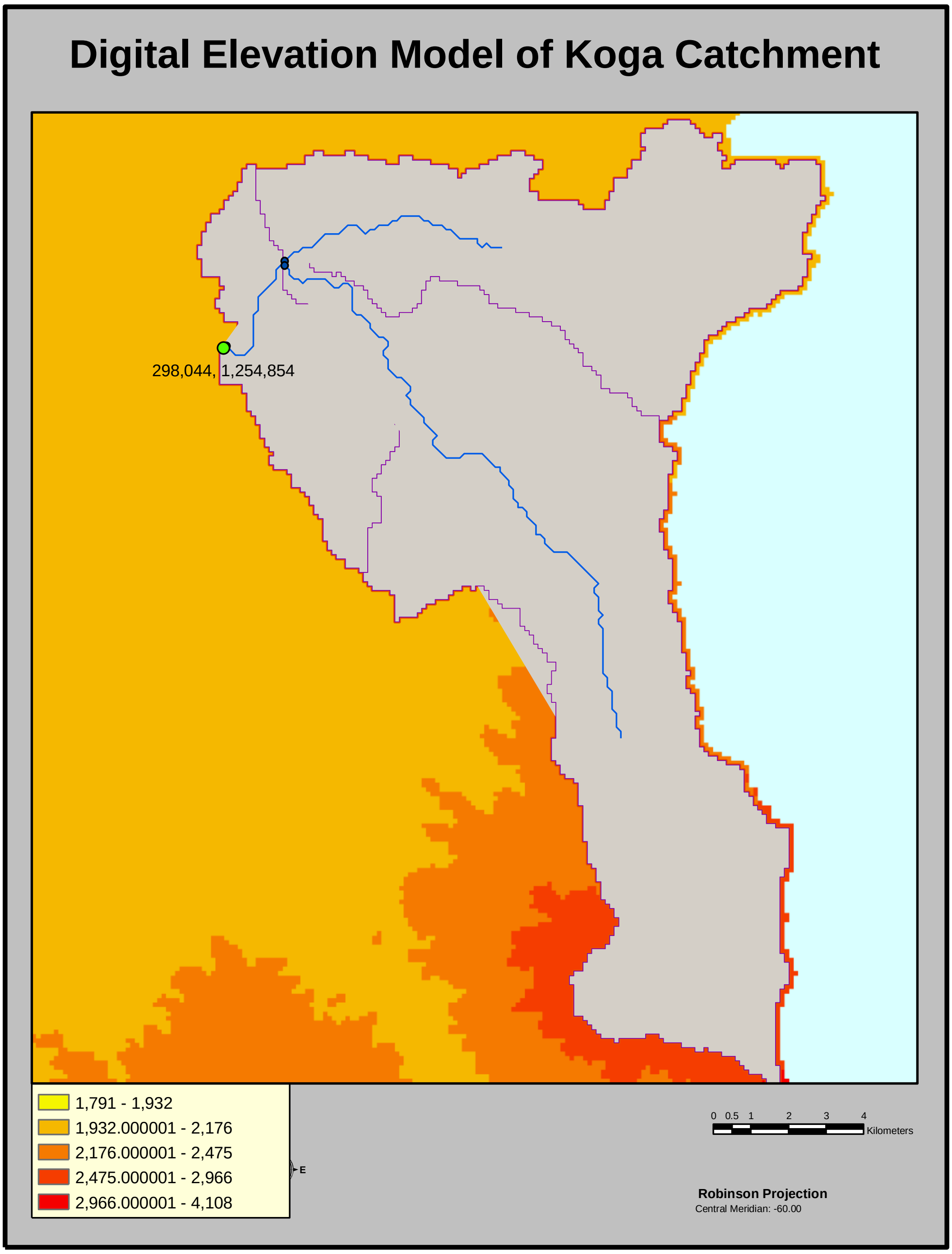

Figure 5: DEM of the Koga Catchment

The watershed slope varies from nil to 67.3 percent. The catchment slope is 8.7 percent on average. Five slope classes were defined for modeling purpose in this study as shown in Figure 6.

Figure 6: Catchment Slope Distribution for Koga Catchment

3.4 Soil Map

Soil data were required for the SWAT model to provide both the distribution of soil types in the catchments and the various parameters describing the soils hydrological and textural properties. The soil parameters were obtained from Abbay river master plan project prepared by BCEOM. The shape file which describes the distribution of soil in the study area were obtained from baseline maps available at MoWR at a scale of 1:250 000. It was observed that Chromicluvisols and chromicvertisols are the most dominant soil in the catchment.

These are verified using HDWS database which is recently releases by a consortium of associations dealing with soil classification.

Table 3: Soil Distribution within the Koga Watershed

Ser. No.	Soil Type	Area, ha	Percent of watershed
1.	CHROMICCA	1093.0927	5.55
2.	CHROMICLU	802.8285	4.07
3.	CHROMICVE	7321.7391	37.15
4.	DYSTRICGL	4971.3065	25.23
5.	EUTRICNIT	996.8100	5.06
6.	LEPTISOLS	14.1592	0.07
7.	NO_SOIL	457.3432	2.32
8.	PELLICVER	4049.5405	20.55

Vertisols dominate the watershed. Glycosols are also relative abundant in the watershed.

Figure 7: Soil Map of the Koga Catchment

3.5 Land Use /Land Cover Map

The information contained in the landuse/land cover map shows how the different uses of the surface are distributed inside the area under study. Spatial distribution and a list of specific land use parameters were required for the modelling. The land use/ land cover map prepared by WBISPP in the year 2000 was used for this research.

SWAT has predefined land uses identified by four letter codes and it uses these codes to link land use maps to SWAT land use databases in the GIS interfaces. Hence, while preparing the lookup table, the land use types were made compatible with the input needs of the model. Hence, the classified land use map and its attribute were adjusted to the SWAT model requirement format and database. Agricultural land is the dominant land use in the catchment.

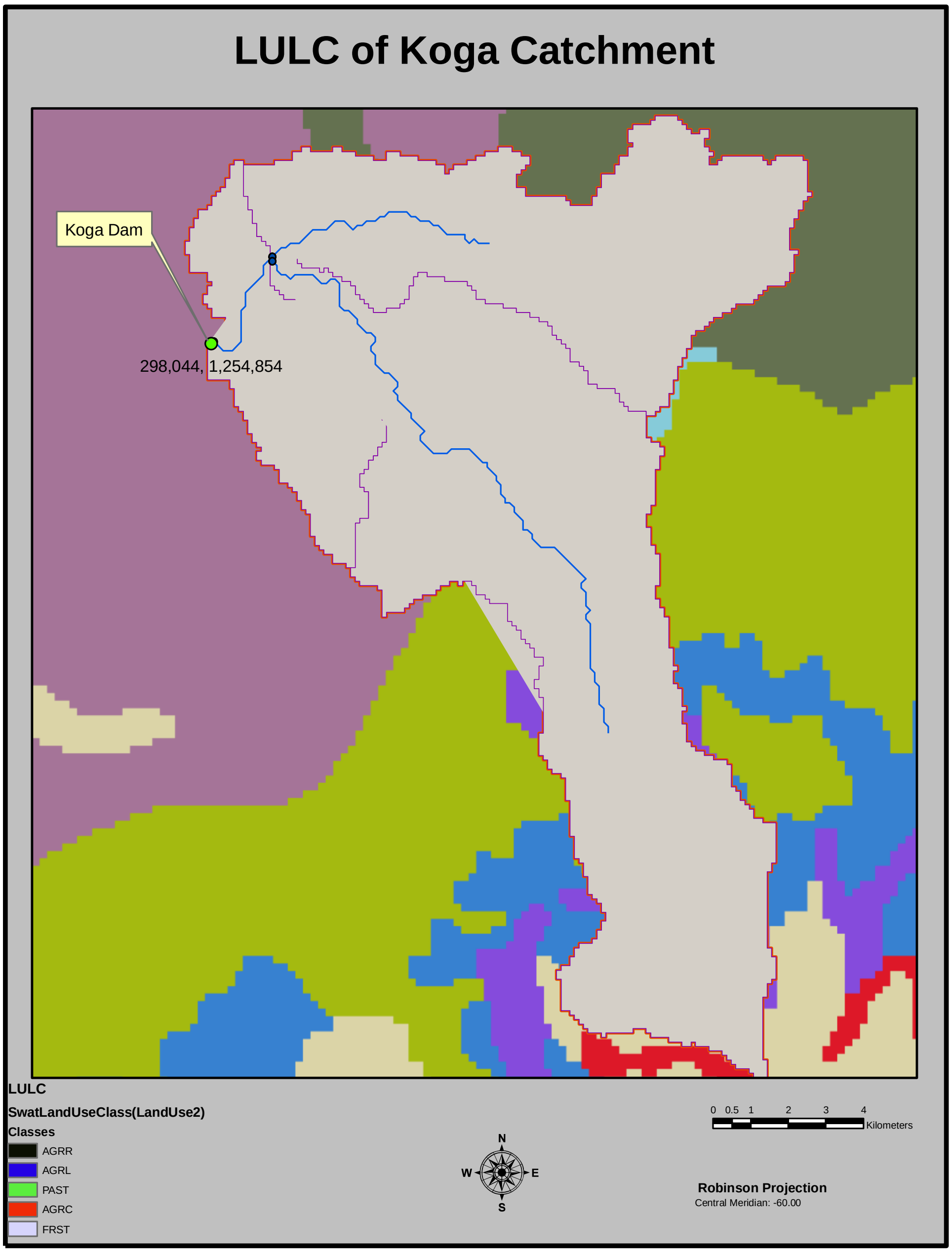

Figure 8: Land Use Map of the Koga Catchment

Table 4: Land use/Land cover distribution within the Koga watershed

Ser. No.	Land use/Land cover Type	Area, ha	Percent of watershed area
1.	Agricultural Land-Row Crops	3821.5768	19.39
2.	Agricultural Land-Generic	6564.2201	33.31
3.	Pasture	7770.5867	39.43
4.	Agricultural Land-Close-grown	225.1318	1.14
5.	Forest-Mixed	1325.3042	6.73

4
MODELING

4.1 Data Analysis

Before the rainfall data were used as input for the model, the data were first checked for their stationarity, consistency, and homogeneity. To do so the following steps were pursued:

1. Rough screening of the data and computation or verification of the totals for the hydrological years or seasons;
2. Plotting the totals according to the chosen time step and note any trends or discontinuities;
3. Test the time series for absence of trend with Spearman's rank correlation method;
4. Test the time series for relative consistency and homogeneity with double mass analysis.

The result showed that the data were consistent and homogeneous.

4.2 Model Set-up

After the data were collected, the model was setup for all the input data. The following were some of the steps carried out before running the model.

One outlet was added at the location were stream flow gauging station was situated, near the town of Merawi. This outlet made the calibration and verification of the model possible without any need for regionalization. Unnecessary outlet points were also removed to obtain better sub-basin classification. As a result, three sub-basins were indentified and/or generated for the modelling.

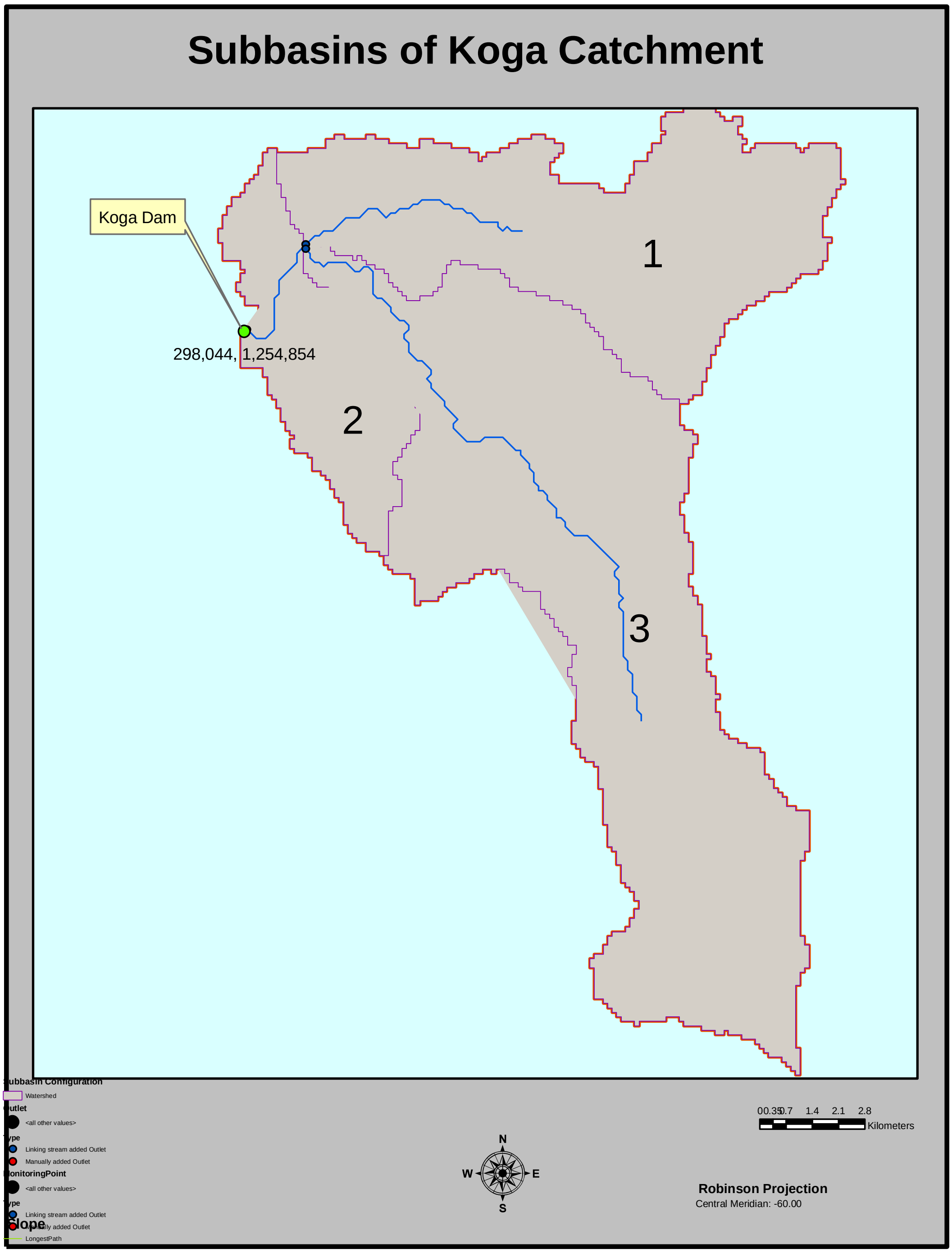

Figure 9: Outlet definition and Subbasin classification

During the processing of the DEM, an existing stream network was deployed in order to guide the generation of the sub-basins. Hence, a stream network was prepared in a shape file format and used as an input for the terrain modelling during "burn in option" in watershed delineation process. In Koga catchment, there are two perennial rivers ,namely, Koga (Main River) and Minzir. The confluence of these rivers lie upstream of the gauging stations.

The required detail of the stream network, the size and number of sub-basins were based on the threshold area which is set to 2400 ha.

4.3 Parameter Selection

The sensitivity analysis, for the selection of hydrologic parameters, was carried out for a period of nine years, which included both the calibration period (from January 1st, 1996 to December 31st, 2002) and the warm-up period (from January 1st, 1995 to December 31, 1995). Even though 28 parameters with ten intervals of Latin Hypercube (LH) sampling (totally 280 iterations) were used for the sensitivity analysis, only 10 of them revealed meaningful effect on the daily flow simulation of the Koga catchment. As shown in Table 5, the first eight parameters showed a relatively high sensitivity, the curve number (CN II) being the most sensitive of all. The four most sensitive parameters controlling the runoff in the subcatchment are curve number (CN II), deep aquifer percolation fraction (Rchrg_dp), threshold water depth in the shallow aquifer for return flow to occur (GWQMN) and Ground water "revap' (GW_REVAP).

Table 5: Results of the sensitivity analysis for Koga catchment

Rank	Parameters	Description	Lower bound	Upper bound	Mean Relative sensitivity (MRS)	Category of sensitivity
1	CN_2	Initial SCS CN II value	-25%	25%	4.92	Very high
2	GWQMN	Threshold water depth in the shallow aquifer for return flow to occur (mm)	0	5000	1.15	Very high
3	Rchrg_dp	Deep aquifer percolation fraction	0	1	0.93	high
4	Sol_z	Soil depth (mm)	0	3000	0.33	high
5	GW_REVAP	Ground water "revap'	0.02	0.2	0.31	high
6	canmx	Maximum canopy storage (mm)	0	10	0.26	high
7	slope	Average slope steepness [m/m]	0	0.6	0.19	medium
8	Sol_K	Saturated hydraulic conductivity [mm/hr]	-25%	25%	0.16	medium
9	Sol_Alb	Soil albido	0	0.25	0.12	medium
10	ESCO	Soil evaporation compensation	0	1	0.11	medium
11	REVAPMN	Threshold depth of water in the shallow aquifer for "revap" to occur	0	500	0.023	small
12	GW_DELAY	Ground water delay	0	500	0.017	small
13	Surlag	Surface lag time	-25%	25%	0.014	small
14	Alpha_BF	Base flow alpha factor	0	1	0.0081	small

4.4 Calibration

Flow calibration was performed on daily and monthly basis for a period of eight years from January 1st, 1995 to December 31, 2002 using the sensitive parameters identified. However, flow was simulated for seven years from January 1st, 1995 to December 31, 2002, within which the first one year was considered as a *warm up* period.

The calibration result in table 4 showed that there is a good agreement between the simulated and gauged monthly flows. This is demonstrated by the correlation coefficient (R^2=0.80) and the Nash-Suttcliffe (1970) simulation efficiency (ENS=0.74) values. Similarly, the daily calibration result showed that correlation coefficient (R^2=0.56) and the Nash-Suttcliffe (1970) simulation efficiency (ENS=0.51) values for Koga subcatchments. The results partly fulfilled the requirements suggested by Santhi *et al.* (2001) for $R^2 > 0.6$ and ENS >0.5 during the calibration period.

Table 6: Initial/default and finally adjusted parameter values for Koga catchment

Rank	Parameters	Description	Range	Initial Value	Adjusted Value on daily flow simulation	Adjusted Value on monthly flow simulation
1	CN_2	Initial SCS CN II value	-25% to 25%	67	84	84
2	Rchrg_dp	Deep aquifer percolation fraction	0 - 1	0.05	0.01	0.08
3	GWQMN	Threshold water depth in the shallow aquifer for return flow to occur (mm)	0 - 5000	0	0	0
4	GW_REVAP	Ground water "revap'	0.02 – 0.2	0.02	0.04	0.04
5	canmx	Maximum canopy storage (mm)	0 - 10	0	0	0
6	slope	Average slope steepness [m/m]	0 – 0.6	0.026	0.036	0.036
7	Alpha_BF	Base flow alpha factor	0 - 1	0.048	0.48	0.48
8	GW_Delay	Ground water delay	0 - 500	31	11	11

Table 7: Calibration statistics of average daily and monthly simulated and gauged flows at Koga gauging station.

Period	Total flow (m^3/sec)		Average flow (m^3/sec)		% error	R^2	E_{NS}
	Observed	Simulated	Observed	Simulated			
Daily (1996-2002)	8510.54	6263.13	5.29	3.89	26.3	56	51
Monthly (1996-2002)	469.60	435.43	5.59	5.18	-7.3	80	74

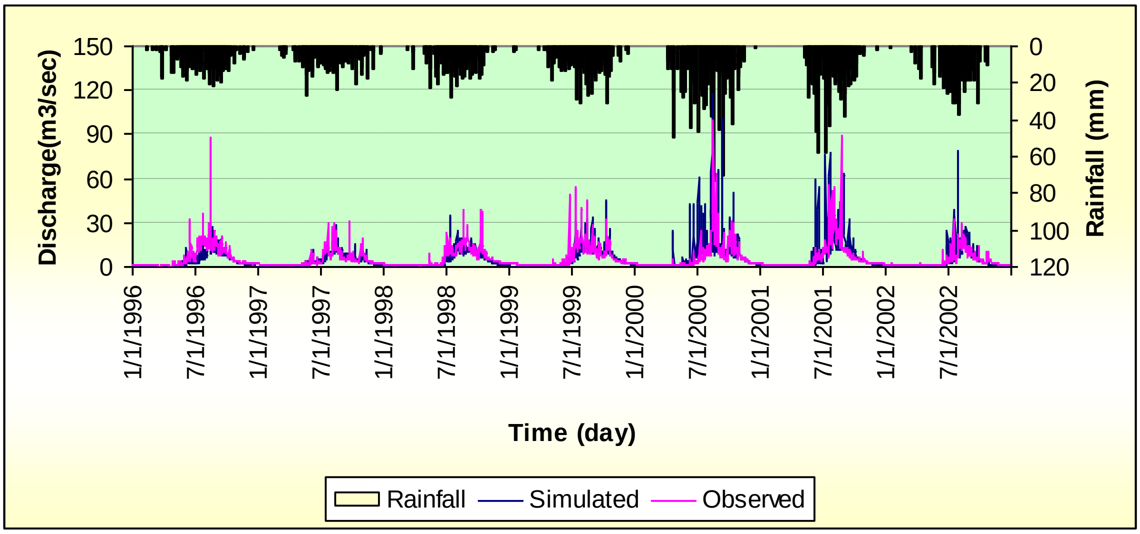

Figure 10: Daily flows during calibration period for Koga subcatchment

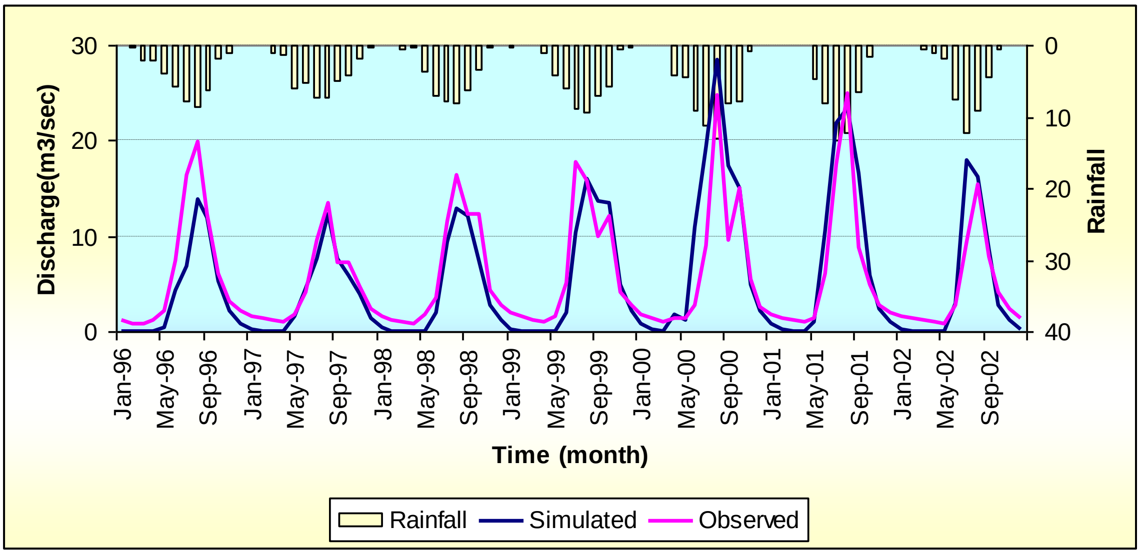

Figure 11: Monthly flows during calibration period for Koga subcatchment

4.5 Verification

Verification is a process of proving the performance of the model. Verification is carried out for time periods differing from the calibration period, but without any further adjustment of the calibrated parameters. Consequently, verification was performed for three years period from January 1st, 2003 to December 31, 2005.

The verification result is summarized in table 8 and showed that there is no good agreement between the simulated and observed flows. This might happen due to the underestimation of the areal rainfall since only Wetetabay gauging station was taken to represent the areal rainfall for Koga subcatchment. Moreover, Koga subcatchment is situated at the higher elevation in the catchment so that there might be high rainfall variability due to elevation variation.

Table 8: Verification statistics of average daily and monthly simulated and gauged flows at Koga gauging station.

Period	Total flow (m^3/sec)		Average flow (m^3/sec)		% error	R^2	E_{NS}
	Observed	Simulated	Observed	Simulated			
Daily (2003-2005)	5668.58	6985.38	5.17	6.37	23	48	40
Monthly (2003-2005)	185.20	228.09	5.18	6.34	23	68	48

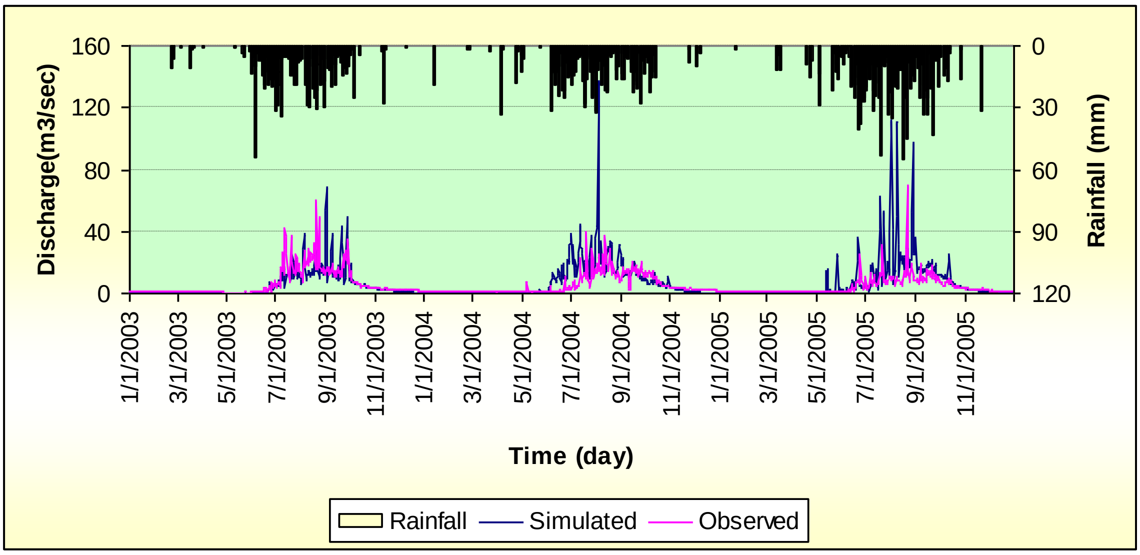

Figure 12: Daily flows during verification period for Koga subcatchment

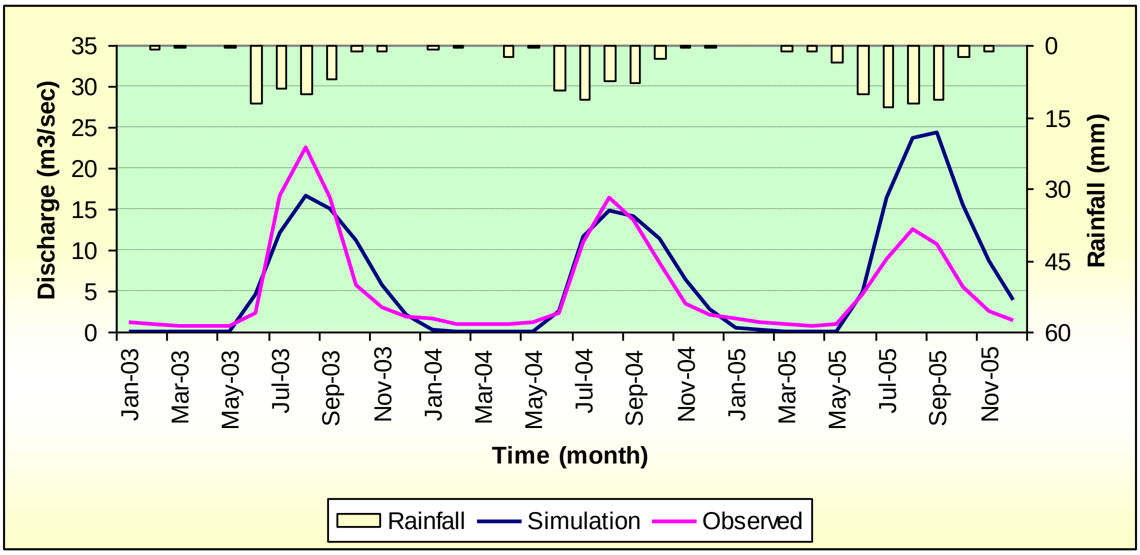

Figure 13: Monthly flows during verification period for Koga subcatchmentt

5
SEDIMENTATION MODELING

5.1 Water and Sediment yield of the three sub basins

The total sediment load carried by the Koga stream is estimated at 92 metric tonnes per hectare over twelve years. The sediment yield is relatively small since the soil cover consists mainly of vertisols. Vertisols are very difficult to dislodge from the catchment since they are highly cohesive.

The sediment yield of subbasin 1 is much smaller that subbasin 2. Subbasin 1 is covered dominantly by forest whereas subbasin 2 is dominantly an agricultural land. The sediment yield for both cases are shown in Figure 14 and 15.

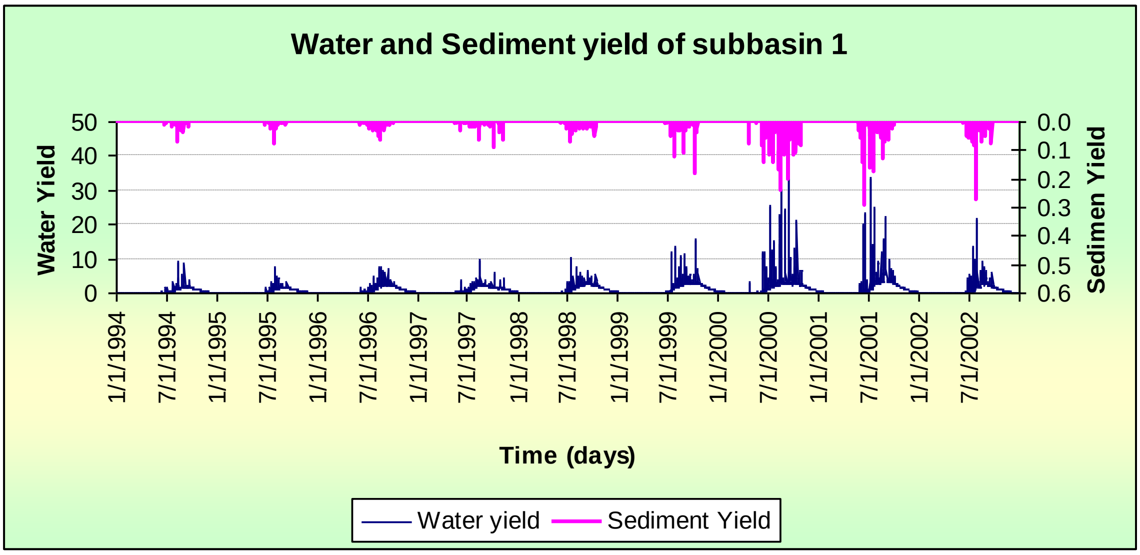

Figure 14: Water and sediment yield at the outlet of subbasin 1

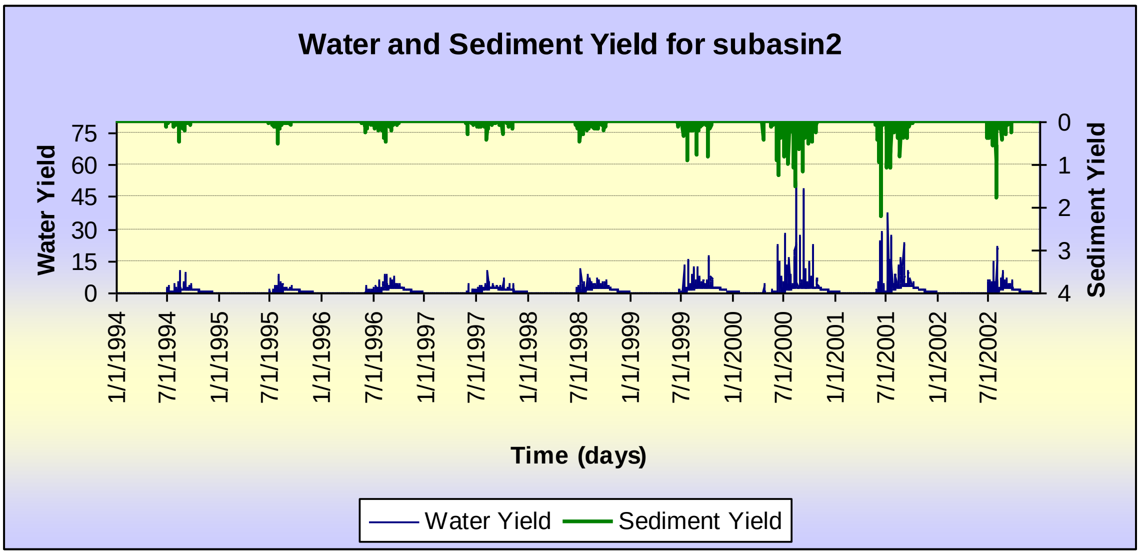

Figure 15: Water and Sediment Yield at the outlet of Subbasin 2

5.2 Sediment load of Koga river

Sediment load at the outlet of Koga subcatchment is shown in figure 15 below during the calibration period. The sediment load is computed in units of metric tonnes. The sediment load is relatively small since the soil cover consists mainly of vertisols. Vertisols are very difficult to dislodge from the catchment since they are highly cohesive.

SWAT models sediment routing in river reaches in a very empirical way. Channels are assumed to have trapezoidal shape. A Manning's roughness of 0.014 is assumed for routing flow and sediment.

The mean monthly sediment load carried by Koga river as computed by the model amounts to 140 kg/ha. The maximum sediment load in the river is estimated at 24 440 kg/ha. Hence, the coefficient of variation is 6.35 kg/ha. Assuming a bulk density of 1.2 tonnes per cubic meters, the sediment load is computed to be 0.117 tonne/ha. The annual ssediment load is then 1.4 tonne/ha.

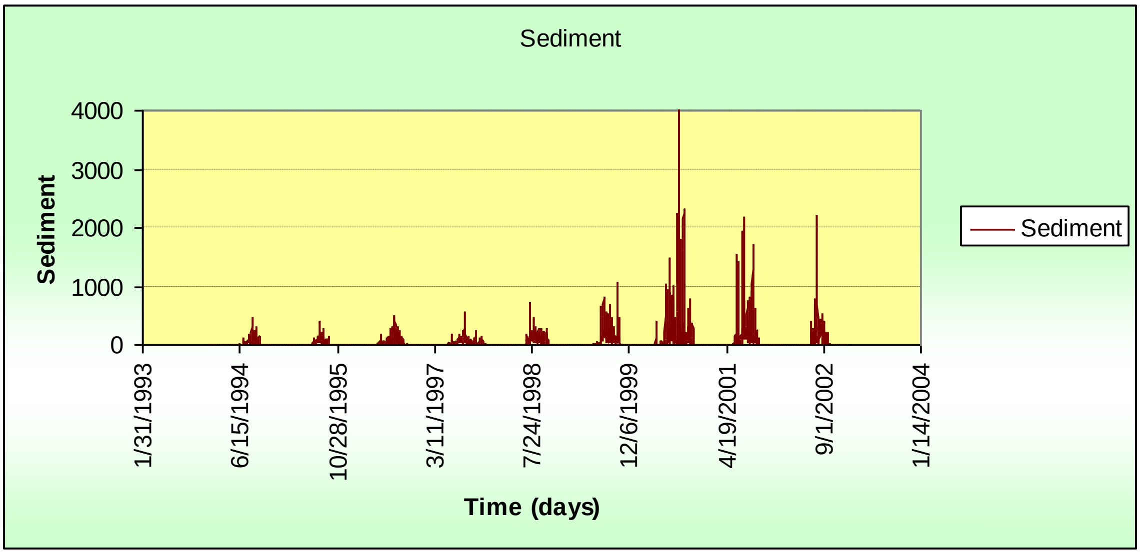

Figure 16: Sediment output for Koga sub catchment during calibration

5.3 Koga Catchment Sedimentation Modeling

Two scenarios were investigated. The scenarios consist essentially of changing the land uses/land covers. In Scenario I, FRSE (Forest ever green) and FRST (Forest mixed) were hypothetically replaced by SHRB (shrub land). In Scenario II, FRSE (Forest ever green) and FRST (Forest mixed) was replaced by Dry land, crop land pasture. Both scenarios were run using SWAT. However, no significant changes in sediment yield were observed expect in scenario II where the sediment yield has shown a slight change.

From the result it can be concluded that there is slight change (negligible) in sediment yield for Koga catchment for the two scenarios developed. This is because the areal extent of the forest in the Koga catchment is very small. The comparison in sediment yield result was made at the channel reaches.

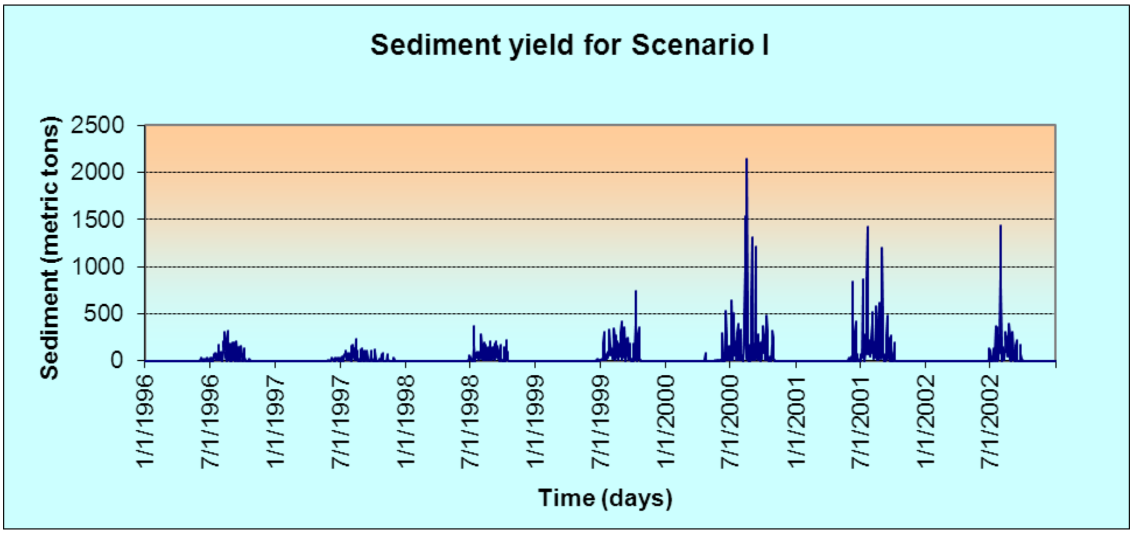

Figure 17: Sediment yield for scenario I

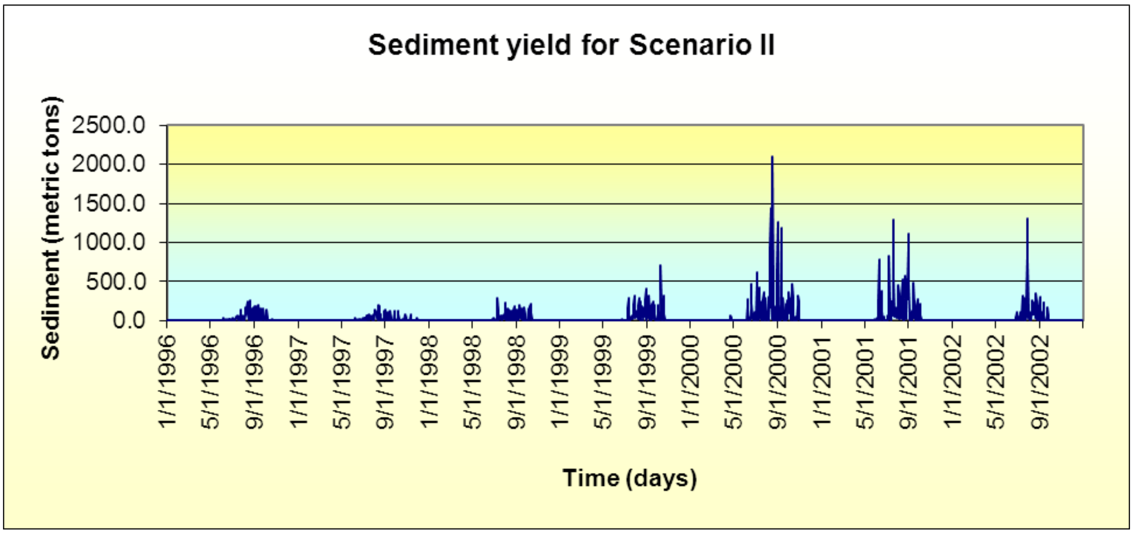

Figure 18: Sediment yield for scenario II

If hydrological events are assumed to recur in the future, then Koga reservoir will suffer from siltation as a result of the sediment transported by Koga river as shown in Figures 17 and Figure 18. The rate has been quantified as shown earlier. This shall result in shifting of the area-elevation and volume-elevation curves. This could affect the intake works and the active capacity of the reservoir. Hence, sediment management measures are required.

6
CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The Koga watershed model is developed in this research, This shall serve a very useful purpose in the future by linking it with reservoir sedimentation models. Since the catchment covered by forest is only 8 percent, then removing the forest does not have a visible effect on the siltation of the reservoir. The suspended sediment concentration profile might also not be affected due to removal of the forest cover.

6.2 Recommendation

It is highly recommended that the Koga Watershed model be updated continually in order to monitor the effect of the upland watershed management intervebtion on the reservoir. Since the reservoir serves some 7000 ha of land, it affects the livelhoods of thousands of farmers residing on the susbsitence agriculture. Hence, it is highly essential to monitor the siltation rate by tracking the land use change which could be easily built into the Koga Watershed Model. If time and fund allows, then it is also essential to couple it with a reservoir sedimentation model. Future research shall be done to accomplish this task.

7
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2010

Effect Of Land Use/Land Cover Management on Koga Reservoir Sedimentation

This research has focused on the effect of land use land cover change on reservoir siltation. Koga Reservoir siltation and/or sedimentation will occur unless a corresponding and appropriate upland watershed management interventions are carried out in time. The reservoir useful time might be shorter than the design period due to siltation which is a slow and gradual process. The watershed management intervention include among others a land use/land cover change which will effect a reduced sheet and gully erosion due to overland flow.

The research question was that if the settlers in the upland catchment try to change the land use/land cover during the service life of the reservoir, then the sediment yield will also vary. But the extent of variation from the base case is not clearly known and hence it is to be estimated. The base case for the land use/land cover is obtained from the baseline maps. In here, it was attempted to change the land use/land cover for two cases. SWAT model is deployed as a watershed model to investigate the problem of land use/land cover changes.

In the first scenario, FRSE (Forest ever green) and FRST (Forest mixed) are changed by SHRB (shrub land). In this case, there was no change in sediment yield in the channel. In the second scenario, the FRSE (Forest ever green) and FRST (Forest mixed) are changed by Dry land, crop land pasture. In this case, the sediment yield in the channel decreased on average by 3 metric tonnes per day. Since it is expected that the forest covers might be removed in search of land, it was only attempted to change the forest cover. However, the forest cover covers only 8 percent of the total catchment. Hence, it is concluded that the removal of the forest shall have no effect on the siltation of Koga reservoir.

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