Maybar Watershed Run off Modeling

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Abstract

A study was conducted in Maybar catchment which is located in Amhara regional state in Debub Wello Zone Dessie Zuria Wereda.Maybar watershed cover's area of 115 ha (1.15km^2). Watershed rainfall run-off modeling using Arc SWAT is an important tool in the study of water resources and water management of the watersheds. Watershed rainfall run-off models are mainly used for river flow forecasting for the management of the resource and to minimize the ill effects through early warning measures. In this thesis we use different data to process the SWAT model properly. The input data for the modal includes digital elevation model land use, land cover, soil, hydrological and weather data which are the main input for Arc SWAT model. Digital elevation model, land use, land cover data and soil data are prepared in raster format and must be projected. Weather data are prepared in text format. Arc SWAT model uses daily rainfall, both daily minimum and maximum temperature, daily relative humidity, daily wind speed, daily sunshine hour and also daily flow data.

*The meteorological data were collected from USGS websites (*http://globalweather.tamu.edu*) with the geographical reference and the data obtained are in text format. The detail land use land cover and soil data were also obtained from the USGS website (http://www.waterbase.org)and the soil maps were used as per FAO classification. Weather generator was also created to fill-in missing gaps and generates climate data Soil and Water Assessment Tool (SWAT 2012) integrated with Arc GIS 10.2 and. We use to model the watershed which accounts spatial and temporal variation of inputs at HRUs level.*

To carry out sensitivity analysis, the most sensitive parameters are calculated; hence, Cn_2 and Alfa-Bf are more relatively sensitive for the year 1993 -2013. Calibration is also done for 15 years, that is, 1993– 2007, as presented in the discussion and result section. The same data arrangement steps are used for all these data. Time series plots and the statistical measures of coefficient of determination (R2), Nash-Sutcliffe Efficiency (ENS) and PBIAS were used to evaluate the performance of the model. The results of the model calibration and validation showed reliable estimates of monthly flow yield with R2=0.78, RNS=0.75 and PBIAS=-0.36 during the calibration period and R2=0.70, RNS=0.61 and PBIAS=0.59 during the validation period.

Key words: Maybar, Arc SWAT, run-off, rainfall ARC, GIS, and HRU

1. Introduction

1.1 Background

The term hydrology can be treated as an important subject for the people and their environment. It treats water of the earth, their occurrence, circulation and distribution, their chemical and physical properties and their reaction with the environment including their relation to living things (Ray, 1975). It also deals with the relationship of water with the environment within each phase of hydrologic cycle. Due to rapid urbanization and industrialization including deforestation, land cover change, irrigation, various changes have been occurred in hydrologic systems. Along with climate change, soil heterogeneity has also got a direct impact on the discharges of many rivers in and around the world.

Hydrological studies require extensive analysis of meteorological, hydrological and spatial data to represent the actual processes taking place on the environment and better estimation of quantities out of it.

Water is the most important natural resource required for the survival of all living species. Since the available amount of water is limited, scarce, and not spatially distributed in relation to the population needs, proper management of water resources is essential to satisfy the current demands as well as to maintain sustainability.

Modeling is the process of organizing, synthesizing, and integrating component parts into a realistic representation of the prototype. Hydrological models are tools that describe the physical processes controlling the transformation of precipitation to stream flows. Models help to sharpen the definition of hypotheses, define and categorize the state of knowledge, provide an analytical mechanism for studying the system of interest, and can be used to simulate experiments instead of conducting the experiments on the watershed itself (USDA, 1980).

Watershed run off models may be either lumped (i.e. using a single rainfall input spatially averaged across the catchment) or distributed (i.e. accounting to some extent for the distribution of rainfall). River flows may be forecasted at specific points along a river to provide warnings at these points, or used as input to flood routing models to provide warnings for further downstream.

Different hydrologic phenomena and hydrologic cycle are to be thoroughly studied in order to find out these variations. Nowdays, various hydrological models have been developed across the world to find out the impact of climate and soil properties on hydrology and water resources. Each model has got its own unique characteristics. The inputs used by different models are rainfall, air temperature, soil characteristics, topography, vegetation, hydrogeology and other physical parameters. All these models can be applied in very complex and large basins.

In recent years, distributed watershed models are increasingly used to study alternative management strategies in the areas of water resources allocation, flood control, impact of land use change and climate change, and finally environmental pollution control. Many of these models share a common base in their attempt to incorporate the heterogeneity of the watershed and spatial distribution of topography, vegetation, land use, soil characteristics, rainfall and evaporation. Many of these watershed models are applied for ru-noff and soil loss prediction, water quality modeling, land use change effect assessment and climate change impact assessment (Abbaspour et al., 2007).

There are also different hydrological models designed and applied to simulate the rainfall run-off relationship under different temporal and spatial dimensions. Many of these hydrological models describe the canopy interception, evaporation, transpiration, snowmelt, interflow, overland flow, channel flow, unsaturated subsurface flow and saturated subsurface flow. These models range from simple unit hydrograph-based models to more complex models that are based on the dynamic flow equations.

1.2. Statement of the Problem

Many Ethiopian and foreign researchers have conducted several project studies and research activities on most of Ethiopian watersheds. For example Maybar, Anjeni, Andittid, Tana are studied by SCP. In fact, flow components of various watersheds vary from one study to another study. This is due to the fact that different rivers in the watershed have different basin characteristics. Different land and rainwater management practices have been implemented in the Ethiopian highlands. One of the major reasons was land degradation and protection of soil fertility losses. This happens in most of the watersheds because of lack of effective land and rainwater management practices. Hence modeling the hydrology of watersheds is required for effective rainwater management strategy. This study is using the Soil and Water Assessment Tool (SWAT) to understand the hydrological process of Maybar watershed so as to plan, design and manage rainwater properly.

1.3. Objective of this Project

1.3.1. General Objective

The main objective of this study is to investigate the hydrology of Maybar river catchment using SWAT model

1.3.2. Specific objective

The specific objectives of this thesis are to:

- setup a SWAT project and also familiarize with the capabilities of SWAT.
- prepare data for SWAT.
- assess the nature and status of land use land covers in the watershed.
- understand the rainfall run-off relationship

2. Description of the Study Area

2.1. Location

Maybar is located in the sub-humid northeastern part of the central Ethiopian highlands situated in Albuko District of South Wello Zone in the Amhara National Regional State (ANRS). The ANRS is located in the northwestern part of Ethiopia between $9^{0} 00^{''}$-$13^{0} 45^{I}$ N latitude and $36^{0} 00^{I}$-$40^{0}30^{I}$ E longitudes covering a total land area of 170,152 km2. Maybar is situated at about 25 km distance from Dessie City in the south-southeast direction and at about 425 km north of Addis Ababa. Geographically, the study site lies at 10^{0} 59^{I} N latitude and 39^{0} 39^{I} E longitudes and at an altitude ranging from 2487 to 2827 meters above sea level.

Maybar watershed is typical for the south Wello Zone and the Albuko District representing average conditions of landscape, climate, land use, population and soil conditions (SCRP, 1982). Maybar watershed consists of two different parts connected by a channel through a rocky area. It is the first of the SCRP research sites and is located at the Kori River, the main river in the Kori Sheleko catchment, which is the main inflow to Lake Maybar. The whole of the Maybar watershed drains into to the Borkena River, ultimately flowing to the Awash River basin. The gauging station is located at 39^{o}39’ E and 10^{0}51’ N and is approximately a distance of 0.5 km uphill from Lake Maybar. From 2003 to 2013, rainfall data was available using the USGS website *(*http://globalweather.tamu.edu*or* www.waterbase.org**)**

2.2. Climate of Maybar

Maybar area is characterized by a bimodal rainfall pattern with erratic distribution. The small rainy season (Belg) occurs from March to May, while the main rainy (Kremt) season occurs from June to September with a dry season from October to February.

4.1.1 Rainfall Characteristics

Precipitation varies greatly across spatial as well as temporal scales. We use rainfall data from USGS wabsites (http://globalweather.tamu.edu) with the geographical reference, South Latitude: 10.5121, West Longitude: 39.0948, North Latitude: 11.3346,East Longitude: 40.1358, Number of Weather Stations: 6

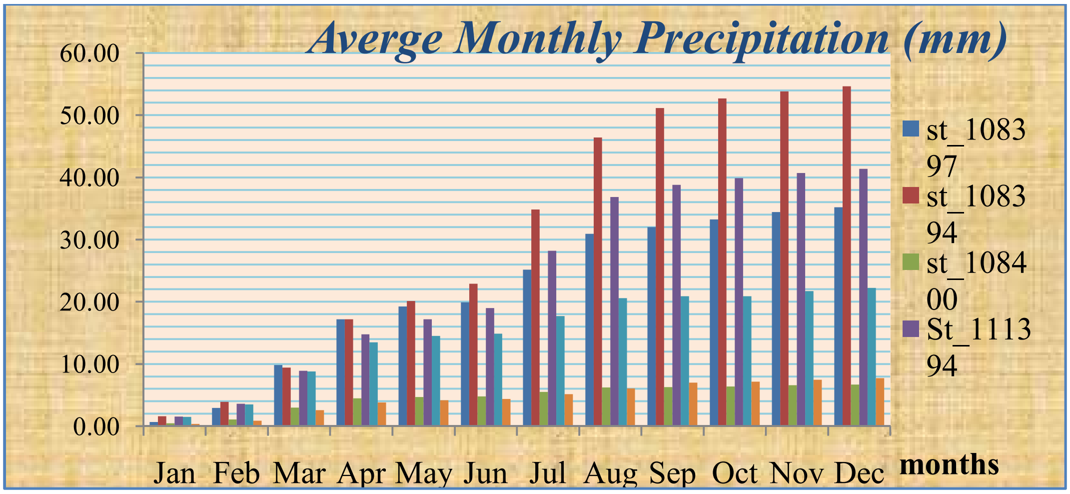

Figure 1: Cumulative mean monthly precipitation of the six stations

4.1.2 Temperature

The temperature data for the research study is used 6 stations. Since both maximum and minimum temperatures were available, the mean temperature of all stations is considered for this research study. Unlike precipitation, temperature is mean value. The main purpose of this temperature is to use as an input for calculations of Potential Evapo-transpiration (EPOT) and it is also input data for the model.

Temperature in the region is fairly constant throughout the year; annual temperatures average around 2.28^{0}c (minimum temperature) to 33.28^{0}c (maximum temperature) which is the average of available station. The data was collected from USGS websites (http://globalweather.tamu.edu) with geograpical referenceboundary of South Latitude: 10.5121, West Longitude: 39.0948, North Latitude: 11.3346, East Longitude: 40.1358, Number of Weather Stations:

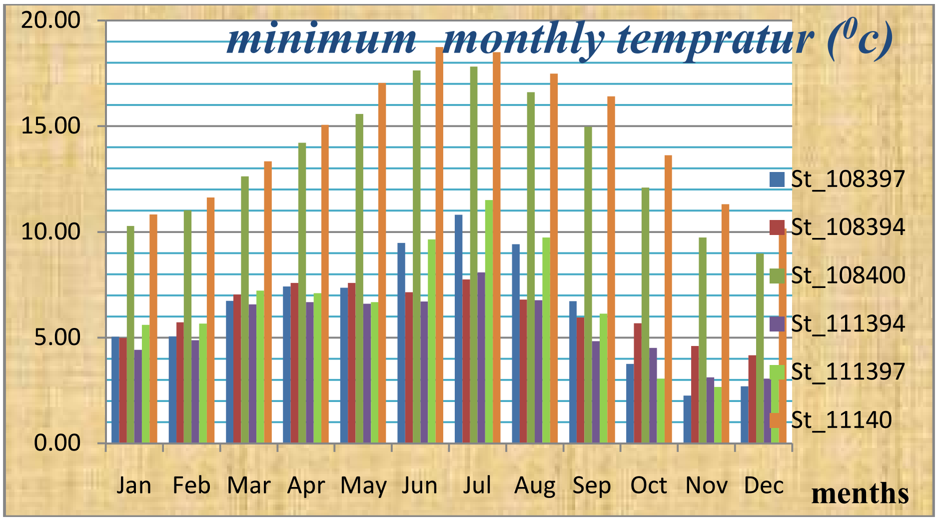

Figure 2: Mean monthly minimum temperatures of the six stations

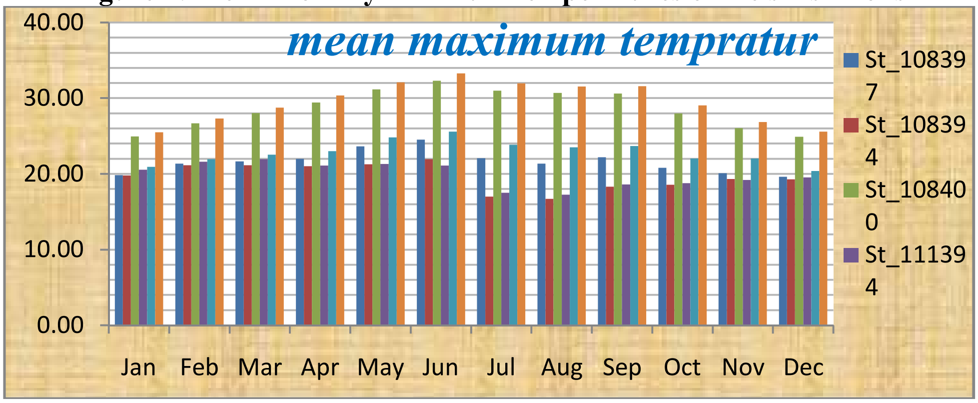

Figure 3: Mean monthly maximum temperatures of six stations

4.1.3 *Topography of the study area*

The area is characterized by highly rugged topography with steep slopes ranging between 2827m and 2487m, a 340 m altitude difference within a 115 ha (1.15km^2) catchment area. Slopes range from over 64 % to less than 7%.

4.1.4 Land use/land cover

As land use/land cover is one of the most important factors that affect run-off, evapotranspiration and other hydrologic parameters in a watershed; it is among the necessary inputs for the SWAT model Soil Conservation Research Program (SCRP) 2000 report. The total size of the Maybar catchment is 115ha. Approximately 60 % of the entire catchment is cultivated. Predominant crops are cereals and maize; they cover about 30 % of the total catchment area. There are two cropping seasons in Maybar: the first, *Belg,* is the small rainy season in spring and the second, *Kremt*, the main rainy season during summer and autumn. With its smaller amounts of rainfall, the *Belg* season is predominantly used to plant cereals; in the *Kremt* season pulses, which require more water, are dominant. Maize is planted during *Belg* and grows over both cropping seasons. The percentage of uncultivated land is generally low. It fluctuates between 1 and 15 % during both cropping seasons. The effects of land use/change on the watershed are manifested at different spatial and temporal scales. The possible changes in land use/cover include deforestation (afforestation) intensification of agriculture, drainage of wetlands and urbanization.

Deforestation which has converse effects to afforestation affects significantly the characteristics of the watershed (Calder, 1992). Forests are thought to make rain regulate low flows, reduce floods, reduce soil erosion and sterilize water. Intensification of agriculture affects the run-off generated through alteration of evaporation and timing of run-off. These effects are compounded by replacement of certain crops, which alter the leaf area index (Calder, 1992)

The natural vegetation of Maybar area consists of trees, bushes and grasses. The trees occurring on slopes are remnants of a once dense evergreen forest and include species such as *Juniperus procera, Olea Africana and Hajenia Abyssinia.* Bushes and shrubs are found on steep slopes and along river valleys. Meadow grasses and species of Lobelia are found along the edges of Lake Maybar. Currently, refilling or replantation strategy is being implemented in the study area (SCRP report 1981 - 1994).

3. Materials and Methodology Used

3.1. Input Data Used for Analysis in SWAT

Input data for SWAT includes metrological data (precipitation, maximum and minimum temperature, radiation, and relative humidity), hydrological data, and digital elevation model (DEM), soil and land use data are required by SWAT. But we don't have hydrological data.

3.1.1 Metrological Data

Arc SWAT model largely depends on meteorological data such as daily precipitation, maximum and minimum temperature, wind speed, relative humidity and solar radiation and hydrological data. SWAT requires daily meteorological data that can either be read from a measured data set or be generated by a weather generator model. These data were obtained from (*http://*www.waterbase*.org)* for stations located within and around the watershed. The quality of those data is important for reliable prediction of model output. Maximum and minimum temperature, relative humidity, precipitation, solar radiation and wind speed data from those websites were collected due to our model requirement.

Precipitation

When measured precipitation data are to be used, a table is required to provide the locations of the rain gages. The precipitation gage location table is used to specify the location of rain gages. The rainfall data are prepared in text format.

Table 1: The Rain Gage Location

ID	NAME	LAT	LONG	ELEVATION
1	p108394	10.772	39.375	2916
2	p111394	11.084	39.375	2500
3	p108397	10.772	39.688	2124
4	p111397	11.084	39.688	2089
5	p108400	10.772	40	1507
6	p111400	11.084	40	1449

The daily precipitation data table is used to store the daily precipitation for an individual rain gage (station). This table is required if the rain gage option is chosen for rainfall in the weather data dialog box. There will be one precipitation data table for every location listed in the rain gage location table. The name of the precipitation data table is "name.txt" where name is the character string entered for name in the rain gage location table. We provide 6 gaging stations with 21 year precipitation data from the web site that is*http: //*www.waterbase.*org* our data is prepared in text format.

Temperature

When measured temperature data are to be used, a table is required to provide the locations of the temperature gages. The temperature gage location table is used to specify the location of temperature gages. The temperature location tables are prepared only in text (ASCII) format

Table 2: The Temperature Gage Location

ID	NAME	LAT	LONG	ELEVATION
1	t108394	10.772	39.375	2916
2	t111394	11.084	39.375	2500
3	t108397	10.772	39.688	2124
4	t111397	11.084	39.688	2089
5	t108400	10.772	40	1507
6	t111400	11.084	40	1449

The temperature data table is used to store the daily maximum and minimum temperatures for a weather station. This table is required if the climate station option is chosen for temperature in the weather data dialog box. There will be one temperature data table for every location listed in the climate station location table.

The name of the temperature data table is "name.txt" where name is the character string entered for NAME in the temperature gage location table. SWAT2012 uses only text format. We use 6 stations with 21 year maximum and minimum temperature data from the website that is *(http://*www.waterbase.*org*) the data is prepared in text format. Daily maximum, daily minimum temperature are expressed in (^{0}c).The daily records must be listed in sequential order with record per day and the maximum and minimum temperatures are written parallel separated by comma.

Solar Radiation, Wind Speed, or Relative Humidity

When measured solar radiation, wind speed, or relative humidity data are to be used, a table is required to provide the locations of the gages. The location table format described below may be used for any of these three types of records. But separate location table is used for each type of weather data. In SWAT2012 location table is prepared only in text (ASCII) format.

Table 3: Location of Solar Radiation

ID	NAME	LAT	LONG	ELEVATION
1	s108394	10.772	39.375	2916
2	s111394	11.084	39.375	2500
3	s108397	10.772	39.688	2124
4	s111397	11.084	39.688	2089
5	s108400	10.772	40	1507
6	s111400	11.084	40	1449

Table 4: Location of Relative Humidity Station

ID	NAME	LAT	LONG	ELEVATION
1	r108394	10.772	39.375	2916
2	r111394	11.084	39.375	2500
3	r108397	10.772	39.688	2124
4	r111397	11.084	39.688	2089
5	r108400	10.772	40	1507
6	r111400	11.084	40	1449

Table 5: Location of Wind Speed

ID	NAME	LAT	LONG	ELEVATION
1	w108394	10.772	39.375	2916
2	w111394	11.084	39.375	2500
3	w108397	10.772	39.688	2124
4	w111397	11.084	39.688	2089
5	w108400	10.772	40	1507
6	w111400	11.084	40	1449

The wind speed data table is used to store the average daily wind speeds recorded at a specific weather station. This table is required if the Wind gages option is chosen for wind speed data in the weather data dialog box. There will be one wind speed data table for every location listed in the wind speed location table.

The name of the wind speed data table is “name.txt” where name is the character string entered for NAME in the wind speed gage location table. This table must be formatted as a comma delimited text table.

Relative Humidity Data Table (ASCII Only)

The relative humidity data table is used to store the fraction relative humidity recorded at a specific weather station. This table is required if the Relative Humidity gages option is chosen for relative humidity data in the weather data dialog box. There will be one relative humidity data table for every location listed in the relative humidity location table.

The name of the relative humidity data table is “name.txt” where name is the character string entered for NAME in the relative humidity gage location table. This table must be formatted as a comma delimited text table.

Solar Radiation Data Table (ASCII Only)

The solar radiation data table is used to store the total daily amounts of solar radiation reaching the ground that are recorded at a specific weather station. This table is required if the Solar gages option is chosen for solar radiation in the weather data dialog box. There will be one solar radiation data table for every location listed in the solar radiation location table.

The name of the solar radiation data table is “name.txt” where name is the character string entered for NAME in the solar radiation gage location table. This table must be formatted as a comma delimited text table.

3.2 Spatial Data/GIS Data Used

3.2.1. Digital Elevation Model (DEM)

Topography is defined by a DEM that de-scribes the elevation of any point in a given area at a specific spatial resolution. Well’ll define the topography of the area by describing the elevation of any point at a given location and specific spatial resolution as a digital file. It is one of essential spatial input for SWAT to delineate the watershed in to a number of sub watersheds or sub basins based on elevation. Drainage pattern, slope, channel width and stream length with in the watershed were processed using DEM. The raw DEM were obtained from United States Geographic Survey (USGS) website that is (http://srtm.csi.cgiar.org*)* with 30x30 resolution and projected using Arc GIS 10.2 software package. Digital elevations Model DEM the purpose of DEM hydro-processing is to extract the watershed and to prepare a dataset for further processing. DEM is required as an input for the DEM hydro-processing; in this study an SRTM (shuttle radar topographic mission) of 30m resolution is used. DEM is a grid in which each cell assigned the average elevation on the area represented by the cell. We convert DEM from vector in to raster format and must be projected to process in swat.

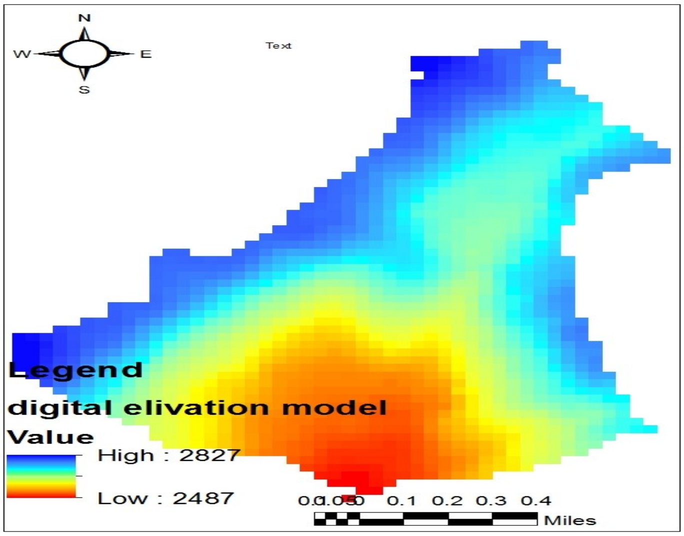

Figure 4: Digital elevation map

3.2.2. Land Use/Land Cover Data (spatial data)

The Land cover of an area is governed by its geographic, climatic and ecological conditions. The definition of land use establishes a direct link between land cover and the actions of people in their environment. Thus, a land use can be defined as a series of activities undertaken to produce one or more goods or services.

Definitions of land cover or land use in this way provide a basis for identifying the possible land suitability for irrigation with precise and quantitative economic evaluation. Like with the DEM, the land cover was then cropped to fit the study area by overlying Maybar watershed. SWAT has predefined land uses identified by four-letter codes and it uses these codes to link land cover maps to SWAT land cover databases in the GIS interfaces. Hence the land cover types were redefined so as to match the input needs of the model. The categories specified in the land cover/land use map will need to be reclassified into SWAT land cover/plant types. The user has three options for reclassifying the categories. The first option is to use a land cover/land use lookup table that is built into the Arc SWAT interface. The interface contains the USGS LULC and NLCD lookup tables in the SWAT2012.mdb database that identifies the different SWAT land cover/plant types used to model the various USGS LULC or NLCD land uses. The second option is to type in the 4-letter SWAT land cover/plant type code for each category when the land cover/land use map theme is loaded in the interface. The third option is to create a user lookup table that identifies the 4-letter SWAT code for the different categories of land cover/land use on the map.

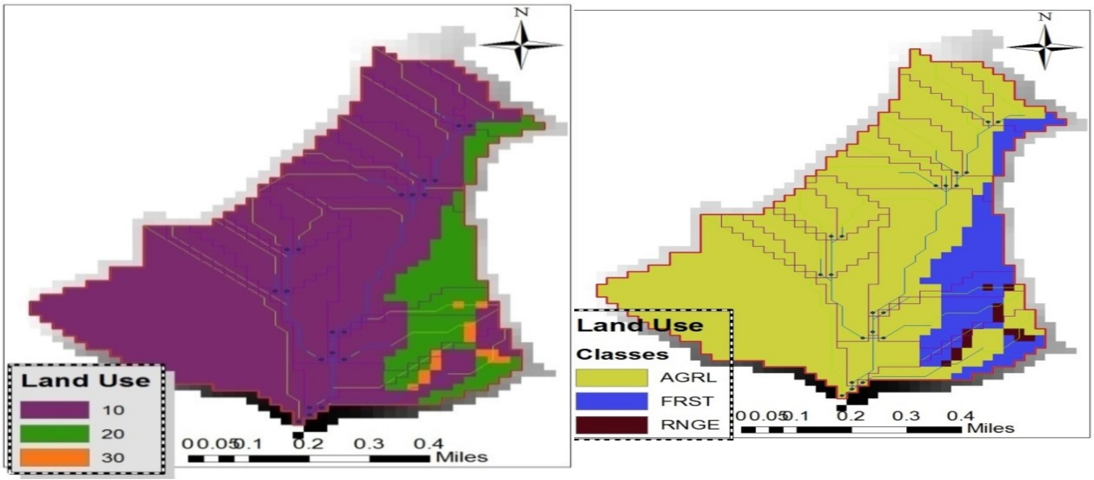

Figure 5: Land use land cover of Maybar

Soil Data (Spatial Data)

Soil data is required as input for hydrological modeling which influences runoff generation. Generally runoff occurs when rainfall intensity exceeds the infiltration capacity of the soil which is a measure of the ability of the soil to absorb and transmit rain water. Soil input data are important because they affect hydrological results where granular or cohesive soils behave very differently in the presence of water. SWAT model basically needs the soil data to define HRUs. As it is required by SWAT'S Soil Database, all physical and chemical properties of each soil types in the watershed were written. In order to integrate and overly the soil map within the SWAT model, it was necessary to make a User Soil Database. In this database all types of soil in the study area were represented, and coupled with their characteristics.

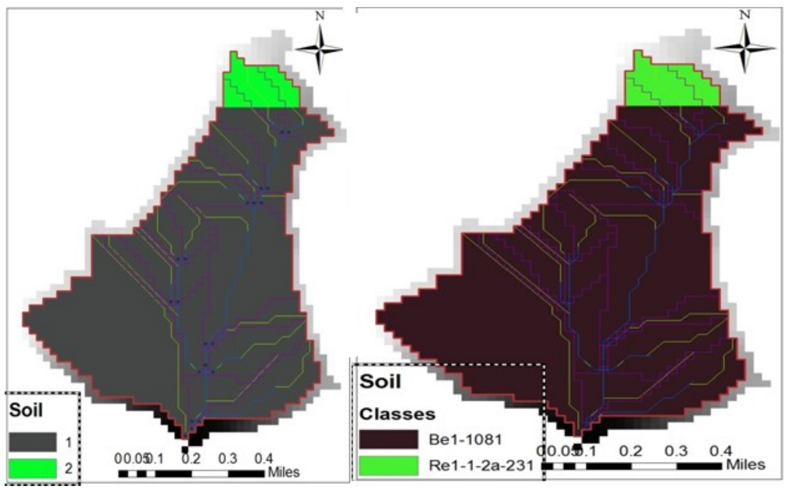

Figure 6: Soil map of Maybar watershed

3.2.1. Weather Generator Data Preparation

SWAT requires daily values of precipitation, maximum and minimum temperature, solar radiation, relative humidity and wind speed. The climatic data collected from *http://*www.waterbase.*org* indicate that there is no missing data. The data downloaded from the website is already prepared in SWAT usable format. It contains precipitation, maximum temperature, minimum temperature, solar radiation and relative humidity and their location in text fo*rm*at. If the data are from manual gaging station we must use PCPSTAT and DEW02 softwares. For the sake of data generation, weather parameters were developed by using the weather parameter calculator PCPSTAT and dew point temperature calculator DEW02, which were downloaded from the SWAT website. The PCPSTAT program reads daily values of solar radiation (calculated from daily sunshine hours), maximum and minimum temperatures, precipitation, relative humidity, and wind speed data. It then calculates monthly daily averages and standard deviations of all variables as well as probability of wet and dry days, skew coefficient, and average number of precipitation days in the month. The DEW02 programs reads daily values of relative humidity, and maximum and minimum temperature values and calculates monthly average dew point temperature.

The weather generator input file contains the statistical data needed to generate representative daily climate data for the sub basins. Ideally, at least 20 years of records are used to calculate parameters in the WGN file. Climatic data will be generated in two instances: when the user specifies that simulated weather will be used or when measured data is missing.

3.3. Materials Used

We use Arc GIS 10.2 tool, SWAT with its extension tools are the main tools. For spatial input–output process GIS tools are used. And also for data preparation and test for saving ASCII or text notepad are used. Here different versions of tools can be used according to working compatibility mode of the tools. In this paper Arc GIS 10.2 is used as compatible mode with Arc SWAT 2012 model. Also model preference in a compatible mode helps to reduce problems in poor output data and repetition of steps.

3.3.1. Arc GIS 10.2 Tools

Here Arc GIS 10.2 the optimum version at which Arc SWAT 2012 to be functional. This tool serves for many purposes as such as modifying SWAT model input as well as adjusting sensitive flow parameters. Arc GIS 10.2 tools also helps to extract, delineate input raster soil and land use land cover roster data set and to export maps. This tool also helps us to create full hydrological response units.

3.3.2. Arc SWAT/Soil and Water Assessment Tool/

SWAT is Arc GIS extension tool which is used for the assessment of soil and water. SWAT is a basin-scale, continuous-time model that operates on a daily time step; and is designed to predict the impact of management on water, sediment and agricultural chemical yields in ungaged watersheds (Arnold, et al., 1995). In other words, it was developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large, complex watershed system with varying soils, land use and management conditions over periods of time.

The model is physically-based, computationally efficient, and capable of continuous simulation over a long period of time. Major model components include weather, hydrology, soil temperature and properties, plant growth, nutrients, pesticides, bacteria and pathogens, and land management. In SWAT, a watershed is divided into multiple sub-watersheds, which are then further subdivided into hydrological response units (HRUs) that consist of homogenous land use, management, and soil characteristics. The HRUs represents percentages of the watershed area and are not identified spatially within a SWAT simulation. Alternatively, a watershed can be subdivided into only sub-watersheds that are characterized by dominant land use, soil type, and management.

4. Data Processing and Analysis

Data processing and analysis involves collecting and preparing data starting from filling missing data and then testing for data quality, consistency and accuracy. In addition to all these data processing also involves inputting data those passes all quality test processing and also spatial inputs such as DEM, soil, LULC data. Finally simulate the result data obtained from the model.

4.1. Infilling Missed Hydrological and Metrological Data

Historical rainfall records are of extreme importance to most hydrologic analyses, including water resource evaluation, impact of land use changes, urban runoff volume and durations, etc., are among other applications.

When undertaking the analysis of runoff data from gauges where daily observations are made, we already faced missing data. In fact rainfall data given are continuous. The continuity of the record may be broken with missing data due to many reasons such as:

- absence of recorder,
- break or failure of instrument,
- inconsistencies during measurement of data.

Data for the period of missing rainfall data could be filled using estimation technique. The length of period up to which the data could be filled is dependent on individual judgment. A number of methods have been proposed for estimating missing rainfall data.

Failurety of any rain gauge or absence of observer from a station causes short break in the record of rainfall at the station. These gaps are to be estimated first before we use the rainfall data for any analysis. The surrounding stations located within the basin help to fill the missing data on the assumption of hydro metrological similarity of the group of stations.

Method mostly used in hydrology for filling the missing data is listed below:

a) arithmetic mean method,
b) normal ratio method,
c) regression method,
d) inverse distance method and Isohyetal method.

The arithmetic mean method is the simplest method of all. In this project we use arithmetic mean method to fill hydrological missing data and the metrological data is already filled when we downloaded from the website so we don't fill any hydrological data. Generally, rainfall for the missing period is estimated by the many methods but the following methods are used to calculate missing data of both hydrological and metrological data if there is missing data.

4.1.1. Arithmetic Mean Method

If the normal annual precipitations at surrounding gauges are within the range of 10% of the normal annual precipitation at station X, then the Arithmetic procedure could be adopted to estimate the missing observation of station X (Chow et al, 1988). This assumes equal weights from all nearby rain gauge stations and uses the arithmetic mean of precipitation. The formula is given by the following:

$$p_x = \frac{\sum p_i}{n}$$

Where P_i = Individual precipitation records, and n = number of records

4.1.2. Inverse Distance (Reciprocal-Distance) Weighting

In this method, a rectangular coordinate system is superimposed over the map marked with rain gauge station in such a way that the origin (0, 0) represents the missing station. The surrounding index stations lie within the quadrants to the point of which rainfall is to be estimated. The distance of index stations from the missing station gives a weightage of the station by which missing rainfall is estimated. The following relation may be used.

The inverse distance (reciprocal-distance) weighting method (Simanton and Osborn, 1980) is the first recommend procedure for estimating missing data.

$$p_x = \frac{\sum_{i=1}^{n} p_i w_i}{\sum_i^n w_i}$$

Prediction at a point is more influenced by nearby measurements than that by distant measurements. The prediction at an ungaged point is inversely proportional to the distance to the measurement points. Compute distance (di) from ungaged point to all measurement points. In order to calculate the distance between two stations we have to convert both latitude and longitude data into X, Y coordinate using UTM geographic coordinate converter.

$$d_i = \sqrt{(x - x_0)^2 + (y - y_o)^2}$$

$$w_i = \frac{1}{d_i^2}$$

4.2. Hydrological and Metrological Data Test

For the model to be functional the data should be adequate and consistently represent the area. From the beginning the processing of data for the adequacy, accuracy, and consistency of data should be checked.

Adequacy is to mean primarily to the length of record, but scarcity of data collecting stations is often a problem. In our thesis the data is almost adequate for our job; all relevant data are available; the length of record is also adequate which in our case is 21year metrological data of six stations and 33 year hydrological data are available.

Accuracy is to mean primarily to the problem of homogeneity of the data. If the data are not homogenous, there will be change in hydrological and metrological characteristics. In Maybar watershed data area we can say almost all have high accuracy.

Also consistency is to mean that if the conditions relevant to the recording of a rain gauge station have undergone a significant change during the period of record, inconsistency would arise in the rainfall data of that station. This inconsistency can be differentiated from the time the significant change took place. Inconsistencies of the records can be checked by using a double mass curve technique (to draw double mass curve rain fall of the main station and 5-8 surrounding station is needed).

4.2.1. Data Consistency Using Double Mass Curve (DMC)

The theory of the double-mass curve is based on the fact that a graph of the accumulation of one quantity against the accumulation of another quantity during the same period will plot as a straight line so long as the data are proportional; the slope of the line will represent the constant proportionality between the quantities. When each recorded data comes from the same parent population, they are consistent. The double mass curve is used to check the consistency of many kinds of hydrologic data by comparing data for a single station with that of a pattern composed of the data from several other stations in the area. The double-mass curve can be used to adjust inconsistent precipitation data. The graph of the cumulative data of one variable versus the cumulative data of a related variable is a straight line so long as the relation between the variables is a fixed ratio. Applications of the double-mass curve to precipitation, stream flow, and sediment data, and to precipitation-run off relations are described. Poor correlation between the variables can prevent detection of inconsistencies in a record, but an increase in the length of record tends to offset the effect of poor correlation.

Causes of inconsistency in records:

- shifting of rain gauge to a new location,
- change in the ecosystem due to calamities,
- occurrence of observational error from a certain date,
- relevant when change in trend is >5years.

The use of a double-mass curve as described is a convenient way to check the consistency of a record. Such a check is one of the first steps in the analysis of a long record, except when the scarcity of other old records makes it infeasible. A double-mass curve is a plot on arithmetic cross-section paper of the cumulative figures of one variable against the cumulative figures of another variable, or against the cumulative computed values of the same variable for a concurrent period of time.

4.2.2. Consistency Check for Temperature

For temperature the consistency check involves plotting the deviation between the accumulated average temperature for a single station and the accumulated average temperature for a large group of stations against time. This is because the relationship between temperature stations is not normally expressed as a difference, i.e., it is said that one location is a certain amount colder or warmer than other locations on the average. Separate plots are generated for maximum and minim um temperatures.

Plotting the graph of cumulative mean versus (X-coordinate) and individual station cumulative (Y-coordinate) will give:

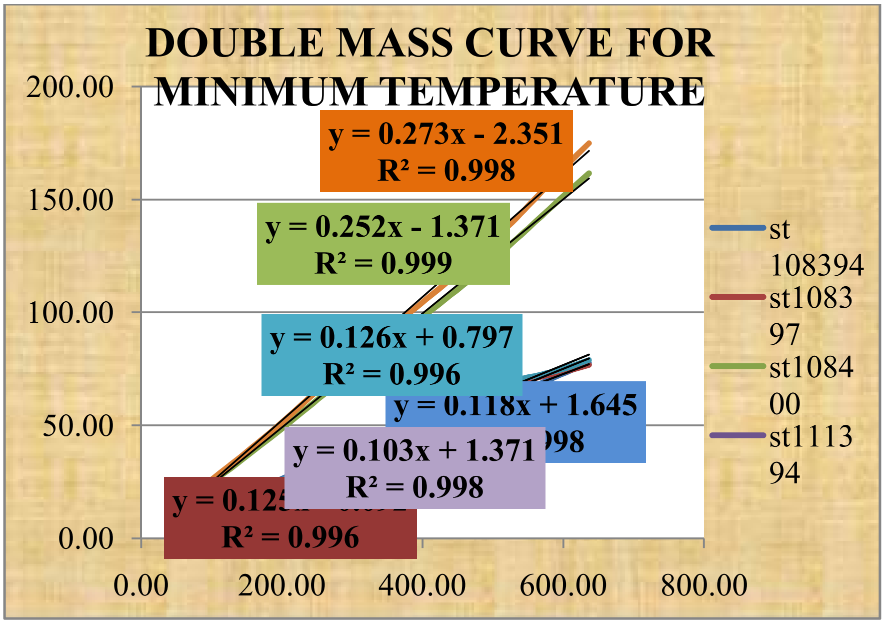

Figure 7: Double Mass Curve for All Stations Minimum Temperature

From the above graph we can see that all R^2 values are too close to 1which implies that the stations have high consistency over minimum temperature. Each station has good relationship and representation of the minimum temperature other correlated station.

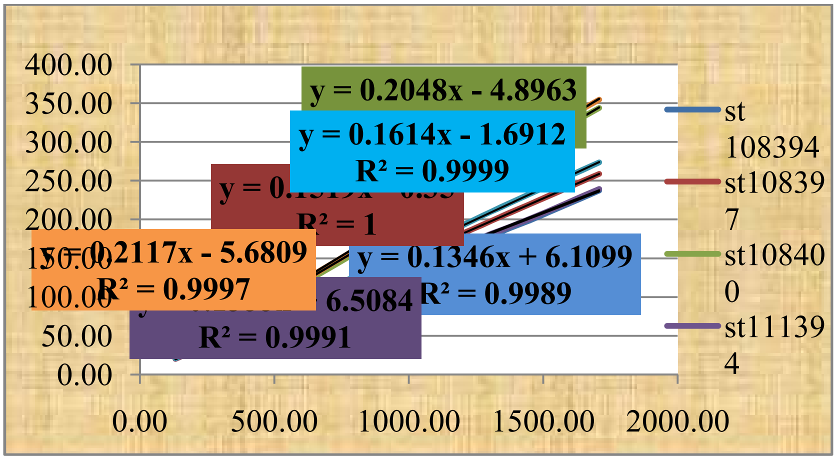

Figure 8: Maximum Temperature Using Double Mass Curve

4.2.3. Checking Consistency for Precipitation

The double-mass curve technique should seldom be used for testing consistency of precipitation data in mountainous areas. The climate within a mountainous area changes with the difference in elevation, and the precipitation at two nearby stations differing greatly in elevation may be due to different meteorological events. Records from areas where the precipitation pattern for one season of the year differs greatly from that of another should be tested by double-mass curves prepared on a seasonal basis rather than a yearly basis. We have already plotted a graph of mass curve as shown below and also we compute R^2 for each station using Excel.

Spatial consistency checks for rainfall data are carriedout by relating the observations from surrounding stations for the same duration with the rainfall observed at the station. This is achieved by interpolating the rainfall at the station under question with rainfall data of neighboring stations. The station being considered is called the test station. The interpolated value is estimated by computing the weighted average of the rainfall observed at neighboring stations. Ideally, the stations selected as neighbors should be physically representative of the area in which the station under scrutiny is situated. The following criteria are used to select the neighboring stations:

- the distance between the test and the neighboring station must be less than a specified maximum correlation distance;
- too many neighboring stations should not be considered for interpolation; and
- to reduce the spatial bias in selection, it is advisable to consider an equal number of stations in each quadrant.

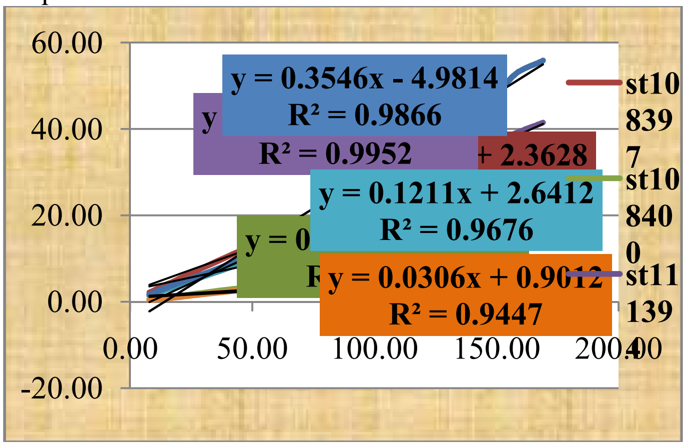

Figure 9: Double Mass Curve for Precipitation

The more the value is close to 1, the greater the consistency we had between all stations. For our case, all R2 values are so close to 1 i.e. R^2= (0.9866, 0.9952, 0.9903, 0.9298, 0.9447,0.9679) ~1. It is possible also to check the consistency of other hydrologic and metrological data using double mass curve method following the same step we have used above.

4.2.4. Test for Outlier

Grubb's Test

Statisticians have devised several ways to detect outliers. Grubbs' test is particularly easy to follow. The first step is to quantify how far the outlier is from the others. Calculate the ratio X as the difference between the outlier and the mean divided by the SD. If X is large, the value is far from the others. Note that you calculate the mean and SD from all values, including the outlier.

An outlier is an observation that deviates significantly from the bulk of the data, which may happen due to error in data collection, or recording or due to natural causes. The presence of outliers in the data causes difficulties when fitting a distribution to the data. Low and high outliers are both possible and have different effects on the analysis. The Grubbs and Beck test (G-B) may be used to detect outliers.

Low and high outliers are both possible and have different effect on the analysis. A value can be regarded an outlier if the statistic X is greater than the critical value. Please note that in the case of the one-sided test the critical values are different. In this test the quantities X_H and X_L can be calculated using the following two equations:

$$X_L = e^{x - kn * s}$$

$$x_h = e^{x + kn * s}$$

Where X and S is the mean and standard deviation of the natural logarithms of the sample, respectively, and K_N were tabulated for various sample size and significance level (mostly 10% were used for outlier test) were as sample value greater than X_H are considered as high outliers, while those less than X_L are considered to be low outliers.

K_N = statistic value that depend on significance level

N= Number of years

$K_N = -3.62201 + 6.28446N^{1/4} - 2.491436N^{1/2} + 0.491436N^{3/4} - 0.037911N$

4.3. ARC SWAT

4.3.1. Model Description

SWAT is a very useful tool for hydrologists when modeling large watersheds. One of the main inputs the model needs is the metrological properties for the basin. The metrological data needed can be divided into precipitation data, temperature data, humidity data and solar radiation data. SWAT also uses spatial input data to determine HRUs units. Hence, they play a large role in determining the movement of water and air within the HRU.

4.3.2. Watershed Delineation

The Arc GIS tool in Arc SWAT partitions watersheds into a number of hydrological connected sub-basins-based on flow directions and accumulations. The watershed and sub-basins delineation was carriedout based on an automatic delineation procedure using a Digital Elevation Model (DEM). In order to simulate hydrology and water quality response within a watershed, SWAT model divides the watershed into sub-watershed sub-basins-based on the DEM and manually added outlets within the watershed by the user. Sub-basins are further subdivided into land areas, called hydrologic response units (HRUs), based on land use, management, and soil properties.

The Arc SWAT interface proposes the minimum, maximum, and suggested size of the sub basin area (in hectare) to define the minimum drainage area required to form the origin of a stream. Generally, the smaller the threshold area, the more detailed are the drainage networks, and the larger are the number of sub-basins and HRUs. However, for this study a default threshold area that is suggested by the model was used.

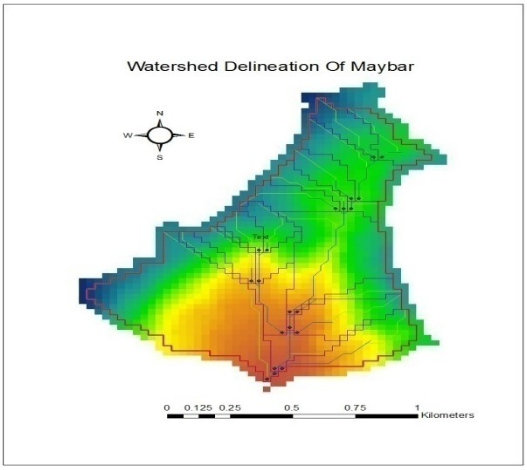

Figure 10: Delineated Watershed of Maybar

4.3.3. Determination of Hydrologic Response Units (HRUs)

A step next to watershed delineation is determination of hydrologic response unit. An HRU is a combination of land use/land cover and soil characteristics, and represents areas of similar hydrologic responses. Each HRU has a unique combination of land use and soil properties. This describes better the hydrologic water balance and increases the accuracy of load predictions. The HRUs can be defined either by assigning only one HRU for each sub-basin considering the dominant soil/land use/slope combinations, or by assigning multiple HRUs for each sub-basin considering the sensitivity of the hydrologic process based on a certain threshold values of soil/land use/slope combinations. For this study, the latter method was adopted as it better describes the heterogeneity within the watershed and as it accurately simulates the hydrologic processes. To model multiple HRUs, a threshold level must be determined so as to eliminate minor land uses/soil/slope in each sub-basin. Land uses/soil/slope that cover a percentage of the sub-basin area less than that threshold level are eliminated and the area of the land uses/soil/slope are reapportioned so that 100 %of the land area in the sub basin is included in the simulation. The Arc SWAT interface user's manual (Winchell, Srinivasan, Diluzio, Arnold et al., 2013) suggests that a 5 % land use threshold and a 10% soil threshold are adequate for most modeling applications. In this study however 5% % threshold for all land use, 10% soil class and 10% slope class over sub basin area have been adopted.

4.3.4. Weather Data Definition

In this stage of SWAT process all weather stations data are entered in batch file of text format. SWAT includes the WXGEN weather generator model to generate climatic data or to fill the gaps in measured records. Weather generator model needs different weather parameters. The occurrence of rain on a given day has a major impact on relative humidity, temperature and solar radiation for the day. The weather generator first independently generates the precipitation of the day. Once the total amount of the day is generated, the distribution of rainfall within the day is computed. Maximum temperature, minimum temperature, solar radiation and relative humidity are then generated based on the presence or absence of rain of the day. Finally, wind is generated independently.

4.3.5. SWAT Model Simulation, Sensitivity, Calibration and Validation

SWAT input parameters are process based and must be held within a realistic uncertainty range. The first step in the calibration and validation process in SWAT is the determination of the most sensitive parameters for a given watershed or sub watershed. The user determines which variables to adjust based on expert judgment or on sensitivity analysis. Sensitivity analysis is the process of determining the rate of change in model output with respect to changes in model inputs (parameters). It is necessary to identify key parameters and the parameter precision required for calibration (Ma et al., 2000).

According to James and Burges (1982), sensitivity analysis is conducted to determine the influence of a set of parameters had on predicting total flow, sediment, and other model output of interest. Sensitivity was approximated using the relative sensitivity S_r

$$s_r = (\frac{x}{y})(\frac{y_2 - y_1}{x_1 - x_1})$$

Where: x is the parameter and y is the predicted output.x_1, x_2, y_1, and y_2, correspond to±10 % of the initial parameter and corresponding output values, respectively.

The greater the relative sensitivity, the more sensitive a model output variable was to that particular parameter. Based on the relative sensitivity, James and Burges (1982), rate the parameters sensitivity as small to negligible, medium, high, and very high for $0 \leq S_r < 0.05$, $0.05 \leq S_r < 0.2$, $0.2 \leq S_r < 1.0$, $Sr \geq 1.0$, respectively.

Model calibration is an important step in watershed modeling studies that helps to check the model prediction efficiency which, in turn, used to reduce uncertainties in model output. Once the setup of the model was completed and the necessary data were overlaid, the model was run and the output of the simulation was printed out. But the result from the simulation cannot be directly used for further analysis of the watershed phenomenon. Instead, the ability of the model to sufficiently predict the constituent stream flow and sediment yield should be evaluated through sensitivity analysis, model calibration and model validation (White and Chaubey, 2005).

Sensitivity Analysis

Sensitivity analysis evaluates the influence of different parameters on simulation result, the response of output variable to a change in input parameter (White and Chaubey, 2005). Model users are often faced with the difficult task of determining which parameters to calibrate so that the model response mimics the actual field conditions as closely as possible. In such cases, sensitivity analysis is helpful to identify and rank parameters that have significant impact on specific model outputs of interest (Saltelli, et al., 2000).The most sensitive parameter corresponds to greater change in output response.

The model considered twenty seven flow parameters for sensitivity analysis from which twenty one of them were found to be relatively sensitive with the category of sensitivity ranging from very high to small. Among the sensitive flow parameters the ground 5 water parameters were found to be more sensitive to stream flow. Deep aquifer percolation fraction; Rchrg-Dp, Initial curve number (II) value; Cn2, Base flow alpha factor [days]; Alpha-Bf, Threshold water depth in the shallow aquifer for flow [mm]; Gwqmn, Soil evaporation compensation factor; Esco, Soil depth [mm]; Sol-Z, Threshold water depth in the shallow aquifer for "revap" [mm]; Revapmin, Maximum potential leaf 10 area index; Blai, Available water capacity [(mmwater) (mmsoil) −1]; Sol-Awc, Maximum canopy storage [mm]; Canmx, Groundwater Delay [days]; Gw-Delay, Saturated hydraulic conductivity [mmh−1]; Sol-K and Surface run off lag time [days]; Surlag were found to be the most effective hydrologic parameters for the simulation of stream flow. A brief description of each hydrologic parameter is listed in the SWAT model user's manual (Neitsch et al., 2005).

Two types of sensitivity analysis are generally performed: local, by changing values one at a time, and global, by allowing all parameter values to change. The two analyses, however, may yield different results. Sensitivity of one parameter often depends on the value of other related parameters; hence, the problem with one-at-a-time analysis is that the correct values of other parameters that are fixed are never known. The disadvantage of the global sensitivity analysis is that it needs a large number of simulations. Both procedures, however, provide insight into the sensitivity of the parameters and are necessary steps in model calibration.

Calibration

The second step is the calibration process. Calibration is an effort to better parameterize a model to a given set of local conditions, thereby reducing the prediction uncertainty. Model calibration is the modification of parameter values and comparison of predicted output of interest to measured data until a defined objective function is achieved (James and Burges, 1982). Sometimes, it is necessary to change parameters in the calibration process other than those identified during sensitivity analysis because of the type of missmatch of the observed variables and the predicted variables (White and Chaubey, 2005).

After each calibration, checking the R2, NSE and PBIAS values and calibrate at least until the minimum recommended values were embraced by the model that is $R^2 > 0.6$, NSE > 0.5 and PBIAS < ±15 (Santhi et al., 2001).

Validation

The final step is validation for the component of interest (stream flow, sediment yields, etc.). Model validation is the process of demonstrating that a given site-specific model is capable of making sufficiently accurate simulations, although "sufficiently accurate" can vary based on project goals (Refsgaard, 1997).

Validation is comparison of the model outputs with an independent dataset without further adjustments of the values of the parameters. The process continued (calibration process) till simulation of validation-period stream flows confirmed that the model performs satisfactorily. After calibration of flow with the given time step the next step was calibration of sediment yield of the watershed. Like flow calibration, it was calibrated based on sensitive parameters that observed at sensitivity analysis of sediment flow. Checking the R^2, NSE and PBIAS values after each simulation and calibrate at least until the minimum recommended values were embraced by the model; $R^2 > 0.6$, NSE > 0.5 and PBIAS < ±20 (Santhi et al., 2001).

Statistical model performance indicators

To evaluate the accuracy of the overall model calibration and validation, different statistical indicators like coefficient of determination (R^2), Nash-Sutcliffe modeling efficiency (NSE), Root mean square error observation standard deviation ratio (RSR) and %bias (PBIAS) have been used.

The statistical indicators used for SWAT model calibration and validation in Upper Awash basin have been calculated using the following empirical relations.

Coefficient of determination (R^2): Is the index of correlation of measured and simulated values. The value of R^2 ranges from 0 to 1. The more the value of R^2 approaches 1, the better is the performance of the model and the values of R^2 less than 0.5 indicate a poor performance of the model.

$$R^2 = \left(\frac{\sum_{i=1}^{n}(O_i - O_{ave})(P_i - P_{ave})}{[\sum_{i=1}^{n}(O_i - O_{ave})^2 \sum_{i=1}^{n}(P_i - P_{ave})^2]^{0.5}}\right)^2$$

Where O_i =Observed stream flow

O_{ave} =Average observed Stream flow

P_i =Predicted/Simulated Stream flow

P_{ave} =Average Simulated Stream flow

n=number of observation

Nash-Sutcliffe Efficiency (NSE): NSE is the normalized statistics which measures the relative magnitude of the residual variance as compared to measured data variance. Similar to R2, the more the NSE approaches 1, the better will be the model performance and vice versa.

$$NSE = 1 - \frac{\sum_{i=1}^{n}(O_i - P_i)^2}{\sum_{i=1}^{n}(O_i \_ P_{ave})^2}$$

%bias (PBIAS): This measures the average tendency of the simulated data to be larger or smaller than the observed values. PBIAS is expressed in percentage; the lower the absolute value of the PBIAS is the better will be the model performance.

$$PBIAS = \frac{\sum_{i=1}^{n}(O_i - P_i) * 100}{\sum_{i=1}^{n} O_i}$$

Root mean square error observation standard deviation ratio (RSR): It is an error index indicator. RSR ranges from 0 to 1, with the lower value closer to zero indicating higher accuracy of the model performance. Values approaching 1 indicate a poor model performance.

5. Results and Discussion

5.1 SWAT Hydrological Model out put

This portion we covers the findings of the study obtained from the SWAT model analysis. A number of output files are generated in every SWAT simulation. These files are: the summary input file (input. STD), the summary output file (output. STD), the HRU output file (output.hru), the sub basin output files (output. Sub), and the main channel or reach output file (output.rch).The standard output summary file provides watershed average annual, monthly or daily loadings from the HRU's to the streams. It is the first file a user should examine to obtain a basic understanding of the watershed's water, sediment, nutrient and pesticide balances. Average watershed or basin values are the weighted sum of HRU loadings before any channel or reservoir routing is simulated. It does not account for channel routing losses (i.e. Water transmission losses, sediment deposition, and nutrient transformations) and does not account for reservoir loss. Generally in Maybar watershed there are 19 sub basin and 35 hydrologic response units (HRU).

5.2 Sensitive Analyses

Flow sensitivity analysis was carried out for a period of 15 years, which includes 6 warm-up period and ten years of the calibration period (from January 1, 1993 to December 31, 2007). SCS Curve Number II, the parameter which is related to run off as a function of soil's permeability, land use and antecedent soil water conditions (CN2) in the figure below is the most sensitive parameter of all, followed by the initial the base flow Alpha factor (ALPHA-BF) or the base flow ression constant which is the direct index of the ground water flow response to changes in recharge was also sensitive.

The other ground water parameters which flow was sensitive were threshold depth of water in the shallow aquifer required for return flow to occur (GWQMN), delay time for aquifer recharge (GW_DELAY.

For accurate model calibration and validation, the direct run off and base flow components from stream flow have to be first separated. For this study the base flow and the direct run off were separated by Web GIS based Hydrograph Analysis (WHAT). WHAT is the model or algorithm developed by Lim et.al, 2005, to provide fully automated functions for base flow separation. The result of flow separation using the WHAT program based on the daily flow data measured at the Maybar gauging station showed that 57.18%of the flow is contributed by from small glacieries and the rest by the surface run off. This shows that the contribution of the shallow aquifer to the total stream flow is significant in the watershed.

5.3 Flow Calibration and Validation

The performance of the model was tested at every stage of the model simulation with the parameters printed out at the respective stages. Before calibration proceeds, the performance of the model was evaluated from the initial simulation with model default parameter values. The monthly simulations were resulted Coefficient of determination (R^2), Nash – Sutcliffe Coefficients (NSE), Root mean square error observation standard deviation ratio (RSR) and %of bias (PBIAS) of 0.78, 0.75, 0.52 and -36.5 respectively. The result shows that except R2, the other performance indicators were below the acceptable limits, i.e. NSE > 0.5 and PBIAS < ±15% (Santhi et al., 2001), and RSR indicated poor performance of the model. So that, the default model flow parameters were required adjustment. Like sensitivity analysis, flow calibration for the watershed was conducted for the total of 15 years (from January 1, 1993 to December 31, 2007) The Coefficient of deter of 0.77, Nash – Sutcliffe Coefficients (NSE) of 0.705, Root mean square error observation standard deviation ratio (RSR) of 0.53 and %of bias (PBIAS) of -0.38% were reported, but still there were the need of further adjusting the parameters value by varying iteratively in their allowable range until satisfactory agreement between measured and simulated stream flow was obtained. At this stage the manual calibration was used by taking the characteristics of each parameter and their respective allowable range into consideration.

The SCS curve number (CN2) value was adjusted by subtracting 15% from each default. Accordingly, the base flow recession constant (ALPHA_BF), which is a direct index of groundwater flow response to changes in recharge was adjusted. The result of the model test shows that the R^2, NSE, RSR and PBIAS of 77.5%, 75.08%, 52.36% and -36.50% as shown below. Therefore the objective functions were satisfied, *mination* (R^2)

Table 6: Initial and Finally Adjusted Parameter Value of Calibration

Parameters	Effect on simulation when parameter values increase	Recommended Range	nitial/default values	Adjusted values
CN2	Increase surface run off	-25 to 25%	61-87	3.77
ALPHA_BF	Increase the ground water flow response to changes in recharge	0-1	0.048	0.688
GWQMN	Decrease base flow	0-5000	Default	3500

Validation of the model results is necessary to increase user confidence in model predictive capabilities. Thus, the model was validated with observed flow data at the same location, but different time period from January 1, 2000 to December 31, 2003, without further adjustment of the parameters of flows. The overall performance of the model during validation has been tested using R2, Nash-Sutcliffe (NSE), RSR and PBIAS. The statistical values in monthly time base of R2, NSE, RSR and PBIAS are 77.98, 75.07, 52.36 and -36.5% respectively. This indicates the objective functions that used for evaluation were in the acceptance range for the validation time period.

Table 7: Calibration and Validation Statistic of Monthly Flows

Simulation	Period (monthly)	Mean annual flow (m3/s)		R^2	NSE	RSR	PBIAS
		Observed	Simulated				
Calibration	1993-2007	22.4517	31.129	77.98	75.07	52.36	-36.5
Validation	2008-2012	5.5694	27.049	70.05	61.40	60.06	-59.67

Table 8: Description of the Output Variables in the Output Summary File

Variable name	Definition
UNIT TIME	Daily time step: the Julian date Monthly time step: the month (1-12) Annual time step:
PREC	Average amount of precipitation in watershed for the day, month or year(mm)
LATQ	Lateral flow contribution to stream flow in watershed for the day, month or year(mm)
GWQ	Groundwater contribution to stream in watershed on day, month or year(mm)
PERCOLET	Water percolation past bottom of soil profile in watershed for the day, month or year(mm)
SW	Amount of water stored in soil profile in watershed for the day, month or year(mm)

ET	Actual evapotranspiration in watershed for the day, month or year (mm)
PET	Potential evapotranspiration in watershed on the day, month or year (mm)
WATER YIELD	Water yield to stream flow from HRUs in watershed for the day, month or year (mm)
HRU	Hydrologic Response Unit number.
SUB	Sub basin in which HRU is located
SOIL	Soil series name
CN	SCS run off curve number for moisture condition
SWC	Amount of water held in the soil profile at field capacity (mm

5.2.1 Land Use

Maybar watershed was found to compose of three land use types: Agricultural land, Range land and forest. But the dominant is agricultural land use and it covers 85% of the total area. The land uses of the area were defined according to SWATs Use system of nomenclature.

Table 9: Land use classification of Maybar catchment using SWAT Model

NO	CODE	AREA (km^2)	CN	LAND USE	SWAT LAND USE CLASS
1	10	0.98	86.76	Agricultural land use	AGRL
2	20	0.16	79.00	Forest	FRST
3	30	0.01	84.00	Range land	RNGE

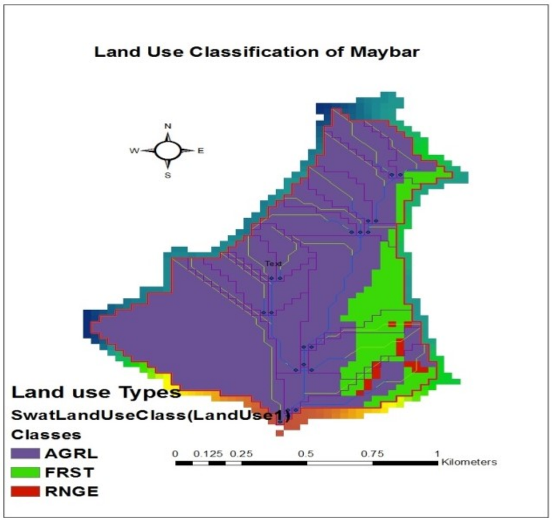

Figure 11: Land use Classification of Maybar According to FAO Soil Classes

5.2.2 Soil

There are two types of soil in Maybar watershed that are Eutric Cambisoil and Eutric Rgosoil. The dominant soil type in the area is Eutric Cambisoil. The textures are loam and sandy loam soil. The dominant soil texture is loam soil. According to the SWAT out put the hydrological soil group is D and curve number 79, 83, 84 and 87.

Table 10: Soil type of Maybar catchment as per FAO-UNESCO soil classification system

No	Soil Type	code	Soil Classes defined In SWAT	Area (ha)	Total Area (%)
1	Eutric camisole	1	Be1-1081	110	95.65
2	Eutric Rgosoil.	2	Re1-1-2a-123	5	0.45
Total				115	100

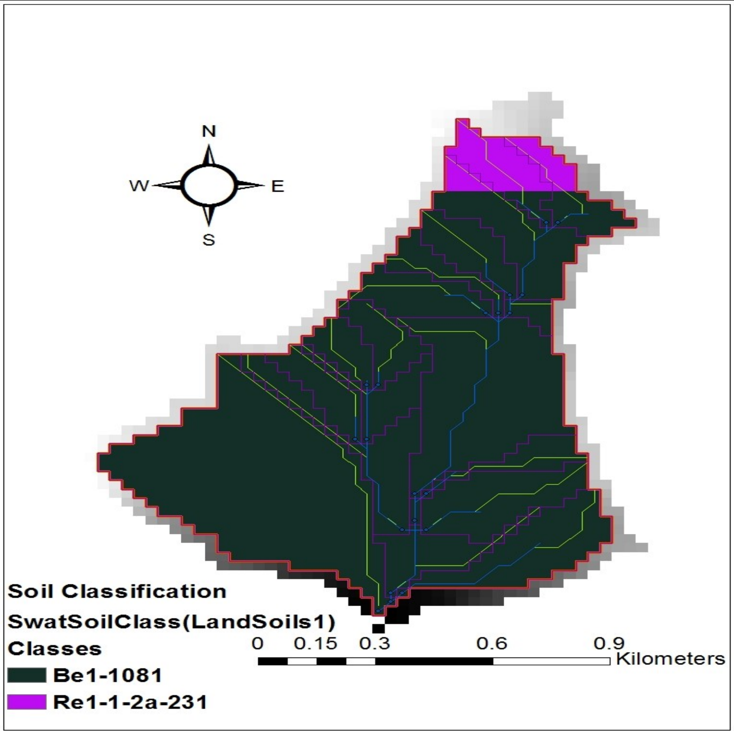

Figure 12: Soil Classification and their Coverage on Maybar

5.2.3 Trend of Precipitation and Surface Run off Output in SWAT

As we see from the figure when the precipitation increase the surface run of also increase but not equally because of different constraints that are infiltration , percolation, interception, evaporation, and transpiration reduces the amount of run off.

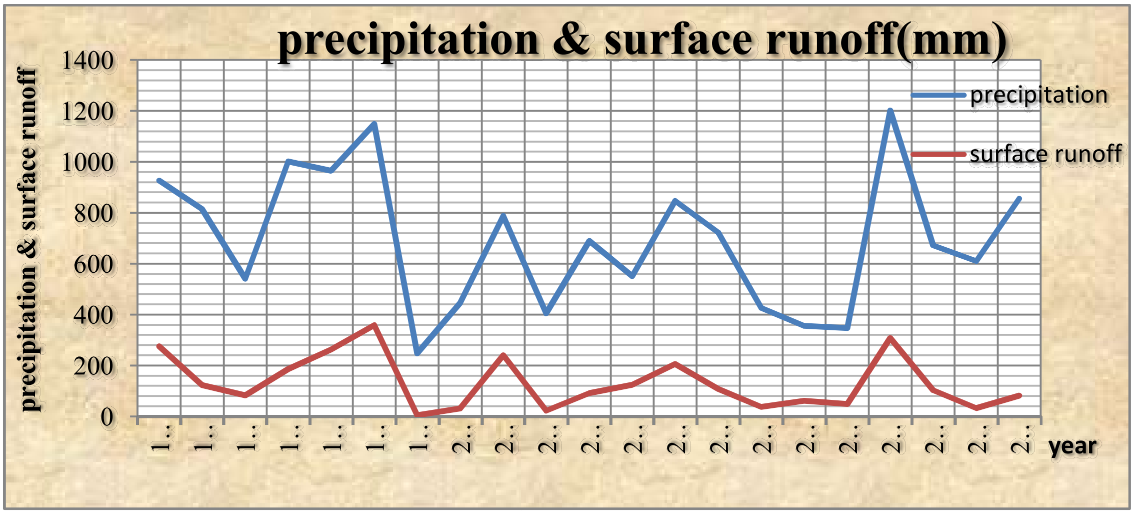

Figure 13: Rainfall and surface run off simulated by SWAT (swat output)

Average Annual Output of Maybar Watershed

Precep = 693.3 mm
Snow fall = 0.00 mm
Snow melt = 0.00 mm
Sublimation = 0.00 mm
Surface run off Q = 133.40 mm
Lateral soil Q = 44.81 mm
Groundwater (shalaQ) Q = 5.77 mm
Groundwater (deep aQ) Q = 1.19 mm
Revap (shalAQ => soil/plants) = 28.05 mm
DeepAQ recharge = 1.20 mm
TotalAQ recharge = 23.95 mm
Total water yld = 185.17 mm
Percolation out of soil = 23.95 mm
ET = 493.5 mm
PET = 1672.3mm
Transmission losses = 0.00 mm
Evaporation from impounded water = 0.000 (mm)
Seepage into soil from impounded water = 0.000 (mm)
Overflow from impounded water = 0.000 (mm)

6. Conclusion and Recommendation

6.1. Conclusion

As the result of Maybar rainfall run off model analysis shows, soil type, land use /land cover and slope the most parameter. From SWAT output the soil Eutric Cambisoil is a dominant soil type covers 85% of the total area. Land use patterns of the area were defined according to SWATs system of nomenclature. Hydrologic response unit (HRU) analysis result showed agricultural land use is the most dominant type. There are three classes of land use /land cover and two types of soil in Maybar watershed.

The previous studies in the basin were limited to giving accounts to spatial and temporal variations of inputs. This study is an attempt to applying rainfall run off modeling, which accounts spatial and temporal variation of inputs in the basin. This study has paramount importance as it is new and original contribution using SWAT rainfall run off modeling approach, to mainly estimate run off from gauged part of the catchments and to study the water resource potential of the catchment.

SWAT model is physically-based, computationally efficient, and capable of continuous Simulation over long time periods. Major model components include weather, hydrology, soil temperature and properties, plant growth, and water management. In SWAT, watershed is divided into multiple sub-watersheds, which are then further subdivided into Hydrological Response Units (HRUs) that consist of homogenous land use, management, and soil characteristics. The HRUs represents percentages of the watershed area and are not identified spatially within a SWAT simulation. In this thesis also data input formats are adjusted according to arc SWAT requirement. Here data inputs are primarily physically-based

The average annual precipitation reaches 693.3 mm and average annual surface run of is 133.4mm.

Calibration and validation are typically performed by splitting the available observed data into two datasets: one for calibration, and another for validation. Data are most frequently split by time periods, carefully ensuring that the climate data used for both calibration and validation are not substantially different, i.e., wet, moderate, and dry years occur in both periods (Gan et al., 1997). For those calibrated values the performance of the model has to be properly and reasonably judged and evaluated else wrong interpretation of the result may occur. The result of sensitivity analysis shown by curve number (CN2) was the most sensitive parameter. The second sensitive parameter identified is base flow Alpha factor (ALPHA_BF).

6.2. Recommendation

Lack of reliable metrological data, digital elevation model, soil and land use/ land cover data were one of the challenges in this study. Responsible bodies should hence give due attention to the acquisition and recording of reliable data. Therefore, the results of this study should be considered with care and be taken as indicative of the likely risk rather than accurate futures.

From the watershed characteristics, the effect of soil has a great impact in the study area. Therefore soil data with a high resolution which can enhance the result has to be prepared.

The result obtained from calibration and validation is not enough. Still other adjustments of sensitivity are needed as such PBIAS and RSR results show these. In fact, other model performance indicators are valid. However, work needs to be done to get more precise results.

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