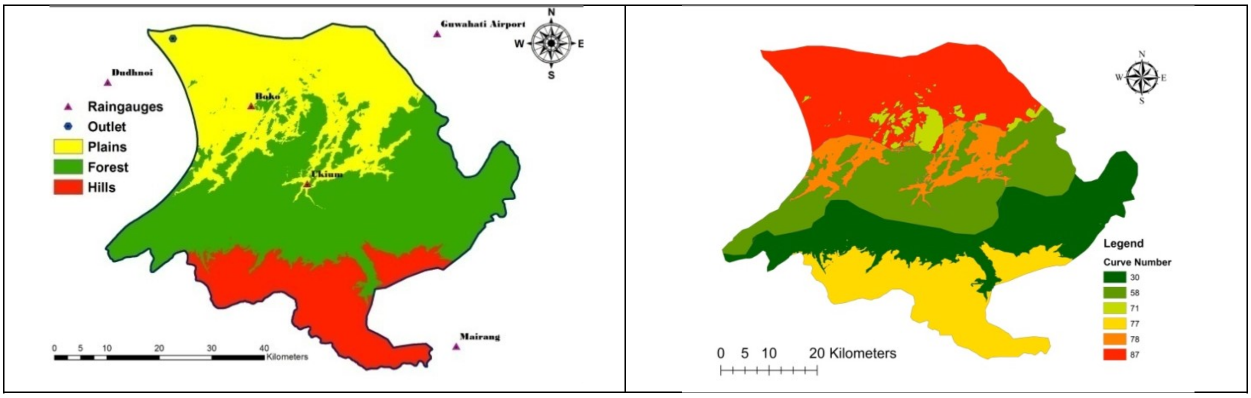
Estimation of Runoff for Kulsi River Basin using NRCS Curve Number and Geographic Information System



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PREFACE

Planning and execution of water resources projects require the estimation of runoff. Several models have been developed in an attempt to estimate the direct surface runoff from storm rainfall. Typical of such models is the soil conservation service (SCS) runoff curve number model (SCS, 1985), which has had wide acceptance in engineering practice. The SCS model computes direct surface runoff through an empirical relation that requires the rainfall and a watershed coefficient namely runoff curve number (CN) as input.The curve number is a function of some of the major runoff producing properties of a basin namely, the hydrologic soil type, land use and treatment, ground surface condition and antecedent moisture condition.

Integrated Water Resources Management (IWRM) is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. National Institute of Hydrology has undertaken a project under XIIth Plan at each of its Regional Centres.

The Kulsi River Basin,a part of the Brahmaputra sub-basin is situated on the south bank of the mighty River Brahmaputra was identified as Pilot Basin for Centre for Flood Management Studies, Guwahati. This sub-basin spreads in the Kamrup District of Assam as well as west Khasi hills and Ribhoi district of Meghalaya.

The objective of the SCS Curve Number Method, now renamed as NRCS method is to determine the right curve number of the catchment of interest that defines the runoff potential. Hydrologic soil group number, land use type, vegetation cover, soil conservation measures, antecedent soil moisture conditions are the basic catchment characteristics used for curve number calculations. Keeping in view the above points, SCS-CN method are used along with remote sensing and GIS datasets for simulation of rainfall runoff relationship for Kulsi River Basin. The study also generate runoff potential map for the Basin.

The report has been prepared by Dr. Sanjay Kumar Sharma, Sc. 'C' and Er. GulshanTirkey, Sc 'B' Centre for Flood Management Studies, Guwahati, under the work programme for 2017-19.

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ABSTRACT

A rainfall-runoff model is a mathematical model describing the rainfall - runoff relations of a catchment area, drainage basin or watershed. In other words, the model calculates the conversion of rainfall into runoff. Estimation of runoff from storm rainfall is frequently needed for water resources planning, design of hydraulic structures and environmental impact analyses. There are several methods available for the estimation of runoff. Among them the SCS runoff curve number now known as NRCS method is the most popular and widely used. The advantages of this method are its simplicity, predictability, stability and its reliance on only one parameter namely, the curve number.

Centre for Flood Management Studies, National Institute of Hydrology, India has identified Kulsi River Basin for undertaking Pilot Basin Study (PBS) as a component of Integrated Water Resource Management (IWRM) under the mandate of XII plan period. The Kulsi River Basin spreads in the Kamrup District of Assam as well as west Khasi hills and Ribhoi district of Meghalaya. The river Kulsi drains out a total area of 2806 sq. km. within the Kamrup District of Assam as well as west Khasi hills and RiBhoi district of Meghalaya. The selected basin is ideal to develop Curve Number and Runoff Maps due to its strategic location encompassing two states in the north-east coupled with the fact that the region experiences maximum floods.

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This study applies ArcCN-Runoff tool, an extension of ESRI@ArcGIS software for determination of CN Grid and runoff map. The tool reduces technical processing time from days to hours for producing spatially varied curve number and runoff maps. The generated maps indicate that the method can be applied to predict runoff depth for ungauged watershed and other water resource applications as well.

Keeping in view the above points, SCS-CN method will be used along with remote sensing and GIS datasets for simulation of rainfall runoff relationship for Kulsi River Basin. The study will generate gridded Curve number and annual runoff map for Kulsi River Basin.

Keywords: NRCS METHOD, CURVE NUMBER, ArcCN-Runoff tool, RUNOFF MAP

1.0 INTRODUCTION

The rainfall-runoff relationship is a complex and dynamic process, affected by many interrelated physical factors. The influence of these combinations of complex factors in generating runoff is not clearly understood. In terms of modeling, the input (rainfall) to the system (basin) undergoes translation in time due to variable source areas of the basin, contributing runoff at the outlet at different times. A rainfall-runoff model is a mathematical model describing the rainfall - runoff relations of a catchment area, drainage basin or watershed. More precisely, it produces the surface runoff hydrograph as a response to a rainfall hydrograph as input. A rainfall runoff model can be really helpful in the case of calculating discharge from a basin.

The modeling and forecasting of floods requires extensive spatial information of catchments and flood risk areas. Geographical Information Systems (GIS) and Remote Sensing offer valuable tools to contribute to the data requirement in modeling. The use of GIS also facilitates visualization of the modeling results which is helpful in enhanced decision making process.

Lack of adequate rainfall and runoff gauge stations makes the understanding of underlying hydrologic condition in River Basin quite difficult. This, it has become inevitable to determine rainfall-runoff model by using Remote Sensing and GIS technologies. This Soil Conservation Model can be used to obtain runoff depth or volume of the basin area. Curve Number (CN) is a model coefficient, which is determined based on the factors based on landuse and landcover from classified RS images and hydrologic soil groups.

Remote Sensing provides measurement of many of hydrological variables used in hydrologic model applications, either as direct measurements comparable to traditional forms, as surrogates of traditional forms, or as entirely new dataset (Melesse and Shih, 2002). In their paper entitled "Spatially distributed storm runoff depth estimation using Landsat images and GIS" they have said that the pixel format of digital remote sensing data makes it suitable to merge it with geographic information system (GIS).

Most of the previous work on adapting remote sensing to hydrologic modeling has involved the Natural Resources Conservation Service (NRCS) runoff curve number (CN) model (US Department of Agriculture, 1972). This involvement used remote sensing data as a substitute for land cover maps which had been obtained by conventional means (Jackson et al., 1977; Bondelid et al., 1982). Still and Shih (1984, 1985, 1991) used Landsat data to develop a basin-wide runoff index and successfully demonstrated how remotely sensed data can be used to track the changes in runoff that occur in a basin due to land use change.

GIS is a computer-based tool that displays, stores, analyzes, retrieves and generates spatial and non-spatial (attribute) data. The GIS technology provides suitable alternatives for efficient management of large and complex databases. It is used in hydrologic modeling to facilitate processing, management and interpretation of hydrologic data.

Several studies have been done to incorporate GIS in to hydrologic modeling of watersheds. These studies have different scopes and can be generally grouped in to four categories. Computation of input parameters for existing hydrologic models (Muzik and Pomeroy, 1990; Stuebe and Johnson, 1990; Djokic and Maidment, 1991;Olivera and Maidment, 1999) is the most active area in GIS related hydrology. Unlike lumped models, distributed models require large amounts of spatial data, which can be computed using GIS. Hydrologic assessment (Moeller, 1991; Ragan and Kossicki, 1991) refers to the mapping and display in GIS of hydrologic factors that pertain to some situation. Measuring the spatial extent of hydrologic variables from paper maps may be tedious, labor-intensive and error-prone. Watershed surface mapping (Band, 1989; Sasowsky and Gardner, 1991; Smith and Brilly, 1992) refers to the uses of GIS in representation of watershed surface through the use of digital elevation model and gridded geographic data. Identification of hydrologic response units (Vieux, 1991) is also another contribution of GIS to identify areas of watershed's having similar hydrologic response.

The traditional method for establishing CN on small watersheds includes field surveys and interpretations of aerial photographs. For large drainage basins, field surveys are prohibitively expensive and an excessive number of aerial photographs may be required for complete coverage. A further disadvantage of conventional techniques may be the infrequency of the surveys and the consequent failure to account for changes in vegetative cover and land use.

One of the major inputs for rainfall-runoff modeling is land cover. Satellite remote sensing is the best source of mapping this information (Parihar, 1995).Advantages of the information acquired by satellite remote sensing are of synoptic coverage, repetitive and spectral characteristics and especially in the easiness to compare the data before and after monsoons

Harbor,1994 had developed a simple rainfall-runoff model based on U.S. Department of Agriculture's CN method, to help land-use planners and watershed managers obtain initial insight into the hydrologic impacts of different land-use scenarios, including historic, current, and future alternatives. The SCS CN method requires numeric catchment characteristics which are the basis of catchment runoff determination. The objective of the method is to determine the right curve number of the catchment of interest that defines the runoff potential. Hydrologic soil group number, land use type, vegetation cover, soil conservation measures, antecedent soil moisture conditions are the basic catchment characteristics used for curve number calculations.

The SCS-CN method has been widely used to compute direct surface runoff. It originated from the proposal of Sherman(1949) on plotting direct runoff versus storm rainfall; the subsequent work Mockus (1949) on estimation of surface runoff for ungauged stations using the soil information, rainfall, storm duration and average annual temperature.

McCuen(1982), Hjelmfelt(1991), Hawkins(1993), Steenhuisetal.(1995), Bonta(1997), Mishra and Singh (1999) and Sahu et al (2007) has done appreciable work in this field. SCS-CN method has wide application in fields like design of discharge system, irrigation system, spillways, sediment yield, non-point source pollution and many more. Besides them Stuebe and Johnston 1990; Ponce and Hawkins 1996; Michel et al 2005; Ramakrishnan (2008) used SCS-CN method in their analysis. Bhuyan et al. (2003) studied event based watershed scale antecedent moisture condition (AMC) values to adjust field-scale CNs, and to identify the hydrological parameters that provide the best estimate of AMC. Patil et al. (2008) has done work in this field using GIS based interface selected sites.

Ponce and Hawkings (1996) in their paper entitled "Runoff Curve Number : Has it Reached Maturity?" summarized that The curve number method does not take into account the spatial and temporal variability of infiltration and other abstractive losses; rather it aggregates them into a calculation of total depth loss for a given storm event and drainage area. The method describes average trends, which precludes it from being perfectly predictive. The observed variability in curve numbers, beyond that which can be attributed to soil type, land use and surface condition, is embodied in the concept of antecedent condition. The method is widely used in the India, United States and other countries.

Perceived advantages of CN method are its: 1. simplicity, 2. predictability, 3. stability, 4. reliance on only one parameter and 5. responsiveness to major runoff producing watershed properties such as soil type, landuse, surface condition and antecedent condition. perceived disadvantages are its 1. sensitivity to CN, 2. Absence of clear guideline on how to vart antecedent condition and 3.fixing the initial abstraction at 0.2, preempting a regionalization based on geologic and climatic setting

In this study, SCS-CN method will be used along with remote sensing and GIS datasets for simulation of rainfall runoff relationship for Kulsi River Basin. The study will also generate runoff potential maps for the Basin. Specifically, the objectives of the study include :

i) To create gridded Curve Number for Kulsi River Basin using NRCS CN Method.

ii) To generate annual runoff map for Kulsi River Basin.

2.0 THEORETICAL CONSIDERATIONS

This chapter deals with the theoretical background of SCS runoff curve number method

2.1 SCS runoff curve number method

SCS Runoff Curve Number method is developed by the United States Department of Agriculture (USDA) Soil Conservation Service (SCS) and is a method of estimating rainfall excess from rainfall (Hjelmfelt, 1991). The method is described in detail in National Engineering Handbook (2004). The chapter was prepared originally by Mockus (1964), and was revised by Hjelmfelt (1998) with assistance from the NRCS Curve Number work group and H.F. Moody. Despite the wide use of the curve number procedure, documentation of its origin and derivation are incomplete (Hjelmfelt, 1991).

The basis of the curve number method is the empirical relationship between the retention (rainfall not converted into runoff) and runoff properties of the watershed and the rainfall. In this method, runoff depth (i.e. effective rainfall) is a function of total rainfall depth and an abstraction parameter referred to as runoff curve number or simply curve number and is usually represented by CN. The curve number varies in the range 1 to 100, being a function of the following runoff producing catchment properties: (1) hydrologic soil type, (2) land use and treatment, (3) ground surface condition, and (4) antecedent moisture condition.

$$\frac{F}{S} = \frac{Q}{P} \tag{1}$$

where $F = P - Q$ = actual retention after runoff begins;

Q = actual runoff

S = potential maximum retention after runoff begins

P = potential maximum runoff (i.e., total rainfall if no initial abstraction).

For most applications, a certain amount of rainfall is abstracted. The three important abstractions for any single storm event are rainfall interception (Meteorological rainfall minus throughfall, stem flow and water drip), depression storage (topographic undulations), and infiltration into the soil. The curve number method lumps all three abstractions into one term, the Initial abstraction

(I_a), and subtracts this calculated value from the rainfall total volume. The total rainfall must exceed this initial abstraction before any runoff is generated. This gives the potential maximum runoff (rainfall available for runoff) as $P - I_a$.

$$\frac{P - Ia - Q}{S} = \frac{Q}{P - Ia} \tag{2}$$

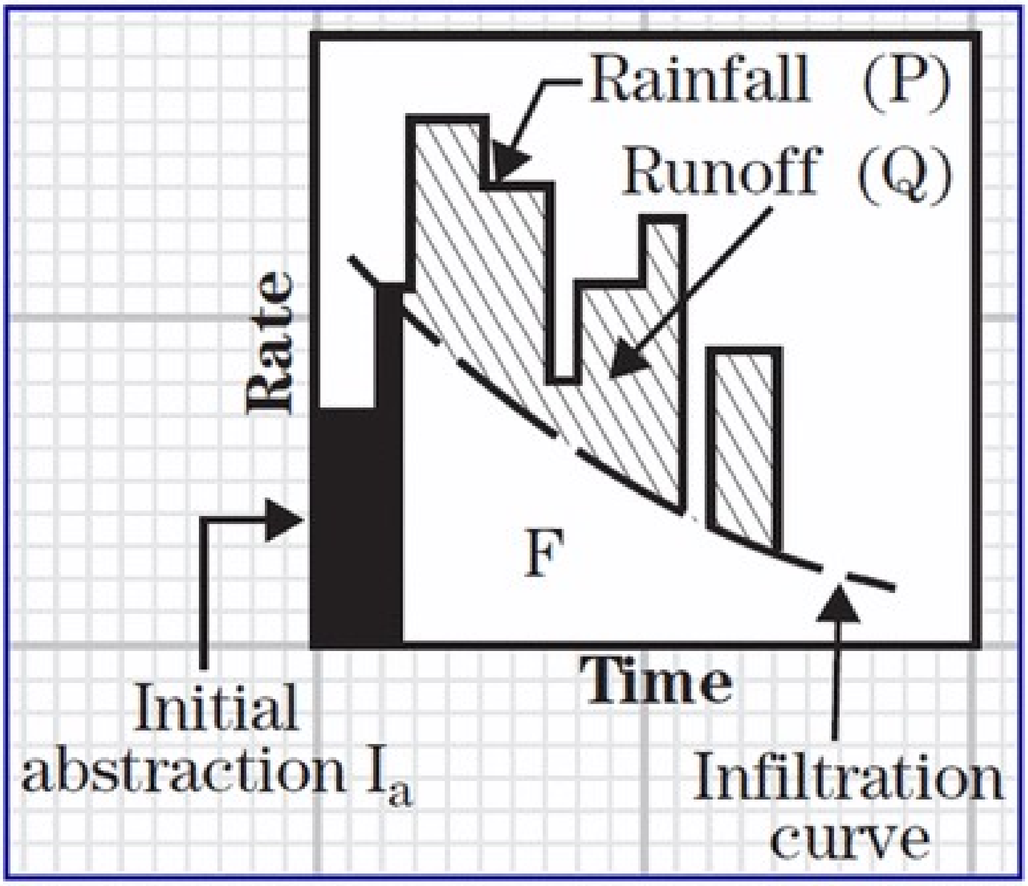

Fig 2.1 Components of SCS Runoff equation

It is important to note the potential maximum retention term, "*S*", excludes I_a. Hence, for a given storm, maximum loss of rainfall is *S* plus I_a. Rearranging terms in Equation 2 for Q gives

$$Q = \frac{(P - Ia)^2}{(P - Ia) + S} \tag{3}$$

Establishing the relation to estimate I_a was challenging. The SCS provided the following empirical Equation 4 based on the assumption *Ia* was a function of the potential maximum retention *S*.

$$\boldsymbol{Ia = 0.2S} \tag{4}$$

The potential maximum retention *S* is related to the dimensionless parameter CN in the range of 0 <= CN <= 100 by Equation 5.

$$S = \left(\frac{1000}{CN}\right) - 10) \tag{5}$$

Substituting Equation 4 into Equation 3 yields,

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \tag{6}$$

Equation 6 has only one parameter that needs to be evaluated (i.e., S) which can be determined by using Equation 5 and curve number tables published by the SCS. The solution of the SCS runoff equation is shown below:

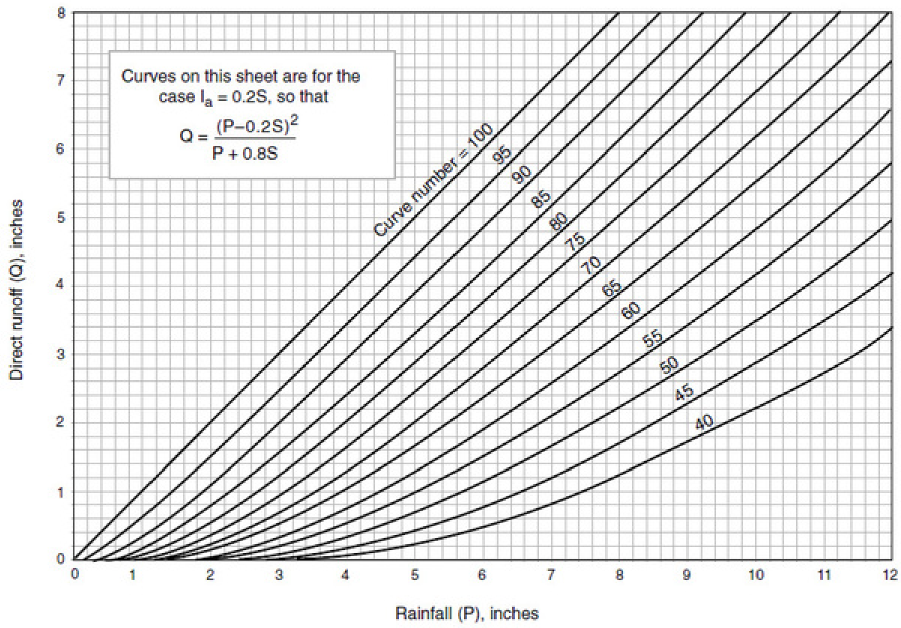

Fig 2.2 Rainfall, runoff relationship w.r.t I_a=0.2S (Source: TR-55, 1986)

3.0 STUDY AREA

3.1 Location

The Kulsi basin, a part of the Brahmaputra sub-basin is situated on the south bank of the mighty river Brahmaputra (Fig 4.1). This sub-basin spreads in the Kamrup District of Assam as well as west Khasi hills and Ribhoi district of Meghalaya. It is located between latitude 25^{o}30’N to 26^{o}10’N and longitude 89^{o}50’E to 91^{o}50’E with an altitude between 100 m to 1900 m above msl. The river Kulsi drains out a total area of 2806 sq. km. within the Kamrup District of Assam as well as west Khasi hills and Ribhoi district of Meghalaya.

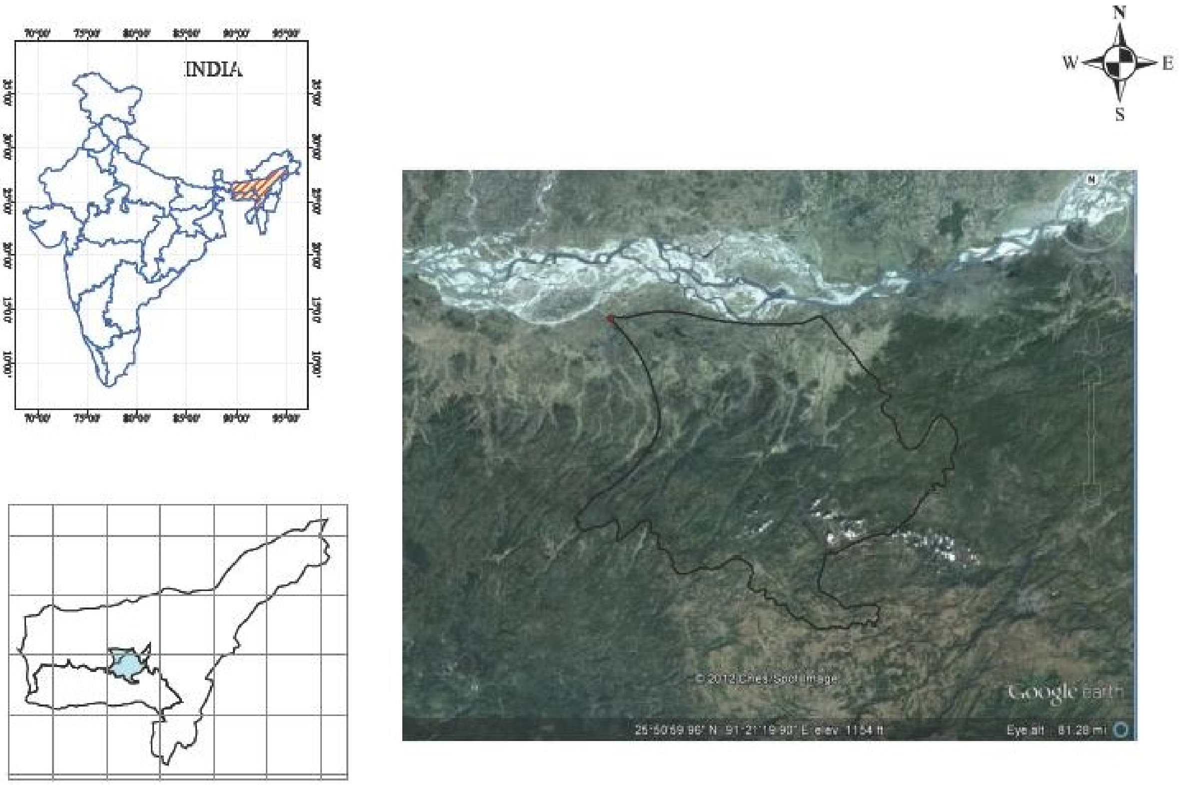

Fig.3.1 Location of Kulsi River Basin

3.2. River System

The Kulsi River is formed by the joining of three rivers namely Khari, Um Krishniya and Um Siri, all of which originate from the west Khasi Hills ranges and flows down north and joins the Brahmaputra (Fig 4.2). This hill range is covered with evergreen forests and gets high rainfall during the summer months. The river Um Krishniya is the centrally flowing river- with Um Siri joining it on the left bank and Um Khri joining it on the right bank. Um Krishniya and Um Sirioriginate almost from the same place, which is having the altitude around 1550m and Um Khiri originate from on area further east, which have got elevation around 1600m. It is interesting to note that all the three rivers originate from more or less the same latitude of 25035'. All the three rivers are joined by innumerable no. of small hilly streams and rivulets till they join together and flow down north by the name Kulsi.

The river Khiri and Um Krishniya join together after they flow respectively for a distance of about 85 km. and 47 km. After joining, the river flows by the name Khri for a distance about 15 km. when it is joined by UmSiri, which flows for a distance of about 52 km., till it joins here. After this point the river flows almost straight south for a distance of about 20 km. by the name Kulsi near to village Kulsi wherein it bifurcated into two branches of by the western side of Kulsi reserve forest and the other the eastern side of it and both flow by the name Kulsi one is eastern Kulsi and the other central Kulsi. The central Kulsi again bifurcates into near village Hatigarh, and the left flowing one flows by the name Kharkhari and the other flows by the original name Kulsi. After these branches off, the river Kulsi enters into the alluvial plain (Flood plain of the river Kulsi and Brahmaputra) and gets shallow and meanders. The eastern most channel (Kulsi) again branches of into 3 channels and again join together before crossing the N.H.- 37, near Kukurmara. In this reach the river is joined by another two small river Batha and Bahwa. After crossing N.H way it takes a complete western turn and flow parallel to the Brahmaputra and joins the other branch of the Kulsi (western Kulsi), which crosses the N.H. at Chaygaon, near village Satghariapara and both flows parallel to river Brahmaputra and meets the other branch of the Kulsi i.e. the Kharkhari near village Chamaria and flows west parallel to the Brahmaputra by the name Jaljali till it joins the Brahmaputra near Bahati. After the bifurcation of the river Kulsi, it is seen that the river takes westerly swing and flows paralleled to Brahmaputra, keeping a distance of 6 to 12 km. from the Brahmaputra and in this reach, it intercepts all the south flowing rivers coming down from the western Khasi Hills and Garo Hills ranges.

The drainage pattern of the Kulsi River systems is often found to be trellis and rectangular type in the upper catchment region, which developed due to structural control on the drainage network.

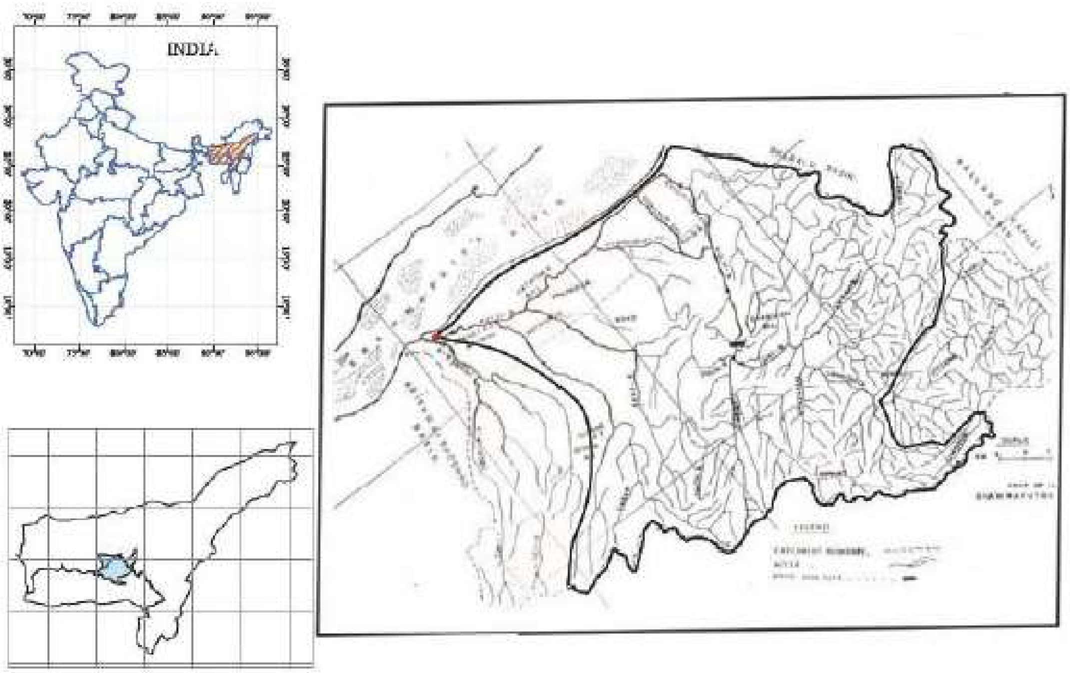

Fig.3.2 Map showing main river system of Kulsi Basin

3.2.1 The tributaries of Kulsi

The Kulsi River receives large number of tributaries in its various reaches. In the upper reach, it is joined by Krishniya and Umsiri on the left bank. In the middle reach its main tributary is Batha while in the flood plain reach it is joined by Boko and Singra. The catchment areas of the main tributaries of Kulsi are as follows (Table.3.1):

Table 3.1 Tributaries of Kulsi and their Catchment Area

Sl. No	Name of the tributaries	Catchment Area (Sq. Km)
1	Krishniya	70 sq.km
2	Umsiri	295 sq.km
3	Batha	285 sq.km
4	Boko	250 sq.km
5	Singra	380 sq.km

3.3. Topography and Basin Characteristics

The topography of Kulsi River Basin is shown by Digital Elevation Models (DEM) downloaded from Shuttle Radar Topography Mission (SRTM) of 90m resolution which is available freely in the internet. Figure 4.3 shows the DEM of the Kulsi River Basin.

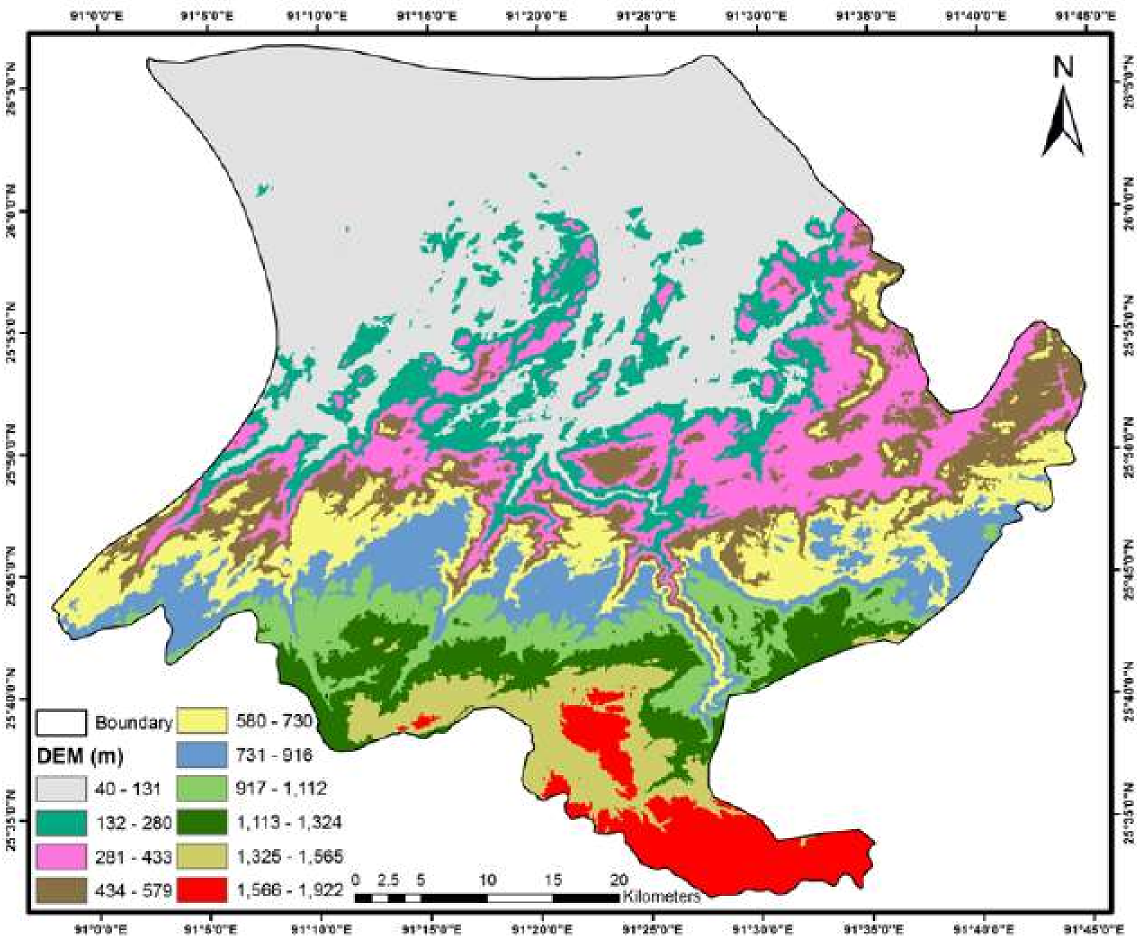

Fig.3.3 Digital Elevation Model of Kulsi Basin

Different parameters like Slope (in percent), Aspect and flow direction can be derived from the DEM using GIS Platform**.**

The area that the Kulsi River drains can broadly be divided into three reaches

(i) The Upper Khasi hill reach

(ii) The middle reserve forest reach

(iii) The alluvial or flood plain reach

The Upper Khasi hill ranges of the catchment extend from the origin of the river Kulsi to Ukium (Assam Meghalaya border) and this reach lies entirely in the west khasi hill ranges, with the general altitude varying from 150 m to 1900 m. the whole area consists of series of hill range with intermittent plain areas. The upper reaches of the region is covered with evergreen and deciduous forest. However, most of the area represents degraded forest and in many places are covered by scrubs. No area in the reach remains under snow cover.

The middle reserve forest reach region consists of areas along the southern bank of river Brahmaputra. The region near Kulsi village, the river Kulsi branches off into three channels and all of them join together after flowing a distance of few kilometres downstream. The middle reserve forests reach consists of two reserve forests namely Borduar and Pantan reserve forest running parallel along the river from Ukium to Kulsi village with the Borduar reserve forest on eastern bank and Pantan reserve forest on the western bank. The river in this reach has got a very narrow valley running between these two reserve forests. The eastern part of the Borduar reserve forest consists of comparatively plain areas with the famous Chandubi beel located therein. No tributary joins the river in this reach.

The alluvial or the plain reach consists of the plain areas along the southern bank of river Brahmaputra. Almost half of this reach is affected by the flood of the River Kulsi and the Brahmaputra. Just at the starting of this reach i.e. near village Kulsi, the river Kulsi branches off into three channels and all of them join together after flowing a few kms and outfalls into the Brahmaputra near Barak. This area is fully cultivable area and sufficiently densely populated

The bed slops of river Kulsi at different reaches are as below:

From source to confluence with Um Trisung	1 in 20
From confluence with Um Trisung to confluence with Khari	1 in 44
From confluence with Khari to Ukium	1 in 80
From Ukium to Dam site	1 in 1570

3.4 Temperature

The climate of Kulsi basin, excluding the upper most reach is similar to that of the other districts in Central Assam. The winter is cold and foggy, while the summer is hot and humid. There is no meteorological centre within the catchment for observation of temperature. However the nearest observatories for the basin are at Guwahati, Umiam and Shillong. Based on long term data from these stations it has been observed that the average maximum temperature in this basinvaries between $15^{0}C$ to $33^{0}C$ and average minimum temperature varies from $3^{0}C$ to $12^{0}C$.

3.5 Humidity

The climate of this sub-basin is generally very humid. There is no meteorological Centre in the sub-basin for observation of humidity. In Brahmaputra valley, Humidity is high at a place where forest cover and vegetation cover is relatively more. Humidity data is available only at Guwahati nearest to the sub-basin. Guwahati city is in the East and situated on the south bank of Brahmaputra.

Observing the data it can be concluded that in the Kulsi-Deosila basin in general, the humidity is maximum during June, July, August and September when average relative humidity various from 82% to 86% at 1730 hours. March is the driest month with humidity fluctuating from 58% to 64% at 08-30 hrs and 46% to 74% at 17-30 hrs.

3.6 Geology

The geology of the river basin consists mostly of gneiss and sandstones overlain by a deep to moderately deep soil layer. Much of the terrain is rough, rolling to steeply sloping. Under saturated conditions, such a formation is highly conducive to rapid subsurface storm flow. The rock types in the Kulsi basin vary from Precambrian stage to recent. The surface Geological formation is newer alluvium sand, gravel, clay and silt. In Assam part of the basin falls in Kamrup District where two distinct groups of rock units i.e. consolidated and unconsolidated formation of rocks are found.

The unconsolidated formations represented by the alluvial deposits of recent age such as sand, gravel, pebble, silt and clay. In the Meghalaya part of the basin, there are two, three types of formations like the Archaen complex, lower, cordovan rocks, and cretaceous tertiary sediments. The oldest formation of upper tertiary sediment occurs in Garo Hills.

3.7 Land Use Pattern

The basin falls under warm humid sub-tropical climate, which is suitable for growth of semi-evergreen and deciduous forests dominated by Sal Plants. Most of the areas were afforested by Forest Department, Government of Assam with Sal & Teak Plants, Banana Plants, Shrubs etc. Bamboo is one type of dominant economic plant available in all parts of the area. The land use consists primarily of evergreen forest, semi-evergreen forest, moist-deciduous forest, bamboo-thickets, jhum and rolling grasslands. The pattern of land use of the Kulsi basin area as follows:

1. Degraded forest	62.33%
2. Dense forest	15.56%
3. Scrub	15.50%
4. Jhum cultivation	0.50%
5. Agricultural plantation	2.41%
6. Agricultural land	2.37%
7. Rivers	1.04%
8. Water bodies	0.29%
Total	100.00%

3.8 Season

There are four numbers of different seasons occurring in Kulsi-Deosila sub-basin. These are: (1) Winter (2) Summer (3) Monsoon and (4) Autumn or post-Monsoon.

i) **Winter:** The winter season sets in December and ends in February. This is the coldest season. The weather changes due to passage of western disturbance over the region. Low winter rainfall also occurs occasionally.

ii) **Summer:** The summer season begins in March and continues up to May. In this season, occasionally marked in instability develops in the atmosphere and severe thunder storms occur, sometimes preceded by dust raining squalls. Rainfall increases both in quantity and frequency, as the season advances and generally associated with thunder storms and squalls. Hail storms occur sometime in the season specially in hills.

iii) **Monsoon:** The monsoon sets in the last week of May or in early June. It generally occurs due to depression in the Bay of Bengal. Subsequently a series of such depression forming at the head of Bay of Bengal and moving inland; give spells of continuous and moderate to heavy rain over the sub-basin. The monsoon withdraws in the last week of September or first week of October.

iv) **Autumn or Post Monsoon (October to December):** This season begins in October and ends in December**.** There is almost no rain during this period and the climate is neither very cold nor hot.

3.9 Rainfall

Rainfall in the sub-basin occurs mainly due to the monsoon which sets in this region in the first week of June and continues till the 1week of September. About 65% of the total annual precipitation occurs during this period in this sub-basin. After September, the intensity of rainfall gradually decreases. Before the onset of monsoon, sometimes considerable thunderstorm occurs in the region in the month of April and May, resulting in significant rainfall of about 25%. Generally December, January and February are the dry months in the sub-basin when there are only occasional rainfalls.

There are 5 (five) nos. of Rain gauge stations in and around the sub-basin. They are Boko, Chamaria, Mirza and Guwahati Airport. The other one is Ukium, which is maintained by Brahmaputra Board.

4.0 DATA ACQUISITION

4.1 Rainfall and discharge data

Daily rainfall data for the year 2007 were collected from India Meteorological Department for five rain gauges in and around Kulsi River Basin. The distribution of the rain gauges is shown in figure 4.1. Out of the five rain gauges, the rain gauges located at Boko and Ukium fall within the basin, while rain gauges at Guwahati Airport, Dudhnoi and Mairang fall outside the River Basin. Daily discharge data is recorded at Kulsi Bazzar location which is at the outlet of the Kulsi River Basin. The daily discharge data for 2007 was collected from CWC, Shillong.

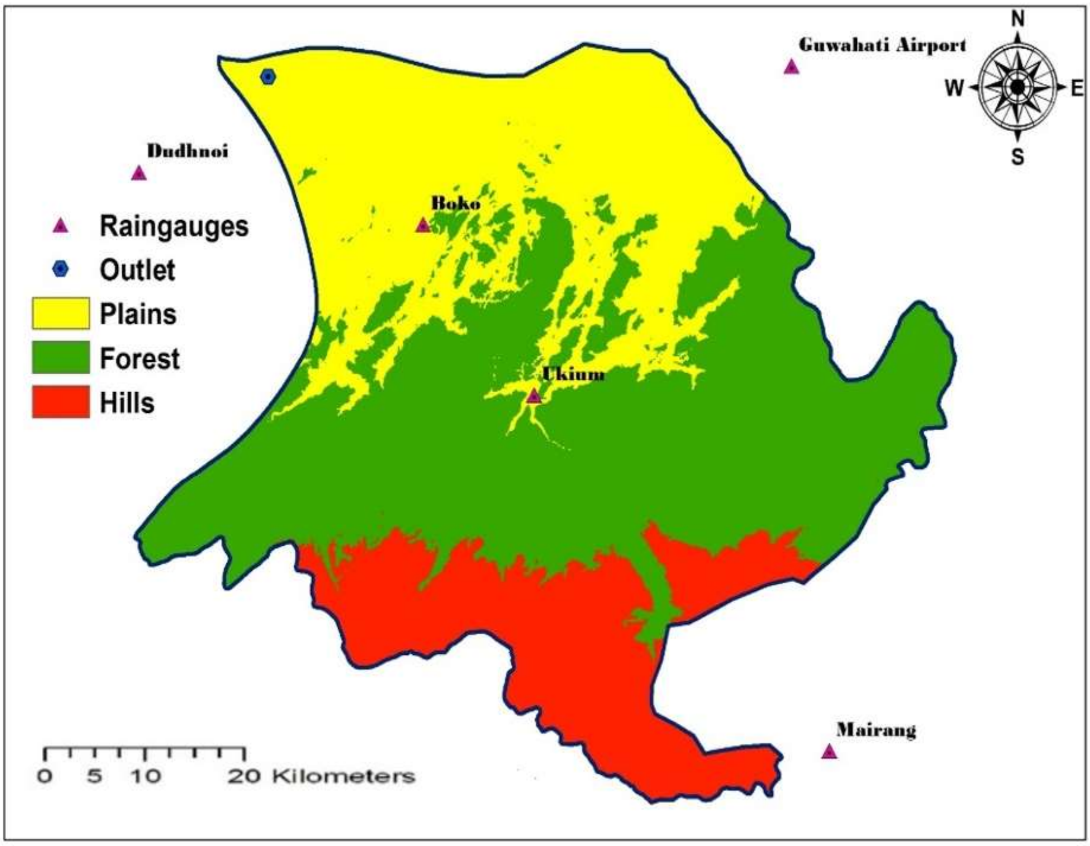

Fig 4.1Location of rain gauges and discharge Site

4.2 Soil data

The soil data for the study has been obtained from the Harmonized World Soil Database v 1.2 of the FAO soil portal. The Harmonized World Soil Database is a 30 arc-second raster database with over 15 000 different soil mapping units that combines existing regional and national updates of soil information worldwide with the information contained in FAO-UNESCO Soil Map of the World . Over 16000 different soil mapping units are recognized in the Harmonized World Soil Database (HWSD) which are linked to harmonized attribute data. Use of a standardized structure allows linkage of the attribute data with GIS to display or query the composition in terms of soil units and the characterization of selected soil parameters.

The soil data for the study area was downloaded from the FAO site with the URL as (http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/). The soil texture of Kulsi River Basin consisted of sandy loam, sandy clay and clay loam. The Phyisco-chemical properties of soil of Kulsi River Basin is given in table 4.2.

Table 4.2Physico-chemical properties of soil

Soil Texture	Sandy Loam	Sandy Clay	Clay Loam
Rock fragment (%)	29.99	18.64	13.35
Sand (%)	49	48	36
Silt (%)	38	12	14
Clay (%)	13	40	50
Organic Carbon (%)	1.75	2.31	2.55
Bulk Density (gm/cm^3)	1.22	1.34	1.42
Available Water Content (mm water/mm soil)	0.1028	0.1027	0.1148
Hydraulic Conductivity(mm/hr)	1.69	1.54	1.36

4.3Landuse

Information on land use and pattern of their spatial distribution is one of the criteria in selecting a Curve number (*CN*).In the present study, Landsat ETM of Kulsi Basin dated 26-10-2006 was used for the generation of land use categories. Supervised classification was performed employing the Bayesian Maximum Likelihood Classifier (MLC). MLC, a parametric decision rule, is a well-developed method from statistical decision theory that has been applied to the problem of classifying image data.

Information collected from Survey of India (SOI) toposheets, google earth images and personal field visits and to the basin are used to identify the signatures representing various land use classes. They are then evaluated to make sure that, there is suitable discrimination of individual classes. After obtaining a suitable grouping for satisfactory discrimination between the classes during signature evaluation, the final classification is carried out. False Color Composite (FCC) draped over DEM of shows the present Landuse Pattern of Kulsi River Basin (Fig 4.2).

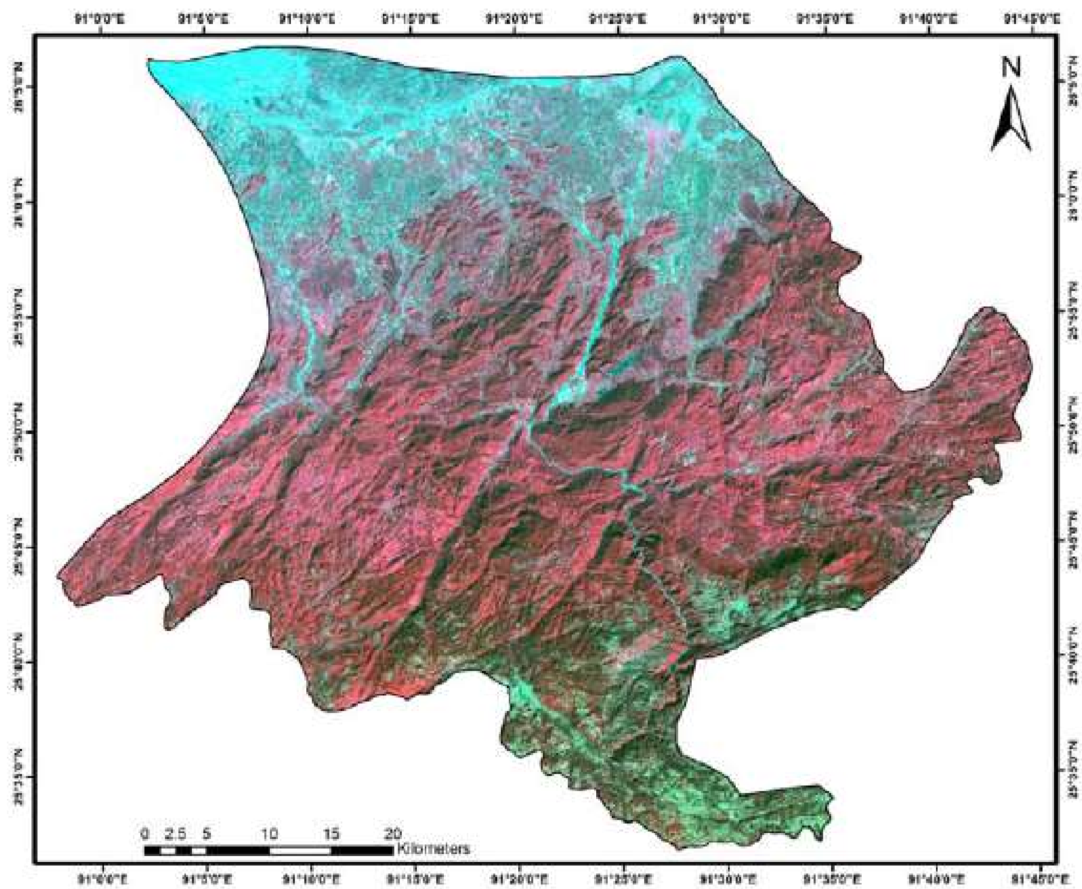

Fig.4.2: FCC draped over DEM of Landsat ETM of Kulsi Basin dated 26-10-2006

5.0 METHODOLOGY

This chapter deals with the methodology used for the determination of CN and generation of runoff maps.

5.1 Determination of Curve Number

5.1.1 Hydrologic Soil Group

In determining the CN, the hydrological classification is adopted. Soils are classified into four classes A, B, C and D based on the infiltration and other characteristics. The important soil characteristics that influence the hydrological classification of soils are effective depth of soil, average clay content, infiltration characteristics and the permeability. Following is a brief description of four hydrologic soil groups:

- Group A (LOW RUNOFF POTENTIAL): Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sand or gravels. These soils have high rate of water transmission.

- Group B (MODERATELY LOW RUNOFF POTENTIAL): Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soil with moderately fine to moderately coarse textures. These soils have moderate rate of water transmission.

- Group C (MODERATELY HIGH RUNOFF POTENTIAL): Soils having low infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soil with moderately fine to moderately coarse textures. These soils have moderate rate of water transmission.

- Group D (HIGH RUNOFF POTENTIAL): Soils having low infiltration rates when thoroughly wetted and consisting chiefly of clay soils with high swelling potential, soil with permanent high water table, soils with clay pan or clay layer at or near the surface and shallow soils over nearly impervious material.

5.1.2Antecedent Moisture Condition (AMC)

AMC refers to the moisture content present in the soil at the beginning of the rainfall-runoff event under consideration. It is well known that initial abstraction and infiltration and are governed by AMC. For purposes of practical application three level of AMC are recognized by SCS as follows:

AMC-I: Soils are dry but not to wilting point. Satisfactory cultivation has taken place.

AMC-II: Average conditions

AMC-III: Sufficient rainfall has occurred within the immediate past five days. Saturated soil conditions prevail.

The present study assumes AMC II condition for determination of CN.

5.1.3Landuse

The variation of curve number under AMC II called CNII for various land conditions commonly found in practice are shown in table 5.1

Table 5.1 Classification of hydrological soil group

Land use	Hydrological soil group	Treatment	Hydrological cover condition
Row crops	C	Straight row	Poor
Paddy fields	C	Straight row	Poor
Forest land	B	NC	Fair
Farmsteads	D	NC	NC
Wasteland	B	NC	NC

CN-II can be calculated from the table 5.2

Table 5.2 Runoff Curve Number (CN_{II}) for Hydrologic Soil cover under AMC II conditions

Land use	Cover		Hydrologic Soil Group			
	Treatment or practice	Hydrologic condition	A	B	C	D
Cultivated	Straight row		76	86	90	96
Cultivated	Contoured	Poor	70	79	84	87
		Good	65	75	82	86
Cultivated	Contoured and terraced	Poor	66	74	80	83
		Good	62	71	77	82
Cultivated	Bunded	Poor	67	75	81	82
		Good	59	69	76	79
Cultivated	Paddy		95	95	95	95
Orchards	With understory cover		39	53	67	72
	Without understory cover		41	45	69	75
Forests	Dense		26	40	52	65
	Open		28	44	60	67
	Scrub		33	47	60	69
Pastures	Poor		68	79	86	88
	Fair		49	69	79	85
	Good		39	61	74	83
Wasteland			71	80	85	89
Roads (dirt)			73	83	88	91
Hard surface areas			77	86	91	95

5.2 ArcCN-Runoff: an ArcGIS tool

This section describes the implementation of ArcCN-Runoff tool, which was developed to facilitate watershed modelling work. The software was developed by () in Visual Basic 6 on ArcGIS 8.3 platform. Its structure includes one clipping tool, one intersecting tool, one working panel and one curve number-database. Traditionally, an area weighted average curve number for the entire watershed is used to study the runoff of a watershed. The details of the spatial variation in the watershed are often lost.

Advantages of this tool are that unlike raster mode, the tool is designed for any shape of polygon in order to keep irregular boundaries unaltered. The curve-number database implemented provides a flexible way to use a reference table for the curve number based on soil and landuse information. The tool also has option for Users to develop their own database by simply editing a Microsoft Excel Spreadsheet. Figure 5.1 shows the flowchart of the software.

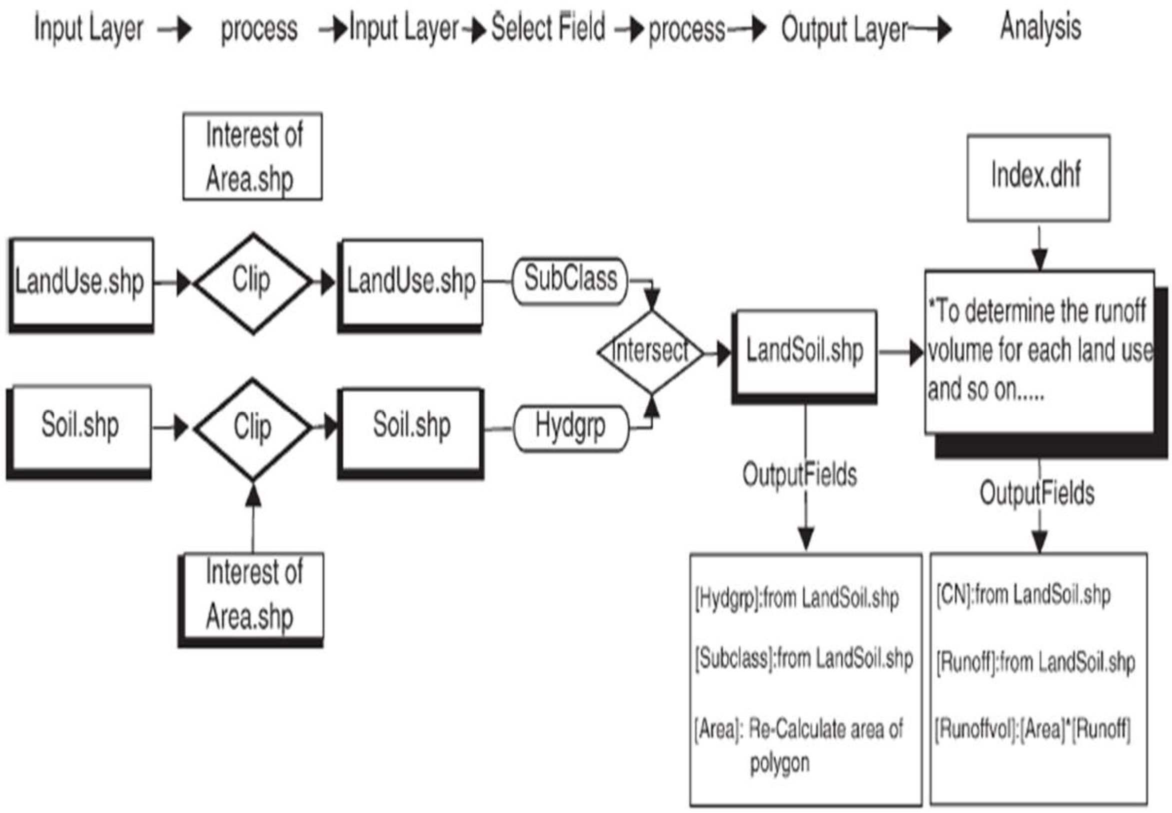

Fig 5.1 Flow chart of ArcCN-Runoff.

5.2.1 Processing Data

After loading the *ArcCN-Runoff* tool in .dll file format into *ArcMap* 9.2™ Software, soil and land data were processed through the following three steps: (1) To focus on study area, the soil and land data for the watershed were clipped using polygon feature from the overlay layer layer such as a boundary of the Kulsi River Basin. (2) To reduce processing time, the soil and landuse layers were dissolved before intersection, based on the attributes of hydrological soil group in soil layer and landcover name in landuse layer.

These steps keep all the details of the spatial variation of soil and landuse and therefore is considered more accurate than using raster grid to calculate runoff or any average or dominant methods to determine CN.

5.2.2 Determination of Curve Number

The CN for each polygon was determined from soil and landuse information The default curve number database of the tool is based on similar curve number database of AnnAGNPS, Basins and other watershed models. The database of ArcCN-Runoff tool was implemented based on Table 5.2. All input and output were stored in a newly generated layer after intersection and operation was performed through the interface of the toolbox shown in Fig 5.2. The map showing spatial variation of the curve number is generated automatically after clicking on the button called "finish match" on the working panel.

5.3 Determination of Runoff

The runoff map is generated based on SCS curve number method assumption that for a rainfall event, the ratio of actual retention of soil after runoff begins to potential maximum retention of soil is equal to the ratio of direct runoff to rainfall (Ponce and Hawkins, 1996). This assumption results in following runoff equation where the curve number $0 \leq CN \leq 100$ represents a convenient representation of potential maximum soil retention (S).

$$runoff = \frac{(rainfall - 0.2S)^2}{(rainfall + 0.8S)} \, if \; rainfall > 0.2S \qquad (7)$$

$$\text{runoff} = 0 \; if \; rainfall \leq 0.2S$$

Where, S=(25400/CN)-254 in mm

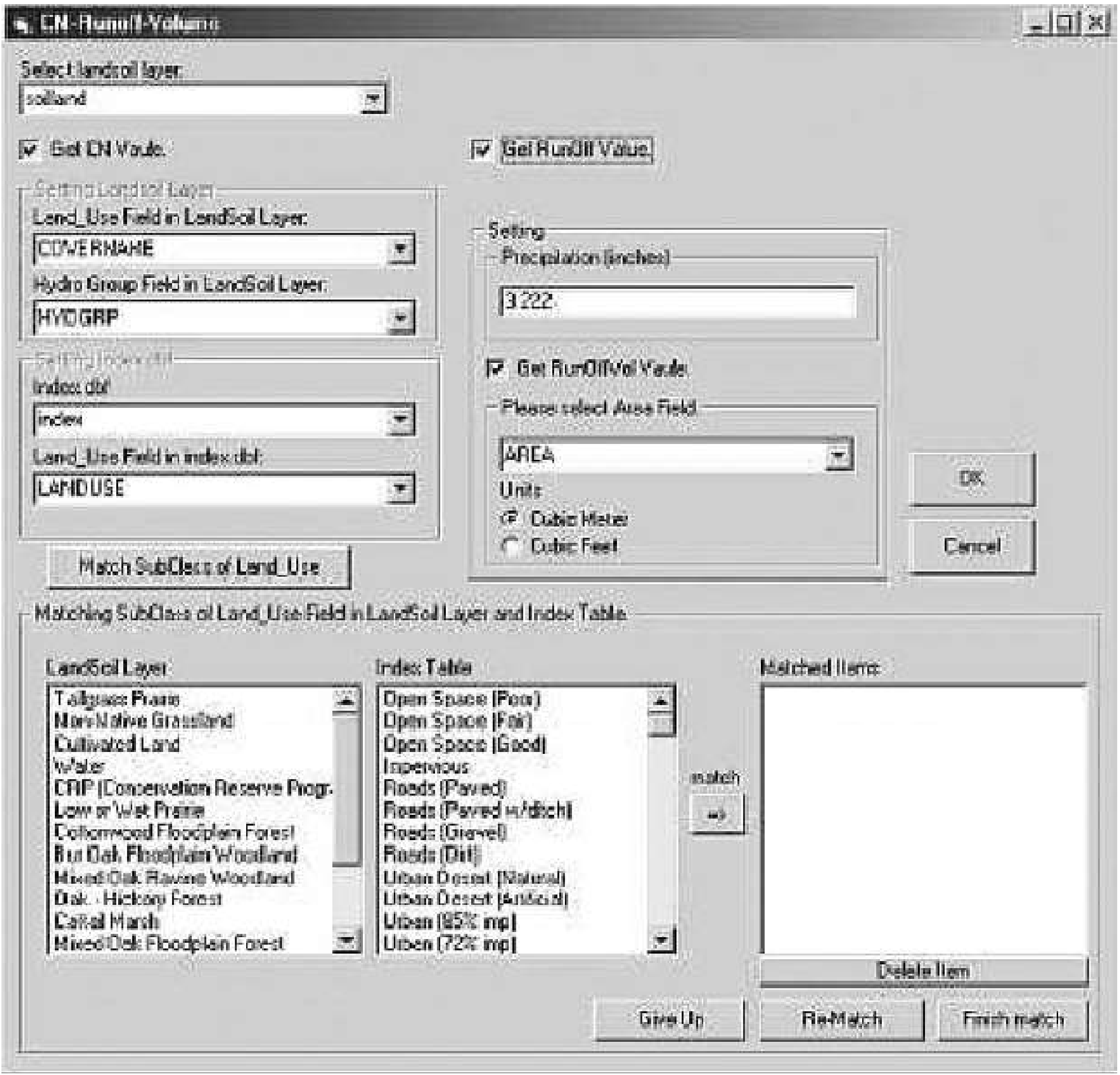

Fig 5.2 User Interface of *ArcCN-Runoff* Tool

6.0 RESULTS AND DISCUSSION

6.1 Preparation of Rainfall Data

In this study gauged rainfall data from five stations spread in and around Kulsi River basin were used as input. The monthly rainfall data corresponding to the monsoon months of June, July, August, September and October for the year 2007 were selected as inputs to ArcCN-Runoff tool.

Interpolation of point raingauge data to gridded rainfall data was carried out using Inverse Distance Weighted Method of *Geostatistical*Tool Box of ArcGIS software. The inverse distance weighted method of interpolation produced 'bull-eye' type of pattern in the generated rasters.

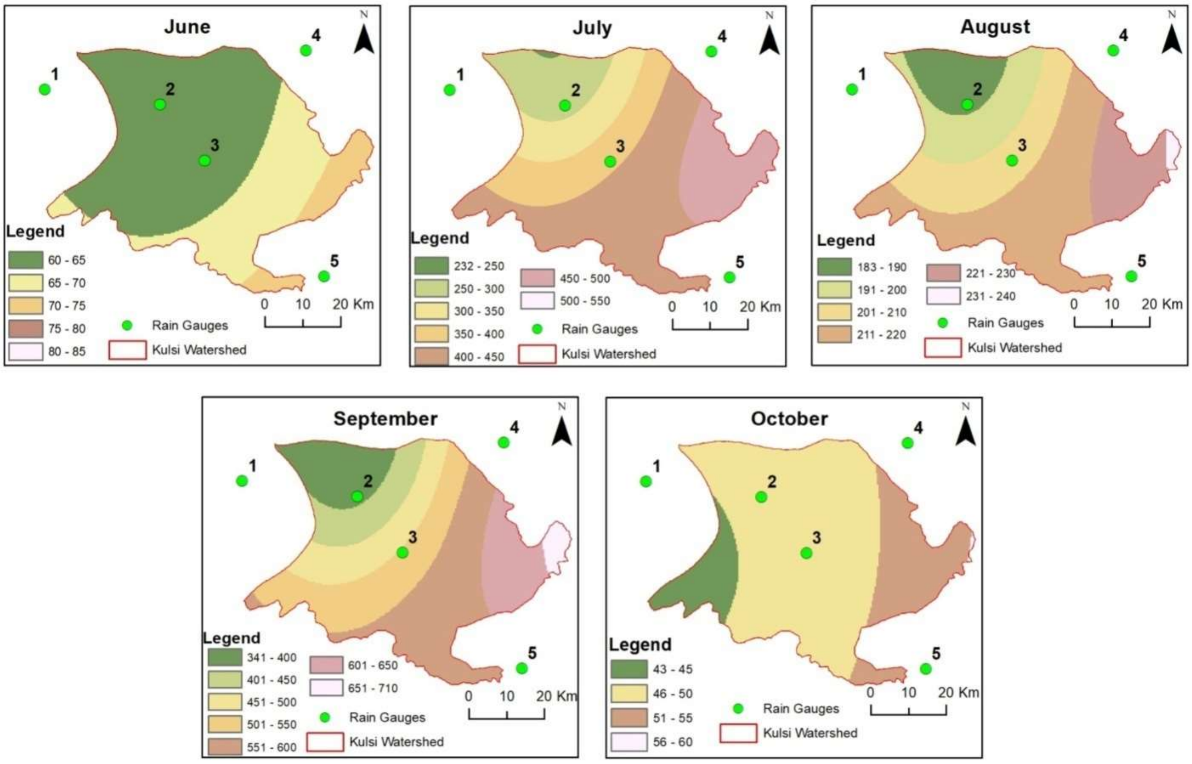

Figure 6.1 Generation of Monthly Rainfall data(mm) for the year 2007 using IDW

6.2 Preparation of soil data

The soil data for the study has extracted taken from the Harmonized World Soil Database v 1.2 of the FAO soil portal.Figure 6.2 shows the distribution of soil in Kulsi River Basin. The figure shows distribution of clay loam type of soil in the plain areas, sandy clay soil in forest area and sandy loam in the hilly areas.

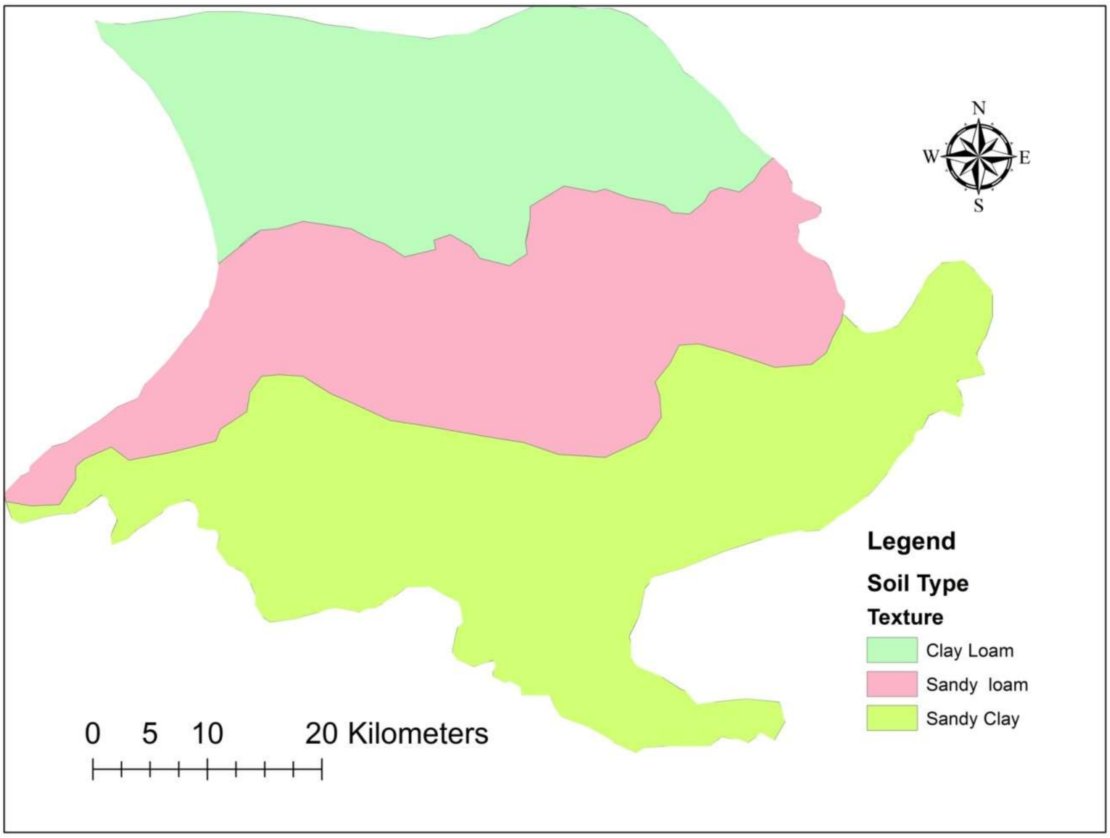

Figure 6.2 Distribution of soil type in Kulsi River Basin

The figure shows distribution of clay loam type of soil in the plain areas, sandy loam soil in forest area and sandy clay in the hilly areas.

6.3Landuse Classification

The methodology for classification of landuse is given in Chapter 4, Section4.3 Landuse classification is shown in Figure 6.3.

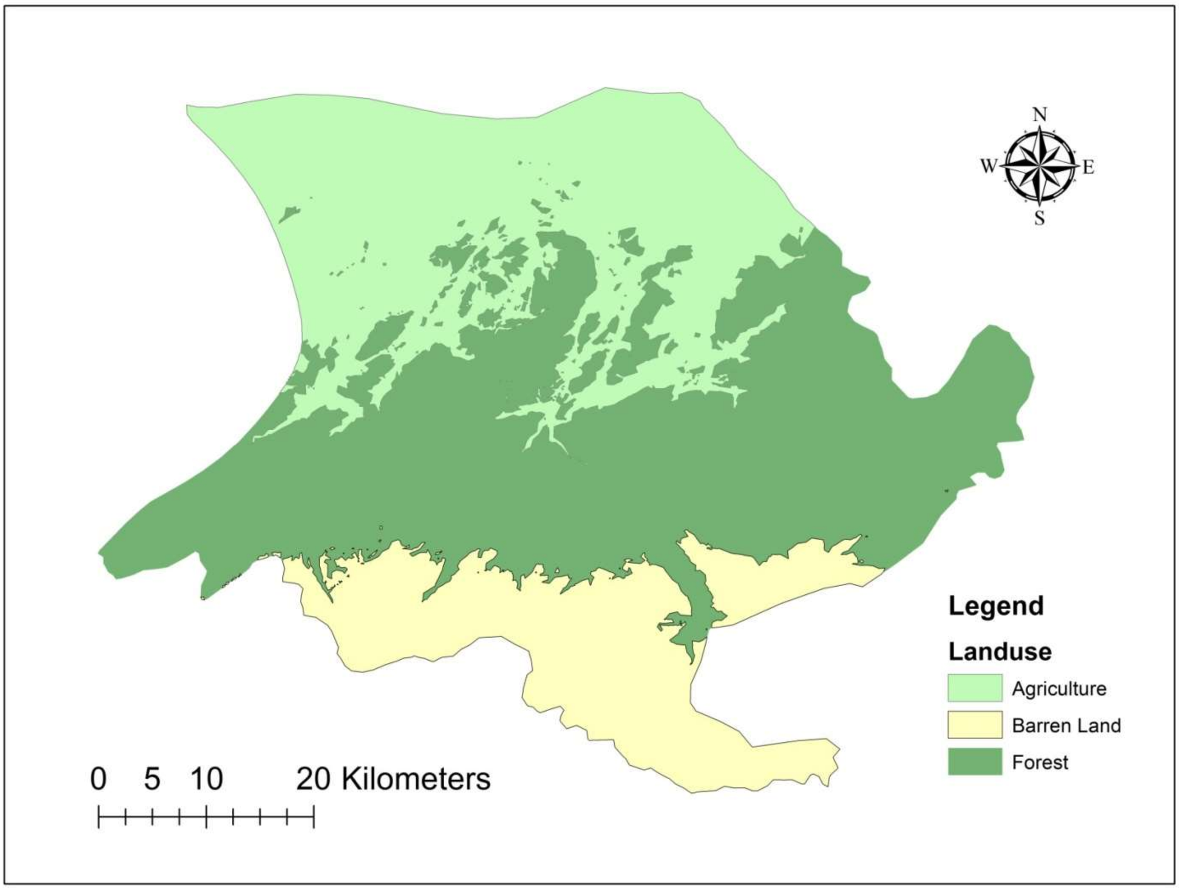

Figure 6.3 Landuse Classification of Kulsi River Basin

The landuse in Kulsi River basin is classified into Agriculture, barren lands and forests.

6.4 Generation of Curve Number

The methodology for generation of Curve Number is given in Chapter 5, Section 5.2.2. The generated spatially distributed Curve Number map is shown in Figure 6.4. The curve numbers in Kulsi River Basin varied from 87 in plains to 30 in the forested area.

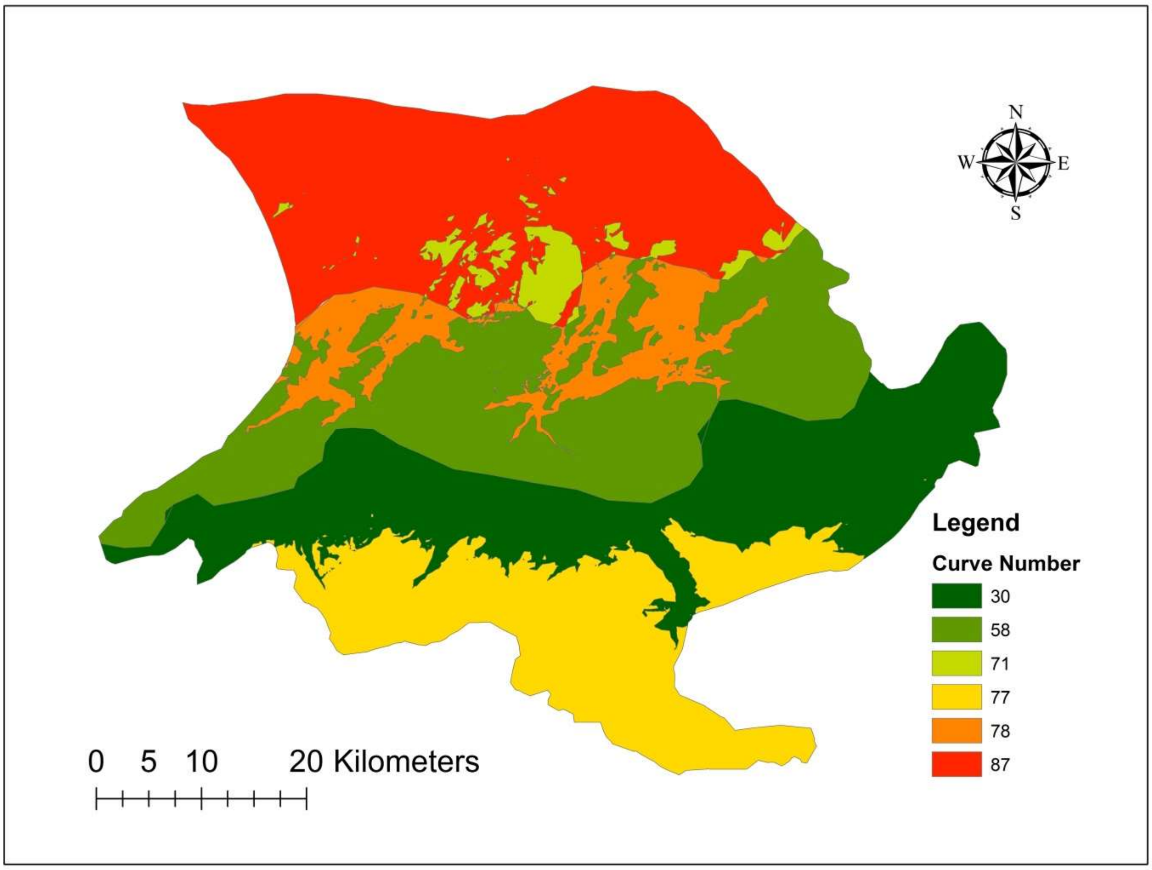

Figure 6.4 Curve Number Map of Kulsi River Basin

6.5 Generation of Annual Rainfall Map

Annual Rainfall map for Kulsi River Basin has been generated by using query builder tool in spatial analyst and adding the monthly grids for June, July, August and September.

Table 6.1 Descriptive Statistics of Annual Rainfall of Rain Gauges in Kulsi River Basin

Rainfall (mm)	Minimum	Maximum	Mean	Std. Deviation
Count = 5	971	1391	1214	173

The resultant map is shown in Figure 6.5. Bulls eye type of pattern were observed in the plain areas.

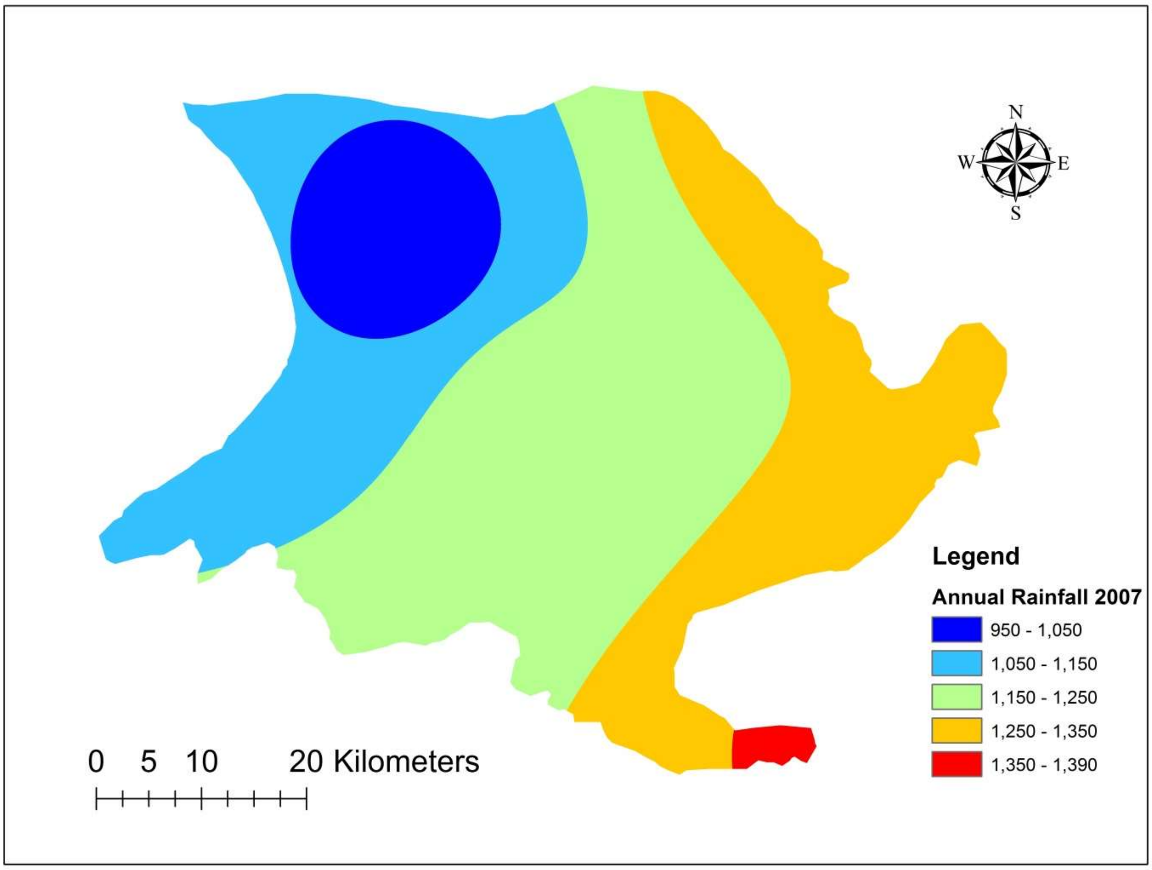

Figure 6.5 Annual Rainfall Map of Kulsi River Basin

6.6 Generation of Annual Runoff Map

Annual Runoff Map has been generated using ArcCN tool box extension. All input and output were stored in a newly generated layer after intersection and operation was performed through the interface of the toolbox. The map showing spatial variation of the curve number is generated automatically after clicking on the button called "finish match" on the working panel. The generated map is shown in figure 3.6.

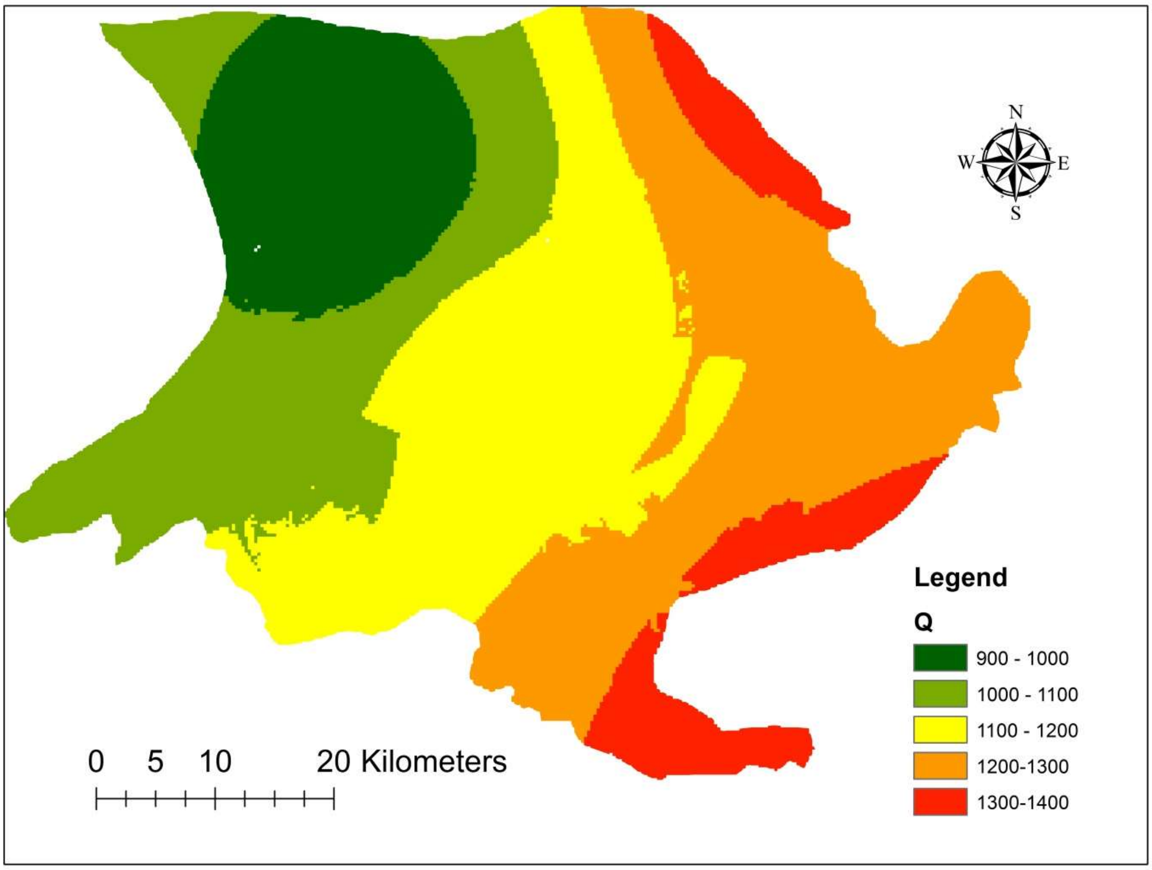

Figure 6.6 Runoff Map for Year 2007 of Kulsi River Basin

7.0 CONCLUSION

The following conclusions were drawn from the study:

1. SCS-CN method considers the infiltration losses and soil properties, so conceptually it is very sound. The SCS runoff curve number method has its obvious advantages viz. simplicity, predictability, stability, responsiveness to major runoff producing watershed properties and reliance on only one parameter namely, the curve number.
2. In this study, it is shown that the remote sensing satellite images are very useful to determine runoff distribution of basin area.
3. The use of remote sensing technique for determination of land use/cover not only saves time but is less expensive as compared to conventional methods like ground surveys. However, the success of remote sensing technique depends on the accurate interpretation of the false color composites.
4. GIS serves as a powerful tool for integration of land use/cover data and hydrologic soil data for computation of areas under different categories. It not only saves time but makes the computations accurate as well.
5. The land use/cover classes interpreted from satellite remote sensing data are more generalized in comparison to ground survey. Therefore, it is necessary to develop more generalized land use classes suitable for remote sensing data in curve number method
6. If we have large number of data set then SCS-CN method is very good otherwise we can opt for models like Bootstrap based Artificial Neural Networks (BANN).
7. Due to limited rainfall (5 nos) and runoff gauge stations (1 nos), it has not been able to understand the hydrologic condition of Kulsi River basin properly. Thus, it has become inevitable to determine rainfall/runoff model by using Remote Sensing and GIS technologies i.e. to predict runoff of the basin area for given rainfall of an ungauged location of river, Soil Conservation Model is efficient
8. Improvements in ArcN-Runoff tool can be made through implementing precipitation time series and considering additional factors, such as dry and wet antecedent moisture conditions, affecting the determinations of curve number and runoff.
9. The spatial distribution of CN and runoff depth reflects the change in the runoff response of the watershed due to change in land use. This shows the shift in the hydrology of the study area.
10. NRCS method is choice of practicing engineers and hydrologies for soil and water conservation planning and design and flood control design. The method is featured in most of the hydrologic computer models in current use. Its practicality as design method is beyond doubt. This study best exemplifies the integrated approach of remote sensing and GIS and in water resource development.

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