ASSESSMENT OF RUNOFF AND EROSION USING GIS

By

ARUN JOSE

RENJITH THOMAS

PROJECT REPORT

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Department of
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KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
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KERALA, INDIA

2007

DECLARATION

We here by declare that this project report entitled **"Assessment of Runoff and Erosion using GIS"** is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, diploma, associate ship, fellowship or other similar title of any other university or society.

Arun Jose
(2002-02-02)

Renjith Thomas
(2002-02-12)

Tavanur,
11-05-2007

CERTIFICATE

Certified that this project report entitled **"Assessment of Runoff and Erosion using GIS"** is a record of project work done jointly by **Arun Jose and Renjith Thomas** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to them.

Er. K.K.Sathian,
Asst. Professor(Sr. Scale),
Department of LWRCE,
KCAET,Tavanur

Tavanur
11-05-2007.

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Arun Jose
Renjith Thomas

Dedicated to

God Almighty,

Loving Parents and

Teachers

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SYMBOLS AND ABBREVIATIONS

AMC	Antecedent Moisture Condition
CN	Curve Number
cm	centimetre
DEM	Digital Elevation Modal
Dept	Department
et al	and others
Etc	et cetra
Fig	Figure
HRU's	Hydrologic Response Units
GIS	Geographic Information System
g	gram
h	hour
ha	hectare
HSG	Hydrologic Soil Group
ILWIS	Integrated Land and Water Information System
km^2	square kilometer
m	metre
m^2	square metre
min	minute(s)
Mj.mm/ha.hr.	Mega Joule.millimetre/hectare.hour
mm	millimetre
K.C.A.E.T.	Kelappaji College of Agricultural Engineering and Technology
NBSS&LUP	National Bureau of Soil Survey & Land Use Planning
pp	page
SWAT	Soil and Water Assessment Tool
SCS	Soil Conservation Service
SYI	Sediment Yield Index
SOI	Survey of India
t	tones
t/ha/yr	tone/hactre/year
Trans	Transaction
USLE	Universal Soil Loss Equation
yr	year
<	less than
>	greater than
/	per
%	percentage
°	degree
'	minutes
"	seconds

INTRODUCTION

1. INTRODUCTION

Soil, water and vegetation are the three vital natural resources required for the very survival of living beings. Sustenance of life on earth depends on the way these resources are conserved and managed. For their efficient management, suitable watershed management measures has to be adopted so that these three resources are utilized in the most judicious and sustainable way.

Soil and water conservation in the broad sense includes not only water harvesting and control over erosion but all those measures like correction of soil defects, application of manures and fertilizers, proper crop rotations, irrigation, drainage etc. which aim at maintaining the productivity of the soil at a high level. In this sense, soil conservation is synonymous to improvement of land use.

Soil erosion though normally a slow process, is a powerful destructive force that directly or indirectly affects human life in a multitude of ways. According to National Commission in Agriculture, 175 million hectares of land in India are degraded which constitutes more than 50% of the total geographical area of 329 million hectares. Severe erosion occurs in sub humid and humid areas due to high rainfall and improper management of land and water. In the state of Kerala, it is estimated that out of the 2.248 lakh hectares of cropped land, 1.757 lakh hectares are in need of conservation measures. The problem of soil erosion and consequent depletion of soil fertility in the state is due to high intensity and duration rainfall, undulating steep sloping topography, low soil depth and consequent high surface runoff.

Similarly, water scarcity is another important aspect to be addressed in natural resources management. Availability of water on the earth surface has very high variation with respect to time and space. The demand of water for agricultural purposes is estimated to increase to produce increasing quantity of food, horticultural products and raw materials for industry. The cumulative requirement of water by different sectors by 2025 is estimated to be 105 M ha m, but the share of water for agriculture is expected to reduce from present level of 85% to 71% by 2025. The demand of water for agriculture is estimated to increase from 50 M ha m in 1985 to 70 M ha m in 2025. During the same period, the demand of water for non-agricultural uses will multiply four fold from 7 M ha m to 28 M ha m.

India's average annual rainfall, about 119.4 cm, when considered over geographical area of 328 M ha m amounts to 400M ha m. Out of this about 70 M ha m is lost to atmosphere by way of evaporation. In Kerala, the receipt of mean annual rainfall is 300cm. The total number of rainy days is 126. The sloping and undulating topography coupled with shallow soil over the hard laterite pan are the main reason for the quick water loss to the seas. A state which has more than 50,000M cubic of fresh water in its 44 streams, 900 odd ponds and 300cm of rainfall spread over 120 days, has water stress affecting at least one third of its inhabitants. What is more alarming is, this scarcity scenario is on the increase.

So there is very urgent need for comprehensive control and management of rainwater, surface water, groundwater and soil moisture to increase water availability and thereby increase Agricultural production. Long-term perspective plans of water resources development and management and efficient technologies to harness maximum potential of irrigation sources are required. To mitigate this problem, proper conservation of water during the rainy season assumes great significance. Along with this, judicious utilization of the conserved water is also a must. For all natural resources management programme, assessment of surface runoff and quantification of soil erosion is the primary step and all conservation and measurement activities are planned based on this.

Surface runoff is one of the most important hydrologic variables used in most of the hydrologic analysis. Reliable prediction of quantity and rate of runoff from land surface into streams and rivers is difficult and time consuming in the case of ungauged watersheds. However, growing rate of watershed management programmes for conservation and development of natural resources has necessitated the quantification of runoff generation. Advances in computational power and the growing availability of spatial data have made it possible to predict the runoff accurately. The curve number method (SCS, 1972), also known as the hydrologic soil cover complex method, is a versatile and widely used procedure for runoff estimation. This method includes several important characteristics of the watershed namely permeability of the soil, land use and antecedent soil moisture conditions.

The erosion process, though normally slow to visualize, is the greatest destroyer of land resources. Soil erosion is a serious problem as it not only causes loss of production, floods, droughts and reservoir sedimentation but also environmental degradation. Reliable soil loss estimation is a valuable design and planning tool in soil conservation and water management. The Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) is the most widely used empirical equation for estimating soil loss from watersheds.

All watershed processes are significantly spatially varying and surface runoff and soil erosion are no exceptions. Hence, to estimate the runoff and erosion, the spatial variability of watershed characteristics and climate variables must be taken into account. Incorporating these spatial variability through manual and conventional procedures are very time consuming and laborious and at times practically impossible. Here comes the utility of Geographical Information System (GIS). Using GIS, spatially varying parameters/characteristics can easily be computed, stored, retrieved and analyzed and many derivative information can be generated.

GIS together with Remote Sensing techniques are changing the way we look at research problems involving spatial analysis. GIS technology is widely used for watershed characterization and assessment, watershed management and planning, watershed restoration and decision support. GIS has been used for restoration studies ranging from relatively small rural watershed to heavily urbanized landscapes. GIS can assist the decision maker in dealing with complex management and planning problems within a watershed, providing geo-processing function and flexible problem solving environments to support the decision research process. Use of these technologies will definitely promote the aforementioned goal of pursuing Development through the ‘Eco-friendly’ route. Hence, the present study is an attempt to utilize the advances in information technology for natural resource management wit the given below specific objectives.

Main Objectives of study are:

1) To assess the characteristics of watershed using GIS.

2) Estimation of surface runoff.

3) Estimation of soil erosion.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1 Runoff

Runoff means the draining or flowing off of water, resulting from precipitation from a catchment area. It represents the output from the catchment in a given unit of time. It is the excess water after initial losses, evapotranspiration, infiltration and detention storage.

2.1.1 Estimation of Runoff

The calculation of runoff volume (watershed yield) is of great importance in all water resources and land development studies. The various methods adopted for the estimation of run off volume are the correlation of run off and rainfall, empirical equations and watershed simulations.

The relationship between rainfall and resulting runoff is quite complex and is influenced by a number of factors related to the catchment and climate. Further, there is a problem of scarcity of data, which forces one to adopt other methods. Watershed simulation is also a difficult method. One of the most common methods used for estimating the yield is the correlation of runoff with rainfall and it is very much suited for places without adequate data.

2.1.2 Estimation of Surface Runoff

Accurate estimation of surface runoff is difficult as it depends on many factors. The following methods evolved after field experience and observation are usually used for estimation of surface runoff from a watershed. Rational method for the estimation of peak runoff rate, Soil Conservation Service method, Soil Conservation Service curve number method, and Cooks method are the most commonly used methods.

2.1.3 Soil Conservation Service – Curve Number Method

The origin of the curve number methodology can be tracked back to the 100 of infiltrometer tests carried out by Soil Conservation Society (SCS) in the late1930 and early 1940.The incident was to develop basic data to evaluate the effects of watershed treatment and soil conservation measures on the rainfall runoff process. A major catalyst for the development and implementation of runoff curve number methodology was the passage of United States watershed protection and flood prevention act of 1954.

This method also known as the Hydrologic Soil Cover Complex Number method, is based on the recharge capacity of the watershed. The recharge capacity is determined by antecedent moisture conditions and by the physical characteristics of the watershed.

Let I_a be the initial quantity of interception, depression storage and infiltration that must be satisfied by any rainfall before runoff can occur. It is assumed that the ratio of the actual runoff Q and the rainfall minus the ideal loss P- I_a (maximum possible runoff) and the ratio of actual retention to the storage capacity S are related by

$$\frac{Q}{(P-Ia)} = \frac{(P-Q-I_a)}{S}$$

I_a is assumed to be a fraction S. On an average, taking I_a =0.2S, then

$$Q = \frac{(P-0.2S)^2}{}$$

(P+0.8S)

Q has the same unit as that of P and expressed in mm.

The curve number as defined by the U.S. Soil Conservation Service (1972) is given by

$$CN = \frac{25400}{(254+S)}$$

Where, S is the storage capacity of the watershed in mm.

Knowing the curve number, the value of the recharge capacity S is calculated and using this value of S, runoff is calculated.

Hydrologic Soil Group-A (Low Runoff Potential)

Soils having high infiltration rates when thoroughly wetted consisting chiefly of deep, well to excessively drained sands or gravels.

Hydrologic Soil Group-B (Moderately Low Runoff Potential)

Soils having moderate infiltration rates when thoroughly wetted consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

Hydrologic Soil Group-C (Moderately High Runoff Potential)

Soils having low infiltration rates when thoroughly wetted consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures

Hydrologic Soil Group-D (High Runoff Potential)

Soils having very low infiltration rates when thoroughly wetted consisting chiefly of clay soils with high swelling potential, soils with a permanent high water table and soils with clay layer at or near the surface.

2.1.4 Antecedent Moisture Condition

Antecedent Moisture Condition (AMC) is used as an index of watershed wetness. Three levels of AMC are in use.

AMC I: Lowest Runoff potential. The watershed soils are dry enough for satisfactory cultivation to take place.

AMC II: Average condition.

AMC III: Highest runoff potential. The watershed is practically saturated from antecedent rains.

The AMC groups are determined using the 5 day antecedent rainfall.

Onstad and Otterby (1980) studied the effect of crop residual on runoff. Crop residues on the soil surface decrease runoff from all storm sizes and eliminate runoff from small storms. Runoff reductions and consequent increases in soil water storage are greatest on less permeable soils.

Borah (1989) developed a dynamic hydrologic model, which simulates spaces and time distributed rainfall excess and runoff in a small watershed resulting from a single rainfall.

Pathak *et al.* (1989) developed a runoff model for small watersheds in the semiarid tropics. A modified SCS runoff model and a soil moisture accounting procedure were used to simulate runoff for small watersheds and validity was tested in small vertisol watersheds at ICRISAT in India.

Fernandez and Garbrecht (1994) studied the effect of trends and long term fluctuations of rainfall on watershed runoff at Little Washita river basin. It resulted the rainfall patterns and amounts can mask the beneficial impacts of floodwater retarding structures.

Steenhuis *et al.* (1995) revisited the SCS-runoff equation for variable source runoff for two watersheds in Australia and three in the north eastern United States. By plotting the effective precipitation defined as the amount of precipitation minus the initial abstraction against the observed runoff for the above watersheds they found that the SCS-curve number equation in its elementary from fitted the data well.

Bingner (1996) simulated runoff from Goodwin Creek watershed SWAT (Soil and Water Assessment Tool). SWAT has predicted the relative trends of runoff on a daily and annual basis from multiple sub basins, except for a completely wooded sub basin.

Montas and Madramootoo (1996) developed and used a model named ANSWERS to predict runoff and soil loss in south-western Quebec in two small agricultural watersheds. This model under estimated the sediment yield for all events. Runoff predictions with adjusted parameters were better than those with measured parameters.

Karvonen *et al.* (1999) developed a hydrological model for predicting runoff from different land use areas. The modelling was based on the subdivisions of the catchments into smaller units called “hydrologically similar units”. The model represented well the extend of variable contributing the areas, which was the main reason for the non linear behaviour of catchment’s response.

Cazier and Hawkins came forward with regional applications of the curve number method.

2.2 Soil Erosion by water

Water related soil erosion is a critical problem spawning serious environmental and economic consequence through out the country. Rainfall and runoff are the two erosive agents for soil erosion by water. Rain drop cause soil splash, detach soil particles and make them available for transport. The amount of soil detached by rain depends on the intensity of rain, its detaching capacity, and character of soil, its detachability and the protective value of any cover present. Erosive capacity of raindrops results from three factors: amount and intensity of rainfall, the diameter of rain drops, and the velocity of rain drops as they strike the soil.

Surface runoff is that part of precipitation which, during and immediately after a storm event appears as flowing water in the drainage network of a watershed. The runoff carries the detached top soil, and produces severe erosion by its abrasive action on the soil. The amount of soil movement is affected by the energy of run off water.

Information on runoff and sediment load provide data base to the watershed development and subsequent activities for conservation of land and water resources with in the watershed.

2.2.1 Soil Loss Estimation

Soil loss estimation is a valuable design and planning tool. Its most immediate advantage is that a well defined conservation objective can be formulated to reduce the soil losses to specified acceptable level and thereby ensure the maximum safe economic use of each piece of land. For locating vulnerable and priority areas, the catchment of a river has to be studied for different types and intensities of erosion and mapping different erosion units.

2.2.2 Universal Soil Loss Equation

Attempts have been made for years to quantify the erosion effects of rainfall, land factors and crop factors in order to predict erosion under a given set of condition. Wischmeier in 1959 presented the universal soil loss equation, which has an adaptability to a wide range of conditions.

The universal soil loss equation (USLE) is given by,

A = R.K.L.S.C.P

Where, A= the average soil loss for the given period

R= rainfall erosivity factor

K= soil erodibility factor

L= length of slope factor

S= steepness of slope factor

C= cropping management factor

P=conservation practice factor.

The different factors in the above equation are to be selected to suit the units under considerations.

2.2.2.1 Soil loss (A)

The factor A represents soil loss per unit area per unit time. Because L,S,C, and P are dimensionless, units for A result from the multiplication of R and K in the solution of USLE. Units may be chosen for R and K to give units for A in metric tons per hectare. The time unit of A depends upon the time period of R, which is usually average annual for a calendar year.

2.2.2.2 Erosivity(R)

The R factor is the sum of individual storm erosivity values, EI, for qualifying storms over a time period, usually average annual or perhaps an average crop stage. Storms of less than 0.5 inch(13mm) are separated from other rain periods by more than 6 hrs are not included in the computations unless as much as 0.25 inch(6mm) of rain falls in 15 minutes. The factor E is the total energy for a storm and I is the storm’s maximum 30-minute intensity.

$$R = \sum_{j=1}^{n} (EI)_j$$

Where n is the number of storms in the series. The variable EI is the product of the total energy for a storm and the storm’s maximum 30-minute intensity.

2.2.2.3 Soil erodibility (K)

The soil erodibility factor, K, is the rate of soil loss per unit of R or EI for a specified soil as measured on a unit plot, which is 72.6-foot (22.1m) length of uniform 9 percent slope continuously in clean tilled fallow. Therefore K has units of mass per area per erosivity unit. In the SI system, one set of units (metric ton.hectare.hour/hectare.megajoule.millimetre) can be abbreviated as (t.ha.h/ha.Mj.mm).

2.2.2.4 The slope length factor, (L), and the slope steepness factor, (S)

These are often evaluated as a single topographic factor, L.S. Slope length is defined as the distance from the point of origin of overland flow to the point where the slope decreases sufficiently for deposition to occur or to the point where the runoff enters a defined channel. Slope gradient is the field or segment slope, usually expressed as percentage. The slope length factor is defined as,

$$L = (X/22)^{m}$$

Where L= slope length factor

X= slope length, meters, and

m= an exponent.

Current recommendations (Wischmeier and Smith, 1978) for the exponent *m* are:

m= 0.5 if slope >= 5 percent

m= 0.4 if slope <= 5 percent and >3 percent

m= 0.3 if slope <=3 percent and >1 percent

m=0.2 if slope <1 percent

Soil loss increases much more rapidly than runoff as slope increases. The combined LS factor is given by:

$$LS = (X/22)^{m} (0.065 + 4.56 \sin\Theta + 65.1 \sin^{2} \Theta)$$

Where Θ is the angle of slope given by $\Theta = \tan^{-1} (s/100)$ where *s* is the field slope in percent.

This equation can be used for single uniform slopes.

2.2.2.5 Crop management factor, (C)

This is defined as the ratio of soil loss from land cropped under specified conditions to corresponding soil loss from continuous fallow on identical soil, slope and rainfall conditions. Soil loss from a field is influenced by density, kind of crop cover, root growth, water used by crops etc.These conditions differ significantly during the crop growth period from planting to harvest of crops. Wischmeier and Smith, 1978 approximated the erosion control effectiveness of each crop on the basis of five crop stage periods. The crop stage periods suggested by them are:

Period F: Rough fallow- summer ploughing or seed bed preparation to sowing
Period 1: seed bed- seeding to one month thereafter
Period 2: establishment- from one to two months after seeding
Period 3: growing period- from period 2 to crop harvest.
Period 4: residue or stubble- from crop harvest to ploughing or new seed bed preparation works.

They computed the ratios of soil losses from cropped plots to corresponding losses from continuous fallow from available basic data separately for each five crop stages along with various combinations of crop sequence and productivity level.

2.2.2.6 Conservation practice factor, (P)

This is the ratio of soil loss for a given practice to that for up and down the slope farming. By evaluating the factors of the soil loss equation, the soil loss from a field under a given set of conditions can be determined. If the soil loss is higher than the soil loss permissible for maintaining productivity, suitable changes in the crop management and conservation practices should be made to reduce the expected soil loss.

2.2.2.7 Applications of USLE

The USLE is used broadly for the following purposes.

1. To predict average annual soil loss from a field with specific land use conditions.
2. To guide the selection of cropping and management system, and conservation practices for specific soils and slopes.
3. To predict the change in soil loss that would result from a change in cropping or conservation practices on a specific field.
4. To estimate soil loss from land use areas other than agricultural lands, and
5. To provide soil loss estimates for conservationists to use for determining conservation needs.

In addition to the above, USLE could be used as a first approximation for estimating the sediment yield of watersheds.

$$Y = E\,(DR)$$

Where, Y= sediment yield
E= gross erosion
DR= sediment delivery ratio.

In this approach, the heterogeneous watershed area is divided into sub areas for which representative soil type, slope length, gradient, cover, and erosion control practice factors can be defined. The USLE is used for each of the subareas. These values are multiplied with DR values obtained based on previous studies for the region in order to obtain approximate sediment yield values.

Wischmeier (1959) found that one hundredth of the products of the kinetic energy of storm (KE) and the 30 minutes intensity (I30) are the most reliable single estimate of rainfall erosion potential and was termed as EI_{30}. Annual total of storm EI_{30} value is referred to as rainfall erosion index.

Young and Muychler (1967*)* studied the effect of slope shape on erosion and runoff. From the studies, they developed a number of empirical relationships between length and degree of slope and soil loss. The results demonstrated that irregular slopes are not accurately evaluated by using average values of slope steepness and soil erodibility in combination with over all length, and that additional very helpful detail can be readily obtained. The proposed technique for evaluating the USLE's topographic factor on irregular slopes has direct application value both on farmland and on construction areas.

Wischmeier *et al.*(1969) initiated studies to see as to which extent various properties of soil affect its erodibility. The significant variables were percent sand, percent silt clay ratio, organic matter content, aggregation index, antecedent soil moisture, bulk density, percent slope, pH of surface and subsoil, soil structure, thickness of soil layer, landuse preceding three year period, volume of pore space filled by air, slope shape, presence or absence of loessial mantle and clay skins on pod surfaces. A multiple regression equation was developed based on various soil properties and their interaction. The equation is so cumbersome and requires the determination of so many properties so it is not used extensively. Work was again carried out to simplify the procedure for determination of K and a simple nomograph based on five soil parameters have been developed

Meyer et al. (1974) studied the effect of flow rate and canopy on rill erosion. They found that a canopy to dissipate raindrop impact energy decrease rill erosion to less than half that without canopy and effectively eliminated interrill erosion.

John (1975) studied the estimation of rainfall erosion index. He formulated empirical relationship for estimation of rainfall erosion index from rainfall depth.

Williams (1975*)* modified USLE for computing the sediment yield of water sheds by replacing R by another factor

$$Y = 95 (Qq_p)^{0.56}KLSCP$$

Where, Y = Sediment yield for an individual storm (P

Q = Volume of runoff (acre-feet)

Q_p= peak flow rate (CF/S)

Foster et al (1976*)* derived an erosion equation from basic erosion principles. An erosion equation from the continuity equation for sediment transport and other equations describing rill and inter rill erosion. The resulting equation is a useful model of explaining the behaviour of the erosion process. The equation might serve as the basis for an operational equation for estimating soil loss for specific storms.

Onstad et al. (1976) developed a runoff erosivity term for the USLE from analysis of erosion equation principles. The analysis also suggested how the slope length exponent of the USLE varies with runoff, soil erodibility, slope steepness and length and erosion control practice. The findings should improve USLE soil loss estimate for specific events and time periods.

Williams and Berndt (1977*)* predicted sediment yield by modifying the USLE by replacing the rainfall energy factor with a runoff factor. The modified model, called MUSLE increases sediment yield prediction accuracy, eliminates the need for delivery ratios and is applicable to individual storms.

The USLE is an erosion model designed to predict the long time average soil from a specified cropping management system. With appropriate selection of numerical values for various soil erosion variables, the equation will compute the average soil loss for a cropping system, for a particular crop year in a rotation or a particular crop stage period within a crop year. It computes the soil loss for a given site as a product of six major factors where most likely values at a particular location can be expressed numerically (Wischmeier and Smith, 1978).

Wischmeier *et al.* (1978) simplified the procedure for determining the L and S factors combining the L and S factors together by considering the two as single topographic factors and a nomograph for determining LS factor was developed for convenience. The information given on C value may be made use of after carefully considering the cropping pattern, crops, cropping stages and crop management variations in the United States and in India and making suitable adjustments for these variations. Based on the intensive studies they have recommended P value for a number of situations.

Mutchler and Greer (1979*)* studied the effect of slope length (L) on erosion from low slopes. Soil loss (A) is generally accepted as being proportional to slope length, $A = aL^m$. Presently used values of the exponent are based on that of slopes of 3% and higher. This study using simulated rainfall, produced erosion data from plots 23, 46, 91 and 813 m long slope of 0.2%. The analysis results in a recommendation of m= 0.15 for slopes less than 0.5%.

Gupta (1980*)* estimated soil erosion by water. Combinations of tillage and crop residue handling, terracing and contouring were evaluated as control alternative and found that all three management inputs were needed on slopes between 12 and 20%.

Smith (1980) developed a kinematic model for surface mine sediment area. It is an extension of the model first developed by Rovery et al in 1977 and includes components for infiltration, surface and channel flow, sediment transport and flow routing through ponds. The model is demonstrated by simulating recently obtained data collected on an experimental watershed established on a reclaimed strip mine area in Western Colorado. Preliminary validation, using one degree of freedom and two recent storm runoff events, was excellent. Comparison with snowmelt runoff data indicated that the developments of more appropriate sediment transport relationship are needed fro steep watersheds with fine sediments.

Foster et al (1981) studied the evaluation of rainfall-runoff erosivity factors fro individual storms. Several erosivity factors that could be used to estimate soil loss of individual storms were investigated. They found that lumped erosivity factors include rainfall amount, rainfall intensity and runoff amount were even better predictors than EI 30.

Hussein and Laflen (1981) studied the effects of crop canopy and residue on rill and interrill erosion. It was found that a coefficient of rill erodibility was elated to surface residue cover and that this relation was little affected by crop canopy for one soil but was reduced by crop canopy fro another field. The effects of crop canopy on interrill soil erosion were not independent of the soil type. The study results were applied to determine the relationship of C values for the USLE to crop residue cover for various slope lands. The relationships were generally independent of slope length but varied with the soil and / or slope.

Meyer (1981) studied the effect of rain intensity on inter rill erosion on crop row side slopes of farm fields using simulated rainfall. For a wide range of soils and cropping conditions, erosion (E) was related to rainfall intensity (I) as the power of equation, $E = aI^b$. The exponent b decreased from slightly above 2.0 for soils of low clay content to about 1.6 for soils with about 50% clay.

Dhruva et al. (1983) estimated the soil erosion in India using USLE. In their analysis existing annual soil loss pattern for 20 different land resources regions of the country, sediment loads of some rivers and rainfall erosivity for36 river basins and 17 catchments for major reservoirs are utilized. In the present study the soil loss was estimated for each of the 20 land resource regions of India. This analysis showed that a total of 16.4 t/ha of soil was being eroded annually.

Douglas and David (1987) evaluated the daily rainfall erosivity model using Richardson et al model. This involved comparison with erosivities determined from hourly rainfall data by Wischmeir and Smith values. Event erosivities produced by the model average of approximately 80% of the Wischmeir and Smith values for 2,5 and 20- year events. The model was easily calibrated and is an operational tool for erosion, sediment yield and non-point source pollution studies.

Desmet *et al*. (1996) made a computer algorithm to calculate the USLE and RUSLE, LS factors over a two dimensional landscape. A comparison of manual calculation and a computer algorithm showed that the manual method leads to an under estimation of erosion risk. The computer procedure has the obvious advantage that it can be easily linked to GIS software. If data on land use and soils are available specific K, C and P values can be assigned to each land unit so that predicted soil loss can then be calculated using a simple overlay procedure

Kusumandari *et al* (1997) conducted a study on soil erosion and sediment yield in forest and agro forestry areas in West Java in, Indonesia. The objective was to measure and compare erosion rates and sediment yield in a watershed in West Java using AGNPS and USLE models. The AGNPS measured about half of erosion rate predicted by USLE. However, AGNPS output appears to be more realistic.

Risse and Kinnell (1998) used USLE – M for the estimation of soil loss. The new K value varied from 1.4-3.9 times the USLE –K value. The new C values varied from 1.1-32.3 times the USLE –C values. They found that the USLE and USLE – M are equally effective in predicting erosion for impervious conditions. But, efficiency of USLE decreases as the proportion of the rain infiltrating increases, while that of the USLE – M does not.

Sikka *et al.* (2003) used the USLE to estimate the soil loss from the 338 on 10km x 10km grid distributed over entire state of Kerala in India. Parameters of the USLE were worked out by synthesizing information on rainfall, soil topography, land use and management practices for each grid. The computed values for soil loss were grouped into six classes. The result showed that major portion of Kerala falls in 0-5 ton/ha year-soil loss category while less than 5 percent of the areas is subjected to serve from of soil erosion. Small areas contribute to soil loss greater than 40 tons/ha.year. About 40 percent of state is subjected to soil loss in the categories of 5-10 and 10-15 tons/ha/year.

Joshi *et al.* (2004) conducted studies at Bhetagad watershed to assess the erosion losses under open pine forest, tea garden rainfed agriculture land and grazing lands. The result revealed that soil in terraced agriculture land was more stable than that in pine forest, tea gardens and grazing lands. The maximum water, soil and nutrient losses are recorded from areas covered with open pine forest and minimum for agriculture land. The well maintained agriculture land had higher conservation values of water, soil and nutrients than the other land use system.

2.3 GIS in Watershed Management

Geographic Information System (GIS*)* is defined as an information system that is used to input, store, retrieve, manipulate, analyze and output geographically referenced data or geospatial data, in order to support decision making for planning and management of land use, natural resources, environment, transportation, urban facilities, and other administrative records. GIS is a very powerful tool for spatial planning and resource management

Water shed refers to the area lying above a common drainage point and can be defined as the area from which surface water drains through a definite drainage point. A watershed can be defined as the natural integrator of all hydrologic phenomena pertaining to its boundaries and as such it is a logical unit for planning optimum development of soil and water resources. A digital representation of the continuous variation of relief over space is known as Digital Elevation Model (DEM).

Green *et al.* (1995) constructed a Geographic Information System for an urban watershed in Bata Rouge, Louisana and used to direct a hydrologic modelling effort for watershed management. The GIS identical hydrologic response units (HRU's) and locational information (coordinates) of the nodes of the storm drain system to guide and direct the model. The location data were also used to determine dimensions of the HRU's as well as all flow lengths. The curve number method was used to determine dimensions of the HRU's as well as flow lengths. The curve number method was used to determine rainfall excess and the discharge was routed using a standard kinetic wave model. System capabilities are demonstrated the lot, polygons, block and multi block scale.

Garbrecht *et al.* (2001) described GIS and distributed watershed models, which addresses selected spatial data issue, data structures and projections, data sources, and information on data solution and uncertainties. Spatial data that are covered include digital elevation data, stream and drainage data, soil data, remotely sensed data and radar precipitation data.

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Chowdary *et a*l.(2002) conducted a GIS-based decision support system for groundwater assessment in large irrigation project areas for Godavari Delta Central Canal Irrigation Project in East Godavari District of Andhra Pradesh State, India In this study, a geographical information systems (GIS) is used to map the spatial distribution of recharge which then serves as input to a regional groundwater flow model for simulating the behaviour of the underlying aquifer. A generalized integrated framework has been developed for assessment of groundwater resources in large canal irrigation project areas with varying soil, weather, crop, and water use conditions.

Prado *et al*.(2003) explained the role of GIS Application to Map Watershed Physical Features Contributing to Reservoir Water Quality in the Barra Bonita reservoir basin, in the Sao Paulo state, Brazil. This paper proposes the integration of watershed physical variables using the GIS technology as a tool to improve non-point load estimates into aquatic ecosystems.

Pandey *et al*. (2004) developed the DEM of Bankduth agricultural watershed using ARC/INFO GIS software from contour map. Flow direction and flow accumulation themes were developed using depression less DEM. Topographical parameters and stream properties relating to land surface of watershed were extracted. The DEM and associated parameters derived from their study may be successfully used for simulation of runoff and sediment yield from Banikdih watershed for planning of management practices.

2.4 GIS in Runoff Estimation

Green *et al.* (1995) constructed a Geographic Information System for an urban watershed in Bata Rouge, Louisana and used to direct a hydrologic modeling effort for watershed management. The GIS identical hydrologic response units (HRU's) and location information (coordinates) of the nodes of the storm drain system to guide and direct the model. The location data were also used to determine dimensions of the HRU's as well as all flow lengths. The curve number method was used to determine dimensions of the HRU's as well as flow lengths. The curve number method was used to determine rainfall excess and the discharge was routed using a standard kinetic wave model. System capabilities are demonstrated the lot, polygons, block and multi block scale.

Saravanan and Sudharsanan (2004) followed a lumped modeling approach for modeling flood events of Valliyar in Tamil Nadu using Remote sensing and GIS. Flow is estimated for the minimum, maximum and average rainfall events and the estimated runoff is compared with the observed stream flow measurements

Pandey *et al*. (2004) developed the DEM of Bankduth agricultural watershed using ARC/INFO GIS software from contour map. Flow direction and flow accumulation themes were developed using depression less DEM. Topographical parameters and stream properties relating to land surface of watershed were extracted. The DEM and associated parameters derived from their study may be successfully used for simulation of runoff and sediment yield from Banikdih watershed for planning of management practices.

2.5 GIS in Soil Loss Estimation

Spanner *et al.* (1983) first demonstrated potential of GIS for soil loss assessment using RS and GIS techniques for quantitatively assessing erosion.

Fook *et al.* (1992) made use of remote sensing techniques and GIS for soil erosion mapping. Soil erosion is most frequently assessed by using Universal Soil Loss Equation.

Kwong Fai (1995) conducted a study on erosion assessment of large watershed in Taiwan. The objective of this study is to integrate the AGNPS (Agricultural Non Point Pollution) model and the technology of GIS to quantify erosion problems at the Bajur river basin and Tswengwen reservoir watershed in Taiwan. He found that the annual sedimentation depth for the Tswengwen reservoir is approximately 5.9 mm, which is not significantly different from the observed rate.

Desmet et *al*. (1996) made a computer algorithm to calculate the USLE and RUSLE, LS factors over a two dimensional landscape. A comparison of manual calculation and a computer algorithm showed that the manual method leads to an under estimation of erosion. The computer procedure has the obvious advantage that it can be easily linked to GIS software. If data on land use and soils are available specific K, C and P values can be assigned to each land unit so that predicted soil loss can then be calculated using a simple overlay procedure.

De Roo (1998) illustrated the modelling of run off and sediment transport in catchments using GIS. He stated that the GIS raster based erosion model do not necessarily produce better results than much simpler and partly lumped erosion models with ‘representative elements’ although they reproduce topography in more details. Reasons for the disappointing results of spatial model must be sought in the uncertainty involved in estimating and measuring the large number of input variables at a catchment scale. He also emphasized the need for much simpler loosely coupled or embedded GIS erosion models simulating only the dominant process operating in the catchment.

Formaggio *et al*. (1998) used USLE for soil erosion modeling. The test site was a watershed in a region of highly intensive agriculture in Sao Paulo State(Brazil) and GIS / Remote sensing techniques were employed for spatialize the soil erosion losses by water. They have tested different approaches of modelling the USLE topographic parameters “L” and “S”. The result showed that for “S” parameters there was no statistical difference, in the final spatialised results, showing the need of improve the methods of modelling the USLE most impacting parameters

Sarangi *et al*.(2001) studied the use of GIS in assessing the erosion status of the watershed. Two watershed viz. Banha watershed at Damoder valley, Jharkand and IARI watershed at Delhi are considered for hypsometric analysis. The hypsometric analysis revealed that the Banha watershed is less susceptible to erosion where as IARI watershed is at stabilized state. This findings point out the need for conservation measures in Banha watershed for controlling further erosion through construction of soil conservation structures

Sharma et al (2001) conducted a study on watershed prioritization based on sediment yield index in eastern part of Doon valley using remote sensing and GIS. The SYI for each sub watershed was computed using GIS technique and priority categories were determined. Priority classification exhibited that the sub watershed having high to very high SYI were located in hills and mountains.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1 Study Area

Gayathri sub basin of the Bharathapuzha river basin has been selected for the study. It lies mainly in Palakkad district and a small portion in Thrissur district of Kerala in peninsular India. Latitude / longitude range of Gayathri sub basin is 10^0 25’ 53’’ N, 76^0 20’ 59’’ E to 10^0 44’ 55’’ N, 76^0 55’ 00’’E. The location map of the area is shown in Fig.3.1.

Total geographical area of the watershed is 1042 km^2.Topography varies from moderately sloping to steep sloping and the elevation ranges from 40 m to 1500 m. Climate is humid tropic. Major soil group of the area are Loamy and Clayey. Seasonal crop paddy and perennial crop such as coconut, arecanut, rubber, coffee, cardamom constitute major vegetation group. About 21% of the total geographical area is covered by forest and scrubs.

3.2 Maps and other data used

- Toposheets from Survey of India (SOI) bearing numbers 58B6, 58B7, 58B10, 58B11 and 58B14 prepared in 1:50,000 scale.

- Soil map of National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) prepared in 1: 5,00,000 scale.

- Daily rainfall data from the Class A meteorological observatory of Kelappaji College of Agricultural Engineering and Technology, Tavanur.

- ILWIS3.3 developed by ITC, Netherlands for GIS data input, analysis and output.

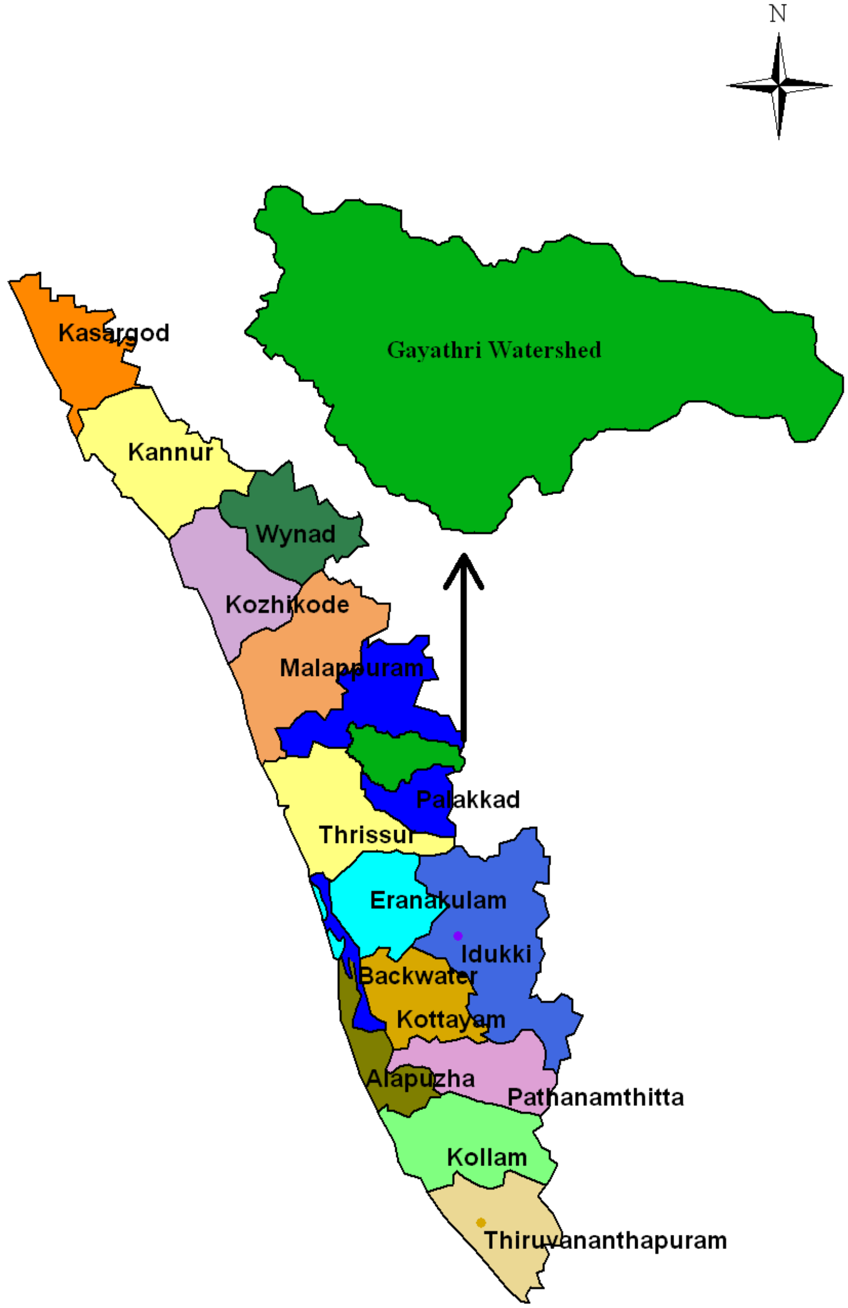

Fig 3.1 GAYATHRI WATERSHED- Location Map

3.3 Base map preparation

3.3.1 Drainage Map

Drainage network of the study area is digitized from the concerned toposheets of the study area using on screen digitization capability of the ILWIS software. Segment map of drainage network corresponding to each toposheet was prepared separately, then all the segment maps were joined together using the “Glue” option in the software. Universal Transverse Mercator (UTM) projections corresponding to zone 43 was used as the co ordinate system for all the thematic maps. Drainage map of the Gayathri watershed is shown in the Fig.3.2.

3.3.2 Digital Elevation Model (DEM)

Contour lines of the toposheets were digitised and separate segment maps corresponding to each toposheet used in the study was prepared separately and finally the segment maps were joined to get the whole contour map for the study area. While digitising the contours, the contour lines lying at the outer adjacent area of the watershed boundary were also included to make the interpolation of the contour values possible at the time of DEM generation. Error corrections were applied to remove the errors caused due to self overlap, dead ends, intersections and code consistency. After the error correction, the segment contour map was rasterised using the segment to raster feature of ILWIS. The contour map of the Gayathri watershed is shown in the Fig.3.3.

Next to this, a point elevation map was prepared for the entire study area. The point elevation data given in the toposheet was used and also some educated guess was made in places of missing data to obtain the point map. The point map was then rasterised to get a raster point map. Using the raster contour segment map and the raster point map DEM was prepared by giving the appropriate map calculation formula.

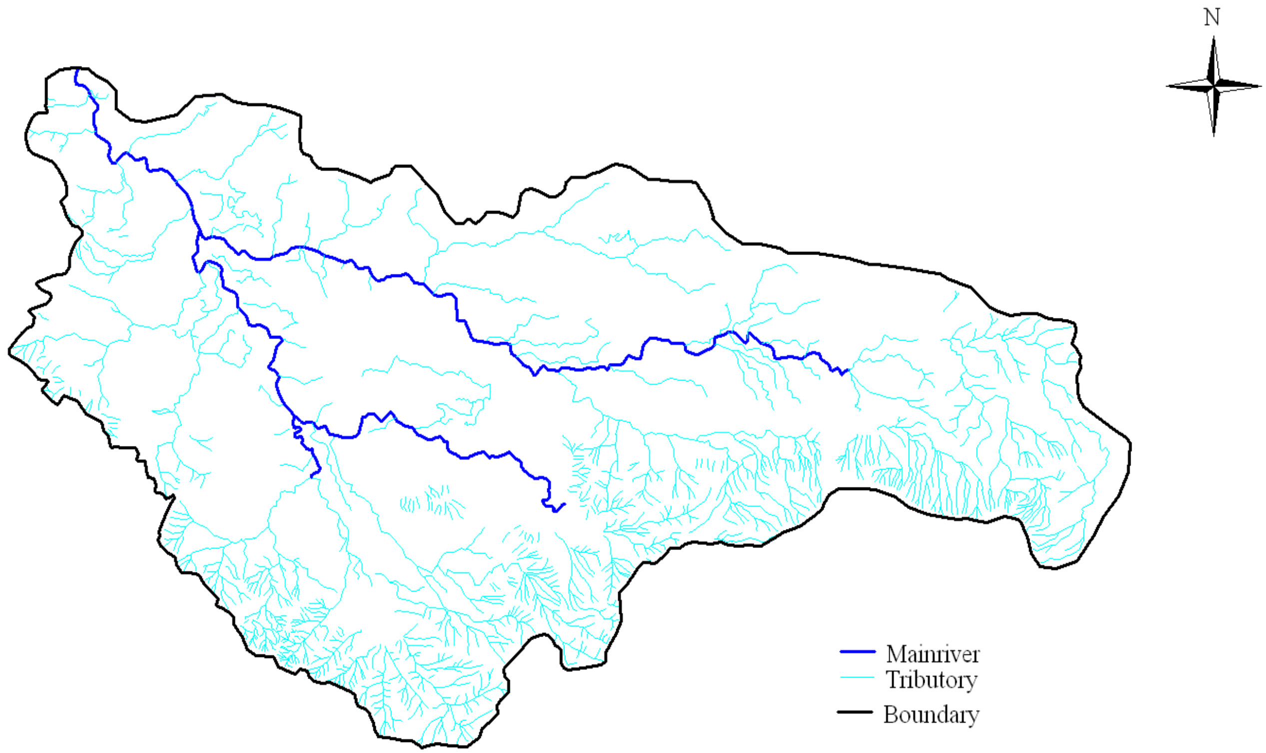

Fig 3.2 **GAYATHRI WATERSHED- Drainage Map**

Scale; 1:300000

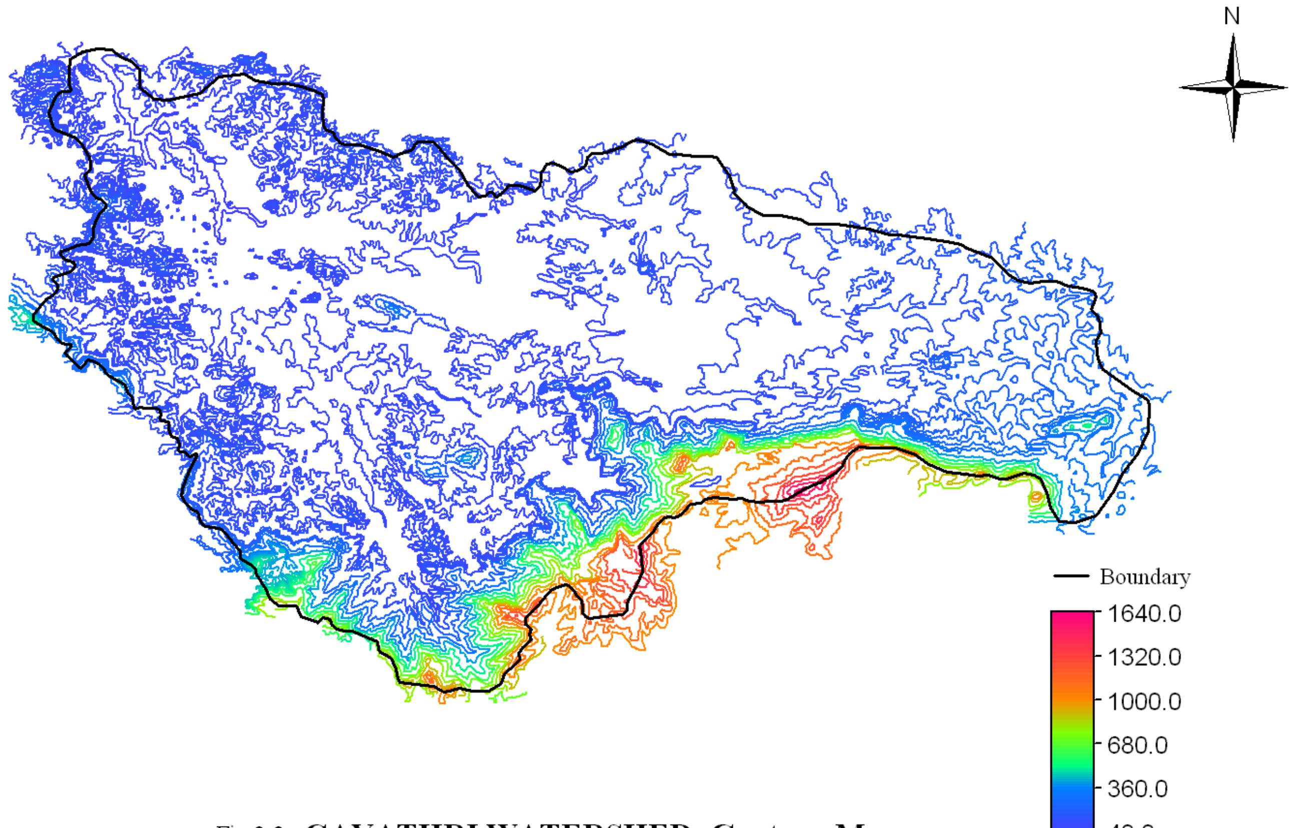

Fig 3.3 **GAYATHRI WATERSHED- Contour Map**

Scale; 1:300000

A three dimensional view of the study area and its immediate surrounding were generated using the hydroprocessing feature of ILWIS. This 3D view was overlaid with the drainage map and an approximate watershed boundary was delineated. This rough boundary segment map was then overlaid with the toposheets and error corrections were applied wherever necessary to get the exact boundary of the watershed.

The segment boundary map thus obtained was polygonised using the “segment to polygon” option and a boundary polygon map was generated. Next, this polygon map was rasterised and using the raster map, the DEM generated earlier was clipped to the watershed boundary using map calculation formula,

New map=iff(raster boundary map=1,DEM,0).

In this way, a DEM for the exact watershed area was prepared.

3.3.3 Soil Map

The analog soil map collected from NBSSC was scanned and the digital map was imported to ILWIS environment using the “File - import” option of the software. Then the boundaries of the different soil group of the map were digitised and a segment soil map was generated. A point map was prepared giving labels to individual soil types as a next step. Using the segment soil maps and the label points, a polygon map of soil was prepared.

A conventional soil map of the state of Kerala prepared by NBSS & LUP has been collected and the same is digitised for the study area. Soil map of the Gayathri watershed is shown in the Fig.3.4 which shows 11 numbers of soil series. The textural properties of the watershed vary from clayey to loamy. 91% of the geographical area is occupied by loamy soil and the rest by clayey soil.

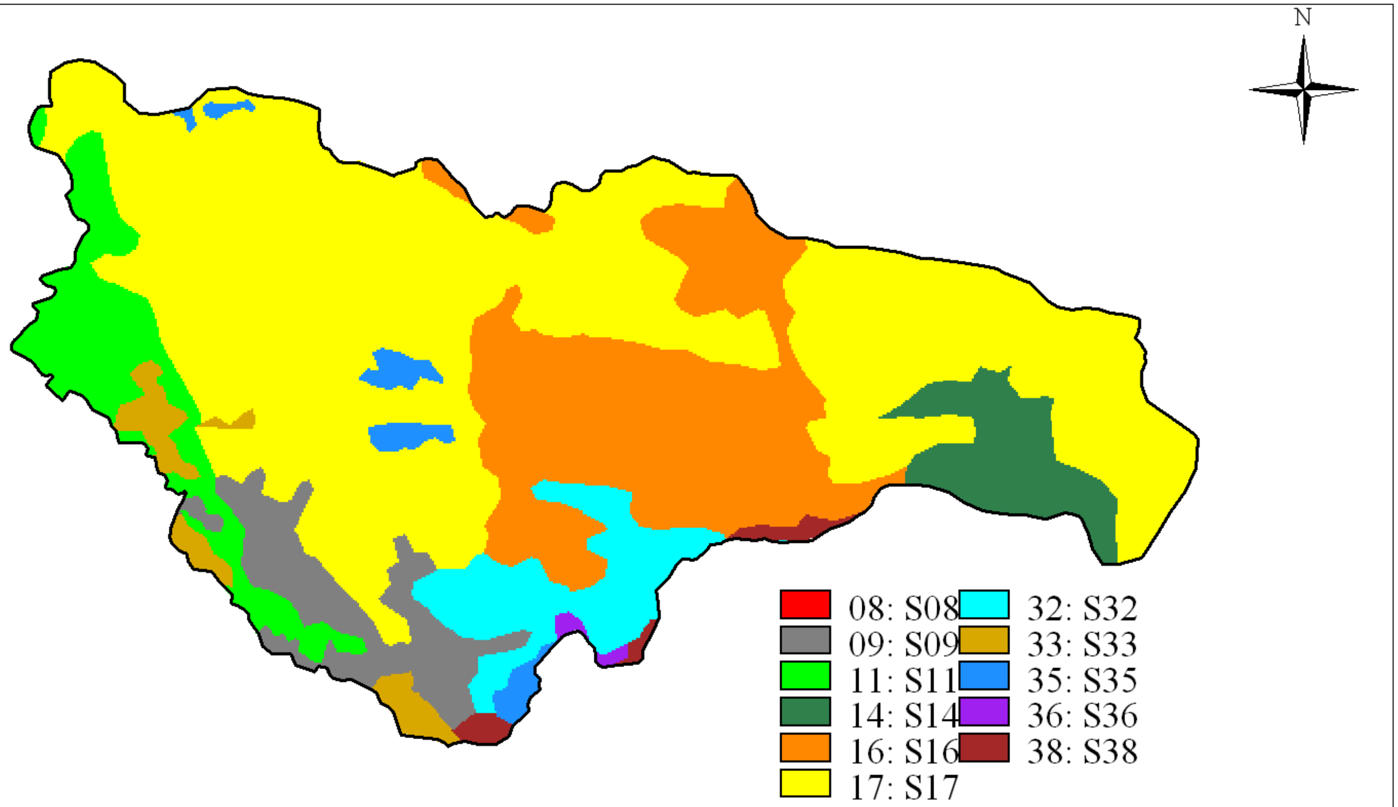

Fig.3.4 **GAYATHRI WATERSHED- Soil Map**

Scale; 1:300000

3.3.4 Landuse Map

The study originally envisaged to procure satellite imagery from NRSA to prepare land use map. However, due to some technicalities the imagery could not be procured in time and as a result the preparation of land use map had to rely on information provided in toposheet. A segment map of different land use categories as is given in the toposheet was digitised and a segment land use map was prepared for each toposheet and later these maps were joined to get the land use map for entire study area. A label point for different land use was also prepared and then a land use polygon map was generated.

Landuse of the Gayathri watershed prepared from the toposheet is presented in Fig.3.5. Major part of the area is occupied by garden land (57%) followed by forest and scrubs (21%), paddy field (12%), rubber (6%) and rock outcrop (2%).

3.3.5.1 SCS Curve number method

Curve number of a land depends on soil texture and land use. Hence, crossing of land use and soil texture map is needed. The land use map is rasterised. Then an attribute soil textural map was prepared from the soil class map earlier generated. To prepare the attribute map with textural details, an attribute table from the "soil domain" was prepared. In this attribute table an attribute column for soil texture was added and information for texture for each soil class was fed. Now using the parent soil map and the attribute table, the attribute textural map is prepared.

Then a two dimensional table was prepared from the rasterised contour and soil texture map. CN values were entered in the individual cells of the table corresponding to each landuse and texture. After the two dimensional table was prepared, a CN map was generated from it. From this CN map weighted CN map of the entire watershed is prepared. Flow chart showing estimation of surface runoff using SCS Curve Number Method is shown in Fig.3.6.

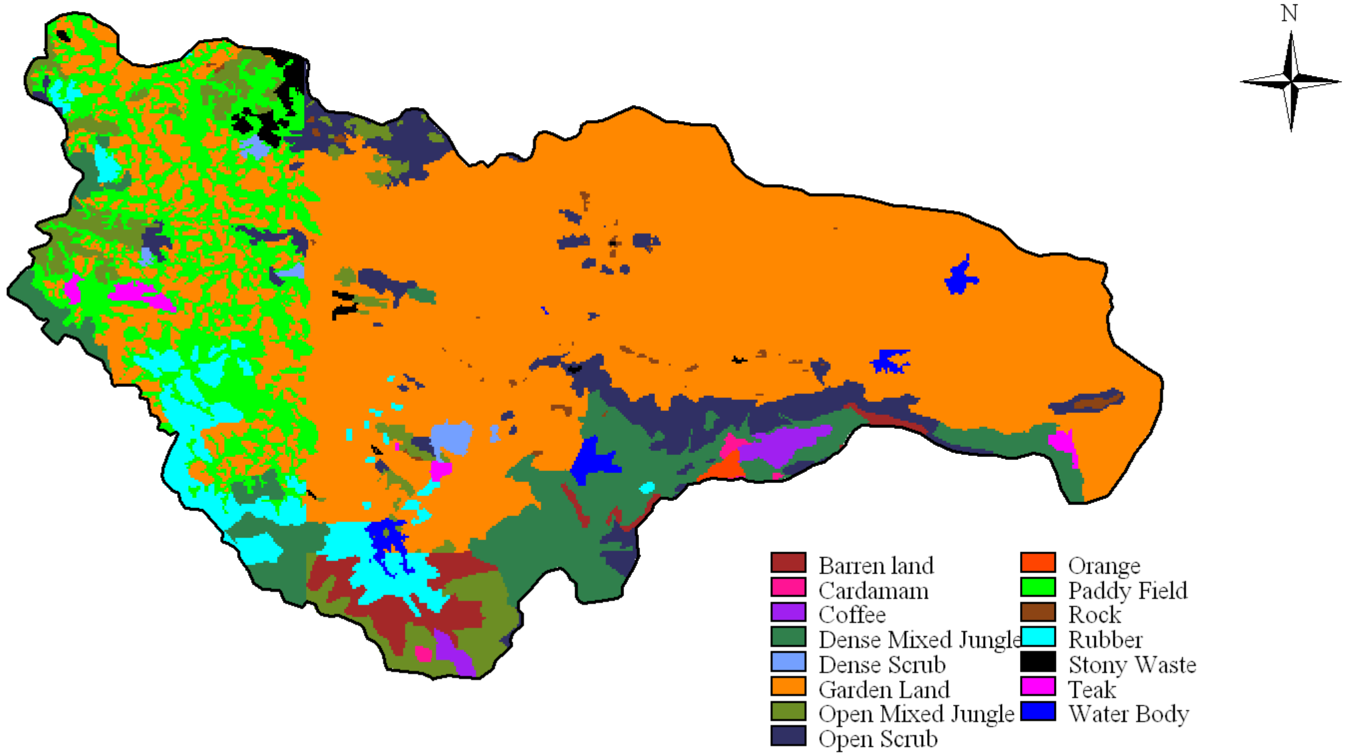

Fig.3.5 **GAYATHRI WATERSHED- Landuse Map**

Scale; 1:300000

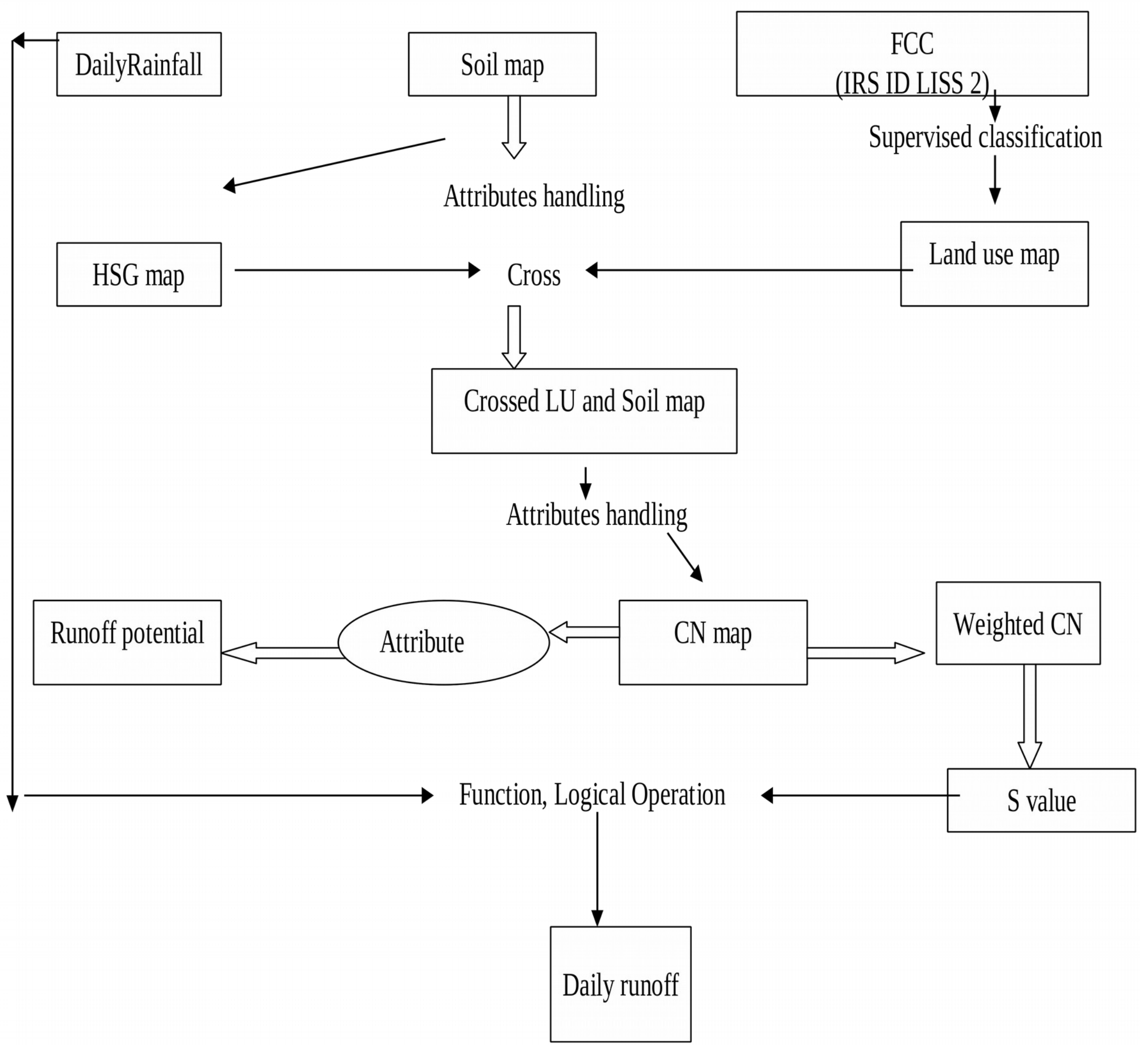

Fig.3.6.The Flow chart showing estimation of surface runoff using SCS Curve Number Method

3.3.5.2 Antecedent moisture condition (AMC)

The curve numbers shown in the CN map are the values of curve number corresponding to average moisture condition. These curve numbers corresponding to average soil moisture condition, known as curve number 2(CNII) is to be modified for extremes of soil moisture status that is for very low and very high. To determine the daily Antecedent Moisture Condition (AMC) status, 5 day antecedent moisture condition is determined from daily rainfall data using excel spreadsheet. Different AMC are determined by referring to Table 3.1 showing AMC status. Then, using the weighted average curve number (CNII), the values of CNI & CNIII are calculated using formula given below, for the corresponding AMC condition of the day.

$$CNI = \frac{(4.2*CNII)}{(10-0.058*CNII)}.$$

$$CNIII = \frac{(23*CNII)}{(10+0.13*CNII)}.$$

. 1^{st} Jan to 31^{st} May is considered as dormant season and 1^{st} Jun to 31^{st} Dec as growing season. Final CN values are separately worked out for dormant and growing season using excel function

A M C	**5 day antecedent rainfall(mm)**	
	Dormant season	**Growing season**
I	<12.5	<35
II	12.5-27.5	35-52.5
III	>27.5	>52.5

Table3.1. Antecedent Moisture Condition

3.3.6 Precipitation

The daily precipitation data for the year 2005 and 2006 gives annual rainfall of 282.4cm and 335.12cm respectively. Average number of rainy days is 148. Maximum daily rainfall intensity reported is13.96cm/day.

3.3.7 Surface runoff

From the final CN values, the value of the potential storage S is determined using the equation,

$$S = \frac{(25400)}{(\text{adjusted CN})} - 254.$$

Then, daily surface runoff is determined using the equation,

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

Where P = daily rainfall in mm

The above equations are entered in the excel formula bar to obtain daily values of both S and Q.

3.3.8 Universal soil loss equation

3.3.8.1 Erosivity (R) Map

Daily rainfall values are collected from the observatory of Kelappaji College of Agricultural Engineering and Technology, Tavanur as data was not readily available for the study area. R values are computed from the annual rainfall values using the equation

$$R = 38.5 + 0.35*P$$

Where R = rainfall erosivity

P = annual rainfall

For this, the boundary map of the study area is rasterised and using ILWIS map formula, the R map is generated.

3.3.8.2 Erodibility (K) Map

A table was created from the domain of the soil textural map. Additional column for organic matter was added to that table using the “add column” option in the software. Then, K factor column was added and its values were entered by referring to published values of K. This table is shown as Table 3.2. Then an attribute map is prepared using the base map of the soil texture and table containing K values.

Table3.2. Erodibilty (K) values for different soil groups.

Soil Group	Texture	Organic Matter (%)	K factor
S08	Clayey	2.0	0.25
S09	Loamy	2.0	0.10
S11	Loamy	2.2	0.10
S14	Clayey	2.0	0.25
S16	Loamy	2.0	0.10
S17	Loamy	2.0	0.10
S32	Loamy	2.0	0.10
S33	Clayey	2.0	0.25
S35	Clayey	2.0	0.25
S36	Loamy	2.0	0.10
S38	Loamy	2.0	0.10

3.3.8.3 Topographic Factor (LS) Map

A slope length (L) map is prepared, as a prerequisite to LS factor map using the equation,

$$L = 0.4S + 40$$

Where L = slope length in m

S = slope steepness in %.

To use in the above equation, a slope (%) map is generated using the equation

$$Slope = (hyp(D_x,D_y)\backslash pixel\ size) *100$$

Where D_x = slope gradient in x direction

D_y = slope gradient in y direction

Thus LS map is generated using the equation corresponding to two conditions slope<21% and slope > 21%.

For slope <21%,

$$LS = (L/72.6) * (65.41*\sin (S) + 4.56 *\sin(S) + 0.065)$$

For slope >21%,

$$LS= (L/22.1)^{0.7} * (6.432*\sin (S^{0.79}) * \cos (S))$$

Where LS = LS factor

L= slope length in m

S= slope steepness in radians

Slope radians are computed from the slope map, first by converting the slope % to slope degree and then slope degree to slope radians. Slope in degree is obtained using the equation,

Slopedegree = raddeg(atan(slope/100))

Slope radians is computed using the equation,

Sloperadians = degrade(slopedegree).

3.3.8.4 Crop Factor(C) Map

Crop factor (C) map is generated as an attribute map by adding a C column to the soil table. Values of crop factor are entered in the soil table according to the type of crop. Crop factor Values for different crops are shown in Table 3.3.

3.3.8.5 Conservation Practice Factor (P) Map

Similar to crop factor (C), a conservation practice factor (P) column is added in the soil map. Corresponding to different land uses conservation practice factor (P) values are assigned by making use of all available information and a conservation practice factor (P) map was generated as an attribute map. Different P values for different landuse are shown in Table 3.3.

Table3.3. Values of Crop factor and Conservation Practice factor

Landuse	C factor	P factor
Barren land	0.55	0.70
Cardamom	0.35	0.40
Coffee	0.35	0.35
Dense Mixed Jungle	0.10	0.70
Dense Scrub	0.10	0.70
Garden Land	0.40	0.40
Open Mixed Jungle	0.30	0.70
Open Scrub	0.30	0.70
Orange	0.40	0.35
Paddy Field	0.30	0.30
Rock	0.20	0.80
Rubber	0.35	0.30
Stony Waste	0.20	0.80
Teak	0.40	0.50
Water Body	0.00	1.00

3.8.6 USLE map

USLE map is generated by multiplying the 5 maps viz. R, K, LS, C and P using the "cross" option in ILWIS. Then the USLE map was classified using the "classify" function of the software. A group domain is needed for the classification and the range of values of each soil loss class is defined in that class. Flow chart showing estimation of soil loss using USLE is shown in the Fig.3.7.

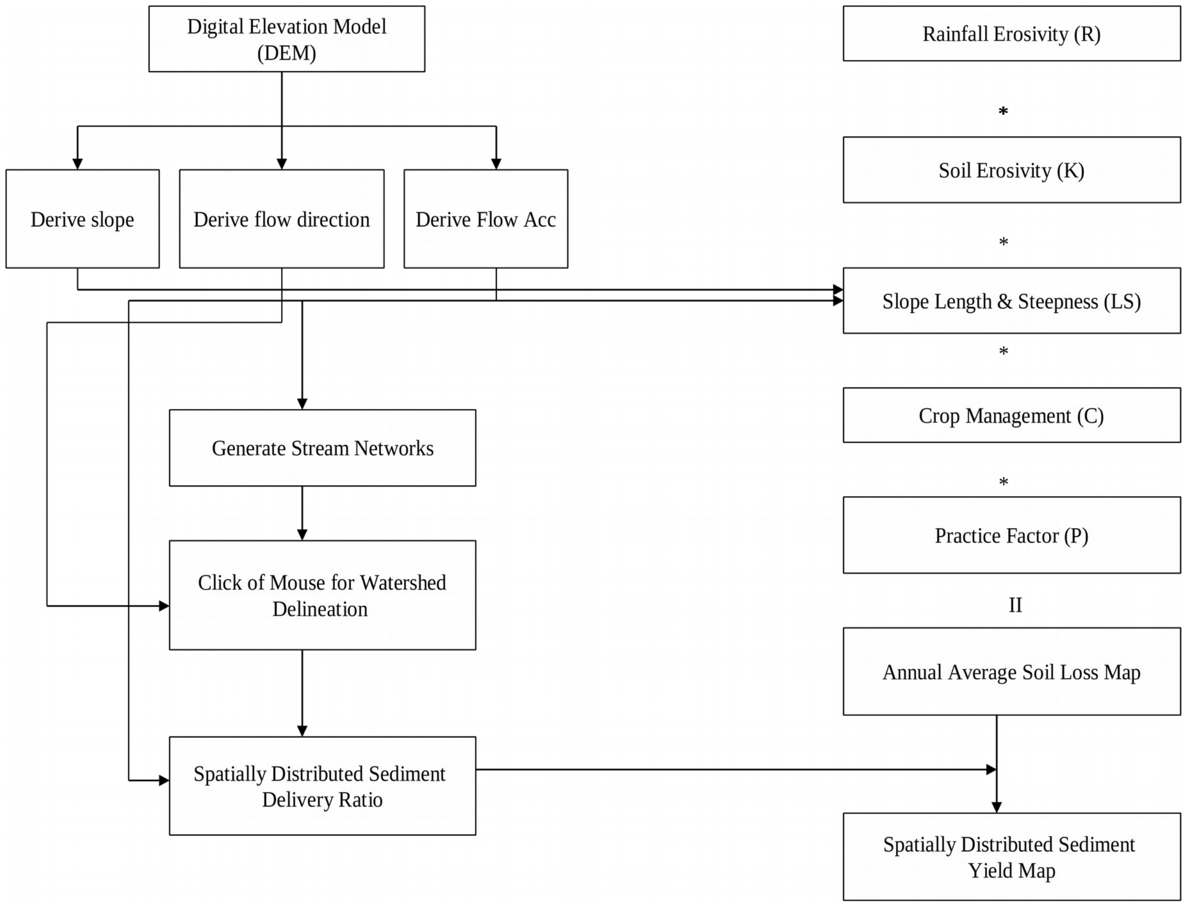

Fig.3.7. The Flow Chart Showing Estimation of Soil Loss Using USLE

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

4.1 Digital Elevation Model (DEM)

A digital elevation model of Gayathri sub basin of Bharathapuzha river basin is prepared with a resolution of 100*100m.The DEM has been classified for different elevation ranges and the classified map showing different elevation ranges are shown in Fig.4.1. Total geographical area of the watershed is 1042 km^2.Elevation ranges from 40m to1500m with average elevation at 730m. The classified map shows that 2% of the total area is below 40m elevation; 68% is between 50m and 200m and 27% is between 200m and 1000m and 5% is between 1000m and 1500m.

4.2 Surface Runoff

The curve number map for the entire watershed is prepared. Curve numbers of Gayathri watershed vary from 45 to 100. According to Curve Number values the entire watershed area is classified into five groups. The curve number map for the watershed according to the curve number classes is prepared and shown in Fig.4.2. The percentage area coming under each class is shown in Table 4.1. Weighted average curve number of the whole watershed is 80.16. Surface runoff is computed on daily basis. The cumulative value of surface runoff for 15 days time interval shown against rainfall, for the years 2005 and 2006 are given in Fig.4.3 and Fig.4.4 respectively.

Table.4.1. Curve Number Classes and Percentage Area under each class

CN Classes	CN Range	% Area
Low	45-55	0.92
Medium	55-65	0.45
High	65-75	18.71
Very High	75-85	73.64
Extremely High	75-100	6.28

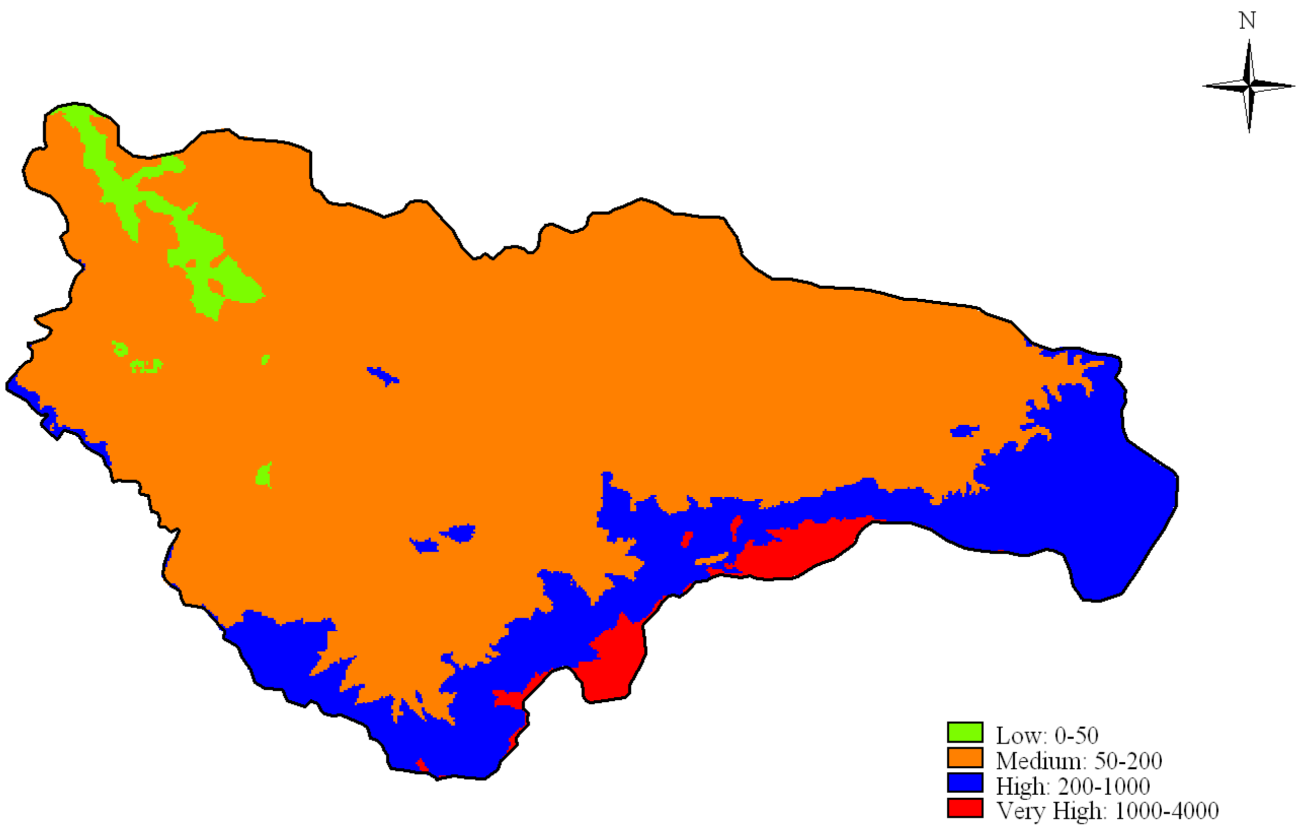

Fig.4.1 **GAYATHRI WATERSHED - Digital Elevation Model**

Scale; 1:300000

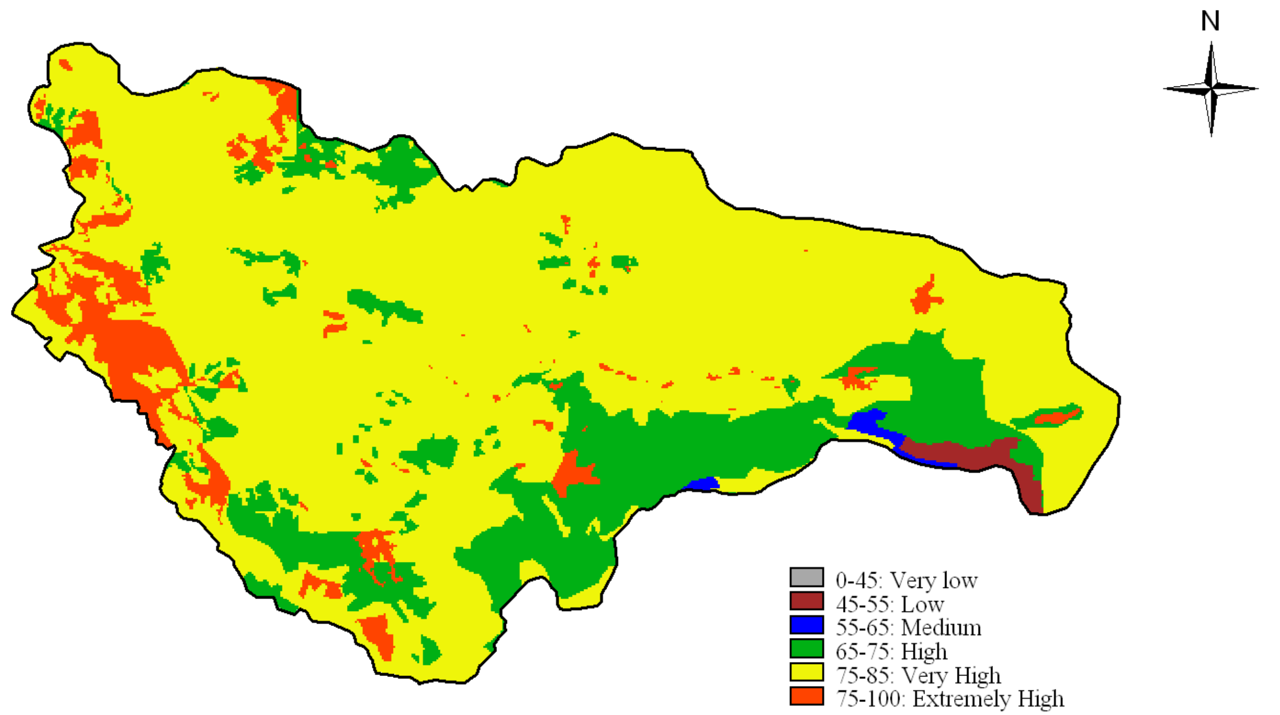

Fig 4.2 **GAYATHRI WATERSHED: Curve Number Map**

Scale: 1:300000

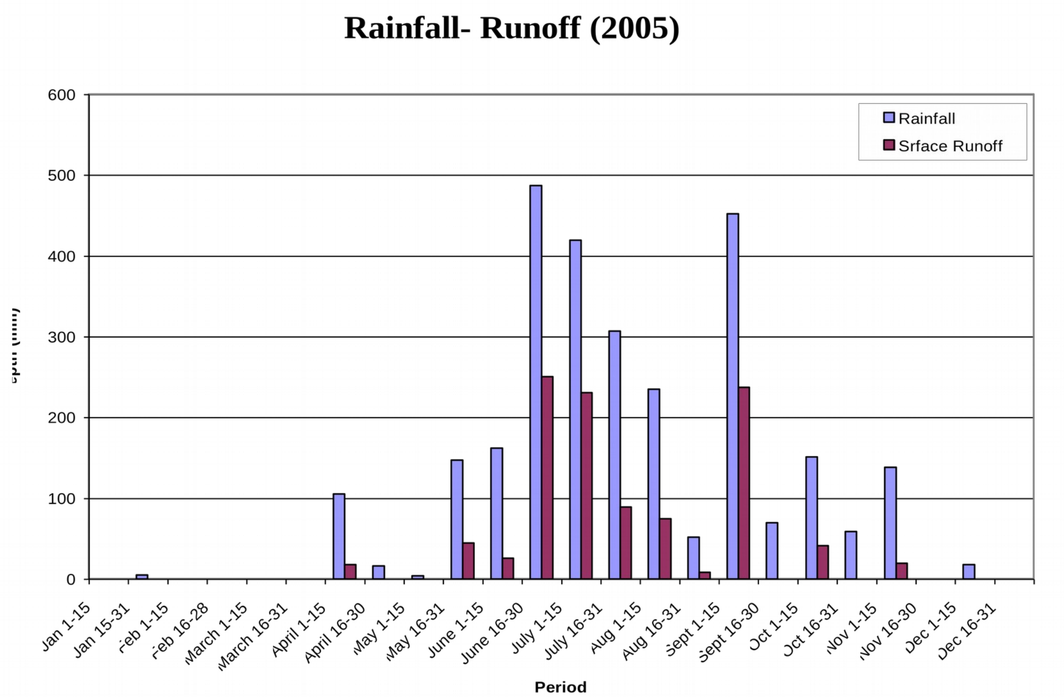

Fig.4.3. 15 days cumulative rainfall and surface runoff for the year 2005

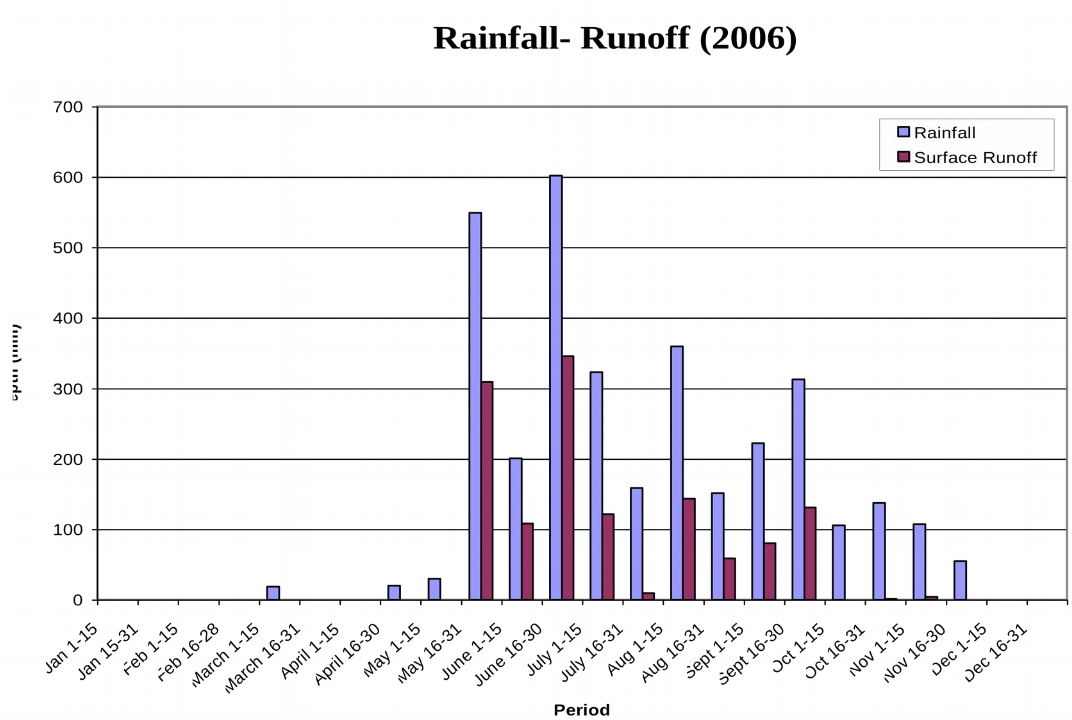

Fig.4.4. 15 days cumulative rainfall and surface runoff for the year 2006

In the year 2005, the watershed received a total rainfall of 2824 mm and generated a runoff depth of 1037 mm. That is, 36.7% of total rainfall contributed to runoff. A maximum rainfall of 486.9mm is received in year 2005 during the period June 16-30 and has resulted in a runoff depth of 250.5 mm. 90% of the rainfall received is during the monsoon season (June 1st to November 15th) and 38.5% of the same is resulted in runoff. Summer rain contribution to the total rainfall is 250.55 mm, which resulted in a runoff of 62 mm.

In the year 2006, the monsoon season started 15 days earlier than in normal years, so monsoon season contributed nearly 96% of the total rainfall. The summer season was very dry and contributed a very meagre amount to the annual rainfall. In this year, the rainfall received by the watershed was more than the average annual rainfall of Kerala (3000 mm). The watershed received a total rainfall of 3351 mm and produced a runoff depth of 1312 mm. That is, 39.1% of total annual rainfall contributed to runoff. During the period from June 16-30 the watershed received maximum rainfall of 602 mm and resulted in a runoff depth of 345 mm.

4.3 Soil Erosion

As the annual rainfall obtained in the year 2005 is nearly equal to the average annual rainfall of Kerala, for the soil erosion calculations, the rainfall data of the year 2005 is used.

4.3.1 Erosivity (R)

Erosivity (R) for the watershed has been calculated using the equation

$$R=38.5+0.35P$$

Where P = annual rainfall in mm

For the year 2005, the annual rainfall, P, is 2824 mm. So, the erosivity value for the entire watershed is 1020 Mj.mm/ha.h.

4.3.2 Erodibility (K) Map

Erodibility map has been generated as an attribute map from the soil texture map and is shown in the Fig. 4.5. In Gayathri watershed region, 91.7% of the total area having an erodibility value of 0.1 and the rest of the area has the erodibility value 0.25. The weighted average of the erodibility value is obtained as 0.11. The minimum value of erodibility factor is 0.1 and the maximum is 0.25.

4.3.3 Slope (S) Map

The slope map of the Gayathri watershed is prepared and has been classified for different slope classes. The classified map is shown in Fig.4.6. The watershed is classified into five classes as shown in Table 4.2. The maximum and minimum slope of the watershed is 616.4% and 0% respectively. The average slope of the entire watershed is 16.44%. In the watershed, majority of the area, 51.33%, is having a slope of 0-3%.

Table.4.2. Slope Classes and Percentage area

Slope classes	Range	% Area
Low	0-3%	51.33
Medium	3-10%	21.08
High	10-25%	13.16
Very high	25-100%	13.53
Extremely high	100-700%	0.89

4.3.4 Topographic Factor (LS) Map

Slope length map of the watershed is prepared from the slope map, and from this, topographic map is generated using ILWIS 3.3. Topographic factor (LS) map is shown in the Fig.4.7. Topographic factor (LS) varies from 0 to 9.62.

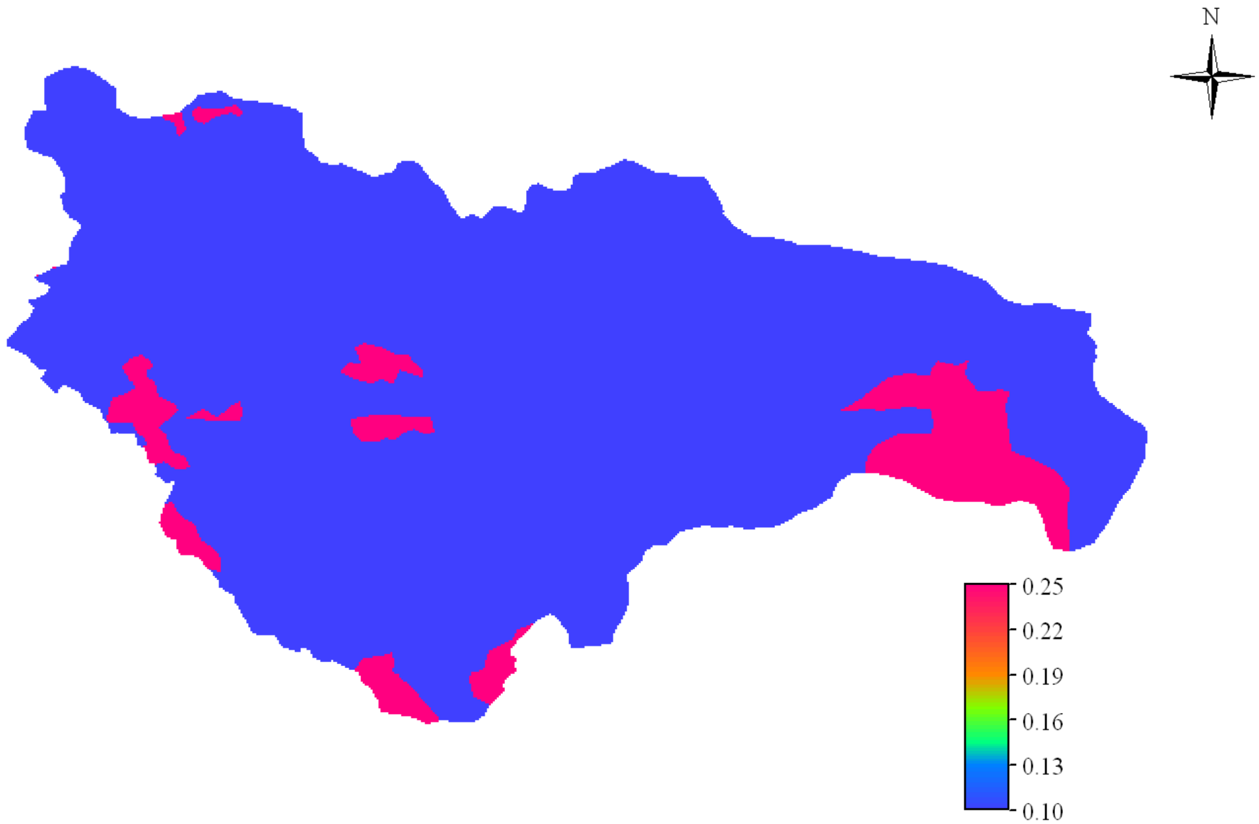

Fig.4.5 **GAYATHRI WATERSHED - Erodibility (K) Map**

Scale; 1:300000

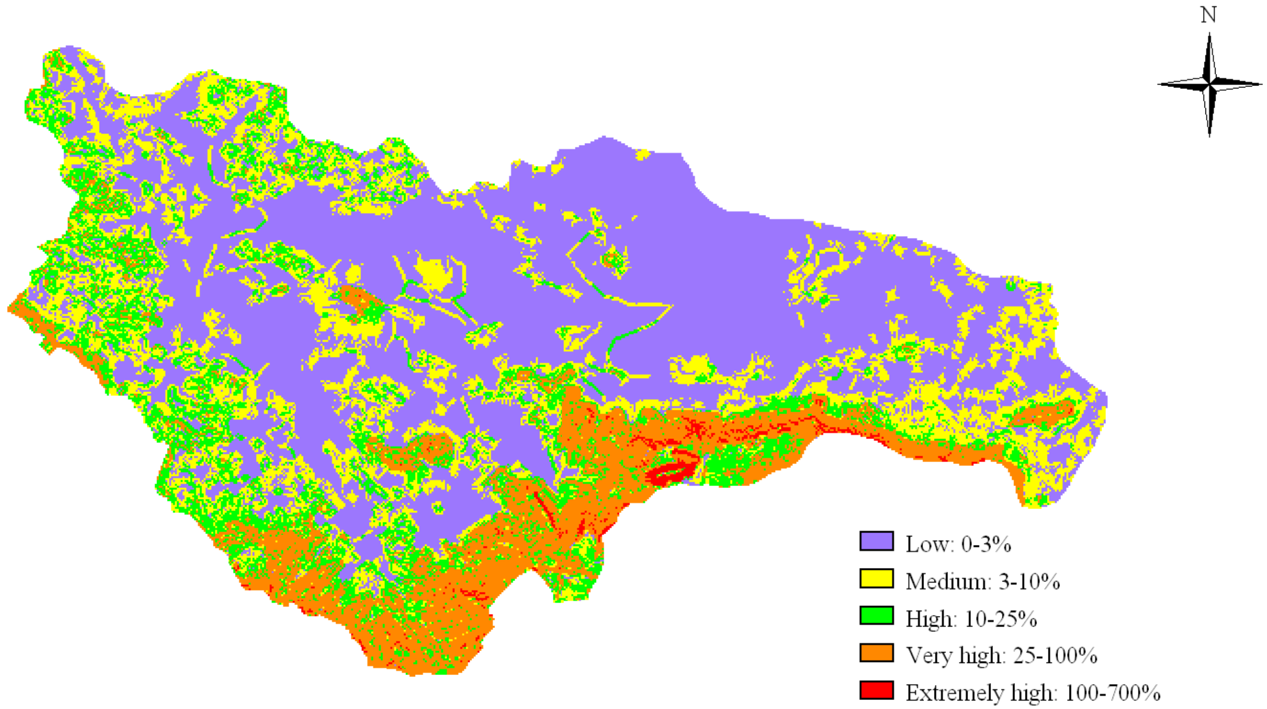

Fig.4.6 **GAYATHRI WATERSHED - Slope Map**

Scale; 1:300000

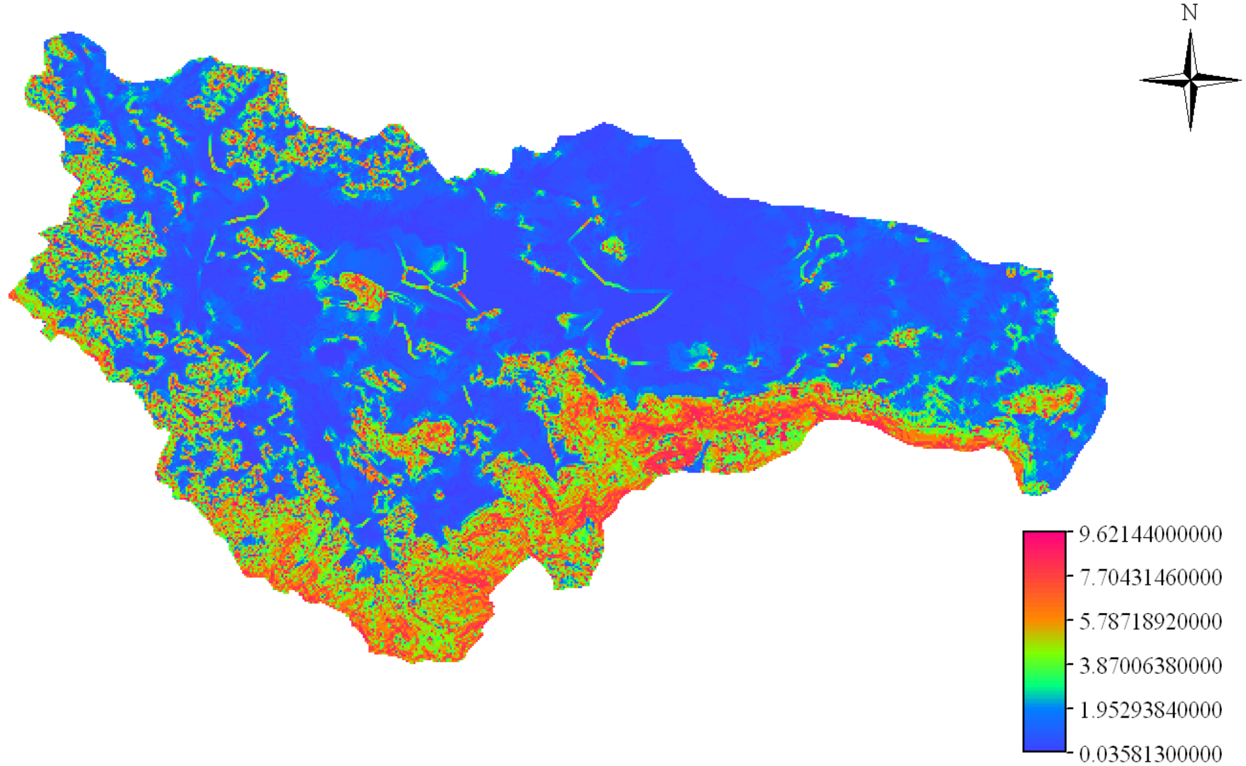

Fig.4.7 **GAYATHRI WATERSHED - Topographic Factor (LS) Map**

Scale; 1:300000

4.3.5 Crop Factor (C) Map

Crop factor (C) map is generated as an attribute map and is shown in Fig.4.8. The crop factor values of the watershed vary from 0 to 0.55 with an average value of 0.34 In the watershed 59.07% of the total area is having a crop factor value of 0.4. Different crop factor values and the corresponding percentage areas are given in Table 4.3.

Table 4.3.Crop Factor(C) values and Percentage area

C Value	% Area
0	0.87
0.1	9.73
0.2	1.11
0.3	21.93
0.35	5.21
0.4	59.07
0.55	2.08

4.3.6 Conservation Practice Factor (P) Map

Conservation practice factor map is generated similar to the crop factor map and is shown in the Fig. 4.9. The maximum value of conservation practice factor in the Gayathri watershed is 1 and the minimum value is 0.3. The average value of conservation practice factor for the entire watershed is 0.46. Different conservation practice factor values and the corresponding percentage areas are given in the Table 4.4.

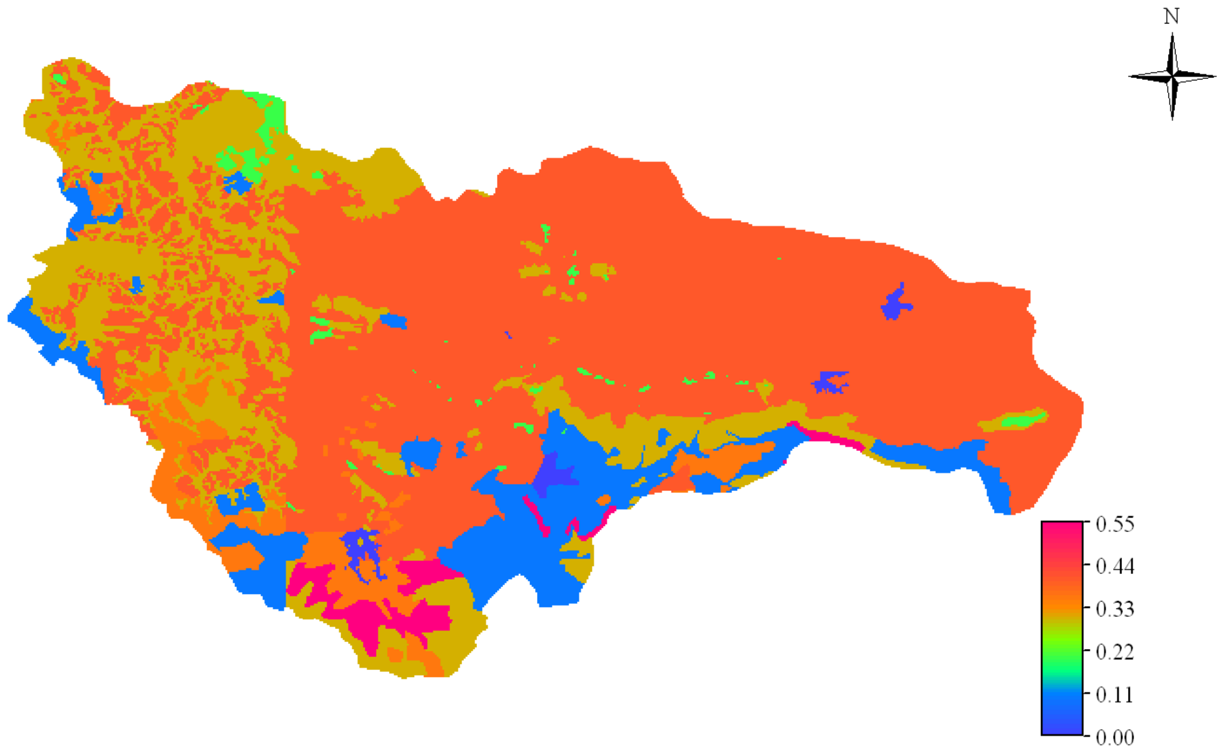

Fig.4.8 **GAYATHRI WATERSHED - Crop Factor (C) Map**

scale; 1:300000

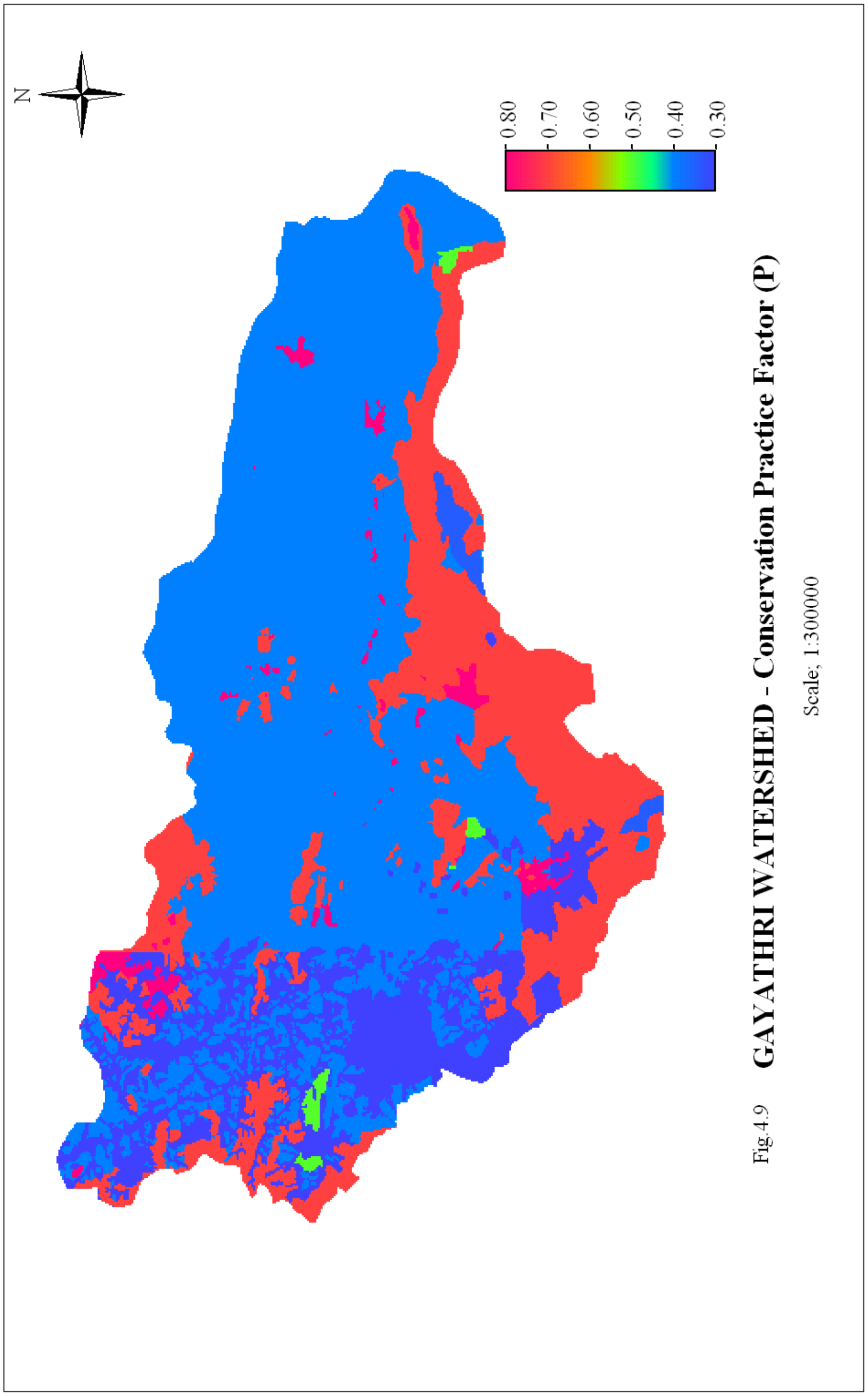

Fig.4.9 GAYATHRI WATERSHED - Conservation Practice Factor (P)

Table 4.4.Conservation Practice Factor (P) values and Percentage area

P Value	% Area
0.3	15.49
0.35	0.91
0.4	58.51
0.5	0.54
0.7	22.56
0.8	1.11
1	0.87

4.3.7. Soil Loss Map

The Universal soil loss has been computed by multiplying the maps of erosivity, erodibility, topographic factor, crop factor and conservation practice factor, having a pixel resolution of 100*100m. The erosion status of the land area of the watershed is estimated for every 100 m of square grid. The classified erosion map is presented in Fig. 4.10. According to the erosion intensity, the entire Gayathri watershed is classified into six erosion classes and the percentage area under each class is shown in Table 4.2

Table 4.5 Soil lose classes and percentage area

Soil Loss Classes	Range (t/ha/year)	% Area
Very Low	0 - 2.5	6.34
Low	2.5 - 5	9.99
Medium	5 - 10	18.16
High	10 - 40	34.48
Very High	40 - 100	18.99
Extremely High	100 - 2000	12.04

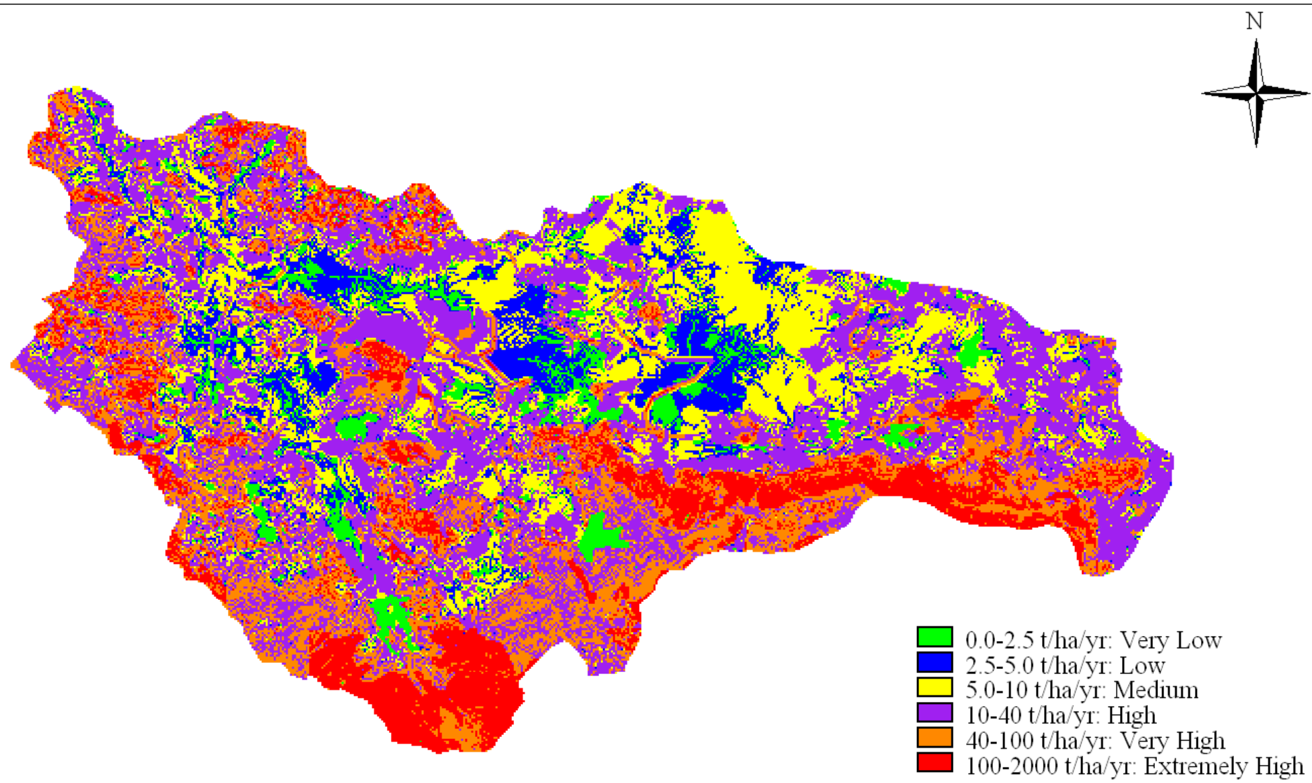

Fig.4.10 **GAYATHRI WATERSHED - USLE Map**

Scale; 1:300000

The erosion status of the entire study area in general ranges from 0 to 100 tons/ha/yr. It was found that soil loss is medium or low in the low land areas of Gayathri Watershed. While in the hilly areas, erosion is found to be varying from high to extremely high. Majority of the area 65.51% of Gayathri Watershed comes in the intolerable rate of erosion. Undulating and rolling topography, low soil depth and high intensity rainfall are the major causes of soil erosion of the study area. In the hilly regions as the land slope is more the velocity of runoff is also high. As a result, runoff has a high erosive power and lead to high soil loss in those areas. So, there should be immediate action plans to bring down the soil loss to acceptable and sustainable limits.

The priority areas from the standpoint of soil erosion have to be earmarked and detailed land and water management measures has to be formulated. Rainfall parameters, slope, soil type and depth, vegetation cover, social preferences etc have to be taken care of while formulating the conservation measures. Separate conservation measures must be taken up for different slope classes to make the interventions effective. Extreme care has to be given to the protection of steep sloping land parcels from the point of view of resources management and calamity mitigation.

SUMMARY AND CONCLUSION

5. SUMMARY AND CONCLUSIONS

A hydrologic study has been conducted in Gayathri sub-basins of Bharathapuzha river basins of Kerala state in India. The geological location of the watershed is from 10^0 25’53’’N, 76^0 20’59’’E to 10^0 44’55’’ N, 76^0 55’00’’E and the total area is $1042km^2$. The main objectives of the study were characterisation of the watershed, determination of the surface runoff and the soil loss to provide key inputs for the decision making in watershed management strategies.

The elevation of the watershed varies from 40m to 1500m and the land slope ranges from 0% to 616.4% as revealed by the digital elevation model. The soil map of the area shows that, 91% of the geography is occupied by loamy soil followed by clayey soil (9%). Main vegetation grown in the watershed are garden land (57%) followed by forests and shrubs (21%), paddy field (12%) and rubber (6%). Most part of the high sloping areas are either barren or under forest and shrubs.

The surface runoff computed from SCS Curve number shows that 38% of annual rainfall flows out as surface runoff. Monthly distribution of surface runoff indicates that maximum per cent of runoff is generated during the months of June and July and next to it. It indicates that most part of rainfall run out due to high AMC status of the soil resulting from continuous rainfall. Runoff potential of summer months is very low (0. to 15%) of rainfall received.

Erosion estimated from USLE shows that 31.03% of area comes under very high erosion (40-100t/ha/yr), 34.48% under high erosion (10-40t/ha/yr), 18.16% under medium erosion (5-10t/ha/yr), 9.9% under low erosion (2.5-5t/ha/yr), and 6.39% area under very low erosion (0-2.5t/ha/yr). Information on conservation practices was not available for the entire study area and some educated guess has been made to compensate the missing information.

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APPENDICES

Date	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	0	0	0	0	0	4.5	42.8	47	0	0	31.0	0.0
2	0	0	0	0	0	0	46.2	36.4	0	0	0.5	0.0
3	0	0	0	32	0	0	23	9	23.2	0	18.2	0.0
4	0	0	0	1	0	2	64.1	5	42.1	0	0.0	17.0
5	0	0	0	0	0	38.8	33.3	6.2	7.2	13	2.6	0.0
6	0	0	0	37.6	0	0	5	0	45.6	0.6	17.2	0.0
7	0	0	0	1	0	5.3	1	0	87.6	0	58.0	0.0
8	0	0	0	1	0	10.2	107	10.2	26.4	0	0.0	0.0
9	0	0	0	0	0	28.3	66	5.2	16.2	22	0.0	0.0
10	0	0	0	0	3.1	8.2	16.1	7	138.2	49.2	1.0	0.0
11	0	0	0	0	0.3	0.3	5.8	2	40	2.9	0.0	0.0
12	0	0	0	0.4	0.3	29	3	0	6	50.25	0.0	0.3
13	0	0	0	0	0.2	4	2.8	32	7.4	3.75	9.5	0.0
14	0	0	0	0	0	0	3	19.8	12	8.1	0.0	0.0
15	0	0	0	32	0	31	0	55	0	1.2	0.0	0.0
16	0	0	0	0	0	107.1	13.1	22.8	0	0	0.0	0.0
17	0	0	0	0	0	45	28.8	0.8	0	0	0.0	0.0
18	0	0	0	0	0	44.8	10.5	11.8	25.4	0	0.0	0.0
19	0	0	0	0	0	56	9.2	0	9.4	1.7	0.0	0.0
20	0	0	0	7.3	0	50.8	9.8	0	33.9	4.4	0.0	0.0
21	0	0	0	3.4	0	29	1.6	0	0.8	0	0.0	0.0
22	0	0	0	0	0.3	17	10	0	0	18.9	0.0	0.0
23	0	0	0	4.1	3.2	0.2	6.7	0	0	9	0.0	0.0
24	0	0	0	0	0	8	22.8	2.4	0	1.4	0.0	0.0
25	0	0	0	0	0	29	3.6	0	0	3.1	0.0	0.0
26	0	0	0	1.3	54.3	2.9	10.8	0	0	0.6	0.0	0.0
27	0	0	0	0	3.1	6.8	17.8	0	0	0	0.0	0.0
28	0	0	0	0	0.2	22	41	0	0	10.2	0.0	0.0
29	1		0	0	51	7.2	27	0	0	5.6	0.0	0.0
30	2.4		0	0	2.9	61.1	70	0	0	0	0.0	0.0
31	1.2		0		32		24.1	13.8		4		0.0

Appendix 1
Rainfall data 2005

Appendix 2.
Rainfall data 2006

Date	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	0.0	0.0	0.0	0.0	0.0	118.2	17.6	14	0	8.8	1.6	0
2	0.0	0.0	0.0	0.0	0.0	10.2	12	4.8	0	8.4	7	0
3	0.0	0.0	0.0	0.0	0.0	1.2	26.8	32	0	2.25	6.4	0
4	0.0	0.0	0.0	0.0	0.0	9.6	6.8	15	0	0	8	0
5	0.0	0.0	0.0	0.0	15.4	33	9.4	19.2	0	5	55.2	0
6	0.0	0.0	0.0	0.0	0.0	16	9.8	0.4	0	1.6		0
7	0.0	0.0	0.0	0.0	0.0	4.4	13.2	0	0	10	27.2	0
8	0.0	0.0	0.0	0.0	14.6	2.1	46.2	11.6	0	35	1.8	0
9	0.0	0.0	0.0	0.0	0.0	1.3	6.2	11	3.2	1.2	0	0
10	0.0	0.0	18.0	0.0	0.0	0	8.2	29.6	6.4	2.9	0	0
11	0.0	0.0	0.0	0.0	0.0	0	67	55.4	25	0	0	0
12	0.0	0.0	0.0	0.0	0.0	0	32.2	54.2	6	0	0	0
13	0.0	0.0	0.0	0.0	0.0	0	26.8	40.2	79	0	0	0
14	0.0	0.0	0.0	0.0	0.0	2.6	34.8	52.2	52.4	2	0	0
15	0.0	0.0	0.0	0.0	0.0	1.6	6	20	18.2	28.2	0	0
16	0.0	0.0	0.0	0.0	0.0	3.6	5	34	32	6	0	0
17	0.0	0.0	0.0	20.0	22.2	0	7.8	33.4	30	5	0	0
18	0.0	0.0	0.0	0.0	0.4	0	16	14.4	50	12.6	0	0
19	0.0	0.0	0.0	0.0	16.8	0	16.2	50.8	33	2	43	0
20	0.0	0.0	0.0	0.0	0	2	2.8	0	10.6	1	0	0
21	0.0	0.0	0.0	0.0	0	115.8	13.2	0	8.6	20	0	0
22	0.0	0.0	0.0	0.0	2.9	5.4	10	0	0	16.6	11.6	0
23	0.0	0.0	0.0	0.0	0	96.4	6.8	0	28.6	0	0	0
24	0.0	0.0	0.0	0.0	60	139.6	1.6	0	3.6	0	0	0
25	0.0	0.0	0.0	0.0	20	106.6	0	0	0	0	0	0
26	0.0	0.0	0.0	0.0	28	22	0	0	92	0	0	0
27	0.0	0.0	0.0	0.0	53.8	11.8	22	0	43	0	0	0
28	0.0	0.0	0.0	0.0	122.8	10.6	0	0	0	0	0	0
29	0.0		0.0	0.0	94.2	30	43.8	8.2	0	74	0	0
30	0.0		0.0	0.0	81	58.2	0.4	10.4	2	0.4	0	0
31	0.0		0.0		47		13		11.2	0		0

ASSESSMENT OF RUNOFF AND EROSION USING GIS

By

ARUN JOSE

RENJITH THOMAS

ABSTRACT OF THE PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree

Bachelor of Technology
in
Agricultural Engineering

Faculty of Agricultural Engineering and Technology
Kerala Agricultural University

Department of
Land and Water Resources and Conservation Engineering

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
TAVANUR- 679 573, MALAPPURAM
KERALA, INDIA
2007

ABSTRACT

A study has been carried out on the Gayathri sub basin of Barathapuzha river basin, one of the major rivers of Kerala, with focus on runoff and erosion generating process of the watershed. The geographical area of the watershed is 1042 km^2 and GIS techniques are made use of to incorporate special variability more thoroughly and effectively. Specific objectives of the study included characterisation of watershed from the stand point of runoff and erosions process and the quantification of these physical processes.

The digital elevation modal of the Gayathri watershed shows that about 85 % of the geographical area lies in the slope range of 0to 25 %. Major textural classes of the soil are loamy and clayey. Vegetation comprises mixed crops in garden land, paddy, rubber and forest. Surface runoff has been computed by SCS curve number method and the result indicate that 38 % of annual rainfall flows out as surface runoff. Gross erosion predicted by USLE indicate that 31 % of the total area is subjected to severe erosions of the order of 40-100 t/ha/yr and 34.5 % of the area experiences an erosions rate of 10-40 t/ha/yr. High surface runoff potential of the watershed throws light on the need of the augmentation of water harvesting measures. In areas with high rate of erosion, an appropriate erosions control practice has to be adopted to book the erosion under sustainable limits.