ESTIMATION OF RUNOFF AND SEDIMENT YIELD USING REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEM FOR MPKV CENTRAL CAMPUS (EAST) WATERSHEDS

by

Thombare Pradnya Dattatraya
(Reg. No. 2016/03)

DEPARTMENT OF SOIL AND WATER CONSERVATION ENGINEERING,
DR. ANNASAHEB SHINDE COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI, 413 722 DIST. AHMEDNAGAR,
MAHARASHTRA STATE (INDIA)

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In partial fulfillment of the requirements for the degree

of

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in

SOIL AND WATER CONSERVATION ENGINEERING

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APPROVED BY

Dr. R. D. Bansod
(Chairman and Research Guide)

Dr. V.N. Barai
(Committee Member)

Dr. B.K. Gavit
(Committee Member)

Dr. A. G. Durgude
(Committee Member)

DEPARTMENT OF SOIL AND WATER CONSERVATIONENGINEERING
DR ANNASAHEB SHINDE COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
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2018

Dedication

Affectionately Dedicated to

Farmers,

Beloved Parents,

Teachers and well wishers

…… Miss Pradnya Dattatraya Thombare

CANDIDATE'S DECLARATION

I hereby declare that this thesis or any part
there of has not been submitted
by me or any other person to any
other University or Institute
for a Degree or
Diploma.

Place: MPKV, Rahuri **(Pradnya Dattatraya Thombare)**

Dated: / / 2018

Dr. R. D. Bansod

Research Guide and Head,
Department of Soil and Water Conservation Engineering,
Faculty of Agricultural Engineering
Mahatma PhuleKrishiVidyapeeth ,
Rahuri-413 722, Dist. Ahmednagar ,
Maharashtra (India)

CERTIFICATE

This is to certify that the thesis entitled **"ESTIMATION OF RUNOFF AND SEDIMENT YIELD USING REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEM FOR MPKV CENTRAL CAMPUS (EAST) WATERSHEDS"**, submitted to the Faculty of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, (M.S.) in the partial fulfillment of the requirement for the award of the degree of **MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING)** in **SOIL AND WATER CONSERVATION ENGINEERING,** embodies the results of bonafide research work carried out by **PRADNYA DATTATRAYA THOMBARE** under my guidance and supervision. The results embodied in this thesis have not been submitted to any other university or institute for award of degree or diploma.

The assistance and help received during the course of this investigation has been duly acknowledged.

Place: MPKV, Rahuri

Date: / /2018 **(Dr.R.D.Bansod)**

Dr. R. D. Bansod
Professor and Head,
Department of Soil and Water Conservation Engineering,
Faculty of Agricultural Engineering
Mahatma Phule KrishiVidyapeeth ,
Rahuri-413 722, Dist. Ahmednagar ,
Maharashtra (India)

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Place: MPKV, Rahuri

Date: / / 2018 **(Dr.R.D.Bansod)**

Dr. D. D. Pawar
Associate Dean,
Faculty of Agricultural Engineering,
Mahatma Phule Krishi Vidyapeeth, Rahuri - 413 722
Dist. Ahmednagar, Maharashtra State (India)

CERTIFICATE

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Place: M.P.K.V., Rahuri

Date: / /2018 **(Dr. D. D. Pawar)**

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Place: MPKV, Rahuri

Date: /   /2018 **(Thombare Pradnya Dattatraya)**

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Abbreviations		Description
A	:	Average annual soil loss
Agri.	:	Agriculture
Agril.	:	Agricultural
AMC	:	Antecedent moisture content
ASTER	:	Advanced Space Borne Thermal Emission and Reflection Radiometer
Avg.	:	Average
B.Tech	:	Bachelor of Technology
C	:	Cover management factor
CN	:	Curve number
DEM	:	Digital Elevation Model
Dept.	:	Department
e.g.	:	For example
Engg.	:	Engineering
ERDAS	:	Earth Resources Data Analysis System
ESRI	:	Environmental Systems Research Institute
et.al.	:	Others
Fig.	:	Figure
g	:	Gram
ha	:	Hectare
HSG	:	Hydrologic Soil Group
Hydrol.	:	Hydrology
i.e.	:	That is

Ia	:	Initial abstraction
ILWIS	:	Integrated Land and Water Information System
IMD	:	Indian Meteorological Department
IRSP6	:	Indian Resource Satellite
J.	:	Journal
K	:	Soil erodibility factor
km^2	:	Square kilometre
LS	:	Slope length and steepness factor
LU/LC	:	Land Use/Land Cover
M.S.	:	Maharashtra State
$m^2\ m^{-1}$	:	Square metre per metre
$m^3\ yr^{-1}$	:	Cubic metre per year
MJ mm $ha^{-1}yr^{-1}$	:	Mega Joule millimeter per hectare per year
mm	:	millimeter
MPKV	:	Mahatma Phule Krishi Vidyapeeth
MUSLE	:	Modified Uviversal Soil Loss Equation
No.	:	Number
NRCS	:	Natural Resources Conservation Services
NRSC	:	National Remote Sensing Centre
OLI	:	Operational Land Imager
P	:	Support practice factor
R	:	Rainfall erosivity factor
Res.	:	Research
RS	:	Remote sensing
RUSLE	:	Revised Universal Soil Loss Equation

Sci.	:	Science
SCS	:	Soil Conservation Services
SOI	:	Survey of India
Syst.	:	System
t ha^{-1} $year^{-1}$	:	Tonnes per hectare per year
USDA	:	United States Department of Agriculture
USLE	:	Universal Soil Loss Equation
UTM	:	Universal Transverse Mercator
Viz.	:	Namely
Vol.	:	Volume
Wt.	:	Weight

LIST OF SYMBOLS

Symbols		**Description**
^0C	:	Degree Celsius
ha	:	Hectare
Min	:	Minimum
Max	:	Maximum
%	:	Percent

ABSTRACT

ESTIMATION OF RUNOFF AND SEDIMENT YIELD USING REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEM FOR MPKV CENTRAL CAMPUS (EAST) WATERSHEDS

By

Thombare Pradnya Dattatraya

Department of Soil and Water Conservation Engineering,

Dr. Annasaheb Shinde College of Agriculture Engineering and Technology,

Mahatama Phule Krishi Vidyapith, Rahuri.

Dist.- Ahmednagar , Maharashtra,

2018

Research Guide	:	**Dr.R.D. Bansod**
Department	:	**Soil and Water Conservation Engineering**

The watershed based approach for planning of conservation measure to conserve water and soil resources is considered to be effective since excess rainfall or runoff from the watershed is drained to a common outlet. Inventory on sediment yield and prediction of soil erosion hazards are playing vital role for effective soil conservation planning of a watershed for sustainable development. Soil conservation is now a necessity in almost every country of the world under virtually every type of land use.

Remote sensing data and GIS techniques have been used to compute runoff and sediment yield from the MPKV, central campus (east) watersheds occupying an area of 3909.3 ha. The runoff volume of the watershed was calculated by SCS Curve Number method and sediment yield is calculated by Revised Universal Soil Loss Equation using remote sensing and GIS techniques.

Information obtained using remote sensing techniques can help decision makers to prepare resource map accurately in less time and cost. GIS, on other hand, helps in linking those maps with other information related to geographic location and helps modelling, analysing and solving complex problems. While determining the results the data sets such as LANDSAT 8 (30 m resolution) satellite image, 1:50,000 standard topographic map, ASTER DEM (30 m resolution), soil map on 1:50,000 scale, Administrative Boundary maps, Slope map, Land Use Land Cover map and meteorological data based rainfall maps were the main inputs for this study.

In Arc GIS 10.2.2 software, LANDSAT 8 image was classified by using digital image techniques for extracting Land Use and Land Cover and integrated with hydrological soil map. Soil Conservation Curve Number method was used to determine Curve Numbers and runoff volume distribution of the basin area. Weighted Curve Number was determined for the study area from LULC map and Hydrological soil group map in Arc GIS 10.2.2 software. Slope adjusted CN values are calculated for both the watersheds from ASTER DEM (30 m resolution)

data. Annual spatial sediment yield estimation was computed using the Revised Universal Soil Loss Equation model (Renard *et al.*, 1997) in conjunction with remote sensing data and GIS techniques.

The results of the present study show that the average rainfall for the year 2017 in the MPKV, central campus (east) watersheds was 638.8 mm whereas for WS_1 average annual runoff was 169.52 mm, amounting 26.57 per cent of the total rainfall received and for WS_2 average runoff depth was 180.25 mm which is 28.21 per cent of total rainfall received. Also, the result of the analysis pertaining to soil erosion revealed that the average annual soil loss of the MPKV, central campus (east) watershed WS_1 was ranged between 0 to 1.3 t ha^{-1} $year^{-1}$ and 0 to 21.72 t ha^{-1} $year^{-1}$, for WS_2. The Sediment delivery ratio for the WS_1 was 0.238 and 0.212 for WS_2. Sediment yield for WS_1 watershed ranged between 0 to 0.273t ha^{-1} $year^{-1}$ and 0 to 4.6 t ha^{-1} $year^{-1}$ for WS_2 watershed. It indicates that the area under these watersheds is under very slight erosion risk class. This approach could be applied easily for other watersheds for efficient and effective planning and implementation for various conservation measures.

1. INTRODUCTION

Land and water are the two most important natural resources. These two resources interact with each other in various phases of their respective cycles. The future of a country largely depends on the effective development, utilization and management of these resources in an integrated and comprehensive manner.

Agricultural systems in India need improved management strategies to increase their level of self-sufficiency in terms of food production. Increased occurrence of extreme hydro-meteorological events due to climate change, population growth and anthropogenic land and water degradation is likely to affect agricultural systems in near future more severely. An increase in food production can only come from sources such as harvesting local rain and horizontal expansion of agriculture. (Rockstrom and Barron, 2007).

In India the main source of water is precipitation and the effective precipitation is the most important for agriculture. Effective precipitation is directly results into runoff. Runoff, the draining or flowing of precipitation from a catchment area through a channel after satisfying all surface and subsurface needs. Rainstorms generate runoff and its occurrence and quantity are dependent on the characteristics of the rainfall event i.e. the intensity, duration and distribution. Apart from these rainfall characteristics, there are number of catchment's specific factors, which have a direct effect on the occurrence and volume of runoff. These include soil type, slope, vegetation cover and catchment type. Knowledge of runoff which depends upon many factors like precipitation, recharge of the basin, type of soil is one such important parameter. In India, the availability of accurate information on runoff is scarcely available and very few selected watersheds have recording and automatic hydrological gauging station, also most of agricultural watershed having no past records of rainfall-runoff processes. Non-availability of continuous rainfall and runoff records in majority of Indian watersheds has led to the development of techniques for estimation of surface runoff from ungauged basins (Chattopadhyay and Choudhury 2006). There is need to generate information on basin runoff and silt yield for the acceleration of the watershed development and management programmes (Zade *et al*. 2005).

The conventional SCS-curve number method is widely used to estimate the direct runoff volume. The curve number method was developed by the USDA, *Soil Conservation Service* or *SCS* which is recently known as Natural Resources Conservation Service. The runoff curve number was developed from an empirical analysis of runoff from small catchments and hill slope plots monitored by the USDA. It is widely used and is an efficient method for determining the approximate amount of direct runoff from a rainfall event in a particular area. Due to its simplicity it becomes the most popular method for small watersheds (Mishra and Singh, 2002). Ponce and Hawkins (1996) explained its concept with its capabilities, drawbacks and uses after critical examination of its conceptual and empirical basis and provided area of research in future. Pradhan *et al*. (2010) used SCS model with using land use/land cover, soil map and rainfall value for estimating runoff. Murmu and Biswas (2012) estimated runoff of a catchment using SCS- CN method in Damodar sub catchment. Nohegar *et al.* (2013) found the weighted curve number of a watershed using the RS and GIS techniques. Dhawale (2013) carried out a case study for highlighting the role of GIS and RS in SCS- curve number method for estimation of direct surface runoff from the Darewadi watershed.

SCS-CN method provides an empirical relationship for estimating initial abstraction (I_a) and runoff as a function of soil type and land use. Rainfall-runoff relationship can be visualized by the factors such as initial abstraction (I_a), direct runoff (Q) and actual retention (F). The Curve Number (CN) is an index developed by the Natural Resources Conservation Service (NRCS) to represent the potential for storm water runoff within drainage area. The CN for a drainage basin is estimated using a combination of land use, soil and antecedent moisture condition (AMC). There are four hydrologic soil groups (A, B, C and D) and Group A have high infiltration rates while group D have low infiltration rates.

Watershed is an important element to consider in ecology. As water flows over the ground and along rivers, it can pick up nutrients, sediment and pollutants. Like the water, they get transported towards the outlet of the basin and can affect the ecological processes along the way as well as in the receiving water source. In hydrology, the watershed is a logical unit of focus for studying the movement of water within the hydrological cycle, because the majority of water that discharges from the basin outlet originated as precipitation falling on the basin.

Soil erosion and sedimentation by water involves the processes of detachment, transportation, and deposition of sediment by raindrop impact and flowing water. The sediment delivery ratio is defined as the ratio of the sediment yield at a given stream cross section to the gross erosion from the watershed upstream from the measuring point. Soil loss is defined as the amount of soil lost in a specified time period over an area of land which has experienced net soil loss. Sediment is a naturally occurring material, broken down by processes of weathering and erosion and transported subsequently by the action of wind, water, ice and by the force of gravity acting on the particle itself. These transported soil particles gets deposited at downstream side of river, watershed and any other watershed structure. Sediment yield depends on erosion, sediment delivery, local topography, soil properties, climate, vegetation cover, catchment morphology, drainage network characteristics and land use.

Since part of the sediment eroded from an area can deposit in the lower reaches, the rate of erosion is usually greater than the rate at which sediment is carried downstream at any section; the latter is known as the sediment yield. It may be mentioned that since landscape formation and changes in it are due to differential erosion and deposition of sediment, erosion, sediment yield and landscape formation are closely interrelated, therefore study of soil erosion and sediment yield assumes great importance in river morphology (Garde *et al.*1987).

Conventional methods of data collection are uneconomical and require more time to provide information. Remote sensing and GIS technique have capability of providing information about the environment parameters more accurately, which is helpful for decision makers with the kinds of information that can't be effectively provided by conventional methods.

Simple methods such as the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1965) and Modified Universal Soil Loss Equation (MUSLE) or the Revised Universal Soil Loss Equation (RUSLE) (Renard *et al*, 1991) are frequently used for the estimation of surface erosion and sediment yield from catchment areas. Both of these quantities are found to have large variability due to the spatial variation of rainfall and catchment heterogeneity. The use of GIS based methodology is well suited for the quantification of heterogeneity in the topographic and drainage features of a catchment.

The Universal Soil Loss Equation (USLE) model was suggested first based on the concept of the separation and transport of particles from rainfall in order to calculate the amount of soil erosion in agricultural areas. Universal soil loss equation (USLE) is the standard soil loss prediction model. RUSLE model is a set of mathematical equations that estimates average annual soil loss. This is a technology for estimating soil loss from most undisturbed lands experiencing overland flow, from lands undergoing disturbance and from newly or established reclaimed lands. Strength of RUSLE is that it was developed by a group of nationally recognized scientists and soil conservationists experienced with erosion processes. The soil loss computed by RUSLE is the amount of sediment lost from a landscape profile described by the user.

Remote Sensing as a direct adjunct to field, recently playing an important role in the study and assess the natural resource in any part of the world. Anthropogenic changes in land use and land cover are often assumed to be identical, they are rather quite different. Land cover may be defined as the biophysical earth surface, while land use is often shaped by human, socio-economic and political influences on the land. Remote Sensing (RS) integrated with Geographic Information System (GIS) provides an effective tool for analysis of land use and land cover changes at a regional level. The geospatial technology of RS and GIS holds the potential for timely and cost – effective assessment of natural resources. The techniques have been used extensively in the tropics for generating valuable information on forest cover, vegetation type and land use changes.

Remote sensing and Geographic Information System (GIS) techniques are increasingly used for planning, development and management of natural resources at regional, national and international level. It is becoming a significant tool in hydrological modeling in view of its capacity to handle large amount of spatial and attribute data. In recent days, an aggregated study of runoff modeling, remote sensing and GIS has gained significance in targeting suitable sites for Simple methods such as the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1965; Wischmeier and Smith, 1978), the Modified Universal Soil Loss Equation (MUSLE) (Williams, 1975), or the Revised Universal Soil Loss Equation (RUSLE) (Renard *et al*, 1991) are frequently used for the estimation of surface erosion from catchment areas (Ferro and Minacapilli 1995; Ferro 1997; Kothyari and Jain, 1997; Ferro *et al,* 1998). Both of these quantities are found to have large variability due to the spatial variation of rainfall and catchment heterogeneity.

With this view in mind, the project titled, "Estimation of Runoff and Sediment yield using Remote Sensing and Geographical Information System for MPKV Central Campus East Watersheds" with the following objectives had been undertaken,

1. To estimate runoff from MPKV central campus (east) watersheds using SCS-CN method in GIS environment.
2. To estimate sediment yield from MPKV central campus (east) watersheds using RS and GIS technique.

2. REVIEW OF LITERATURE

Some of the selected reviews are considered with following points

1. Estimation of runoff using SCS-CN method in GIS environment.
2. Estimation of sediment yield using RS and GIS technique.

2.1 Estimation of Runoff Using SCS-CN Method in GIS Environment.

Yu (1998) gave theoretical justification of SCS for runoff estimation. The SCS-CN method is widely used to estimate runoff from small to medium sized watersheds. The most critical assumption of SCS-CN method is that ratio of the actual retention to the potential is the same as the actual runoff to the potential runoff, but this assumption has not been theoretically or empirically justified. They reported that the exact relationship between rainfall and runoff in the SCS method can be derived theoretical if two simple but realistic assumptions are made. A theoretical basis for the SCS method allows an independent validation of the method by testing how rainfall intensity and infiltration capacity actually vary in time and space respectively.

Sharma and Kumar (2002) applied the SCS model with GIS database for estimation of runoff in an arid watershed about 509 ha is a part of upper Jojri basin in Nagapur district of Rajasthan. LULC map was prepared by interpretation of satellite data (IRS-1C) and topographical maps were obtained from Survey of India. All information was converted into raster format at a scale 1:50,000 and used as input to derive the modified SCS-CN. The SCS model was then applied to estimate the runoff for daily storm and was validated by comparing it with the five measured runoff events of mansoon period during the year 2000.

Nayak and Jaiswal (2003) studied Rainfall-Runoff Modeling using Satellite Data and GIS for Bebas River in Madhya Pradesh. Use of Remote Sensing technology combined with Geographical Information System (GIS). The remote sensing data provide spatial information on land cover, soils as input to SCS model. ILWIS 2.2 GIS has been used to store, manipulate and estimate sub-basin wise weighted average rainfall and runoff curve numbers. These curve numbers were finally used as input to the SCS model for runoff estimation. In general good correlation was found between the measured and estimated runoff volume. The seasonal correlation coefficient varied between 0.92 to 0.94.

Kulkarni *et al*. (2004) proposed Modified SCS Model for estimating runoff for Warasgoan Catchment which is located in the Pune district, M.S. Catchment area was divided into fifteen sub-watersheds and the runoff of each sub – watershed was estimated. Runoff varied from 320.93 to 3914.76 mm from East to West of the study area.

Pandey *et al*. (2006) studied the methodology for determination of Runoff for Karso watershed using GIS and SCS model and the calculated runoff was found out to be 244.40 mm for monsoon season of the year 1993 which was 35.52 per cent of the total rainfall.

Mishra *et al*. (2007) used rain duration and modified AMC- dependent SCS-CN procedure for long duration rainfall- runoff events. They presented rain duration- dependent procedure based on the popular SCS- CN methodology for computation of direct surface runoff from long duration rains. The CN were derived from long term daily rainfall- runoff data. The proposed procedure was tested on the separate (measured) rainfall- runoff event data sets from the same watersheds, which suggested satisfactory workability of the method.

Dabral *et al.* (2008) studied soil erosion assessment of Dikrong river basin of Arunachal Pradesh (India). A quantitative assessment of average annual soil loss on grid basis was made using the well-known USLE with a view to know the spatial distribution in the study watershed. The use of GIS and remote sensing data enabled the determination of the spatial distribution of the USLE parameters. The average annual soil erosion for Dikrong river basin was found to be 51 t ha^{-1} $year^{-1}$.

Gupta and Panigrahy (2008) studied SCS model and overland flow models for runoff modeling over major land mass of India. It was observed that there was a great difference between the runoff generation (SCS model) and its actual accumulation (overland flow model) in the field because of flow of runoff water to the down gradient.

Amutha and Porchelvan (2009) studied Surface Runoff in Malattar Sub-watershed using SCS-CN Method. The SCS– CN method integrated with GIS can be used in watershed management effectively. The results of the study showed that from the monthly runoff values and the seasonal runoff in the watershed could be studied for reliable accuracy along with the spatial variation of soil type and land use type.

Ramakrishnan *et al.* (2009) studied SCS-CN and GIS-based approach for identifying potential water harvesting sites in the Kali watershed, Mahi river basin, India. In this study augmentation of water resource is proposed by construction of runoff harvesting structures like check dam, percolation pond, farm pond, well and subsurface dyke. The site suitability for different water harvesting structures is determined by considering spatially varying parameters like runoff potential, slope, fracture pattern and micro-watershed area. GIS was utilised as a tool to store, analyse and integrate spatial and attribute information pertaining to runoff, slope, drainage and fracture. The runoff derived by SCS-CN method is a function of runoff potential which can be expressed in terms of runoff coefficient (ratio between the runoff and rainfall) which can be classified into three classes, viz., high (>40 per cent), moderate (20–40 per cent) and low (<20 per cent).

Samah *et al.* (2009) studied watershed having geographical area of 1.87 km^2 and average annual rainfall was around 500 mm. The study showed that the average annual runoff depth for the study area (WadiSu'd watershed) was 36.3 mm, and the average volume of runoff from the same watershed was 67840.2 m^3year^{-1}. The amount of runoff represents 7.3% of the total annual rainfall. The methodology for determination of runoff for WadiSu'd using GIS and SCS method was described. This approach could be applied in other Palestinian watershed for planning of various conservation measures.

Shahid and Almasri (2010) studied application of GIS-based SCS-CN method in West bank catchments, Palestine. A GIS-based SCS-CN approach was developed in this study to calculate the composite curve number of West Bank catchments. The insufficiency of rainfall runoff records has limited the verification of the validity of the proposed approach to generally arid and semi-arid catchments. However, four rainfall events were simulated in the Al-Badan sub-catchment of the Al-Faria catchment using the generated curve number map. Estimated and observed runoff depths of the four events were close enough to assume the applicability of the GIS-based SCS-CN approach for the region.

Sunder Kumar *et al.* (2010) studied SCS-CN method for predicting direct runoff volume for a given rainfall event. There was strong correlation between the CN values obtained from measured runoff and rainfall depth. The results indicated that combination of remote sensing and SCS model makes the runoff estimate more accurate and fast.

Geena and Ballukraya (2011) estimated runoff from Red hills watershed using SCS method and GIS. The watershed encompasses an area of 83.59 km^2 and is part of Korattaliyar river basin catchment, situated in Thiruvallur district of Tamil Nadu state in India. The results showed that a good correlation exists between rainfall and runoff and a minimum of about 66 mm rainfall per month is required to generate runoff in the area.

Kudoli (2015) carried out runoff estimation by using SCS-CN method for micro watershed located in Sangli region, Maharashtra and results were compared with empirical method. The land use, land cover and soil details were extracted from satellite images. The rainfall data of micro watershed was collected and analysed. From the runoff calculations, it was found that SCN Curve number method results are closure to strange table method, Khoslas method and Englis desouza method. Laceys method shows very low runoff and Irrigation department method shows very high runoff as compared to all other methods.

Mamata (2017) carried out study on Soil Conservation service and Curve Number model in study area of 453.5km², of which fall in Kuakhai river basin so considered for runoff model assessment in a watershed is a precondition for the design of artificial recharge structures, reservoir and soil erosion control. Soil Conservation Service and Curve Number model have been utilized in the present work by land use map and soil map described in Arc GIS, as input. The monthly rainfall runoff simulation found good in the watershed. The amount of runoff represents 1.8% of the total annual rainfall. The methodology for the tenacity of runoff utilizing GIS and SCS approach could be applied in other Mahanadi watershed for orchestrating of sundry conservation measures In SCS Curve number method Antecedent moisture condition of the soil plays a very consequential role because the CN number varies according to the soil and that is considered while estimating runoff depth. Kuakhai watershed CN number was calculated equals to 75.4 for AMC -I, 28.4 –AMC-II and 87.5 for AMC-III.

2.2 Estimation of Sediment Yield Using RS and GIS Technique.

Wischmeier and smith (1978) developed universal soil loss equation (USLE) method for plot scale loss estimation, including all the relevant terrain and climatic factors like topography, soil type, rainfall etc. The model was developed as A= R.K.L.S.C.P. where, A= average annual soil loss tons/ha, R= rainfall erosivity factor, K= soil erodibility factor, L= slope length, S= steepness factor, C= crop management factor and P= supporting conservation practice factor.

McCool *et al.* (1995) studied the Revised Universal Soil Loss Equation (RUSLE). In this study the Universal Soil Loss Equation has been revised to more accurately estimate soil loss from both crop and rangeland areas. All factors R, K, LS, C and P have received attention. R-values for the western United States were developed from hourly precipitation data. A time-variant K factor was included for the eastern United States. New length and steepness (LS) factor relationships were developed. C factors are now computed by a sub factor approach, and P factors were developed using the CREAMS model. The USLE has been revised to reflect new technology and analysis of data required since 1978 when Agriculture Handbook 537 was completed.

Atawoo and Heerasing (1997) studied estimation of soil erodibility and erosivity of rainfall patterns in Mauritius. Empirical studies on the erosivity (R) of 3 rainfall patterns in Mauritius were conducted to test two models for predicting R. The erodibility factor (K) of soils from five erosion-prone areas was calculated in parallel using the nomograph developed by Wischmeier *et.al.* (1971). Results in the first case showed that the model developed by Arnoldus (1977) gives a close approximation to calculated R. In the other case there were indications that the soils tested are relatively resistant to soil erosion.

Renard *et al*. (1997) derived an improved equation widely known as Revised Universal Soil Loss Equation (RUSLE). This equation was improved form of soil erosion equation widely known as Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith (1965, 1978) in United State Department of Agriculture (USDA) The revised equation was expressed as, $A = R\,K\,L\,S\,C\,P$, Where, R = average annual energy and intensity of rainstorms.

Huang *et al*. (1999) have carried out series of experiments to determine detachment and deposition processes in process based erosion models. It was observed from experimental results that at 5 percent slope under drainage conditions, deposition occurred at low rainfall intensities.

Jain *et al.* (2000) proposed a Geographical Information System (GIS) based method and demonstrated for the identification of sediment source areas and the prediction of storm sediment yield from catchments. The Integrated Land and Water Information System (ILWIS) GIS package has been used for carrying out geographic analyses. An Earth Resources Data Analysis System (ERDAS) Imagine image processor has been used for the digital analysis of satellite data for deriving the land cover and soil characteristics of the catchments. The catchments were discretized into hydrologically homogeneous grid cells to capture the catchment heterogeneity. The cells thus formed were then differentiated into cells of overland flow regions and cells of channel flow regions based on the magnitude of their flow accumulation areas. The gross soil erosion in each cell was calculated using the Universal Soil Loss Equation (USEE) by carefully determining its various parameters. The sediment delivery ratio of a cell in the overland flow region was hypothesized to be a function of the travel time of overland flow from the given cell to the nearest downstream channel cell. For channel cells, the sediment delivery ratio was assumed to be unity.

Sekhar and Rao (2002) calculated the sediment yield according to the Garde's equation, which was 882.389 $m^3km^{-1}year^{-1}$ and was more than the siltation value calculated for the Sriramsagar project designs and therefore the soil conservation measures were required for the watershed. The soil conservation measures recommended the conversion of wasteland of 301.485 km^2 into cropped land and the construction of check dams at study area. These measures could bring down the soil erosion rate to 401.571 $m^3km^{-1}year^{-1}$, which would be within the design value of the Sriramsagar project.

Rojas-González (2008) proposed that a number of parametric models have been developed to predict soil erosion at drainage basins, yet USLE (Wischmeier and Smith, 1978) is most widely empirical equation used to estimate annual soil loss from agricultural basins. This methodology can be applied to the island and small basins. The application of remote sensing images and GIS tools are useful to approximate the land cover and potential soil erosion of a basin.

Chowdary *et al.* (2009) demonstrated an approach for evaluating sediment yield potential by RS, GIS and MCDA technique considering Mayurakshi watershed. In this study, area and locale specific watershed development plans were generated for Mayurakshi watershed,water resource development plan was generated by using the overlay and decision tree concepts.Indian Remote Sensing Satellite (IRS-1C), Linear Imaging Self Scanner (LISS-III) satellite data along with other field and collateral data on lithology, soil, slope, well inventory, fracture have been utilized for generating land use/land cover and hydro geomorphology of the study area, which are an essential prerequisites for water resources planning and development. Spatial data integration and analyses are carried out in GIS environment.

Arekhi *et al.* (2010) investigated spatial distribution of annual soil loss and sediment yield using RUSLE model, remote sensing and GIS technologies were used for erosion and risk mapping. The result was found that RUSLE model with RS and GIS technologies has great potential for providing accurate and inexpensive erosion and sediment yield risk maps in Iran.

Karaburun (2010) studied C factor for soil erosion modeling using Normalized Difference Vegetation Index (NDVI) in Buyukcekmece watershed. A regression analysis was performed between NDVI and C factor. C factor values were assigned to pixels of NDVI image through regression equation. The C factor map of Buyukcekmece watershed was produced to use in soil erosion methods such as USLE and RUSLE based on an assumption that NDVI and C factor values are correlated with each other. The results revealed that large parts of areas were assigned to C factor classes that vary between 0.2 and 0.4.

Elangovan and Seetharaman (2011) studied Rainfall Erosivity using Revised Universal Soil Loss Equation from daily rainfall depth in Krishanagiri watershed region of Tamil Nadu, India. Rainfall depth for every 15 minutes from self recording rainguages was measured at four locations in the watershed and a simple model was established between rainfall erosivity and depth of rainfall. It is established that the relationship between the erosivity and rainfall depth can be expressed in a potential form. The regression model and the erosivity map here provided to represent a helpful mean for soil erosion assessment and mapping, both at watershed and at regional scale.

Kefi *et al. (*2011) studied assessment and mapping of soil erosion risk by water in Tunisia which is located in the North of the African continent bordering the Mediterranean Sea. The results indicated that Tunisia has a serious risk of soil erosion. Indeed, about 24.57 per cent of the study area had a soil loss rate more than 30 t ha^{-1} $year^{-1}$. This study focused only on the prediction of soil loss useful to identify areas with high risk of soil erosion by water but this phenomenon is not necessarily a dominant geomorphic process in Tunisia.

Saleh *et al. (*2011) studied a large ungaged catchment area (Hemren basin) of 10953.261 km^2. Practically the Hemren basin was divided into three sub-basins according to the tributary. The rainfall-runoff relationship were found for each sub-basin, also the results obtained showed the strong connection between the runoff and the varying topography and land cover for each sub-basin. The relationship (runoff-rainfall) was verified by using the field data which recorded by the Hemren dam project management, acceptable coincidence between observed and calculated runoff depth was found.

Shinde *et al*. (2011) studied quantitative determination of soil erosion and prioritization of micro-watersheds using Remote Sensing and GIS. This study focuses application of most widely used Universal Soil Loss Equation (USLE) to determine soil erosion and prioritization of micro-watersheds of Upper Damodar Valley catchment (UDVC) of India. The result shows that, annual average soil loss for the entire basin is 23.17 t ha^{-1} $year^{-1}$ for micro-watersheds. The main advantage of the GIS methodology is in providing quick information on the estimated value of soil loss for any part of the investigated area.

Yue-Qing *et al.* (2011) studied the RUSLE and GIS to model soil erosion risk in a mountains Karst watershed, Guizhou Province, China. The RUSLE model and GIS and RS techniques were very effective in this study to assess soil loss and erosion risk. The method and results described in this study are valuable for understanding the relationship between soil erosion risk and environmental factors and are useful for managing and planning land use that will avoid soil erosion.

Kamaludin *et al.* (2013) estimated potential soil losses and sediment yield by utilizing information on 10 rainfall erosivity (R) using interpolation of rainfall data, soil erodibility (K) using field measurement and soil map, vegetation cover (C) using satellite images, topography (LS) using DEM and conservation practices (P) using satellite images. The sediment yield of Pahang river catchment with an area of 5120 km^2 ranged from 0.01 ton ha^{-1} $yr^{-1}$to 1.38 ton ha^{-1} yr^{-1}, averaging at 1.19 ton ha^{-1} yr^{-1}. Diversity level of potential erosion and sedimentation yield in the study area depends very much on ontopography and soil erodibility factors as the major factor, while the minor factors are land cover factor and rainfall erosivity factor. The monsoon season is associated with the accumulated sediment yield at the Pahang river mouth.

3. MATERIAL AND METHODS

The research work was conducted to estimate the runoff and sediment yield from watershed using Remote Sensing and GIS. The quantitative estimation of sediment yield with sufficient accuracy are of extreme importance for designing and implementing appropriate soil and water conservation practices. The research work was conducted at Department of Soil and Water Conservation Engineering , Dr. Annasaheb Shinde College of Agriculture Engineering and Technology, Mahatma Phule Krishi Vidyapeeth, Rahuri, Central Campus (East) watersheds. The details of material used and methods adopted for analysis for present study are discussed in this chapter.

3.1 Location and Climatic Features of Study Area

Study area is located in Ahmednagar district, situated on Ahmednagar- Manmad Highway, 35 km from the district place. The neighboring districts to Ahmednagar are Solapur (South-East), Osmanabad (South-East), Beed (South-East), Aurangabad (North-East), Nashik (North-West), Thane (North-West), Pune (South-West). Ahmednagar district is the largest district of Maharashtra state in Western India. The study area of the research was Mahatma Phule Krishi Vidyapeeth, Central Campus, Rahuri (East) watersheds. The total area is 3909.4 ha and located in extends from 17º24’ to 17º50’ N Latitude and 73º46’ to 74º0’ E Longitudes. Total area under WS_1 watershed is 1005.93 ha whereas for WS_2, 2897.1 ha.

Average daily temperature in this zone is about 27 ºC and May is hottest month. Average annual rainfall is 638 mm. The area falls in semi arid subtropical zone. The maximum temperature of the region ranges from 35°C to 43°C and minimum temperature from 4.3°C to 5.4°C. The climate of MPKV is dry except during the south –west monsoon season. The mean annual relative humidity at morning and evening is 70% and 40% respectively.

3.2 Collection of Data

The data from multiple sources in different formats were collected keeping in view the requirements of the present study and used for analysis as per the need of the study. Ancillary data were collected in different formats, whereas the map database was generated by following Department of Space designed codification scheme. It was envisaged to use a range of datasets as detailed below:

- Satellite image of LANDSAT 8 for the year 2017
- Survey of India toposheet (1:50,000).
- Ground truth information during different field validation visits and by using Google earth pro.
- Administrative boundary maps, Census and Other attribute data.

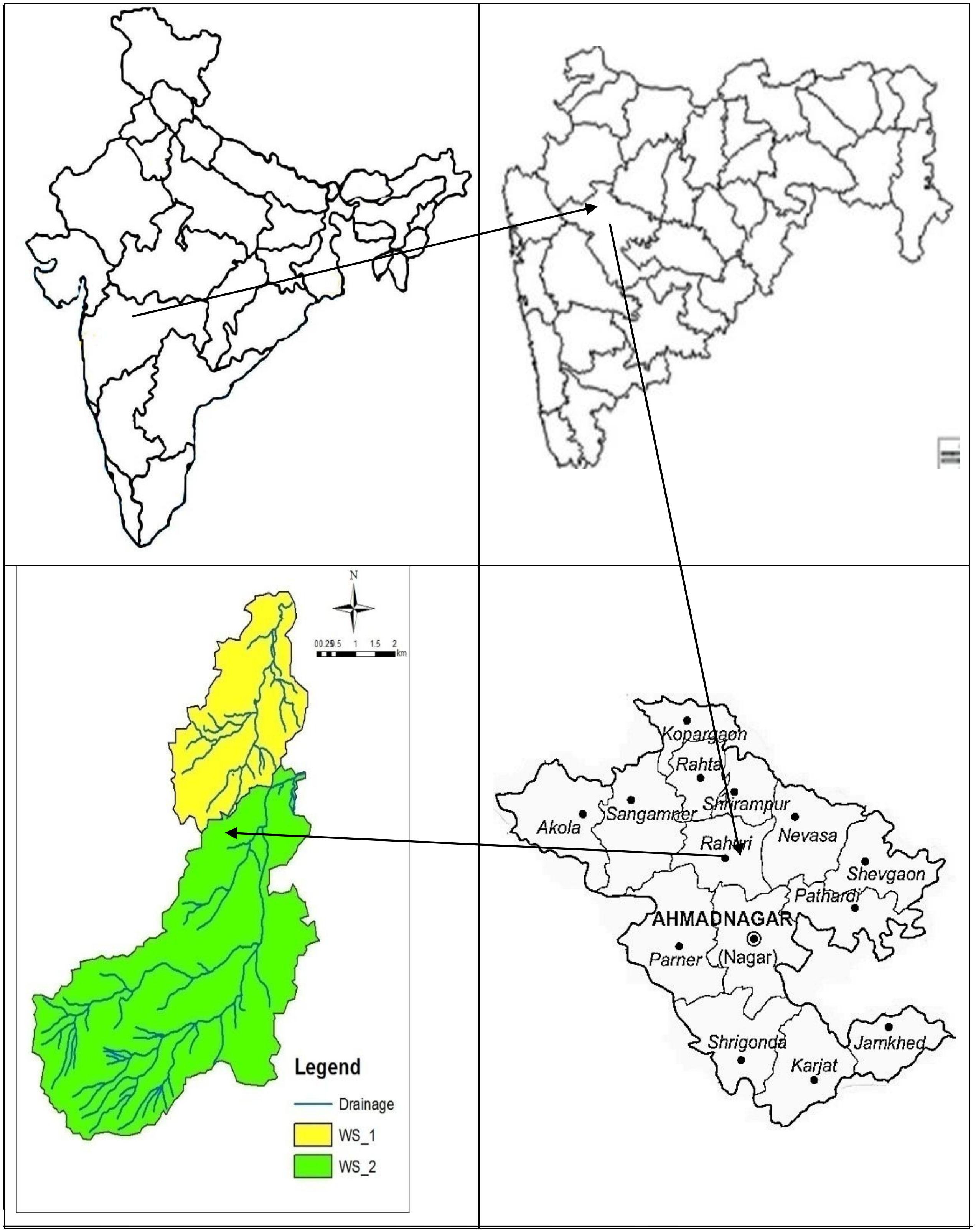

Fig. 3.1 Location map of study area

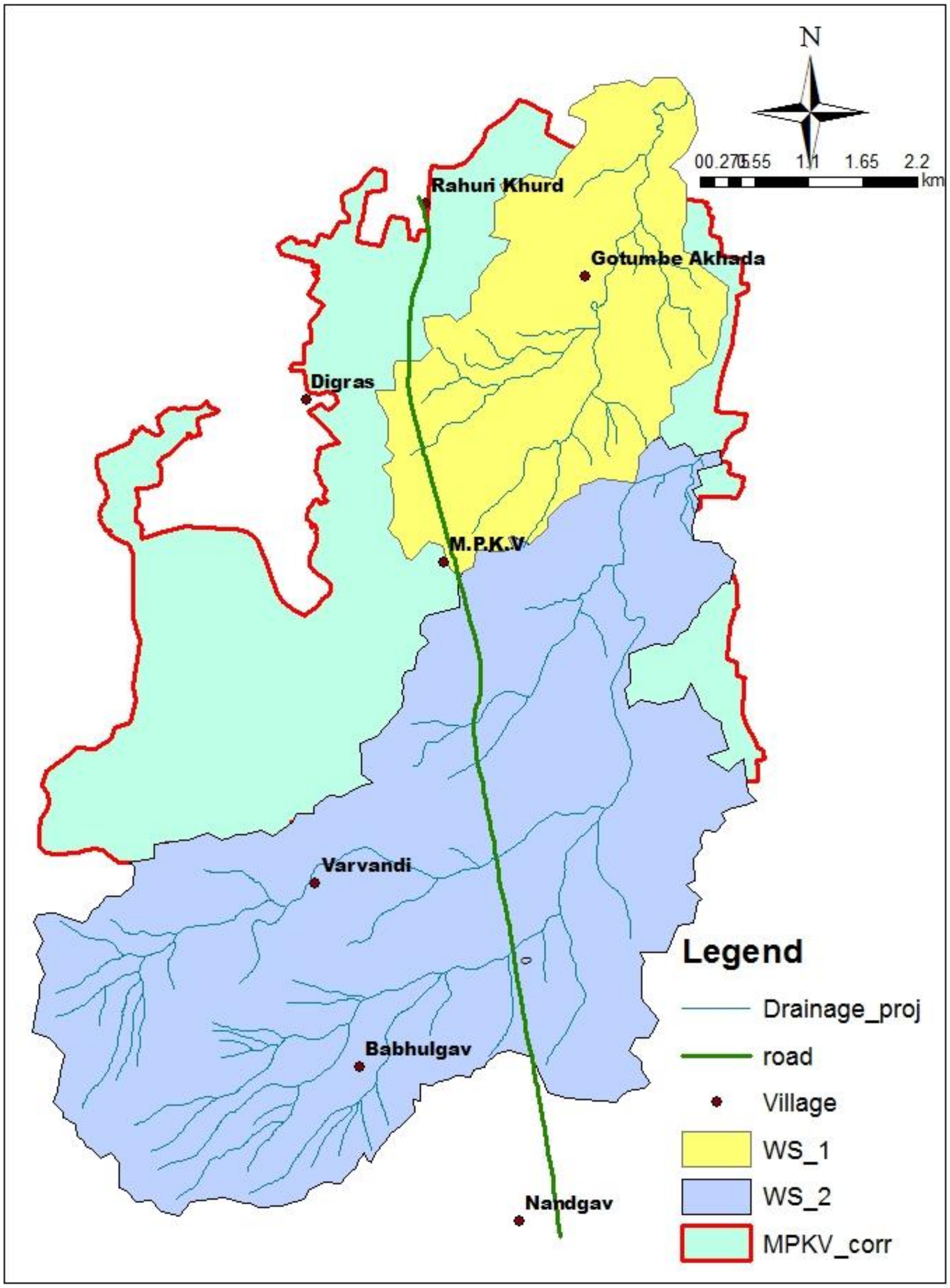

Fig.3.2 Map showing MPKV Campus and East watersheds

3.2.1 Remote Sensing Data

Satellite data were used for the present investigation having different spectral bands viz. red, infrared, near infrared etc. The data provided by LANDSAT 8 with spatial resolutions of 30 m depict a wide range of heterogeneity while homogeneity occurring in the study area owing to a synoptic coverage of remote sensing data. The details of the satellite datasets used in the present investigation are as given in Table3.1

Table 3.1 Satellite data used in the study

1	Satellite	American Earth Observation Satellite
2	Date of imagery	18^{th}-April -2017
3	Resolution	30 m
4	Product type	Level 1T (Terrain corrected)
5	Map projection	UTM
6	WGS	1984
7	Orientation	North up (map)

Landsat 8 gives 700 scenes a day while Landsat 7 gives only 250 scenes a day. A location map of MPKV Central Campus East watersheds (WS_1 and WS_2) is shown in Fig.3.2.

3.2.2 Collateral, Ancillary and Ground Data

Collateral, ancillary and ground data increase the interpretation accuracy and reliability of remotely sensed data by enabling verification of interpreted details and by supplementing it with information which cannot be obtained directly on satellite imagery. The toposheet 47I/11 (1:50,000) was used for base map preparation and ground truth of various features. Soil map was obtained from National Bureau of Soil Survey and Land Use Planning, Nagpur. Terrain data was obtained from ASTER DEM (Advanced Space borne Thermal Emission and Reflection Radiometer) having 30 m resolution. ASTER DEM was downloaded from earth explorer website https://earthexplorer.usgs.gov.

3.2.3 Other Thematic Maps

Thematic maps, Digital Elevation Model (DEM), watershed delineation and meteorological data based rainfall maps are the main inputs for hydrological studies.

- Land use map was prepared using Landsat 8 (30 m resolution) image in Arc GIS 10.2.2 software and validated through field observations during present study period.

- Soil map prepared by NBSS and LUP, Nagpur was used to derive the hydrological soil groups' maps.
- ASTER DEM (30 m resolution) data downloaded from the website of http://glcf.umiacs.umd.edu/index.shtml and processed to derive slope map.
- Daily rainfall data for 14 tehsils of Ahmednagar district for the year 2017 were downloaded from Agriculture Department, Govt. of Maharashtra web site of http://www.mahaagri.gov.in
- Daily rainfall data of the MPKV Central Campus were collected from the Water Management Department, MPKV, Rahuri.

These thematic maps were prepared using remote sensing data, DEM data and rainfall data. Methodology adopted and database used are described in subsequent sections of this chapter.

3.2.4 Ground Truth Collection

Ground truth depends upon the extent of doubtful areas verified, the sampling procedure adopted during field traverses, accessibility, classification accuracy, etc. During ground truth verification, abstraction of ground photographs of various categories of land use, enabled to compare the identification of each category on imagery with ground relevance were snapped. Interactions with local official / individuals were also made during ground visit. Detailed information like geology and rock type, growth stage of crop, ground cover percentage, soil type, moisture condition, ground water condition etc. was collected during field visit.

3.2.5 Software and Systems

Arc GIS 10.2.2**,** Arc-Info workstation, Arc View and MS-office suit were used for digital analysis, data creation and output generation. Arc GIS 10.2.2 is a suite of integrated applications that allow to perform GIS tasks, from simple to advanced, including mapping, geographic analysis, hydrology and spatial analysis, data editing and compilation, data management, visualization, and geo-processing. MS-Office suite was used for statistical analysis, documentation and for presentation purpose.

3.3 Methodology

Various interpretation techniques and methodologies were adopted to prepare thematic maps for these hydrological studies which include estimation of runoff and sediment yield from the watershed.

3.3.1 Watershed Delineation

Concept of watershed as planning unit for development of land and water resources is widely accepted. A drainage basin or watershed is a natural unit draining runoff water to a common point. Watershed forms a convenient, clearly defined unambiguous topographic unit conceived on the basis of stream network, contour configuration and rock types. The size of watershed is dependent on the stream size, point of interception of stream, the drainage density, contour configuration and application project need.

Survey of India toposheet (1:50,000) in combination with satellite image were used for watershed delineation. Toposheet provides location, drainage network and contours, satellite image helps in updating the information on waterbodies and drainage. Survey of India toposheet numbering 47 I /11 was used for watersheds delineation. Contours, spot height and elevation along with drainage pattern exhibited on the toposheet were the guiding features for watershed delineation. Streams were digitized using toposheet by creating shapefile having polyline feature. With help of streams and contours on toposheet, ridgeline of watershed was digitized by creating new boundary area shapefile having polygon feature. Two watersheds were delineated for the project area in similar way and shown in Fig.3.2.

3.3.2 Land Use Land Cover

Land use land cover is one of the most important thematic inputs in any study as it provides the present status of land utilization and its pattern. The change in the land use land cover is very dynamic that is why satellite remote sensing is widely used for its mapping. Land use refers to “man’s activities and the various uses which are carried on land”. Land cover refers to “natural vegetation, water bodies, rock/soil, artificial cover and others resulting due to land transformations”. Land use encompasses several different aspects of man’s relationships to the environment e.g. activity, ownership and land quality.

Satellite data interpretation is defined as, “the art of examining images for the purpose of identifying surface features and their relationships through logical deductive process. Interpretation/analysis is carried in conjunction with other collateral and ground data”, (Lilliesand and Kiefer, 1987). Interpretation of satellite data was carried out to generate the land use land cover map of the study area. These detailed categories so delineated are grouped into broad land use classes so as to make it compatible with classes suggested by Soil and Water Conservation Service 1972 to assign the CN numbers. The pre-processing techniques need to be employed on the satellite data before it can be used for actual interpretation. Pre-processing and image processing techniques of satellite data interpretation were elaborated below.

3.3.2.1 Geometric correction / Image rectification

Geometric correction of satellite images involved modeling the relationship between the image and ground coordinate systems. There are both systematic and non-systematic geometric errors present in satellite imagery (Jenson, 1996). The systematic errors in satellite imagery were well documented, and were primarily functions of scan skew, mirror scan velocity, panoramic distortion, platform velocity, perspective and earth rotation (Mather, 1999; Jenson, 1996). Satellite images were Geo-corrected using 1:50,000 topographic map and were projected by Lambert Conical Conformal projection, which is a real world coordinate system by giving appropriate projection parameters in terms of datum, spheroids, northing and easting, origin of centre latitude etc.

3.3.2.2 Image enhancement

Image enhancement techniques are usually applied to remote sensing data to improve the appearance of an image for human visual analysis. Enhancement method range from simple contrast stretch techniques to filtering and image transforms (Jensen 1996). Image enhancement techniques, although normally not required for automated analysis techniques, have regained a significant interest in recent years. Applications such as virtual environments or battlefield simulations require specific enhancement techniques to create ‘real life’ environments or to process images in near real time.

3.3.2.3 Image classification

Image classification refers to the task of extracting information classes from a multiband raster image. The resulting raster from image classification can be used to create thematic maps. Depending on the interaction between the analyst and the computer during classification, there are two types of classification: supervised and unsupervised. The purpose of classification is to link the spectral characteristics of the image to a meaningful information class value, which can be displayed as a map so that resource managers or scientist can evaluate the landscape in an accurate and cost effective manner (Weber and Dunno, 2001). Image classification is the process of establishing a link between a category of interest and a related spectral class. In the present study, hybrid classification approach (supervised, unsupervised and NDVI threshold) was adopted to classify the area into different land use classes. Supervised and Unsupervised classification is based on the fact that most remotely sensed image composed of spectral classes that are reasonably uniform with respect to reflectance across one or more spectral channels and can therefore be defined and mapped (Tou and

Gonzalez, 1974). ISODATA (Iterative Self Organizing Data Analysis Technique) clustering or unsupervised approach had been adopted to separate out agriculture and non-agriculture areas. Within the agriculture areas, combination of raw bands and various other indices were attempted and finally best separable bands were selected for analysis. Spectral vegetation indices that measure NIR and R radiance in visible and infrared bands were excellent inputs for characterization of agricultural area and helps in differentiating them from wasteland, water bodies and built-up areas.

3.3.3 Soil Mapping and Hydrological Soil Groups

The soil map of the Ahmednagar district prepared by NBSS and LUP (National Bureau of Soil Survey and Land Use Planning, Nagpur) was used in the present study. Soil classification systems organize soils based on their characteristics and use. By comparing properties of the soil data of the study area with properties of soil with different hydrological groups, hydrological soil groups are assigned to them in attribute table. Soil scientist, hydrologist, construction designers, builders, engineers use soil classification systems which including hydrological groups to determine soil's suitability for projects. Hydrological soil groups define and describe the rate at which water enters the soil surface and the rate at which it transmits through the soil. Soil properties greatly influence the amount of runoff. In the SCS method, these properties are represented by a hydrological parameter such as rate of infiltration obtained for a bare soil after prolonged wetting. The influence of both the soil’s surface condition (infiltration rate) and its horizon (transmission rate) were important consideration in hydrological groupings. This parameter, which indicates a soil’s runoff potential, was the qualitative basis of the classification of all soils into four groups. The Hydrological Soil Groups defined by the SCS are:

- **HSG Group A** (low runoff potential): Soils with high infiltration rates even when thoroughly wetted. These consist chiefly of deep, well-drained sands and gravels. These soils have a high rate of water transmission (final infiltration rate greater than 7.6 mm per hour). Examples are deep, well to excessively drained sands or gravels.
- **HSG Group B** (moderate runoff potential) Soils with moderate infiltration rates when thoroughly wetted. These consist chiefly of soils that are moderately deep to deep, moderately well drained to well drain with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (final infiltration rate of 3.8–7.6 mm per hour).
- **HSG Group C** (moderately high runoff potential) Soils with slow infiltration rates when thoroughly wetted. These consist chiefly of soils with a layer that impedes downward

movement of water or soils with moderately fine to fine textures. These soils have a slow rate of water transmission (final infiltration rate 1.3–3.8 mm per hour).

- **HSG Group D** (high runoff potential): Soils with very slow infiltration rates when thoroughly wetted. These consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission (final infiltration rate less than 1.3 mm per hour).

3.3.4 Slope Extraction from ASTER DEM

Digital Elevation Model (DEM) is the continuous representation of elevation values over a topographic surface by a regular array of z-values, referenced to a common datum. DEM represents a very important geospatial data type in the analysis and modeling of different hydrological studies such as runoff and soil loss estimation. DEMs are typically used to represent terrain relief and are relevant for many applications such as lake and water volumes estimation, soil erosion volumes calculations, flood estimate, quantification of earth materials to be moved for channels, roads, dams, embankment etc. Surface-water hydrologic applications begin with raster data of the terrain due to the wide availability of DEMs and intrinsic GIS software functions to conduct digital terrain processing, (Johnson, 2009).

In this study, terrain data which was acquired by ASTER DEM which was downloaded from (http://glcf.umiacs.umd.edu/index.shtml) website and was used after re-projecting it into Lambert Conical Conformal projection and clipping to study area boundary. ASTER DEM is used to understand the drainage networks, elevation and generate slope by using Spatial Analyst module of GIS. Many hydrological functions were supported by this module.

3.3.5 Runoff Estimation by SCS Curve Number Method

The 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 Soil Conservation Service (SCS)-Curve Number (CN) method (SCS, 1972) also known as the Hydrologic Soil Cover Complex Method. It is a versatile and widely used procedure for runoff estimation. The conceptual basis of the curve number method has been the object of both support and criticism (Ponce and Hawkins, 1996). The major disadvantages of the method are sensitivity of the method to Curve Number (CN) values, fixing the initial abstraction ratio, and lack of clear guidance on how to vary Antecedent Moisture Conditions (AMC). However, the method is used widely and is accepted in numerous hydrologic studies. The SCS method originally was developed for agricultural watersheds in the mid-western United States; however it has been used throughout the world far beyond its original developers would have imagined.

The requirements for this method are rainfall amount and curve number. CN is dimensionless and its value varies from 0 to 100. The curve number is based on the hydrologic soil group, land use treatment and hydrologic condition. As defined by SCS soil scientists, soil were classified into four hydrologic groups (A, B, C and D), (USDA, 1985), depend on infiltration and soil classification. Land use and treatment classes were used in the preparation of hydrological soil-cover complex. It is used in estimating direct runoff. Overall methodology adopted in the study for estimating runoff is depicted in the Fig.3.3.

Antecedent Moisture Condition (AMC) is an indicator of watershed wetness and availability of soil moisture storage prior to a storm, and has a significant effect on runoff volume. Recognizing its significance, SCS developed a guide for adjusting CN according to AMC based on the total rainfall in the 5-day period preceding a storm. Three levels of AMC are used in the CN method: AMC-I for dry, AMC-II for normal, and AMC-III for wet conditions. Table 3.2 gives seasonal rainfall limits for these three antecedent moisture conditions.

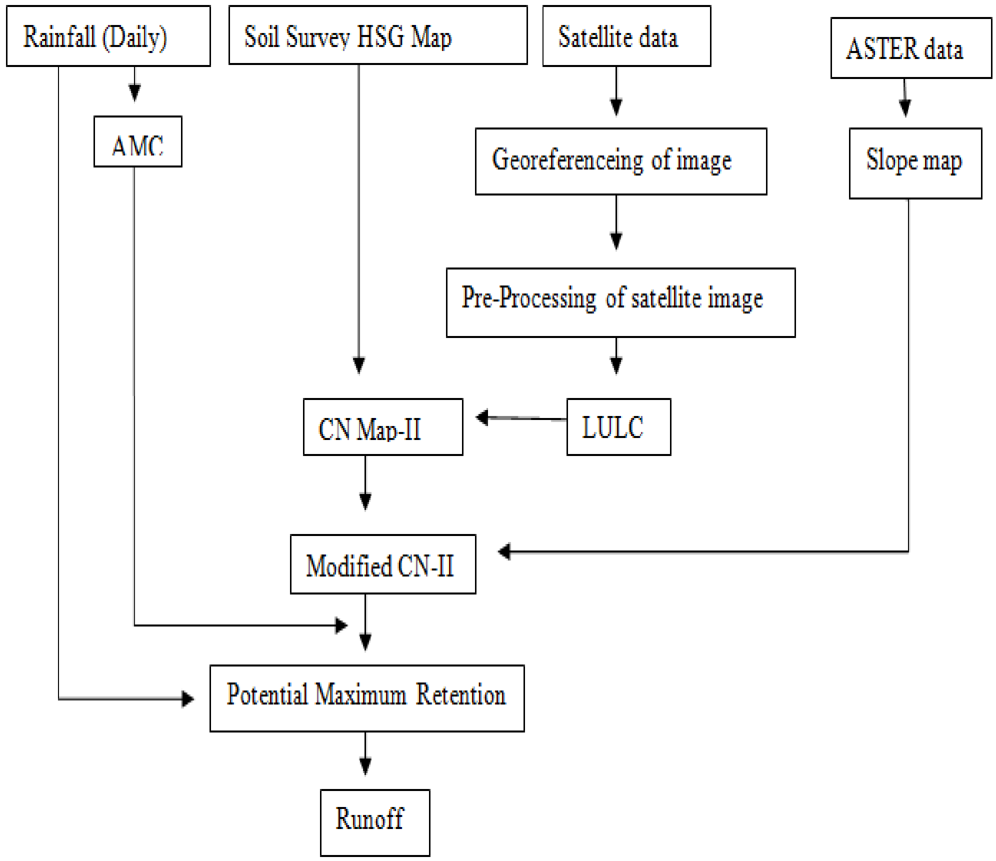

Fig.3.3 Methodology for Runoff Estimation

Table 3.2: Classification of Antecedent Moisture Condition

AMC	**5-days Antecedent Rainfall (mm)**	
	Active growing season	**Dormant season**
I	Dry (< 35)	Dry (< 3.5)
II	Medium (35 to 52.5)	Medium (3.5 to 27.5)
III	Wet (> 52.5)	Wet (> 27.5)

(Source: Soil Conservation Service 1964)

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. Mockus found equation 3.1 appropriate to describe the curves of the field measured runoff and rainfall values (National Engineering Handbook, 2004). Equation 3.1 describes the conditions in which no initial abstraction occurs.

$$\frac{F}{S} = \frac{Q}{P} \qquad \ldots(3.1)$$

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 (*Ia*), 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 – Ia.* Substituting this value in equation 3.1 yields following equation:

$$\frac{P-I_a-Q}{S} = \frac{Q}{P-I_a} \qquad \ldots (3.2)$$

The storage capacity (S) can be obtained from CN by using the following relationship

$$CN = \frac{25400}{S+254} \qquad \ldots (3.3)$$

Where

S = maximum recharge capacity of watershed after 5 days rainfall antecedent (mm)

CN = curve Number.

In the past 30 years the SCS method has been used by a few researchers because it gives consistently usable results (Rao *et. al*., 1996; Sharma *et al.,* 2001; Chandramohan and Durbude, 2001; Sharma and Kumar, 2002) for runoff estimation. Putting the value of Curve Number in above, the recharge capacity 'S' was calculated. The direct runoff of the watershed was calculated using following equation.

$$Q = 0, \qquad \text{If } P <= 0.2S \qquad \ldots(3.4a)$$

$$Q = \frac{(P-I_a)^2}{(P-I_a+S)} \qquad \text{If } P >= 0.2S \qquad \ldots (3.4b)$$

Where,

Q = runoff depth (mm)

P = rainfall (mm)

S = potential maximum retention after runoff begins (mm)

3.3.5.1 Generating weighted CN value

The SCS-CN method is the most popular method for computing surface run off for rainfall event. This approach involves the use of simple empirical formula and readily available data. SCS-CN method is a viable method for estimating the effects of land treatment and land use changes on volumes of run-off under the wide range of climatic conditions. The advantages of this method are its simplicity, predictability, stability and its reliance on only one parameter namely the Curve Number (CN). The weighted CN value was calculated by using Land Use and Land Cover map integrated with Hydrologic Soil group map in Arc GIS environment.

The CN values for different land uses and hydrologic soil groups were adopted from Technical Release 55, (USDA-NRCS, 1986). Weighted CN map was generated using following equation

$$CN = \frac{\sum CN_i \times A_i}{A} \qquad \dots (3.5)$$

Where,

CN = weighted curve number.

CN_i = curve number from 1, 2, 3,…,i.

A_i = area with curve number CN_i

A = total area of the watershed.

3.3.5.2 Antecedent moisture condition (AMC)

The CN values for each polygon were calculated for average conditions (i.e. Antecedent Moisture Condition Class II). To determine which AMC class was the most appropriately related to study area, the use of rainfall data is necessary. The CN values are documented for the case of AMC-II (USDA, 1985). To calculate CN values for AMC-I and AMC-III conditions, the following equations are used (Chow, 2002):

CN for AMC I $$CN_I = \frac{4.2 \times CN_{II}}{10-(0.058 \times CN_{II})} \qquad \dots (3.6)$$

CN for AMC II $$CN_{III} = \frac{23 \times CN_{II}}{10+(0.13 \times CN)} \qquad \dots (3.7)$$

Where,

CN_{II} = curve number for normal condition,

CN_I = curve number for dry condition, and

CN_{III} = curve number for wet condition.

3.3.5.3 Slope-adjusted CN

Slope has profound impact on determination of CN values therefore incorporating slope values in CN and adjusting CN values accordingly is essential from hydrology study point of view. To achieve this slope and CN maps were intersected to get slopes of each polygon. Since each polygon has different slopes, calculating weighted slope is needed for each polygon. Weighted slope of a polygon was computed using formula (3.8).

$$\text{Weighted slope} = \frac{\sum_{i=1}^{n} a_i \times s_i}{A} \quad \dots (3.8)$$

Where,

a_i = area of slope (ha).
s_i = slope (per cent)
A = polygon area (ha)

Weighted slope of polygon was applied in equation (3.8) to compute slope adjusted CN values. The Huang *et al*. (2006) approach was used because of the improvement made to incorporate the slope factor into the analysis.

The CN values for AMC II condition is calculated by formula (3.8) considering the slope correction and then CN II modified is converted in to CN values for AMC I and AMC III condition by using following equations (3.9) and (3.10),

$$CN_I = CN_{II} - \left(\frac{20(100-CN_{II})}{(100-CN_{II}+\exp[2.533-0.0636(100-CN_{II})])}\right) \quad \dots (3.9)$$

$$CN_{II}\ \text{Mod-II} = CN_{II}\left(\frac{322.79+15.63\alpha}{\alpha+323.52}\right) \quad \dots (3.10)$$

$$CN_{III} = CN_{II} \times \exp\,[0.00673(100\text{-}CNII)] \quad \dots (3.11)$$

The daily rainfall data for the years 2017 for the study area and the values of maximum potential retention, S obtained from the CN for the watershed area were used for the estimation of runoff from SCS (model).

3.3.6 Sediment Yield by Revised Universal Soil Loss Equation (RUSLE)

The Revised Universal Soil Loss Equation (RUSLE) (Renard *et. al*, 1997) is a modified and revised version of Universal Soil Loss Equation (USLE) suggested by Wischmeier and Smith, 1978, originally developed to predict erosion on croplands in the United States. With the revision, the equation can be employed in a variety of environments including rangeland, mine sites, construction sites, etc. In this study RUSLE an empirical equation is used and estimated annual soil loss in croplands (tons / ha / year) resulting from sheet and rill erosion. The RUSLE is based on series of factors, each quantifying one or more processes and their interactions, are combined to estimate overall soil loss. The overall schema of estimating annual soil loss using remote sensing and GIS techniques are given in Fig. 3.4.

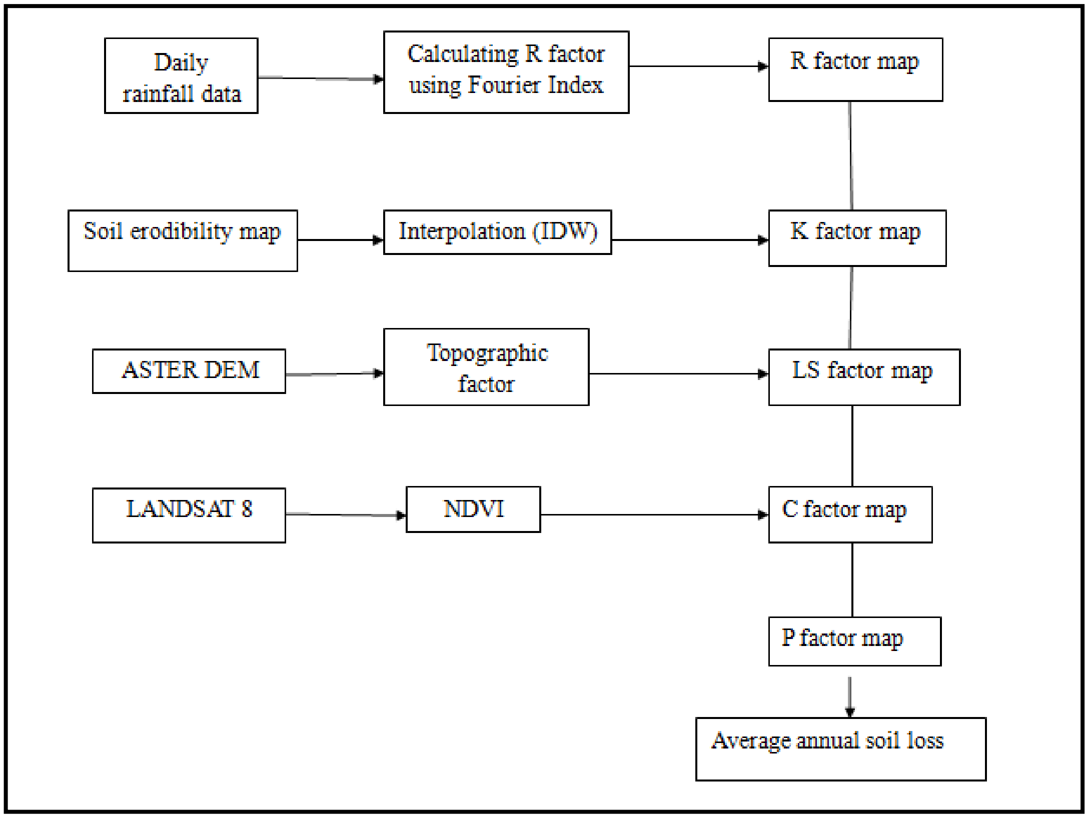

Fig. 3.4 Methodology for Estimation of Annual Soil Loss

The sediment delivery ratio is the ratio of sediment yield to total soil loss. The equation of SDR was developed by Wischmeier and Smith (1978).

$$\mathrm{SDR} = 0.51 \times \mathrm{A}^{-0.11} \qquad \dots (3.12)$$

Where,

A = area of watershed (ha)

The Revised Universal Soil Loss Equation (RUSLE) computes soil erosion as follows

$$\mathrm{SY} = \mathrm{SDR} \times \mathrm{A} \qquad \dots (3.13)$$

Where,

SY = sediment Yeild

SD= sediment Delivery ratio

A= average Annual soil loss

Average annual soil loss is calculated by using Universal Soil loss Equation (USLE) as given,

$$A = R.K.LS.C.P \qquad ....(3.14)$$

Where,

A = average soil loss per unit area by erosion (t ha^{-1} $year^{-1}$)

R = rainfall erosivity factor (MJ mm ha^{-1} $h^{-1}year^{-1}$)

K = soil erodibility factor (t h MJ^{-1} mm^{-1})

L = slope length factor

S = slop steepness factor

P = support practice factor (t ha^{-1} $year^{-1}$)

3.3.6.1 Rainfall erosivity factor (R- factor)

Soil loss is closely related to rainfall partly through the detaching power of raindrops striking the soil surface and partly through the contribution of rainfall to runoff (Morgan, 1994). Rainfall data from 14 rainfall stations surrounding the M.P.K.V. watersheds (East) was used in this study to calculate rainfall erosivity factor (R-value). Monthly precipitation for these stations was collected for the year 2017 from the website http\\:www.mahaagri.gov.in. An equivalent R factor had been developed for the climatic conditions of the study area. The monthly precipitation data converted to annual precipitation and was interpolated to determine the value of each cell. Inverse Distance Weighted (IDW) technique was adopted to generate interpolated rain image (rain.img) to find the R-factor. The R-factor was calculated in the raster calculator module of Arc GIS 10.2.2 incorporating following formula. (Ram Babu *et. al.*, 2004.)

$$\text{R Factor} = 81.5 + [0.380 \times (R_N)] \qquad .... (3.15)$$

Where,

R-Factor = rainfall erosivity factor

Rn = average annual rainfall (mm) (rain.img)

3.3.6.2 Soil erodibilty factor (K-factor)

The erodibility of a soil is an expression of its inherent resistance to particle detachment and transport by rainfall. The K factor accounts for the susceptibility of soil particles to detachment and movement by water (Romkens *et al.*, 1997). Soil erodibility index (g / J) is the weight of soil detached from the soil mass per unit of rainfall energy. It is integrated effect of the processes that regulate rainfall acceptance and the resistance of the soil to particle detachment and subsequent transport. These processes are influenced by soil particle, of which soil texture is an important factor that influences erodibility. It is determined by the cohesive force between the soil particles, and may vary depending on the presence or absence of plant cover, the soil's water content and the development of its structure (Wischmeier and Smith, 1978). K values have been obtained from the soil erodibility factor map prepared for Central Campus M.P.K.V, Rahuri. Soil map of the study area (Atre and Bangal, 1997) was geo-referenced and then by creating new shapefile of point features having field as soil erodibility factor in attribute table. There were 16 points are assigned with their soil erodibility factor. For determination of the value of each cell, Inverse Distance Weighted (IDW) technique was adopted to generate interpolated soil erodibility image (k.img) to find the K-factor.

3.3.6.3 Slope length and steepness factor (LS-Factor)

The L and S factor (topographic factor) accounts for the effect of topography on erosion in RUSLE method. The slope length factor (L) represents the effect of slope length on erosion, and the slope steepness factor (S) reflects the influence of slope gradient on erosion. For this study L is the flow length and S is slope steepness which is given by meter and percent, respectively. Basically, the LS factor can be estimated through field measurement. In the present investigation LS factors were computed in Spatial Analyst module of Arc GIS using ASTER DEM of 30 m resolution. Slope gradient (S) and slope length (L) were determined and combined to form a single factor known as the topographic factor. The accuracy of estimation depends on the resolution of DEM. The Topographic factor in the present study was therefore computed by using the equation stated by Moore and Wilson (1992).

$$\mathrm{LS} = \left(\frac{As}{22.13}\right)^{0.4}\left(\frac{\sin\beta}{0.0896}\right)^{1.3} \qquad \ldots \quad (3.16)$$

Where,

As = the specific area (=Alb), defined as the upslope contributing area for an Overland cell (A) per unit width normal to the flow direction (b)

β = the slope gradient in degrees

n = 0.4; for 3 to 4 % slope

m = 1.3

As is specific catchment area, i.e. the upslope contributing area per unit width of contour drains to a specific point (flow accumulation × cell size). LS- factor was computed in Arc GIS raster calculator using the map algebra expression in eq.3.17 suggested by Mitasova and Mitas (1999) and Simms et al. (2003).

$$POW\left(\frac{flow\ accumulation * cell\ size}{22.13}, 0.6\right) * POW(\sin\ (slope\ * 0.01745)/0.09\ , 1.3) \ldots (3.17)$$

The combined topographic (LS) factor was computed rather than the individual slope length and slope angle factors. The inputs for the computation include the slope in percent and the slope length as a flow length.

3.3.6.4 Cover management factor (C-Factor)

The C factor is the cover management factor. One of the most important parameters in USLE is the crop cover management factor (C) that represents effects of vegetation and other land covers. The C factor reflects the effect of cropping and management practices on the soil erosion rate. The C factor indicates how conservation plans will affect the average annual soil loss and how that soil loss potential will be distributed in time during construction activities, crop rotations or other management schemes. Vegetation cover protects the soil by dissipating the raindrop energy before reaching the soil surface. As such, soil erosion can be effectively limited with proper management of vegetation, plant residue and tillage. In USLE the C factor is computed using empirical equations that contain field measurements of ground cover. Since the satellite image data provide up to date information on land cover, the use of satellite images in the preparation of land cover maps is widely applied in natural resource surveys.

Researchers developed many methods to estimate C factor using NDVI for soil loss assessment with USLE. These methods employ regression model to make correlation analysis between C factor values measured in field or obtained from guide tables and NDVI values derived from remotely sensed images. The unknown C factor values of land cover classes can be estimated using equation obtained from linear regression analysis. The aim of this study is to estimate C factor values of land cover classes using NDVI values by regression analysis for erosion modeling. In present study the cell size of 30 m × 30 m has been used for all the raster computations and for preparation of C factor map of the study area.

Currently, due to the variety of land cover patterns with spatial and temporal variations, satellite remote sensing data sets were used for the assessment of C factor (Karydas *et al.* 2009; Tian *et al.* 2009). The Normalized Difference Vegetation Index (NDVI), an indicator of the vegetation vigor and health are used along with the following formula to generate the C factor image for the study area (Zhou *et al.* 2008; Kouli *et al*. 2009).

$$NDVI = \frac{NIR-R}{NIR+R} \quad \dots (3.18)$$

Where,

NDVI = Normalized Difference Vegetation Index (ratio varying from -1 to +1)

NIR = Near Infrared Band.

R = Red Band

As the cover management factor is the ratio of soil loss from an area with specified cover and management to that of an area in tilled continuous fallow. The Normalized Difference Vegetation Index (NDVI), an indicator of the vegetation vigor and health is used along with the following formula (eq. 3.19) to generate the C-factor value image for the study area (Zhou et al., 2008; Kouli et al., 2009)

$$C = exp\left[-\alpha \frac{NDVI}{(\beta - NDVI)}\right] \qquad \text{…..(3.19)}$$

Where,

α and β are unitless parameters that determine the shape of the curve relating to NDVI and the C-factor.

Van der Knijff et al.(2000) found that this scaling approach gave better results than assuming a linear relationship and the values of 2 and 1 were selected for the parameters α and β, respectively. This equation was successfully applied for assessing the C-factor of areas with similar terrain and climatic conditions (Prasannakumar et al., 2011a,b). Raster Calculator tool of the Spatial Analyst extension of Arc GIS software was used to calculated C - factor from NDVI. NDVI is a spectral ratio between near infrared (NIR) and red (R) reflectance and was extracted from satellite image of study area (18 April 2017) and the linear equation developed (Van der Knijff *et al*., 2000).

3.3.6.5 Support practice factor (P-Factor)

The management practice factor (P-factor) reflects the effects of practices that will reduce the amount and rate of runoff thereby reducing the erosion (Renard *et al.* 1997; Dabral *et al.* 2008; Yue-qing *et al.* 2008). The P-factor represents the ratio of soil loss by a support practice to that of straight-row farming up and down the slope. In the study the watershed was broadly divided into three zones by considering the present land use land cover practices and support factors (rabbi season image reflects the management practices undertaken in the watershed in terms of soil moisture and vegetation cover). The values of P-factor ranges from 0.25 to 1, in which the highest value is assigned to areas with no conservation practices (forest / natural vegetation) and the minimum values corresponds to crop land with strip and contour cropping. P values were determined by the extent of individual conservation practices, such as contouring, strip cropping and terracing, which can also be used in combination. The values of conservation practice factor for different management practices were adopted for the MPKV Central Campus (East) watersheds as suggested by Hann *et al.* (1994).

Soil erosion calculated by above method is classified according to following classes to estimate severity of the erosion and this is also useful for prioritization of watersheds using RS and GIS.

Table 3.3. **Soil Erosion Severity Classes/Risk Levels (adopted from Haregeweyn et al., 2017)**

Soil erosion severity (t/ha)	Erosion class
0-5	Very Slight
5 to 15	Slight
15 to 30	Moderate
30 to 50	Sever
> 50	Very Sever

4. RESULT AND DISCUSSION

The results of the study conducted for MPKV central campus (east) watersheds (WS_1 and WS_2) on estimation of runoff and sediment yield using remote sensing and Geographical Information System based on various thematic and derived maps. The results obtained are discussed below,

4.1 Delineation of Watershed

MPKV central campus (east) watersheds i.e. WS_1 and WS_2 were delineated using the Survey of India toposheet (1:50,000) 47 I /11 in GIS environment in Arc GIS 10.2.2 software. For delineation of watersheds, the toposheet was geo-referenced and rectified in GIS environment in Arc GIS 10.2.2 software. The toposheet was geo-referenced in World Geodate Survey (WGS 1984) with zone 43N. Once the toposheet was geo-referenced, further it was used for base map generation which includes drainage network, roads, settlements etc. The drainage order map for both watersheds is shown in Fig.4.1. The WS_1 is having 4^{th} as highest order whereas WS_2 is of 4^{th} order drainage network.

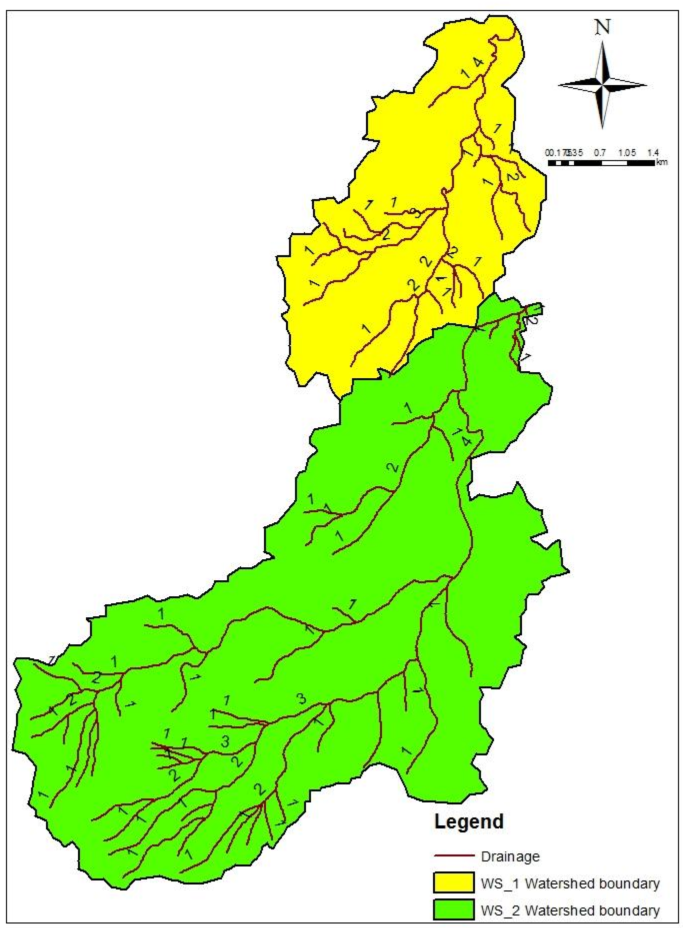

Fig.4.1 Drainage network of watersheds

4.2 Remote Sensing Data

The Landsat 8 (30 m resolution) satellite imagery was downloaded from earth explorer (https://earthexplorer.usgs.gov) website as it is available as free data source. The downloaded image was summer season of dated 18th April, 2017. All those bands data was layer stacked to made composite image. False Colour Composites (FCC) image was generated using bands 5, 4 and 3 combination. Both the watersheds were in the same scene. For different operation the image was masked using watershed boundary. The part of Landsat 8 image is presented in Fig.4.2. The False Colour Composite images of WS_1 and WS_2 are shown in Fig.4.3 and Fig. 4.4.

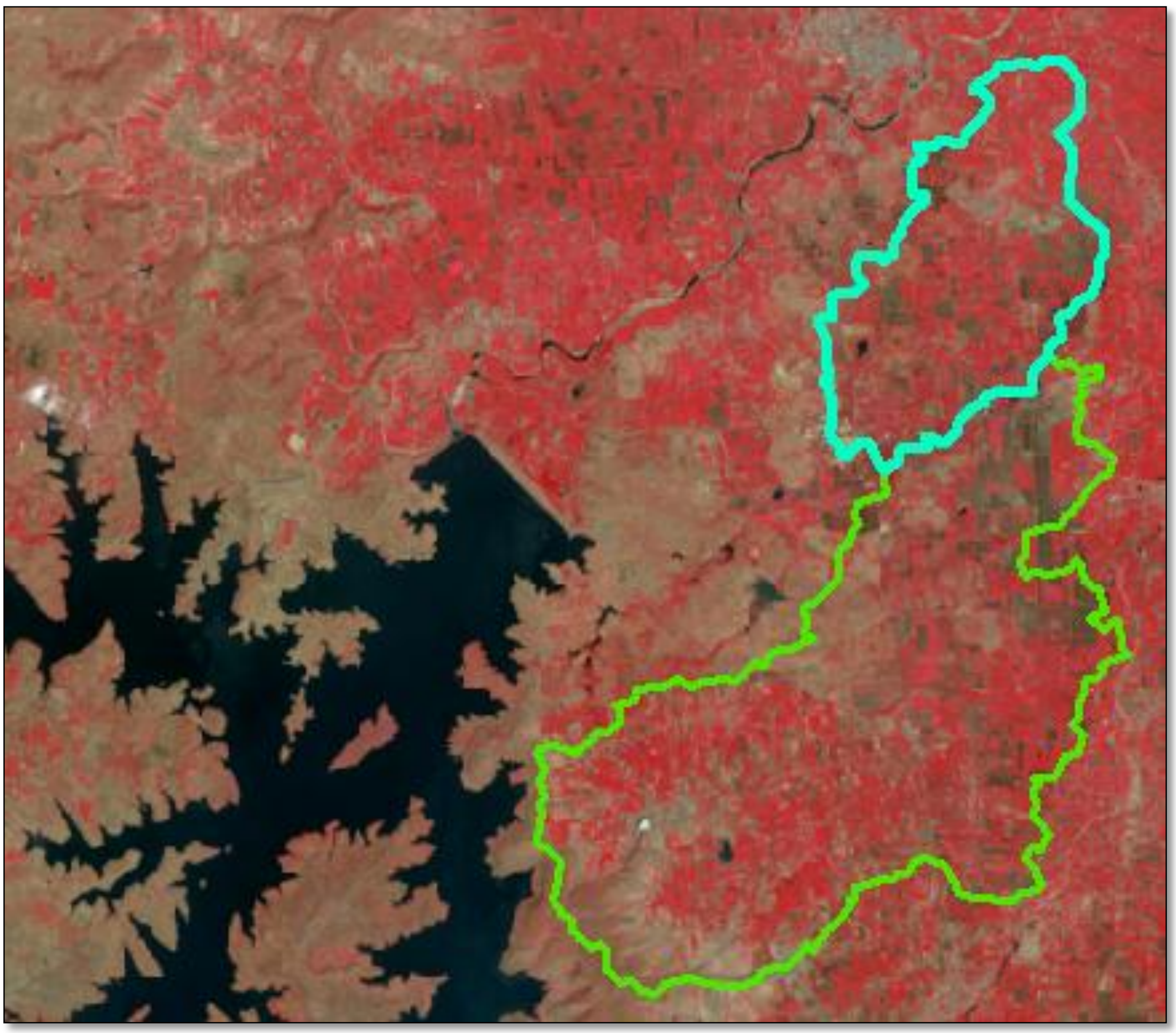

Fig. 4.2 FCC imagery of the LANDSAT 8 for 18 April 2017

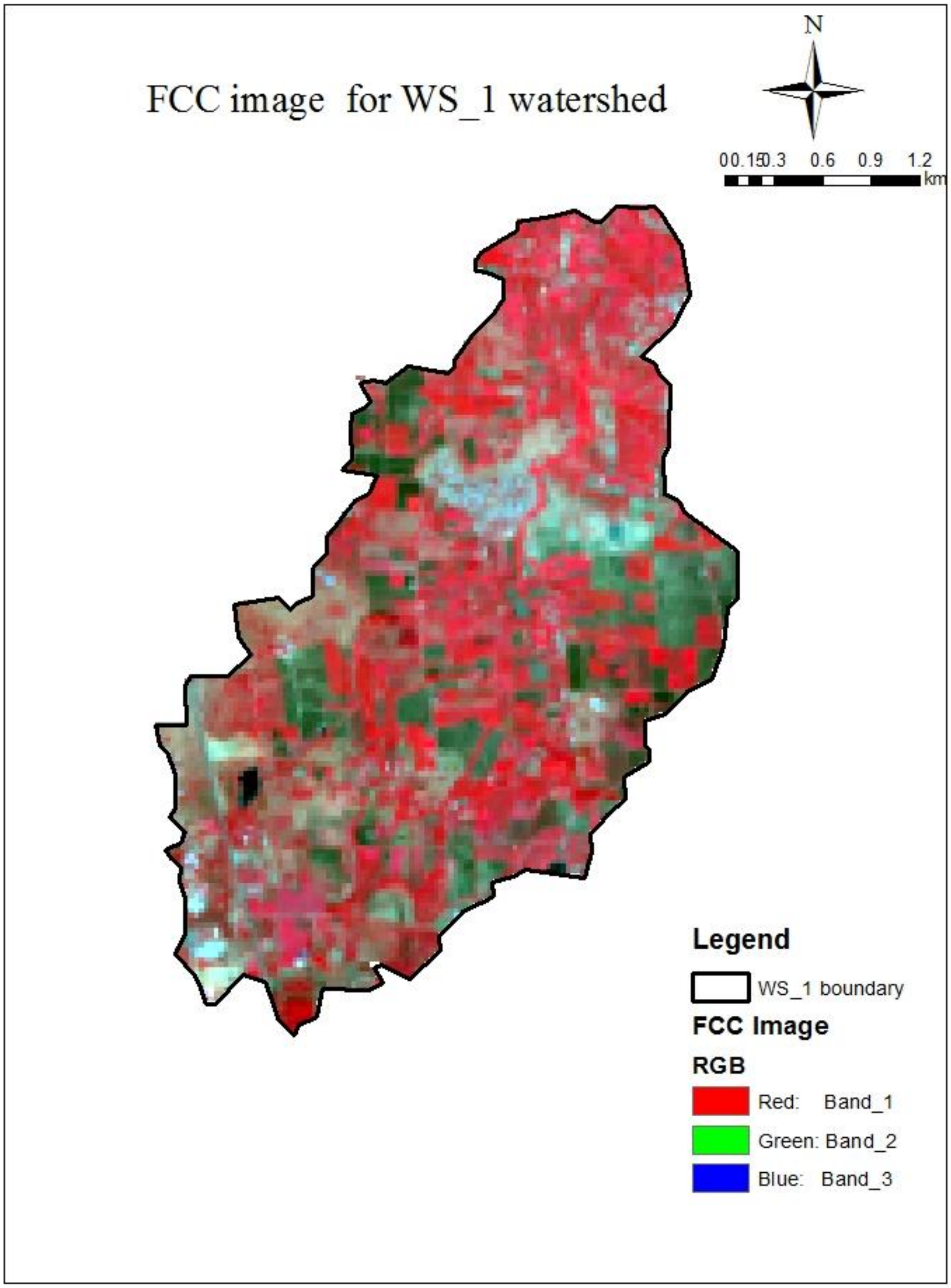

Fig.4.3 Satellite imagery for the WS_1 watershed

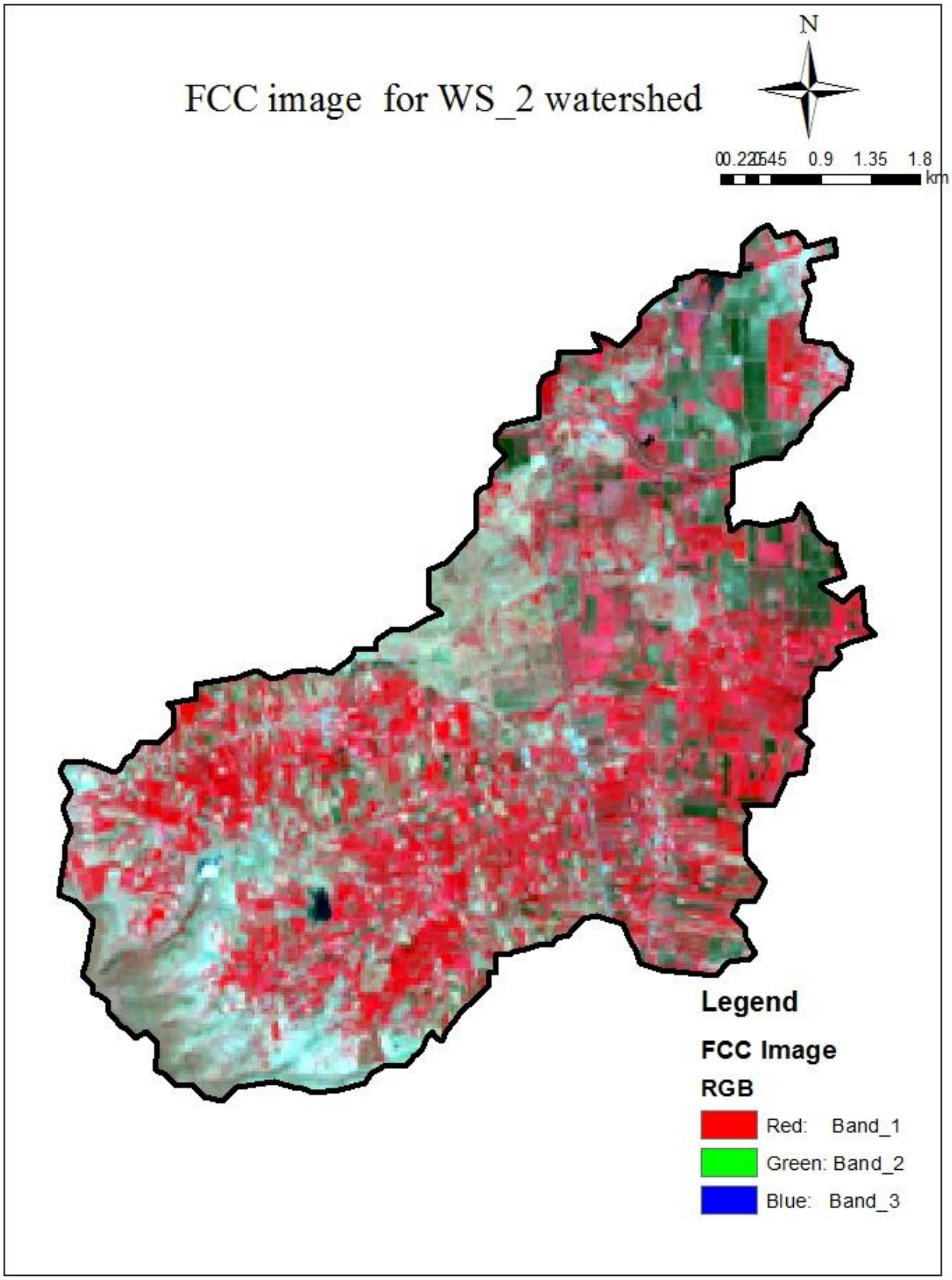

Fig. 4.4 Satellite imagery for the WS_2 watershed

4.3 Land Use/Land Cover in 2017

The land use and land cover characteristics of the study area in 2017 described using land use/land cover (LU/LC) maps and the statistics generated on this aspect are as follows,

Table 4.1 Land use/land cover classes of WS_1 in 2017

Watershed_1			
Sr. No	**Land Use / Land Cover**	**Area (ha)**	**Area (%)**
1	Water bodies	2.88	0.28
2	Settlements	24.48	2.43
3	Horticulture plantation	43.02	4.27
4	Cultivable land	404.1	40.17
5	Barren land	439.2	43.66
6	Cultivable fallow land	92.25	9.17
		1005.93	100

In 2017, Land use land cover pattern of M.P.K.V. central campus east watershed WS_1 revealed that majority of land was under barren land class (439.2 ha) which was 43.66 per cent of the total area of watershed followed by cultivated land (404.1 ha) which covers about 40.17 per cent of total area followed by cultivable fallow land (92.25 ha, 9.17 per cent), horticulture plantation (43.02 ha, 4.27 per cent), settlement (24.48 ha, 0.28 per cent) and water bodies (2.88 ha, 0.28 per cent) shown in Fig.4.7. It is inference that almost 85 percent of the land was covered by major two classes barren land class and cultivated land which are most vulnerable for flood condition. Forecasting of stream flows would minimize the losses of natural resources to large extend.

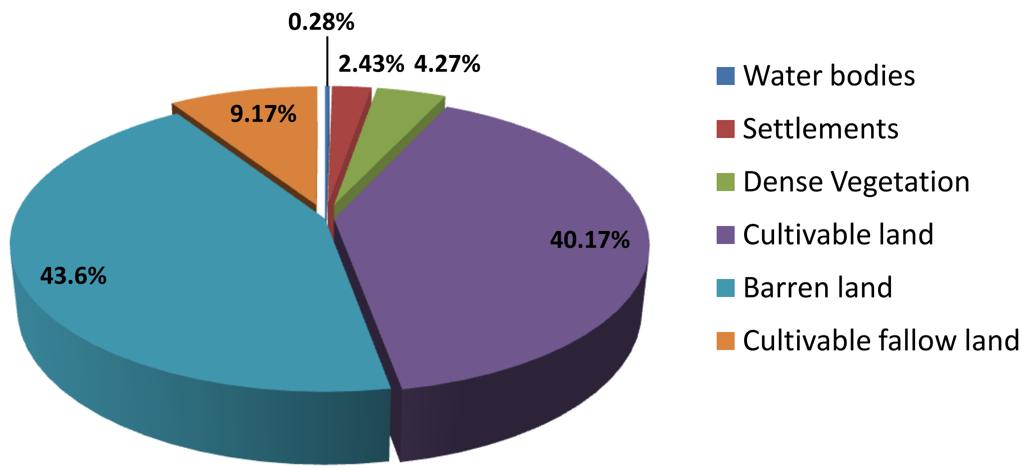

Fig.4.5 LULC classification for WS_1 watershed

Table 4.2 Land use/land cover classes of WS_2 in 2017

Watershed_2			
Sr. No	**Land Use / Land Cover**	**Area (ha)**	**Area (%)**
1	Water bodies	9.27	0.31
2	Settlements	63.63	2.19
3	Horticulture crops	231.48	7.99
4	Cultivable land	817.74	28.22
5	Barren land	1573.92	54.32
6	Cultivable fallow land	201.06	6.94
		2897.1	100

In 2017, Land use land cover pattern of M.P.K.V. central campus east watershed WS_2 revealed that majority of land was under barren land class (1573.92 ha). It was 54.32 per cent of the total area of watershed followed by class was cultivated land (817.74 ha) which covers about 28.22 per cent of total area followed by horticulture crops (231.48 ha, 7.99 per cent), cultivable fallow land (201.06 ha, 6.94 per cent), settlement (63.63 ha, 2.1 per cent) and water bodies (9.27 ha, 0.31 per cent) which is shown in Fig.4.8. It is inference that almost 80 per cent of the land was covered by major two classes barren land class and cultivated land which are most vulnerable for flood condition. Forecasting of stream flows would minimize the losses of natural resources to large extend.

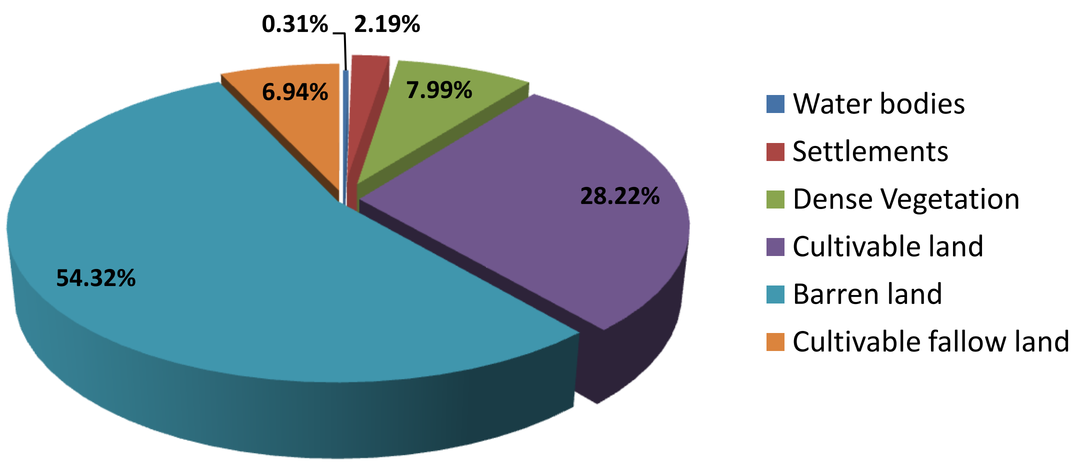

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Fig.4.6 LULC classification for WS_2 watershed

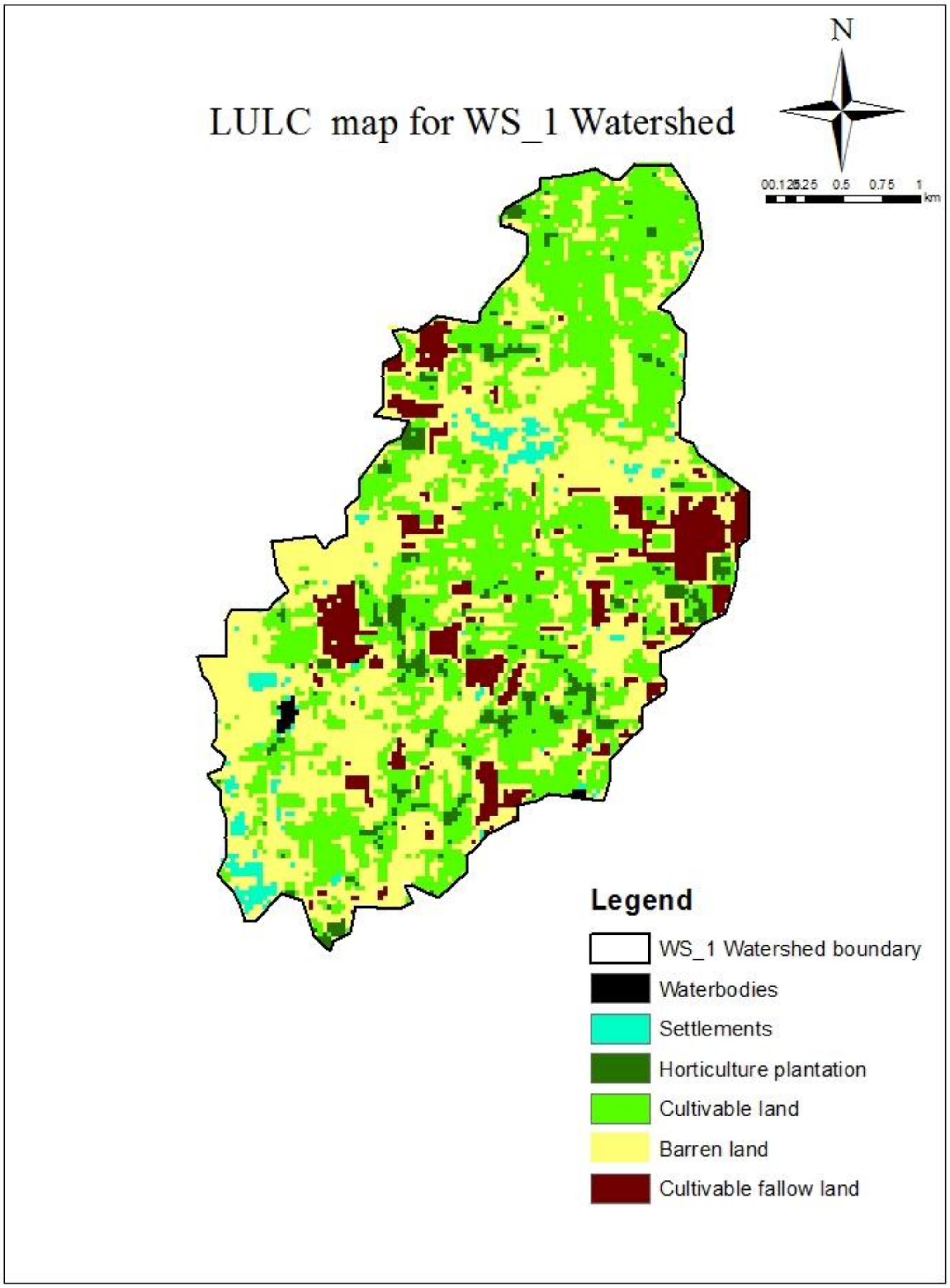


Fig. 4.7 Land use/ Land cover map of WS_1 in 2017

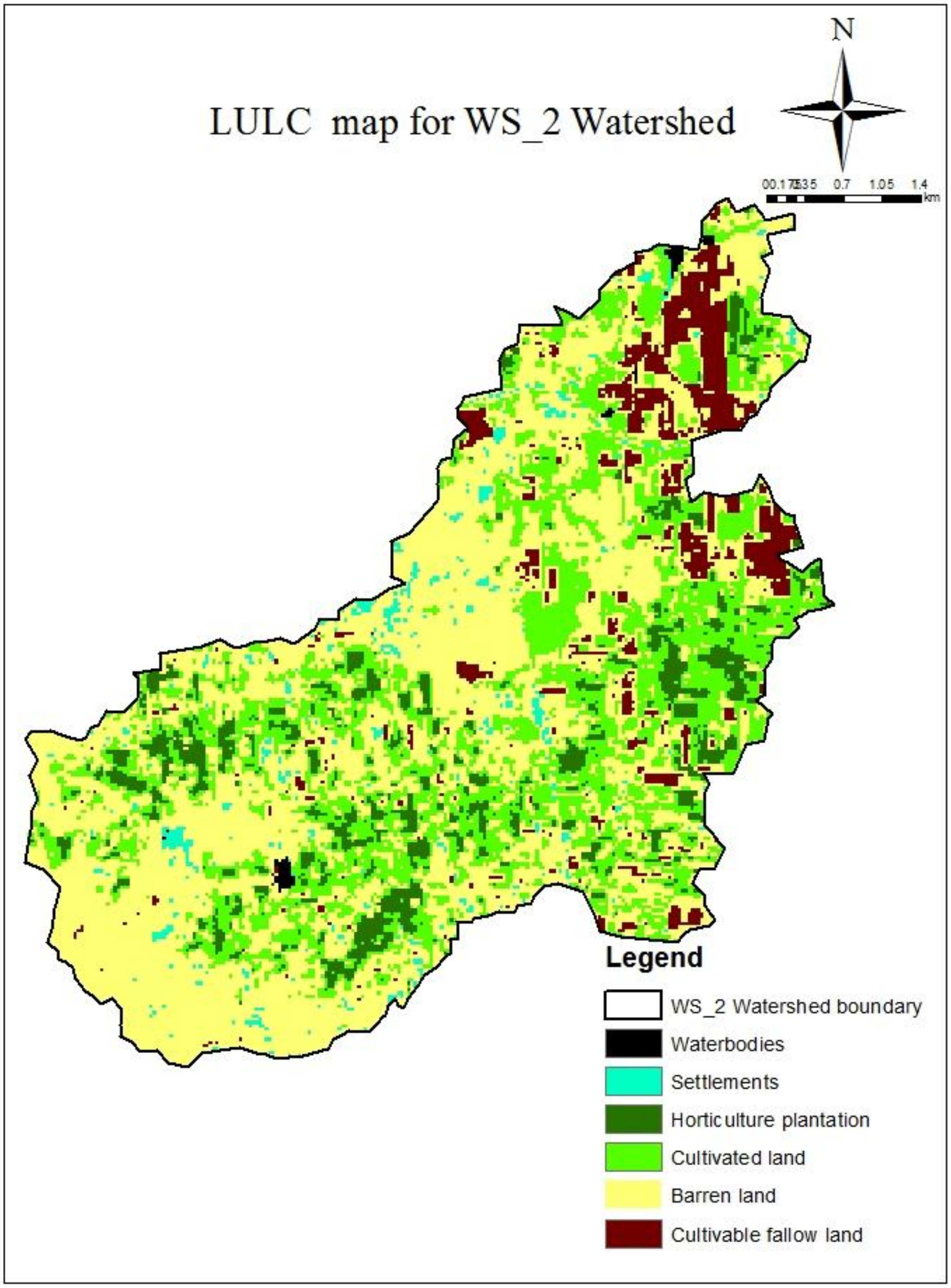


Fig.4.8 Land use/ Land cover map of WS_2 in 2017

4.4 Preparation of Soil Map

Soil map was obtained from National Bureau of Soil Survey and Land Use Planning, Nagpur. From soil map of Ahmednagar district the study areas soil was extracted using watershed boundary using extraction tool in Arc GIS 10.2.2. The existing attributes / properties are compared with Hydrological Soil Group properties. These attributes were then grouped into Hydrological Soil group (HSG) classes. The Hydrologic Soil Group (HSG) B, C and D was observed in both watersheds. The WS_1 watershed is having HSG B and WS_2 watershed was having HSG B with two polygons and HSG C and D with one polygon each. The HSG map of the study area is shown in Fig.4.9. The WS_1 watershed has only HSG B type of soil. Therefore total 1005.93 ha area is under HSG B. The watershed Ws_2 is having 48 % HSG B, 49 % HSG D and 3 % HSG C. In both the watersheds most soil is under HSG B. The Fig.4.9 also clearly shows it.

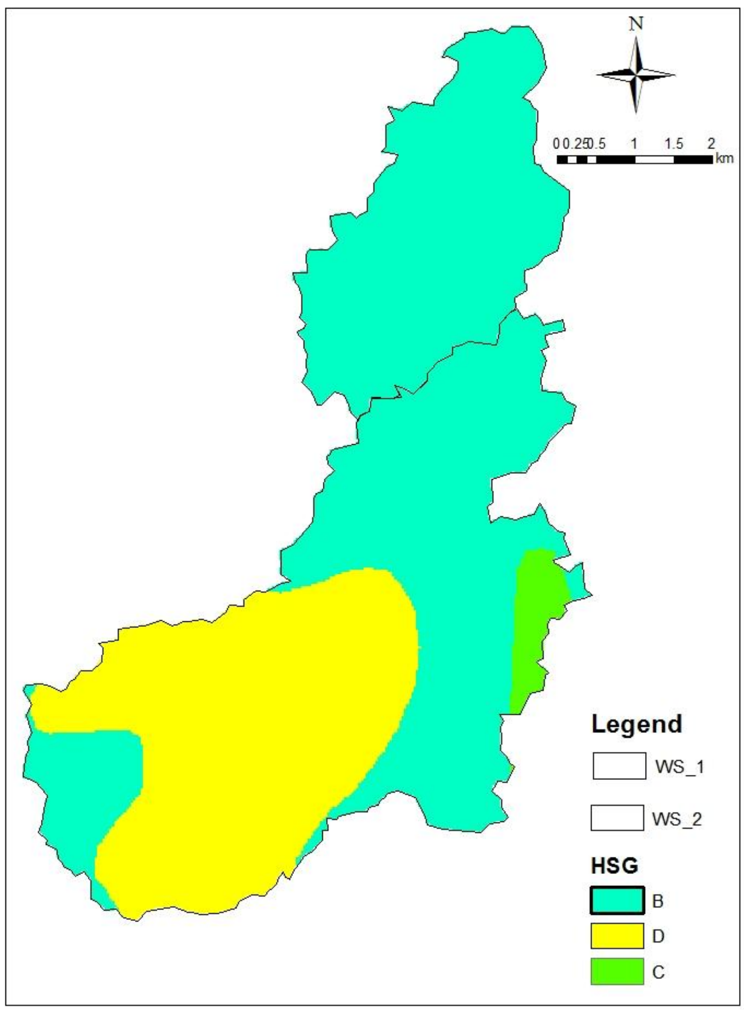


Fig.4.9 Hydrologic soil group map of the MPKV Central Campus (east) watersheds (WS_1 and WS_2)

4.5 Estimation of CN Value and Runoff

The Soil Conservation Services (SCS) model developed by United States Department of Agriculture (USDA) computes direct runoff through an empirical equation that requires the rainfall and watershed coefficient as input. The watershed coefficient is called the Curve Number (CN), which represents the runoff potential of land cover and soil complex. Land use/ land cover map and hydrologic soil group map were integrated in Arc GIS environment and CN map is generated. The daily rainfall data for the MPKV central campus was recorded by Water management Department, MPKV, Rahuri. By using this storm wise rainfall data runoff depth for each storm was calculated for both the watersheds. By using equation 4.11, weighed CN calculated for WS_1 was 80.59 and 81.86 for WS_2 which is shown in Table 4.3 and Table 4.4. CN map generated for the study area are shown in Fig.No.4.10 and Fig. 4.11 for WS_1 and WS_2 respectively.

Table 4.3 Weighed CN for WS_1 watershed

WS_1				
HSG Polygon	**Area (ha)**	**CN**	**Area*CN**	**Weighted CN**
B	2.88	100	288	80.59
	24.48	74	1811.52	
	43.02	81	3484.62	
	404.1	76	30711.6	
	439.2	86	37771.2	
	92.25	76	7011	
	1005.93		81077.94	

Table 4.4 Weighed CN for WS_2 watershed

WS_2				
HSG Polygon	**Area (ha)**	**CN**	**Area*CN**	**Weighted CN**
B(1)	1231.92	81.13	99945.67	81.86
B(2)	209.34	84.35	17657.83	
D	1352.43	82.35	111372.6	
C	94.32	78.96	7447.507	
	2888.01		236423.6	

4.6 Slope-Adjusted CN

Slope has profound impact on determination of CN values therefore incorporating slope values in CN and adjusting CN values accordingly is essential from hydrology point of view. To achieve this slope and CN maps were intersected to get slopes of each polygon. Slope adjusted CN values for

WS_1 and WS_2 watersheds were shown in Table 4.5. Slope adjusted CN calculated for WS_1 was 80.78 and 81.93 for WS_2.

Table .4.5 Slope adjusted CN values for MPKV Central Campus east watersheds

Sr.No.	Slope (Radian α)	Weighted CN	322.79+15.63α	α+323.52	(323.79+15.63α)/(α+323.52)	Slope adjusted CN
WS_1	0.1007	80.59	324.364	323.621	1.002	80.775
WS_2	0.0685	81.86	323.861	323.589	1.001	81.929

4.7 Runoff Estimation

Estimation of runoff is very essential factor for planning, management and monitoring of watersheds. In order to have accurate idea of available water runoff is to be computed. Runoff of the study area was calculated by SCS-CN method. In this method, several important characteristics of the watershed are used. Like land use /land cover, permeability and infiltration capacity of soil are taken. Different soils produce different volume of runoff according to the soil type. It can be expressed by numerical number which is called as Curve Number. The value of curve number varies from 0 to 100.

The thematic maps developed by using satellite data with the help of Arc GIS 10.2.2 software. Land use land cover calculated with percentage and shown in Fig.4.5 for WS_1 and Fig 4.6 for WS_2. Soil map in the study area was also prepared according to hydrologic soil group type as shown in Fig.4.9. Runoff is mostly depends upon amount of rainfall, initial abstraction & moisture content in the soil. The land use and land cover characteristics of the study area described using land use/land cover (LU/LC) maps and the statistics generated on this aspect. The LU/LC in the study area was classified in to six classes: (i) Water bodies (ii) Settlements (iii) Horticulture crop (iv) Cultivated land (v) Barren land and (vi) Cultivable fallow land.

CN map of WS_1 is shown in Fig.4.10 and CN map of WS_2 is shown in Fig.4.11. Weighed CN calculated for WS_1 was 80.59 and for WS_2 CN calculated was 81.86. Modified slope adjusted CN for watershed WS_1 is 80.78 and 81.93 for WS_2. Soil moisture retention for WS_1 watershed was 60.47 mm and for WS_2 watershed 56.05 mm. Runoff depths for the year 2017 for WS_1 watershed was 169.52 and for WS_2 runoff depth was 180.25 m, respectively.

Table 4.6 Soil moisture retention and runoff for the MPKV Central Campus East Watersheds

Sr.No.	Weighted CN	Slope adjusted CN	Soil moisture retention (mm)	Runoff Depth (mm)
WS_1	80.59	80.78	60.47	169.52
WS_2	81.86	81.93	56.05	180.25

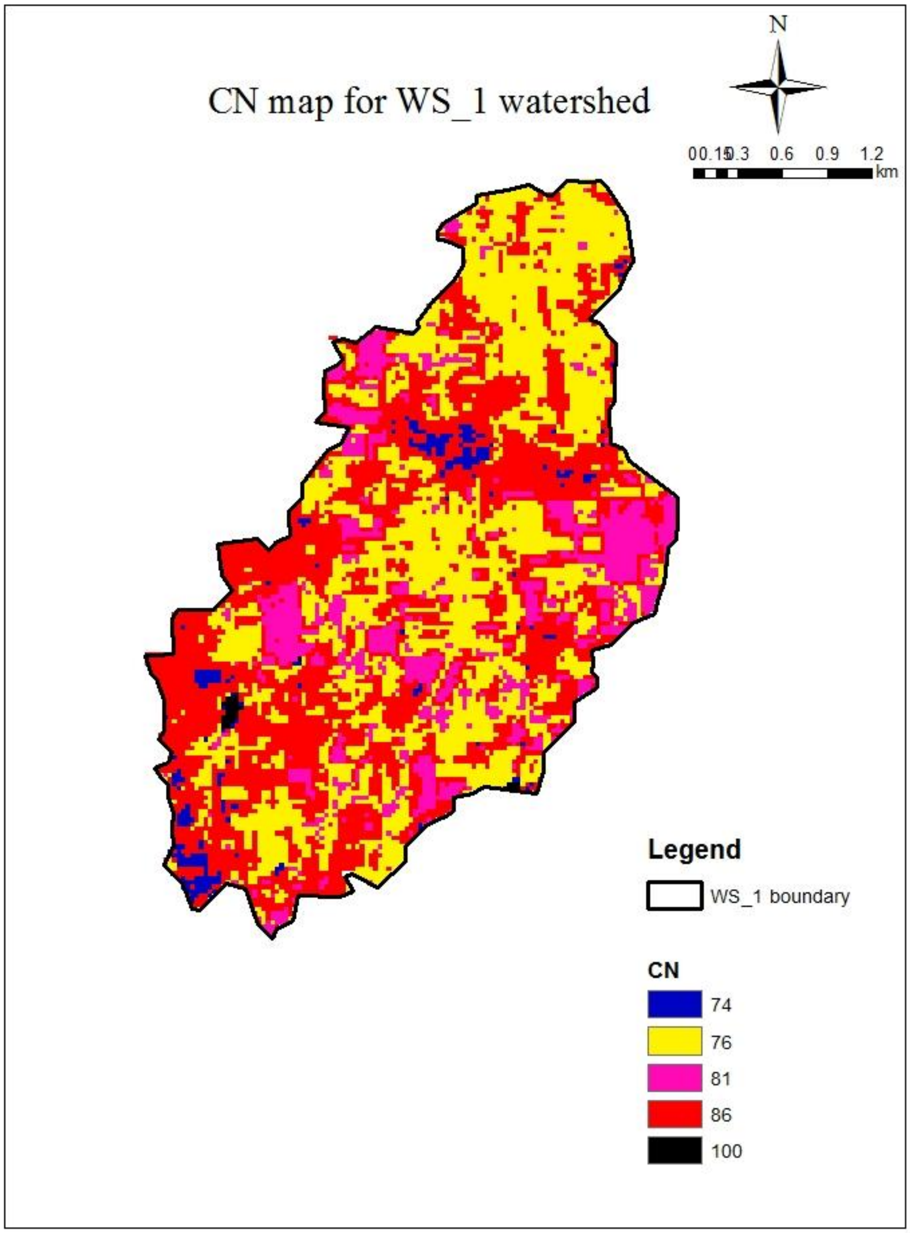


Fig.4.10 Curve number map of WS_1 watershed

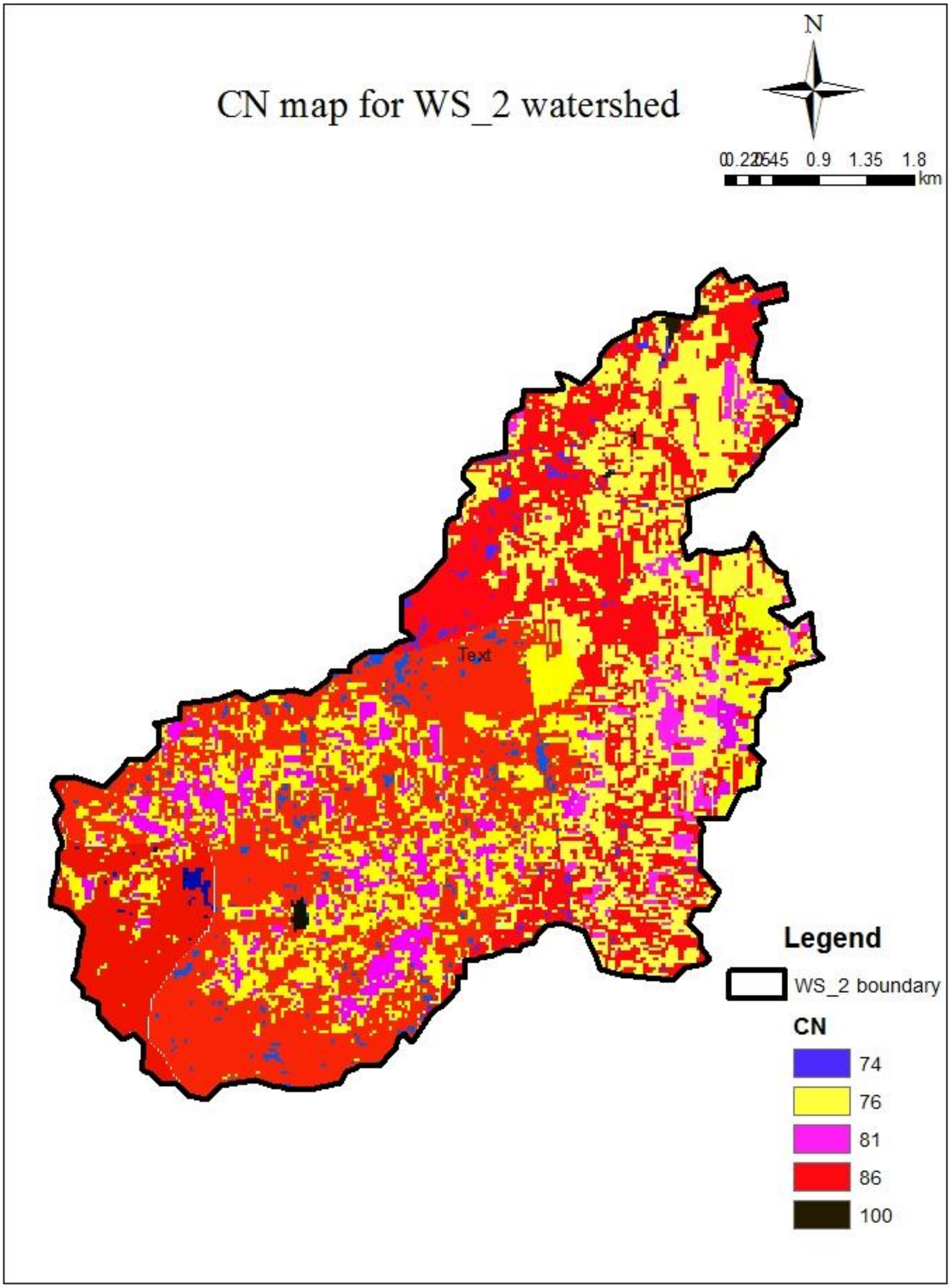


Fig.4. 11 Curve number map of WS_2 watershed

4.8 Estimation of Sediment Yield

The Revised Universal Soil Loss Equation (RUSLE) (Renard *et. al*, 1997) is a modified and revised version of Universal Soil Loss Equation (USLE) suggested by Wischmeier and Smith, 1978, originally developed to predict erosion on croplands in the United States.

4.8.1 Rainfall Erosivity factor (R factor)

Rainfall erosivity is ability of the rain to cause erosion, measured in MJ mm ha^{-1} h^{-1}year^{-1}. The rainfall distribution is not homogeneous all over the study area, for this reason an interpolation of annual precipitation data was applied (using IDW interpolation technique) to have a more representative rainfall distribution. The precipitation data from 14 stations were used for estimating the average annual precipitation. Annual rainfall of all 14 stations is presented in Table 4.7.

Table 4.7 Annual rainfall depth of 14 tehsils in Ahmednagar district for the year 2017

Tehsil	Latitude	Longitude	Rainfall (mm)
Ahmednagar	19.0952°N	74.7496°E	542
Parner	19.0001°N	74.4394°E	456
Shrigonda	18.6175°N	74.6981°E	360
Karjat	18.5522°N	75.0101°E	370
Jamkhed	18.7380°N	75.3121°E	633
Shegaon	19.0952°N	74.7495°E	547
Patherdi	19.1761°N	75.1750°E	470
Newasa	19.5512°N	74.9281°E	522
Rahuri	19.3927°N	74.6488°E	638
Sangamner	19.5771°N	74.2080°E	523
Akole	19.5406°N	74.0054°E	464
Kopargoan	19.8917°N	74.4791°E	341
Shrirampur	19.6222°N	74.6576°E	557
Rahata	19.7127°N	74.4833°E	311

The rainfall erosivity factor values were calculated by Inverse Distance weighted (IDW) technique with the use of rainfall data from 14 tehsils of Ahmednagar district. The interpolation was performed with the use of spatial analyst tool of Arc GIS toolbox. The rainfall erosivity factor map of watershed WS_1 and Watershed WS_2 are shown in Fig.4.12 and Fig.4.13 respectively. Fig. 4.12 shows that rainfall erosivity factor for WS_1 varies from 242.3 to 245.4 MJ mm ha^{-1} h^{-1}year^{-1}

whereas Fig.4.13 for WS_2 watershed rainfall erosivity factor varies from 244.7 to 251.7 MJ mm ha^{-1} $h^{-1}$$year^{-1}$.

R-factor values for the study area tending higher values at south and south-west part of the watershed and gradually decreasing down to north part of the study area. This shows that the value of R-factor varies according to rainfall distribution.

The spatial distribution of erosivity factor (R) ranges from 185 to 2990 (Fig.6). It is high in Konkan Coast and Western Ghat area (900-2990). The high erosivity in this region could be attributed to the orographic high intensity rains received during the South-West monsoon. The annual rainfall in these areas ranged from 2000-6000 rom and mostly received during June to September. While the rain shadow region comprising Western and Central part of Maharashtra receives 450 to 600 mm rainfall and has low R-values.

4.8.2 Soil erodibility factor (K factor)

The K factor accounts for the susceptibility of soil particles to detachment and movement by water (Romkens *et al*., 1997). Soil erodibility index (g / J) is the weight of soil detached from the soil mass per unit of rainfall energy. K factor reflects the fact that different soil erodes at different rate when the other factors affecting erosion remains same. Soil texture is the principal cause affecting the K-factor along with soil structure, organic matter content and permeability. K factor map was obtained from the soil erodibilty map prepared for MPKV central campus, Rahuri.(Atre and Damale, 1997). Soil map of MPKV central campus prepared by department of Soil Science and Agriculture Chemistry was geo-referenced in Arc GIS software. By comparing the soil erodibility map and soil map for the study area 16 points were selected and new shapefile of point feature was created. These 16 points were assigned with their soil erodibility factor and soil series in their attribute table. K factor maps were prepared for the Study area by using interpolation technique in spatial analyst tool which is depicted in Fig.No.4.14 and 4.15. For WS_1 watershed, K factor ranged between 0.1 to 0.24 t h MJ^{-1} mm^{-1} and 0.03 to 0.24 t h MJ^{-1} mm^{-1} for WS_2.

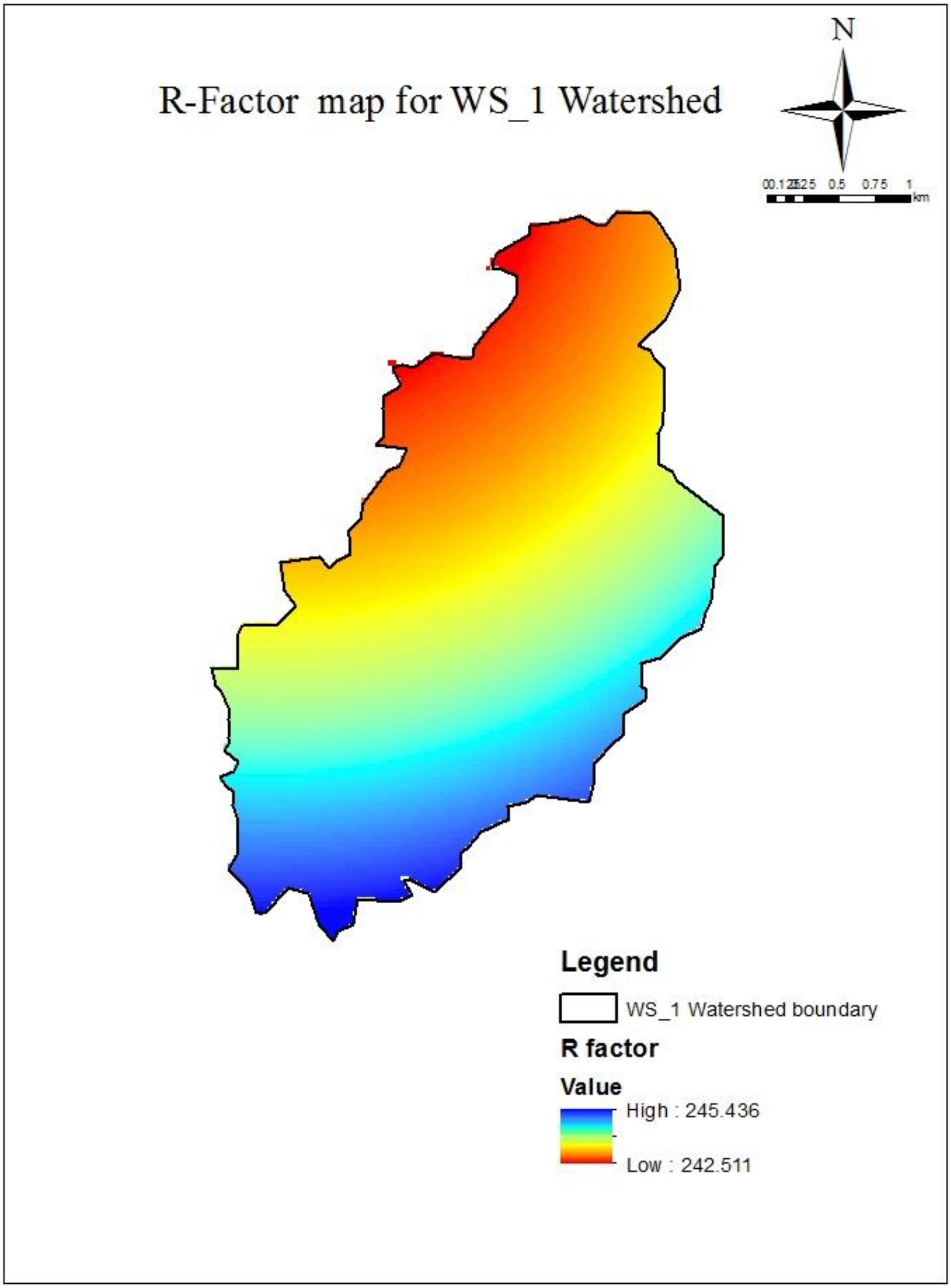


Fig.4.12 Rainfall erosivity factor map of WS_1 watershed

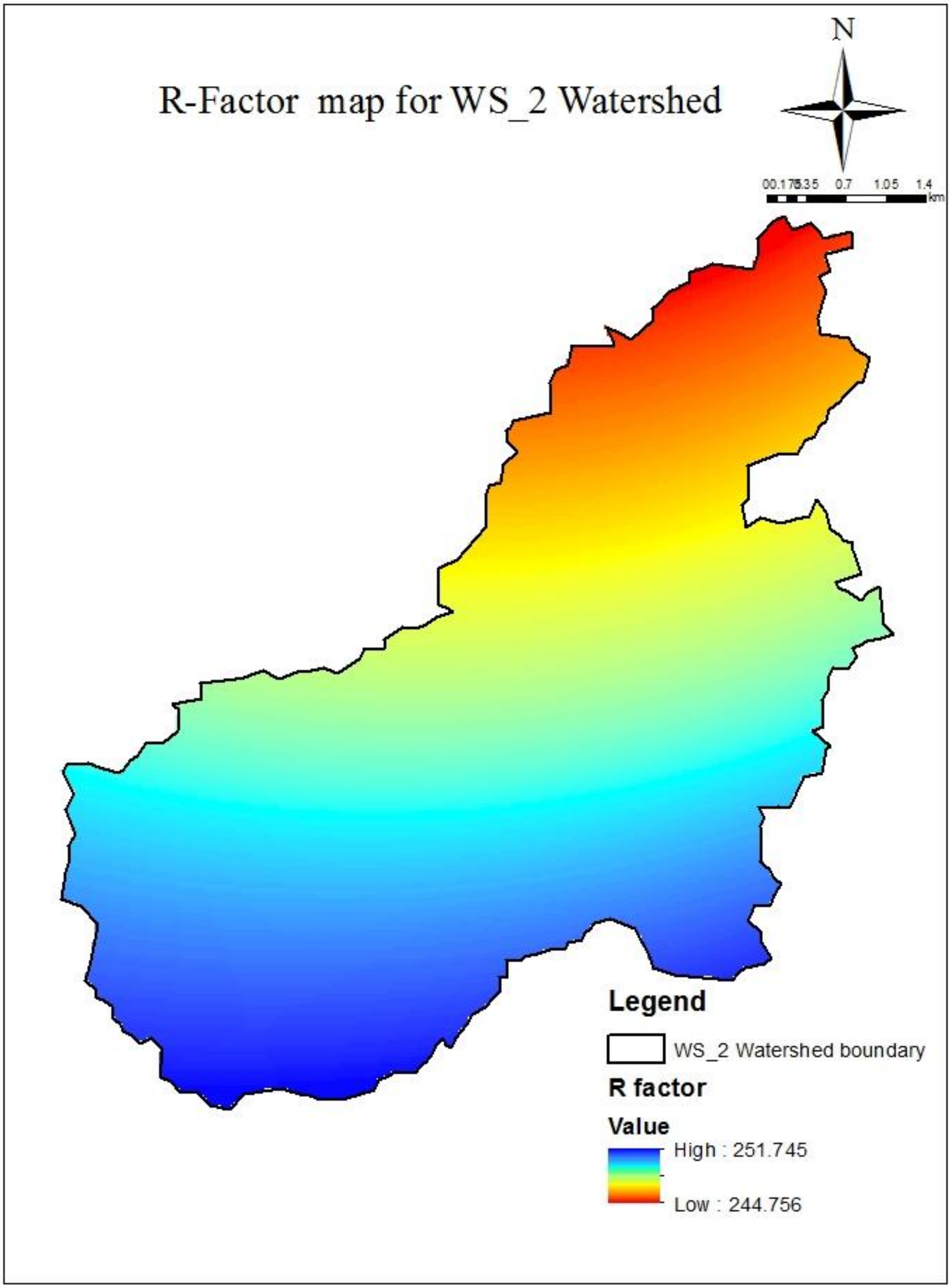


Fig.4.13 Rainfall erosivity factor map of WS_2 watershe

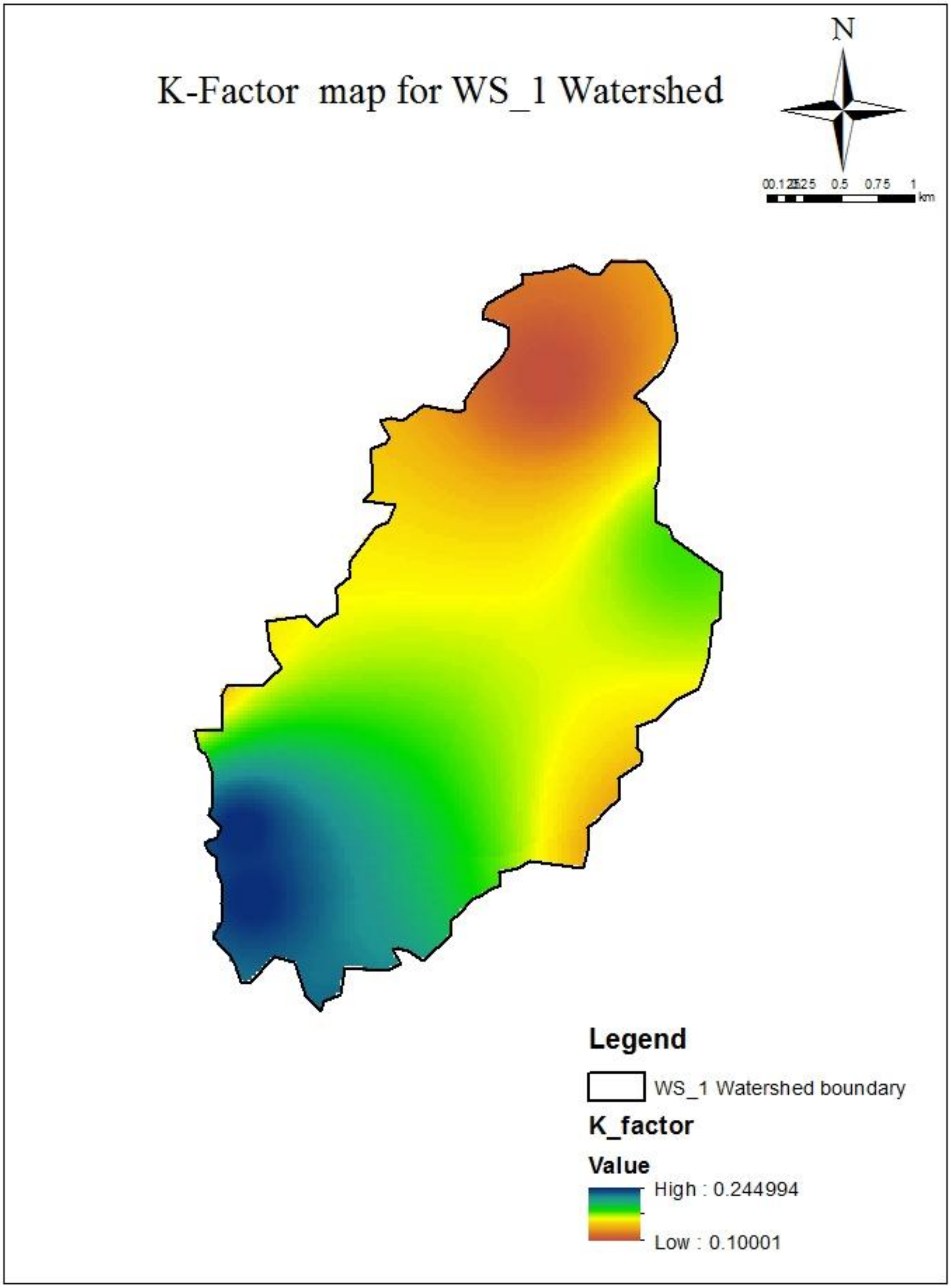


Fig.4.14 Soil erodibility factor map of WS_1 watershed

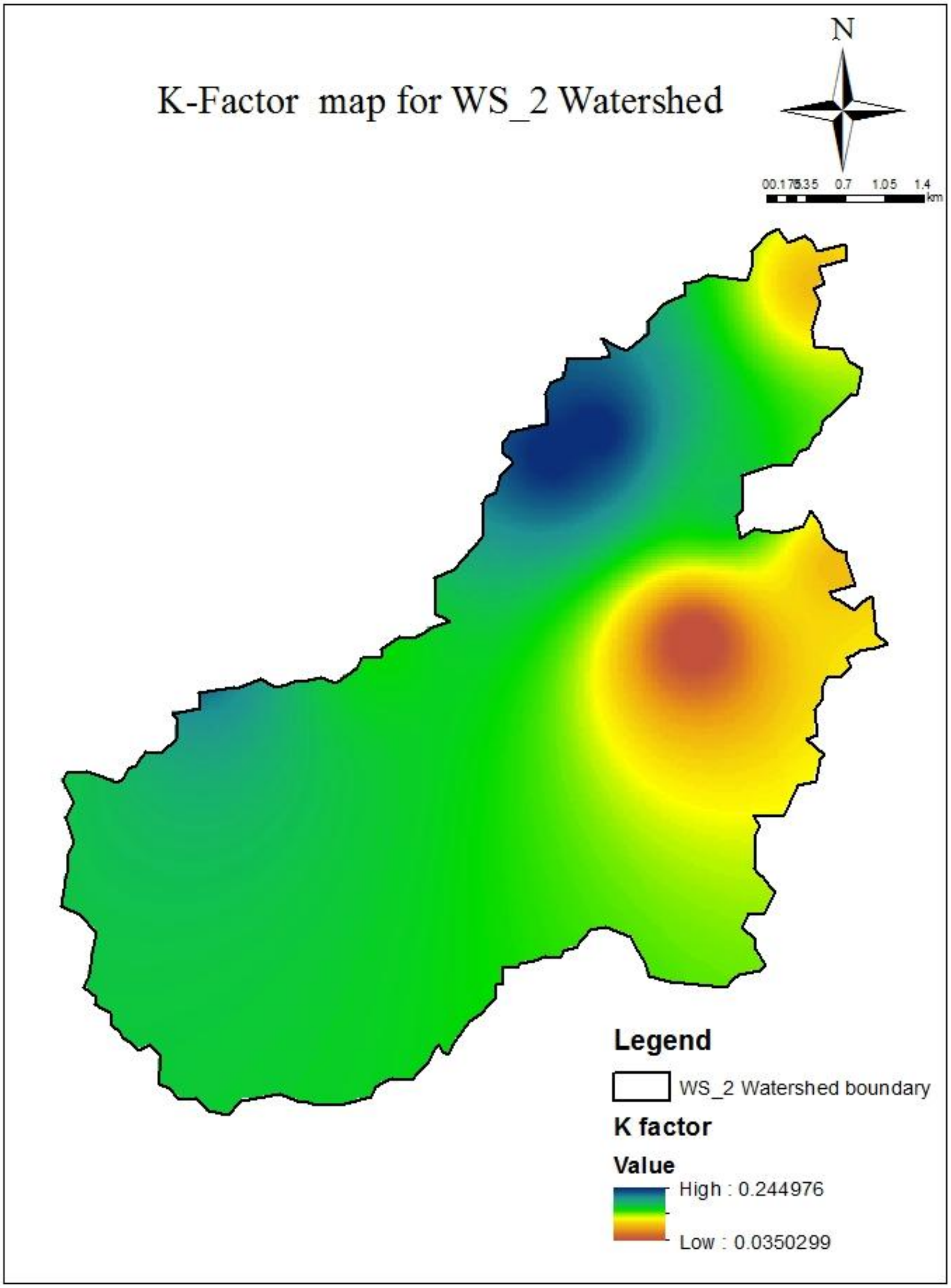


Fig.4.15 Soil erodibility factor map of the WS_2 watershed

4.8.3 Slope length and slope steepness factor (LS factor)

LS factor is also called as topographic factor which is calculated by using Digital Elevation Model (DEM). ASTER DEM having 30 m resolution was downloaded from earth explorer. Fill maps for both watersheds were generated from ASTER DEM which are depicted in Fig.4.16 and Fig.4.17 for WS_1 and WS_2 respectively. Filling a DEM can be described as identifying artificial sinks (cells that have a lower elevation value than the surrounding cells) and giving them a higher elevation value (Jennings, 2001). When the sinks were filled the area is given an average value, which was calculated using the value of the neighboring cells. Hydrology functions in Arc GIS were used to derive topographical factor. Flow direction map was generated from fill map and further flow accumulation map was generated by using flow direction map. The slope map for the study area was generated from the ASTER DEM. The slope map of the watersheds WS_1 and WS_2 are shown in Fig.4.20 and Fig.4.21 respectively. The watershed WS_1 is having 0 to 25 slope in percentage rise form and 0 to 51 for WS_2. Higher slopes are concentrated at south-west corner of watershed whereas it is gradually decreasing towards north-East side of watershed. Flow accumulation maps were generated from flow direction mapwhich is further used to generate LS-factor map. Flow accumulation map Showed the accumulation of runoff. Slope length is defined as the horizontal distance from the origin of overland flow to a point where deposition begins, or runoff becomes concentrated in a defined channel (Renard *et al.*,1997). The values of the slope length and slope steepness are derived from flow accumulation map and slope map. LS factor in RUSLE reflects topography. The LS factor in the present study was computed for overland cell by using equation given by Moore and Wilson (1992). Slope length and slope gradient values gives LS factor. For WS_1 watershed LS factor ranges from 0 to 0.13 and for WS_2 topographic factor ranges from 0 to 1.31. Flow accumulation map and slope map of watersheds were used for runoff estimation of slope length and slope steepness factor of the watershed.

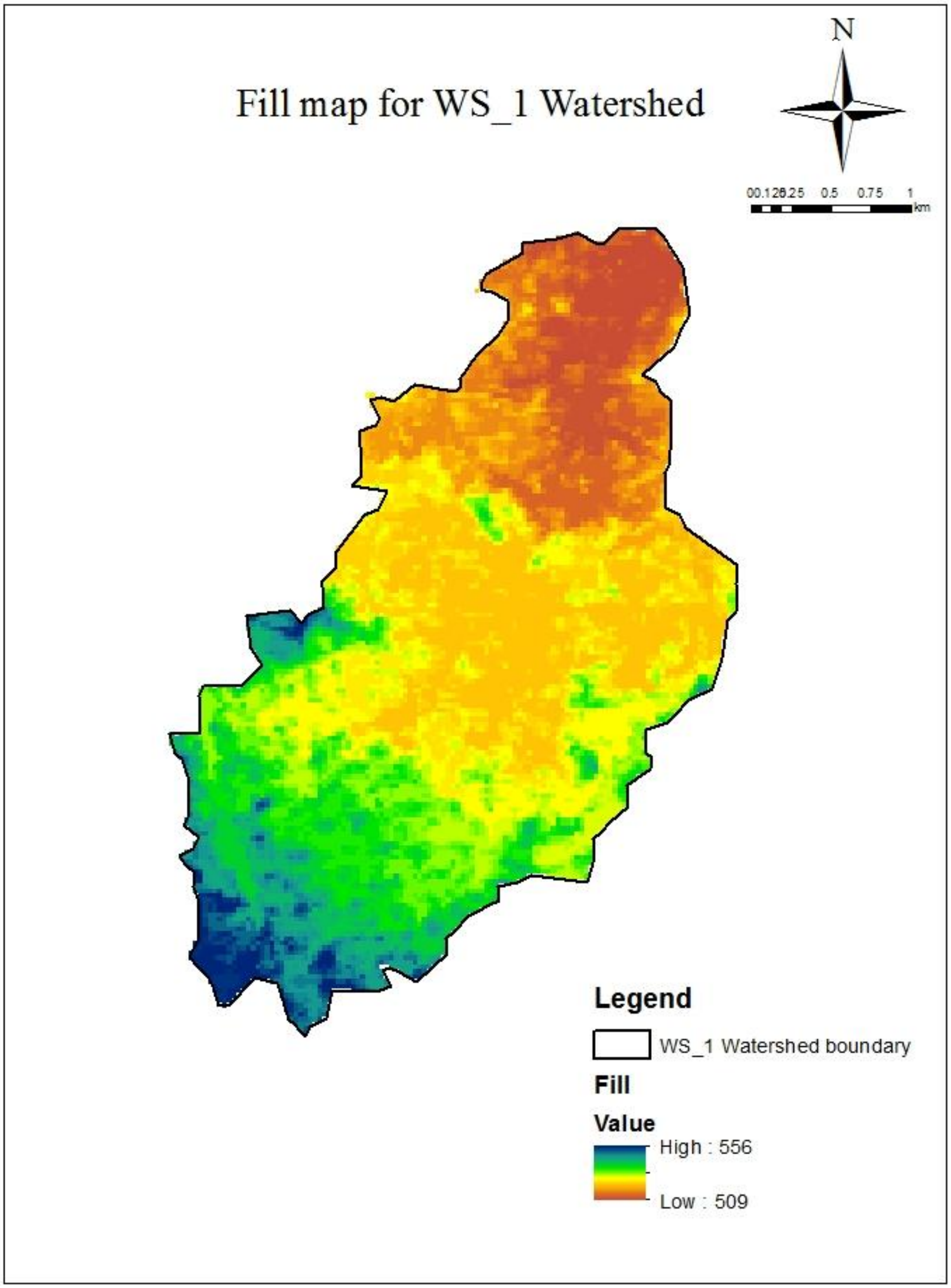


Fig.4.16 Fill map of WS_1 watershed

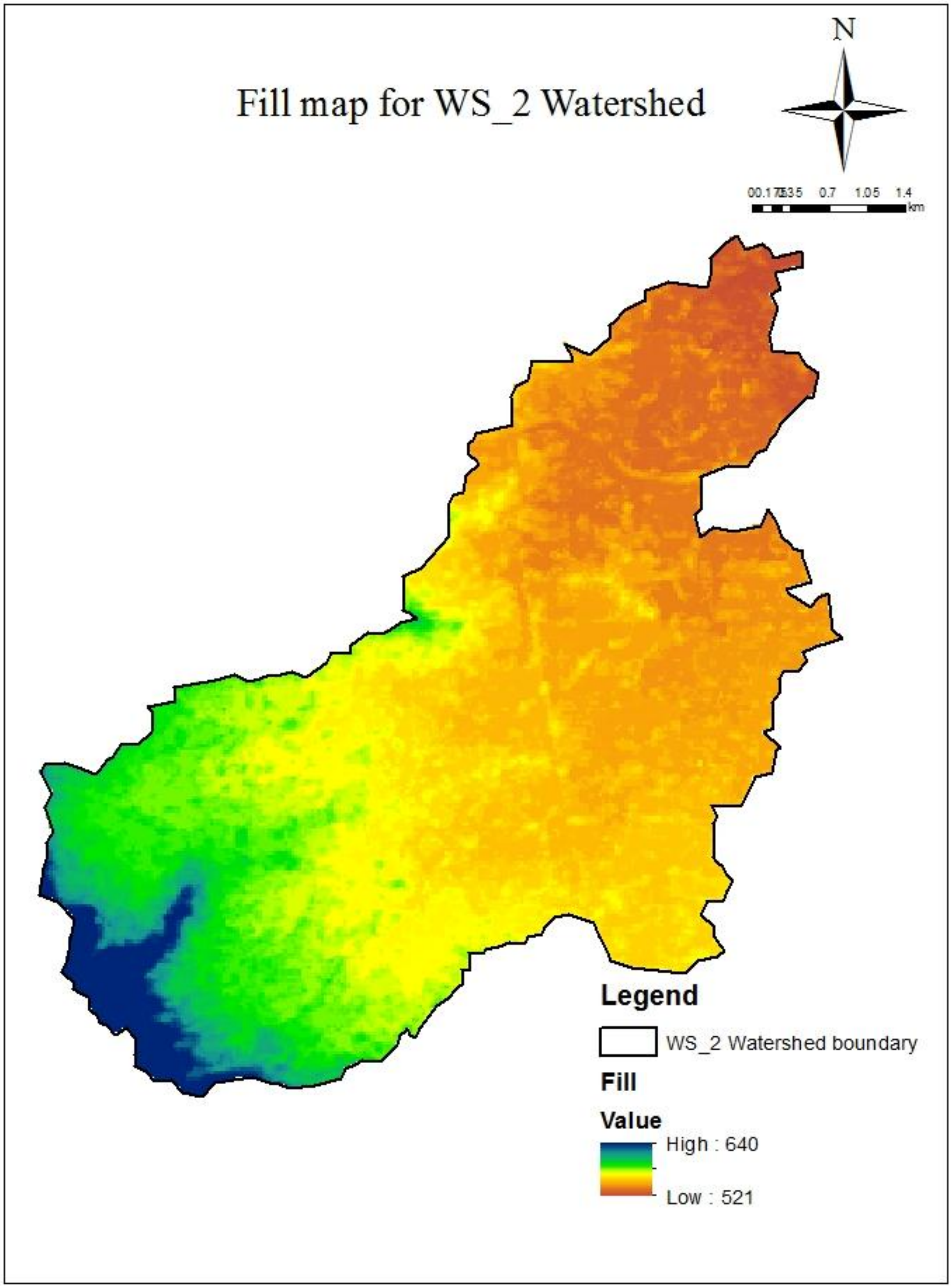


Fig.4.17 Fill map of WS_2 watershed

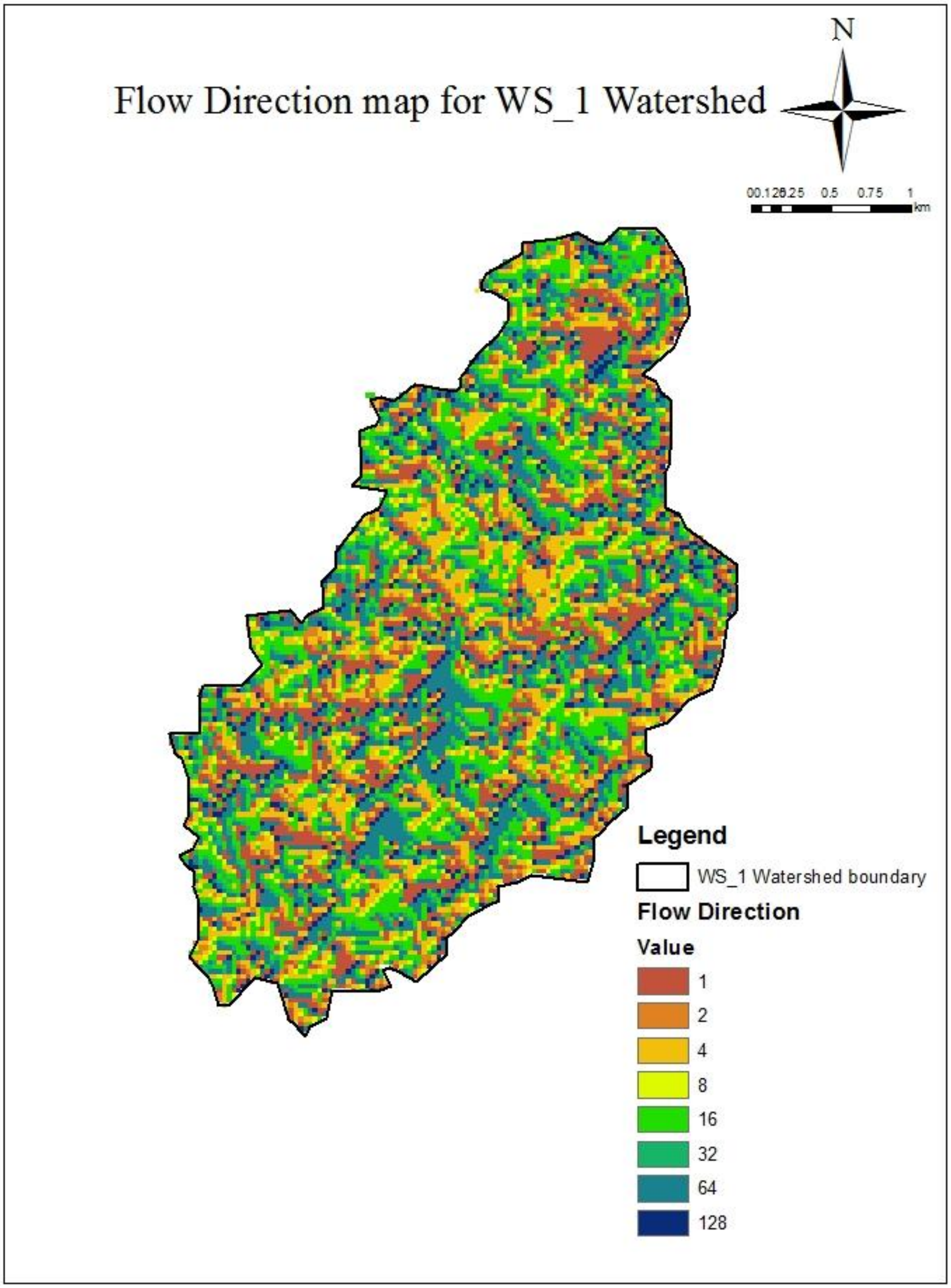


Fig.4.18 Flow direction map of WS_1 watershed.

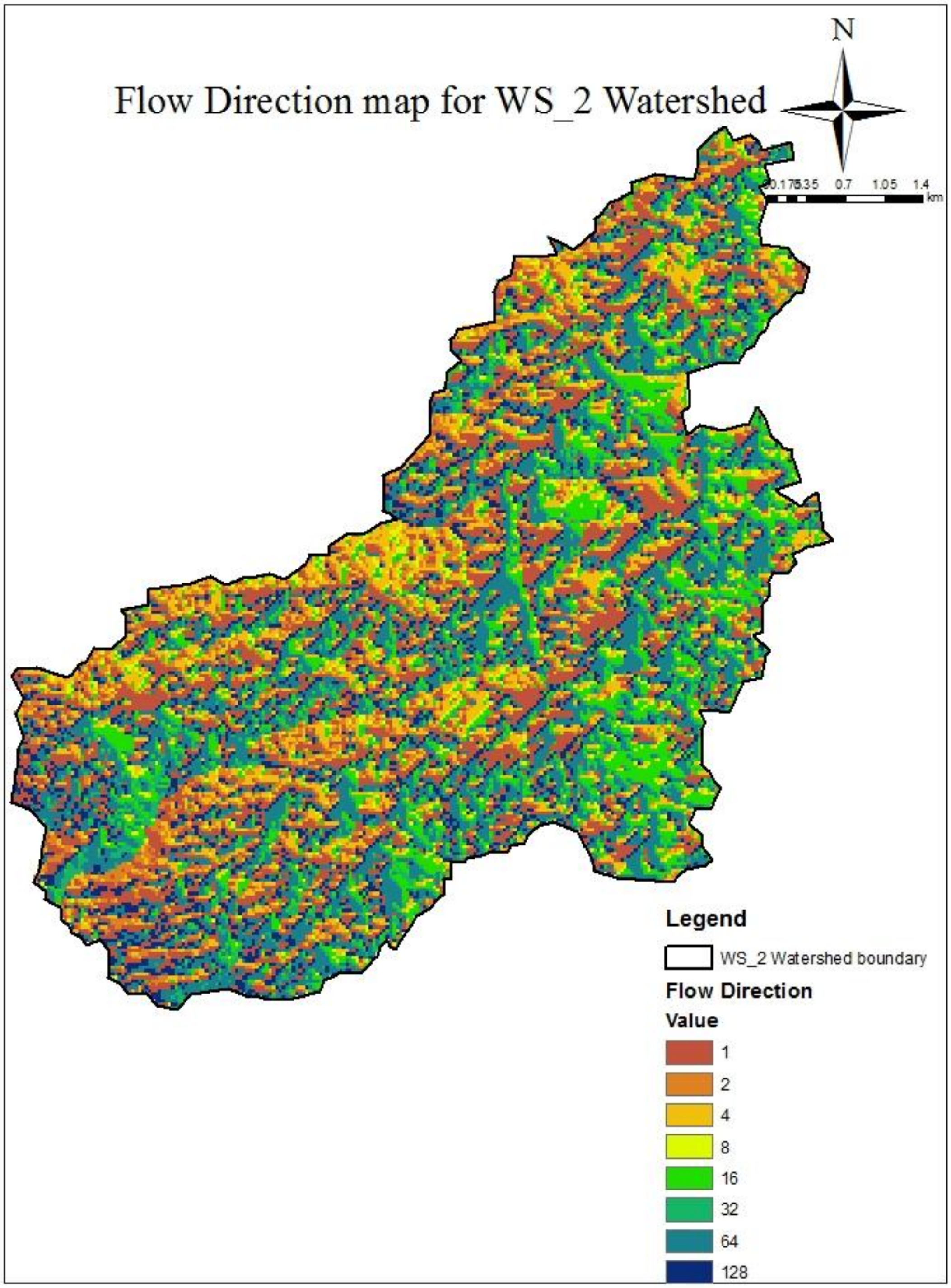


Fig.4.19 Flow direction map of WS_2 watershed

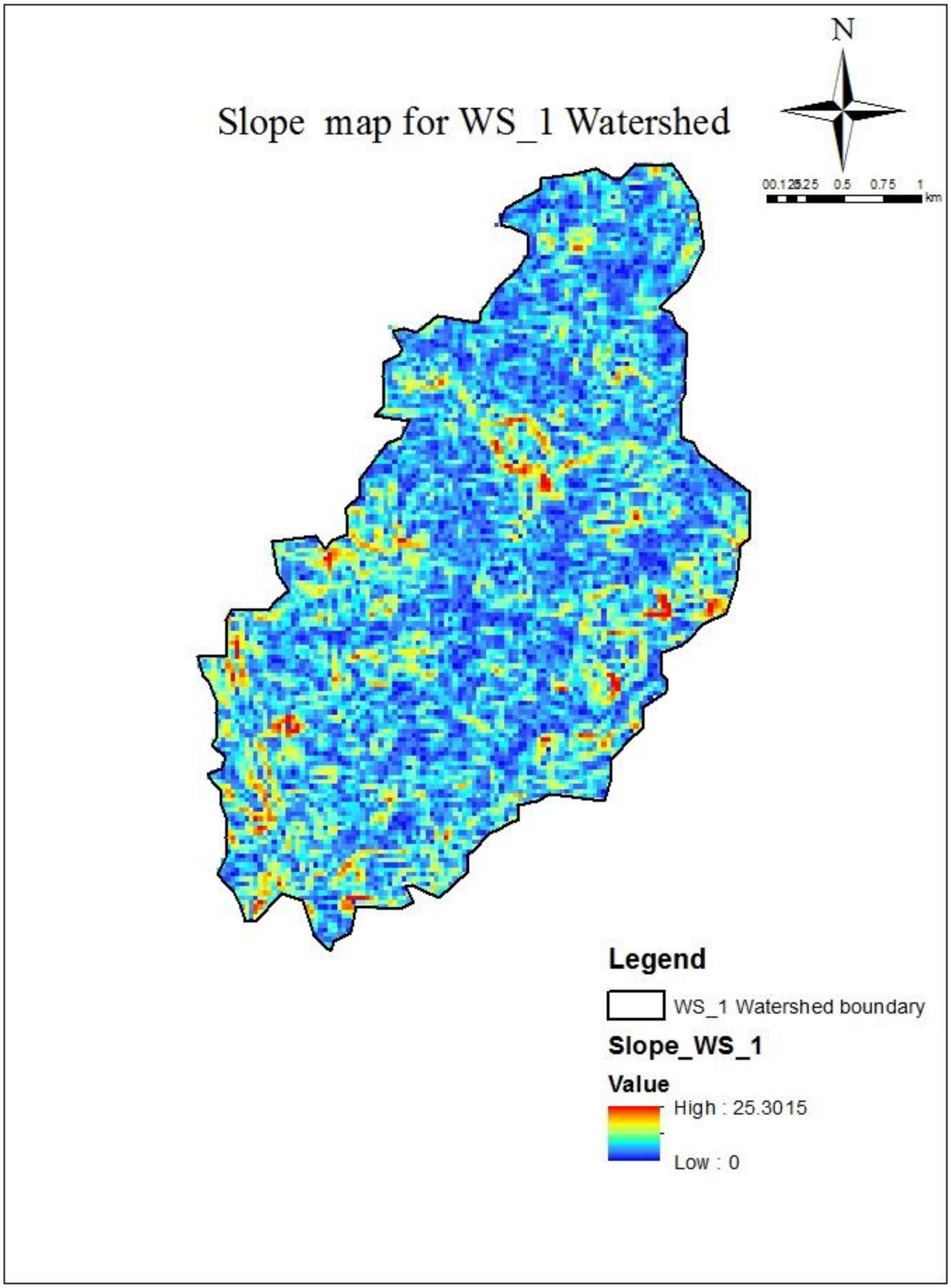


Fig.4.20 Slope map of the WS_1 watershed

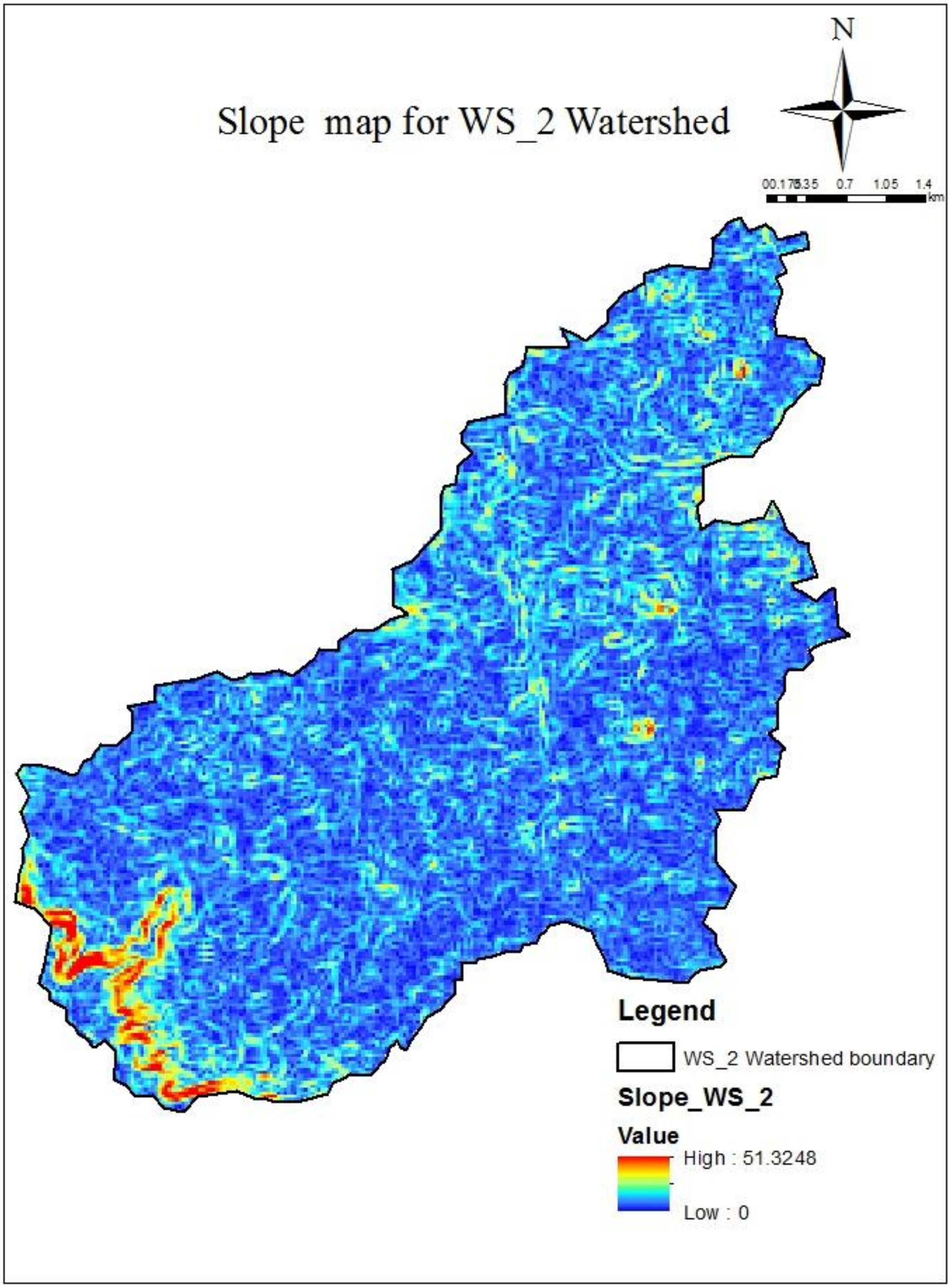


Fig.4.21 Slope map of the WS_2 watershed

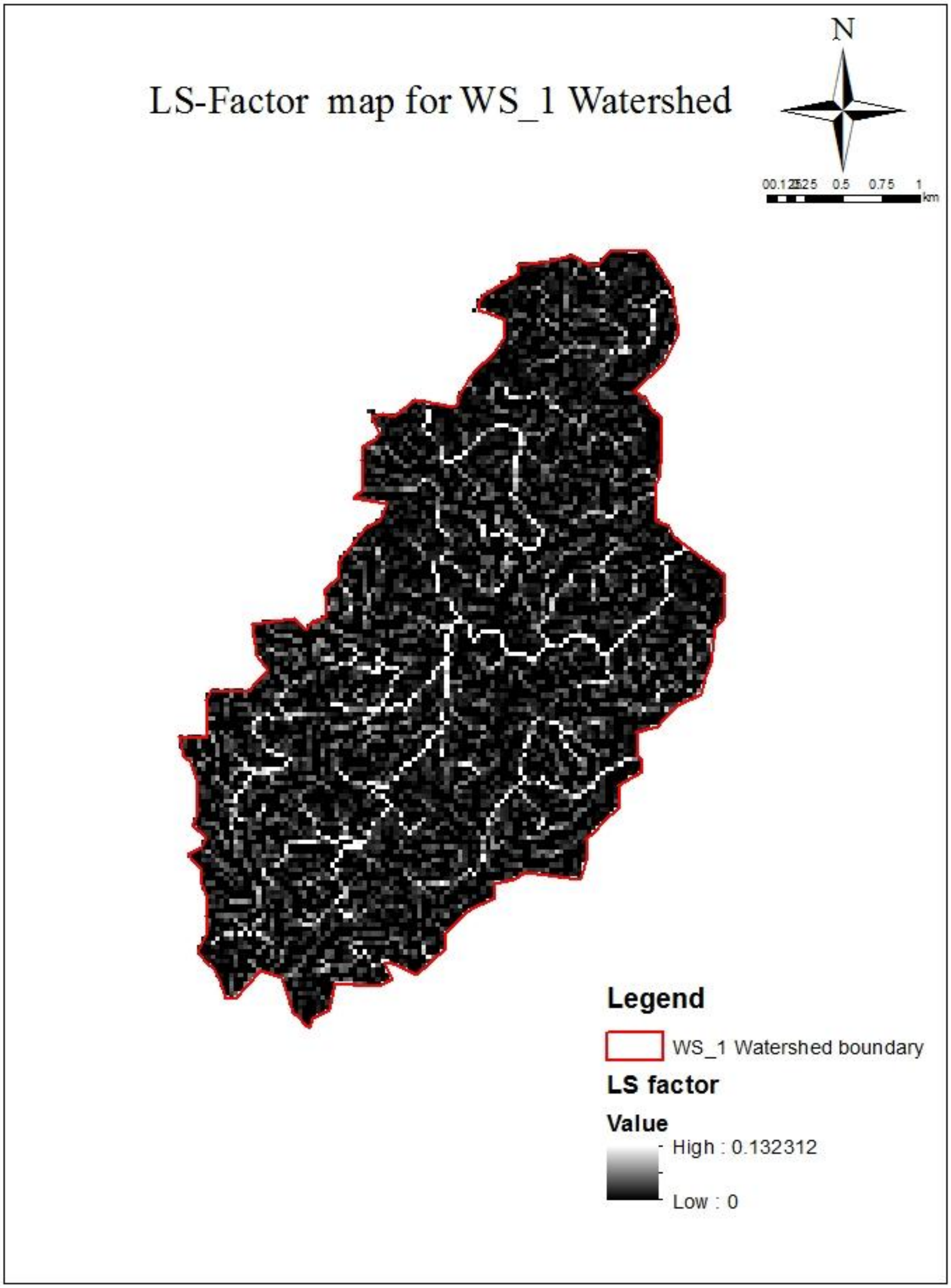


Fig.4.22 LS factor map of WS_1 Watershed

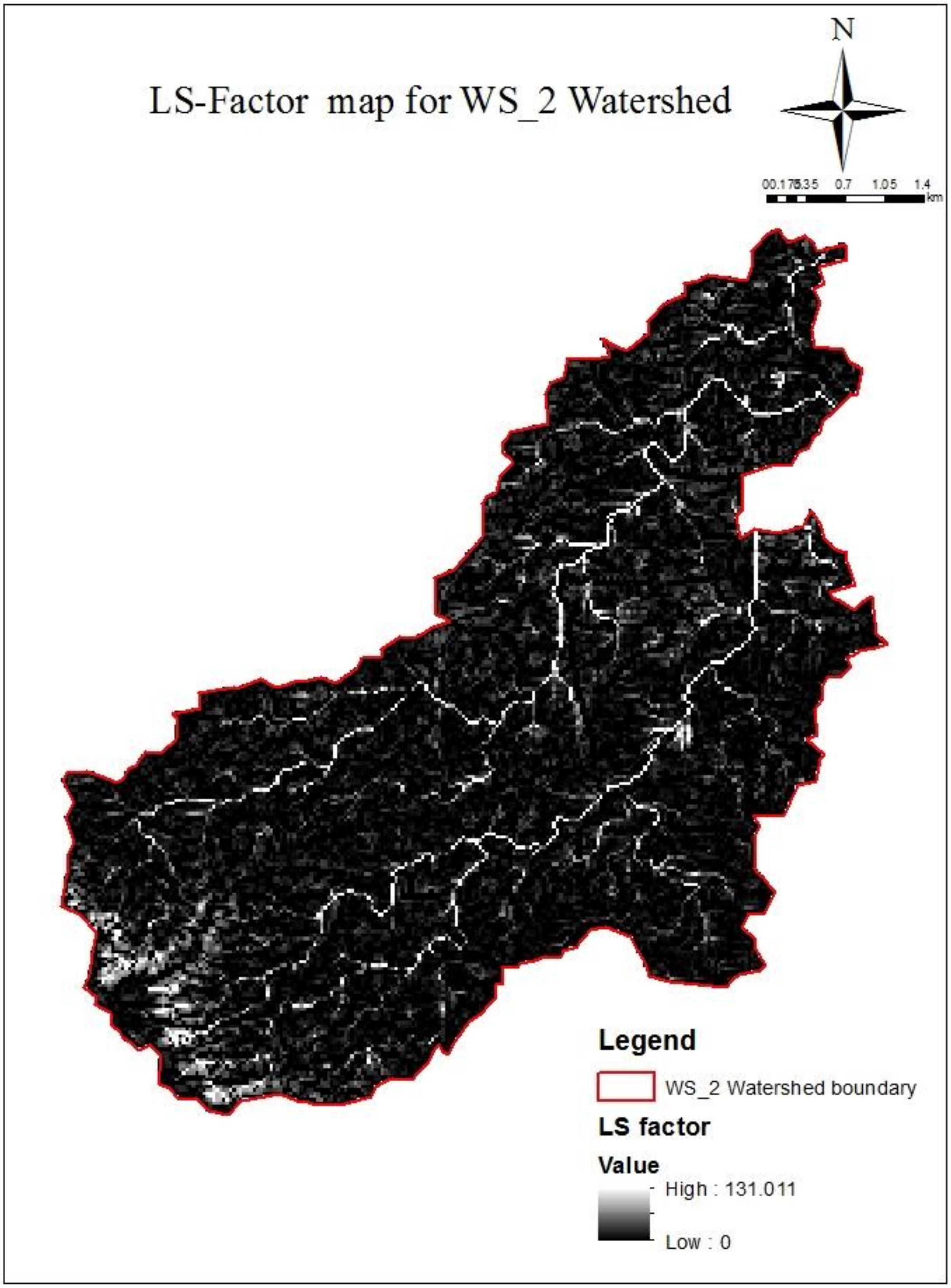


Fig. 4.23 LS factor map of WS_2 Watershed

4.8.4 Crop management factor (C factor)

The remote sensing technique is very good for forecasting and mapping of the vegetative growth condition. The vegetative cover is shown as vegetative indices. Vegetation index is a representation of crop growth condition and development. The Normalized Difference Vegetation Index (NDVI), measures the amount of green vegetation. The spectral reflectance difference between Near Infrared (NIR) and Red (R) is used to calculate NDVI. NDVI image of MPKV central campus (east) watersheds was generated from Band 4 and Band 5 as imagery is from LANDSAT 8 satellite. For NDVI calculation, Near Infrared Radiation (NIR) and Red band were used for generation of NDVI map. The NDVI values generally ranges from -1 to +1. The NDVI map of watershed WS_1 and WS_2 shown in Fig. 4.24 and 4.25 respectively. From NDVI image crop management factor is derived from the regression model in raster calculator tool of the spatial analyst extension of Arc GIS software. From Fig. 4.24 it is clear that NDVI value for WS_1 ranges from -0.02 to 0.50 whereas for WS_2 it ranges from -0.06 to 0.54. The NDVI values less than zero indicates water and other non-vegetated features, so the negative values are not considered in preparing the C-factor equation. Crop management factor ranges from 0 to 1. For MPKV central campus (East) watersheds, Crop management factor is calculated from regression model formula in raster calculator tool of Arc GIS 10.2.2. For WS_1 C factor ranges from 0.24 to 0.51 and for WS_2, C factor ranges from 0.22 to 0.53 which is shown in Fig.4.26 and Fig.4.27.

4.8.5 Conservation Practices Factor (P factor)

The supporting practice P-factor describes the effects of practices such as contouring, strip cropping, terraces, sediment basins, grass hedges and surface drainage. Supporting practices typically affect erosion by redirecting runoff around the slope so that it has less erosivity or by slowing down the runoff to cause deposition. The lower the P factor value, the more effective the conservation practice is deemed to be at reducing soil erosion. If there are no support practices, the P factor is 1.0. In this study area, slope map of the study area was reclassified according the defined intervals according to support practice factor according to cultivation method and slope. Total area is divided into 5 classes i.e. 0 to 7 %, 7 to 11.3%, 11.3 to 17.6 %, 17.6 to 28.8 % slope and another class was slope greater than 28.8 %. For WS_1 P factor calculated was 0.55 to 0.9 and for WS_2 watershed P factor ranges from 0.55 to 1.0 which is shown in fig 4.28 (WS_1) and fig 4.29 (WS_2).

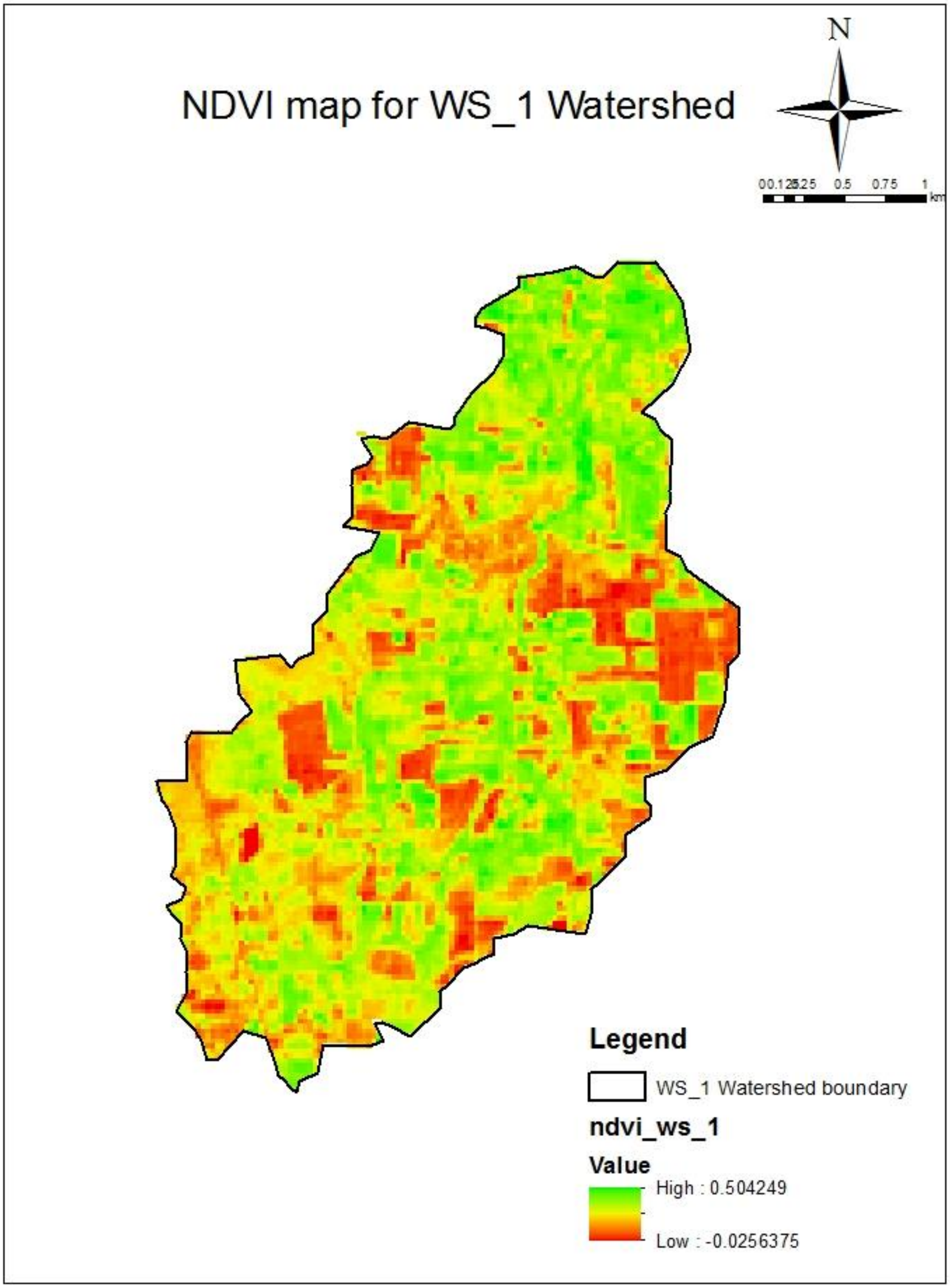


Fig.4.24 NDVI map of WS_1 watershed

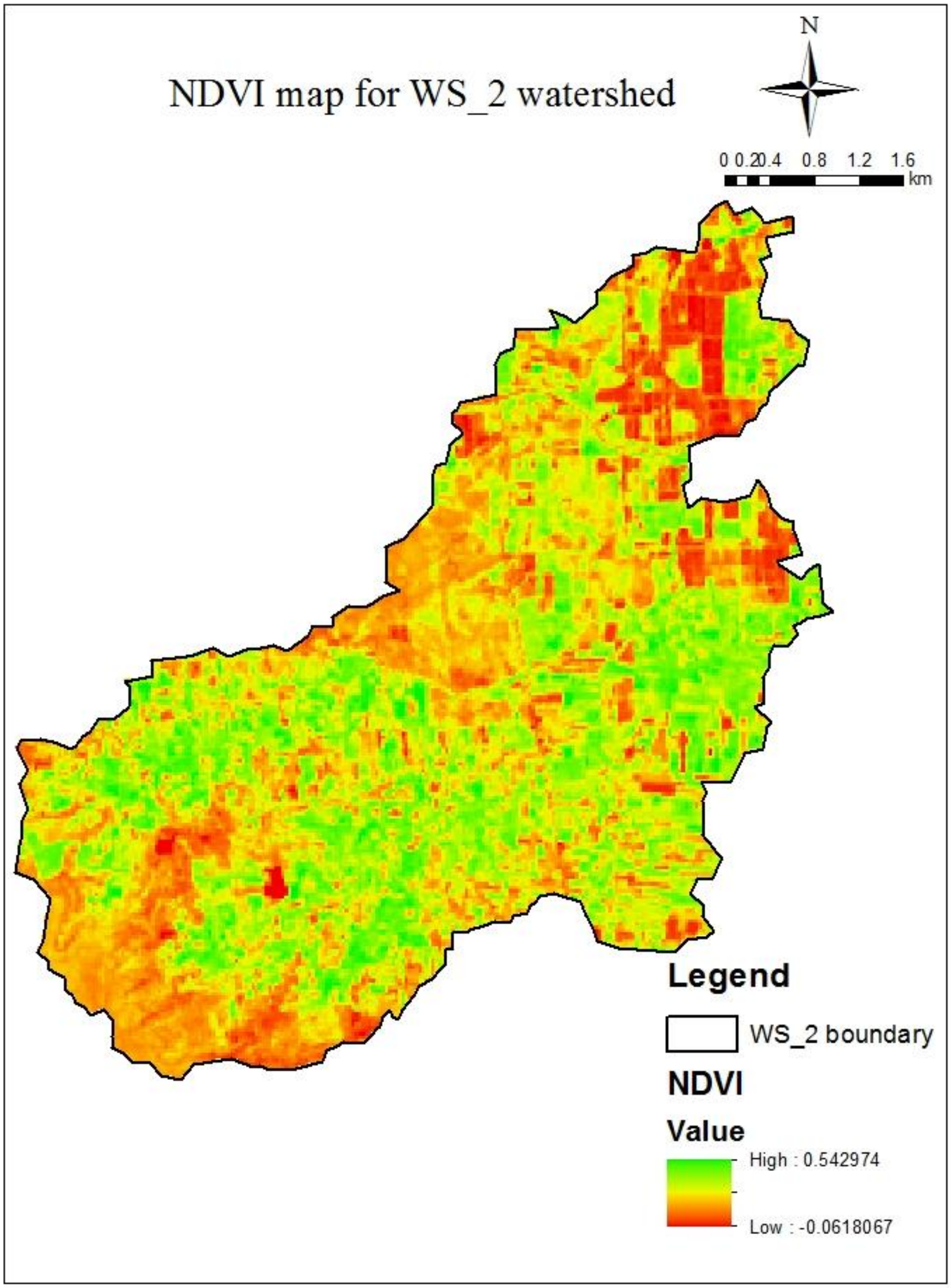


Fig.4.25 NDVI map of WS_2 watershed

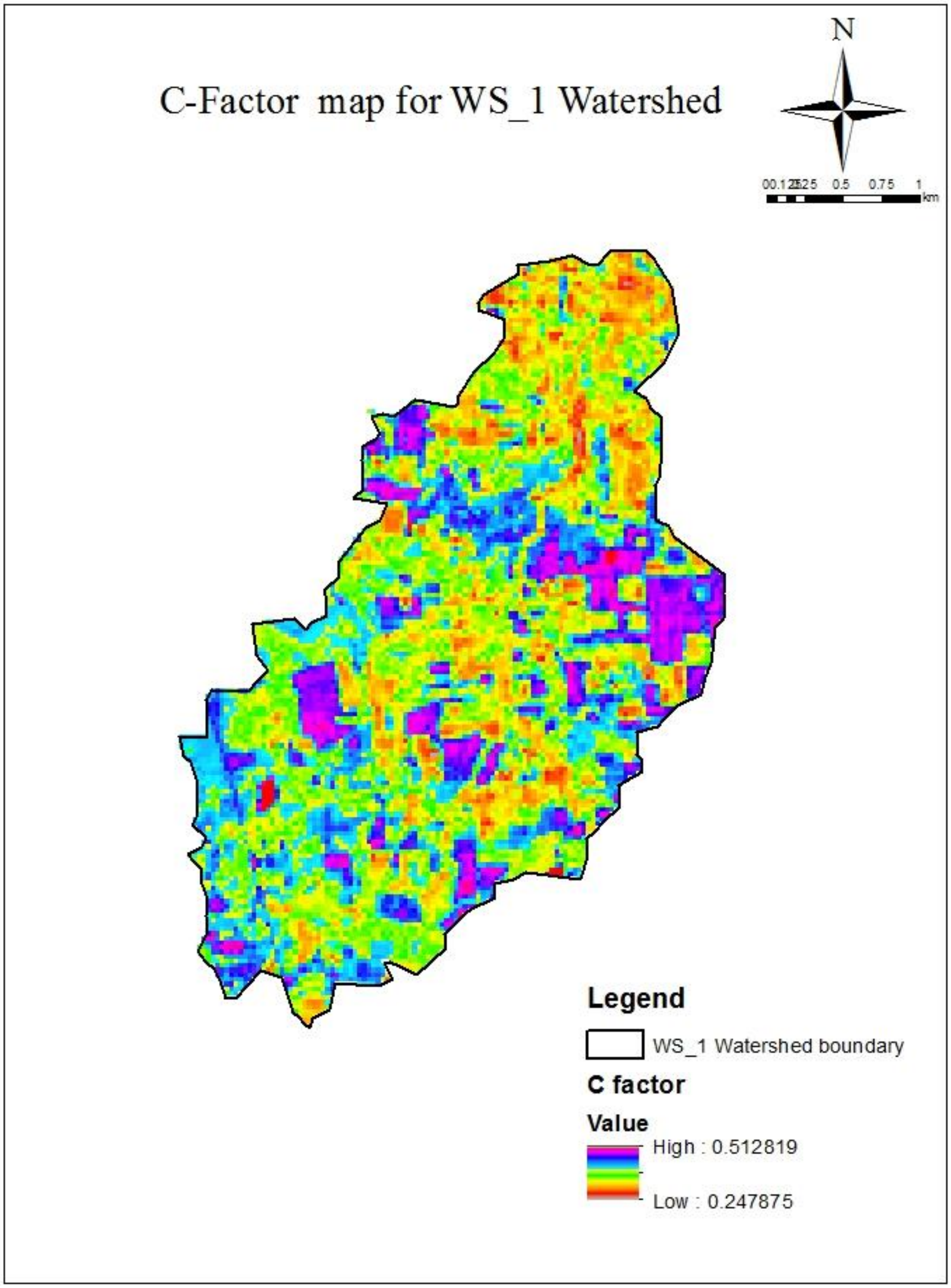


Fig.4.26 C factor map of WS_1 watershed

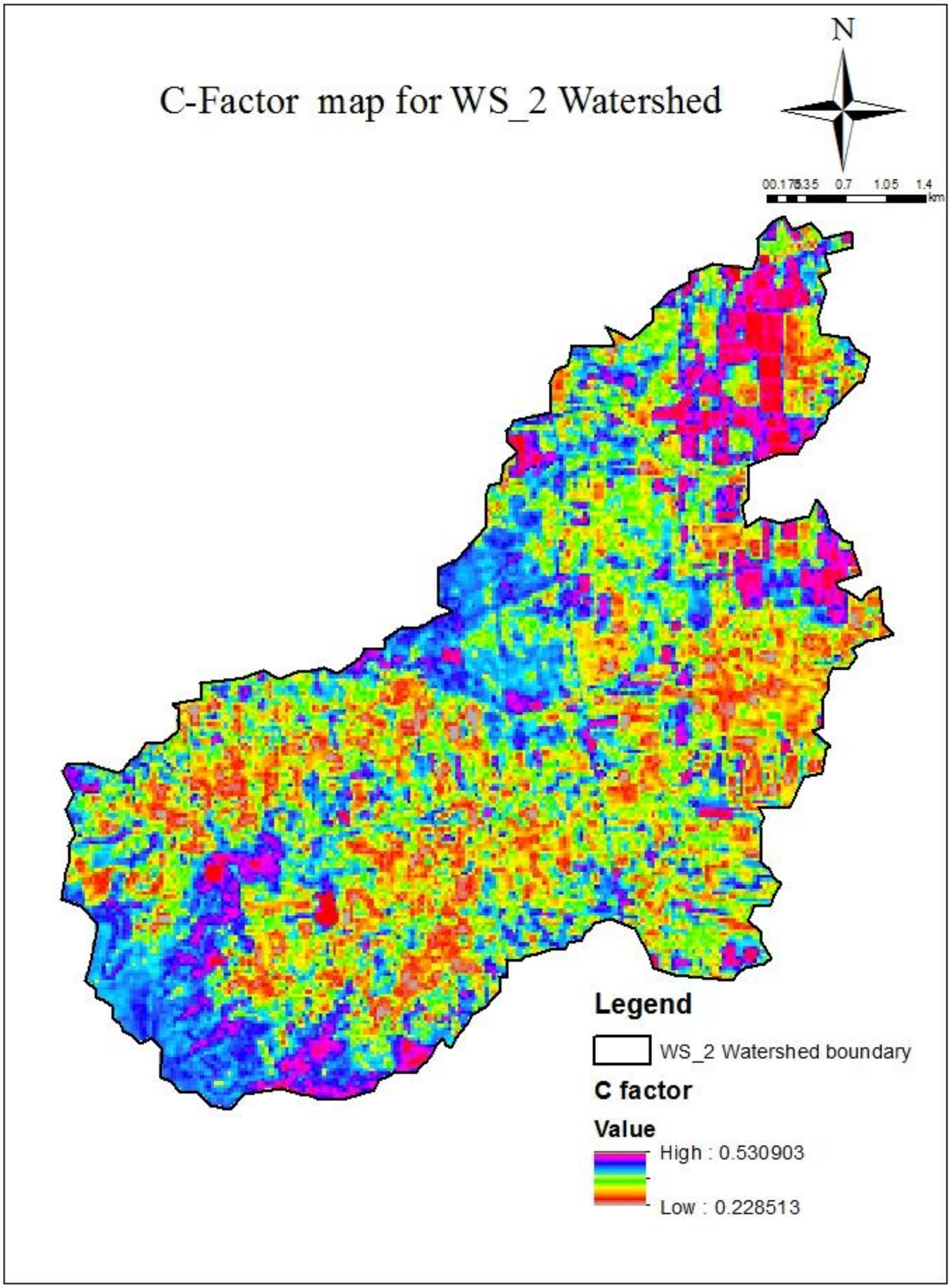


Fig.4.27 C factor map of WS_2 watershed

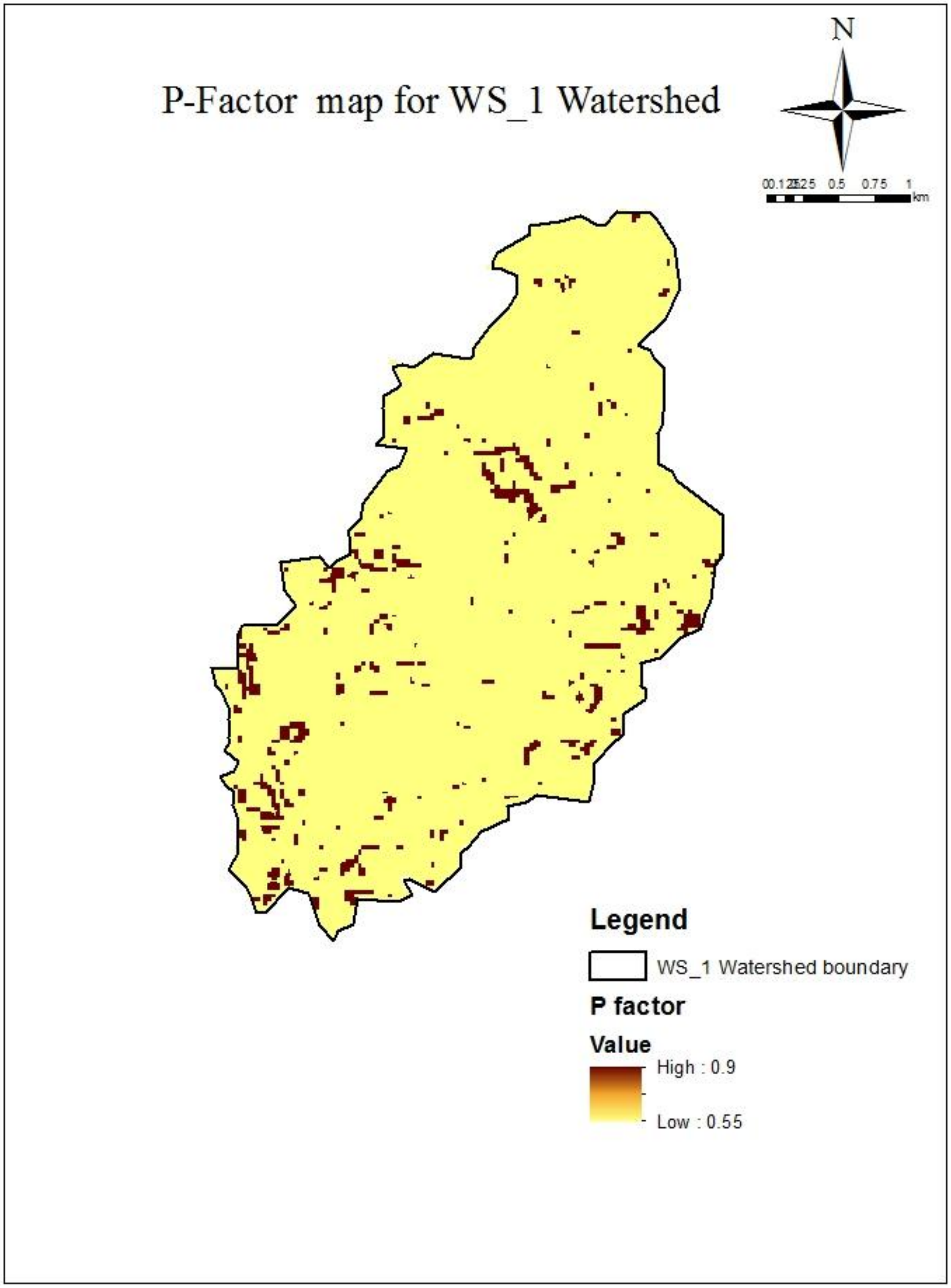


Fig.4.28 P factor map of the WS_1 watershed

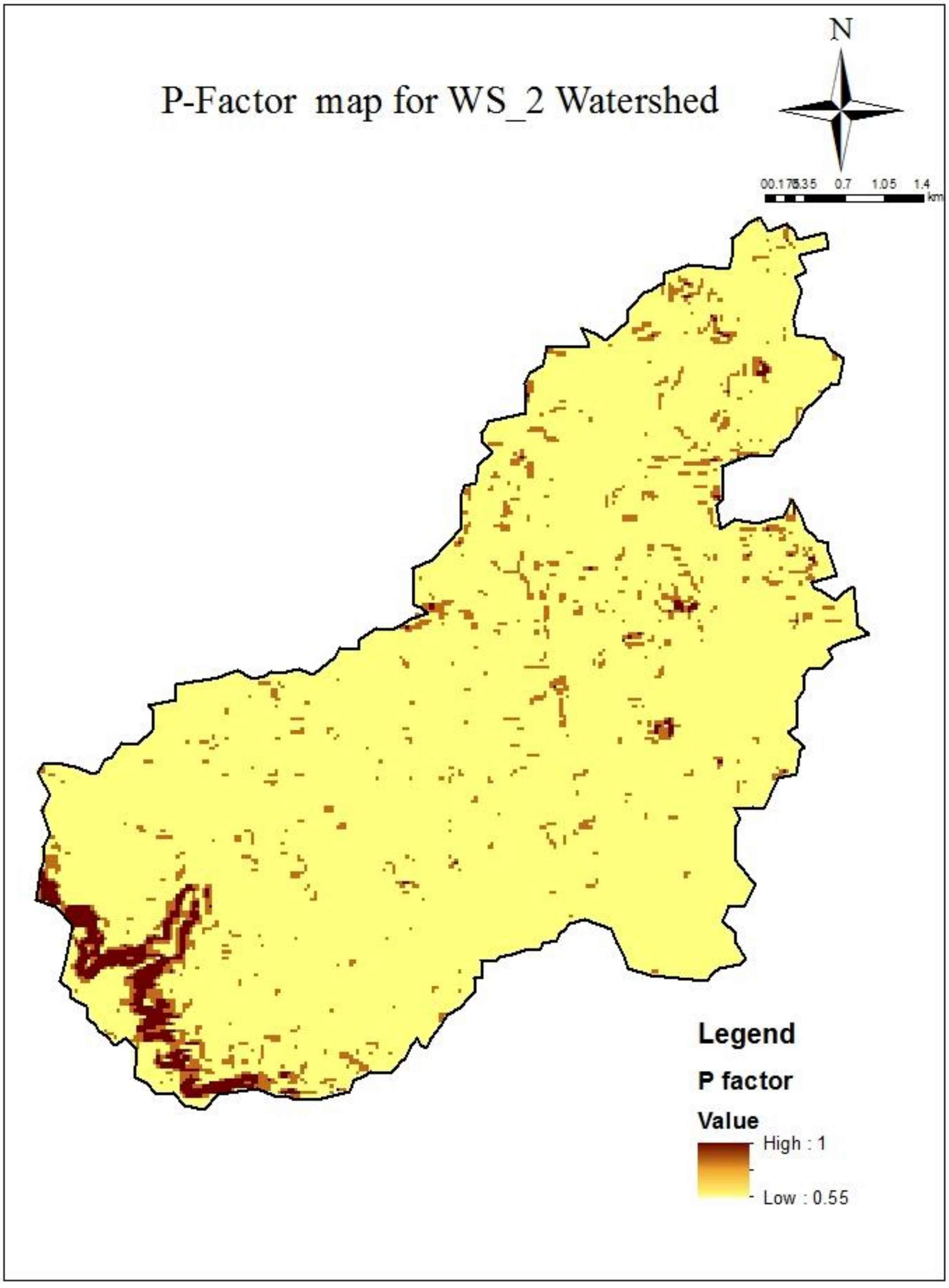


Fig.4.29 P factor map of the WS_2 watershed

4.9 Estimation of Annual Soil Loss

By using USLE in raster calculator all the parameters (R-factor map, K-factor map, LS-factor map, C- factor map, P-factor map) are multiplied and soil loss map for the study area is generated. Soil loss for WS_1 watershed was ranged between 0 to 1.3 t ha^{-1} $year^{-1}$ 0 to 21.7 t ha^{-1} $year^{-1}$ for WS_2 which is depicted in fig 4.30 (WS_1) and fig 4.31 (WS_2).

4.10 Estimation of Sediment delivery ratio

The sediment delivery ratio is the ratio of sediment yield to total soil loss. It was calculated by using equation 3.11and was 0.238 for WS_1 and 0.212 for WS_2.

4.11 Estimation of sediment yield

To calculate Sediment yield Wischmeier and Smith (1978) developed the formula is given in equation 3.4. From soil loss and sediment delivery ratio, sediment yield was calculated. Area of MPKV Central Campus (East) watersheds was 3909.03 ha. By using equation 3.11, sediment delivery ratio calculated and it was 0.238 for WS_1 and 0.212 for WS_2. From equation 3.12 sediment yield calculated for the WS_1 watershed it ranged between 0 to 0.273 t ha^{-1} $year^{-1}$ and 0 to 4.6 t ha^{-1} $year^{-1}$ for WS_2 which is depicted in fig 4.32 and fig 4.33.Soil erosion ranges from 0 to 5 t ha^{-1} $year^{-1}$ shows very slight erosion class and soil erosion ranging from 5 to 15 t ha^{-1} $year^{-1}$ shows slight erosion class. Entire area of WS_1 lies in the permissible soil erosion limit i.e. 0 to 5 t ha^{-1} $year^{-1}$ while 95 per cent area of both the watersheds has soil loss below 5 t ha^{-1} $year^{-1}$. Thus both the watersheds show very slight erosion.

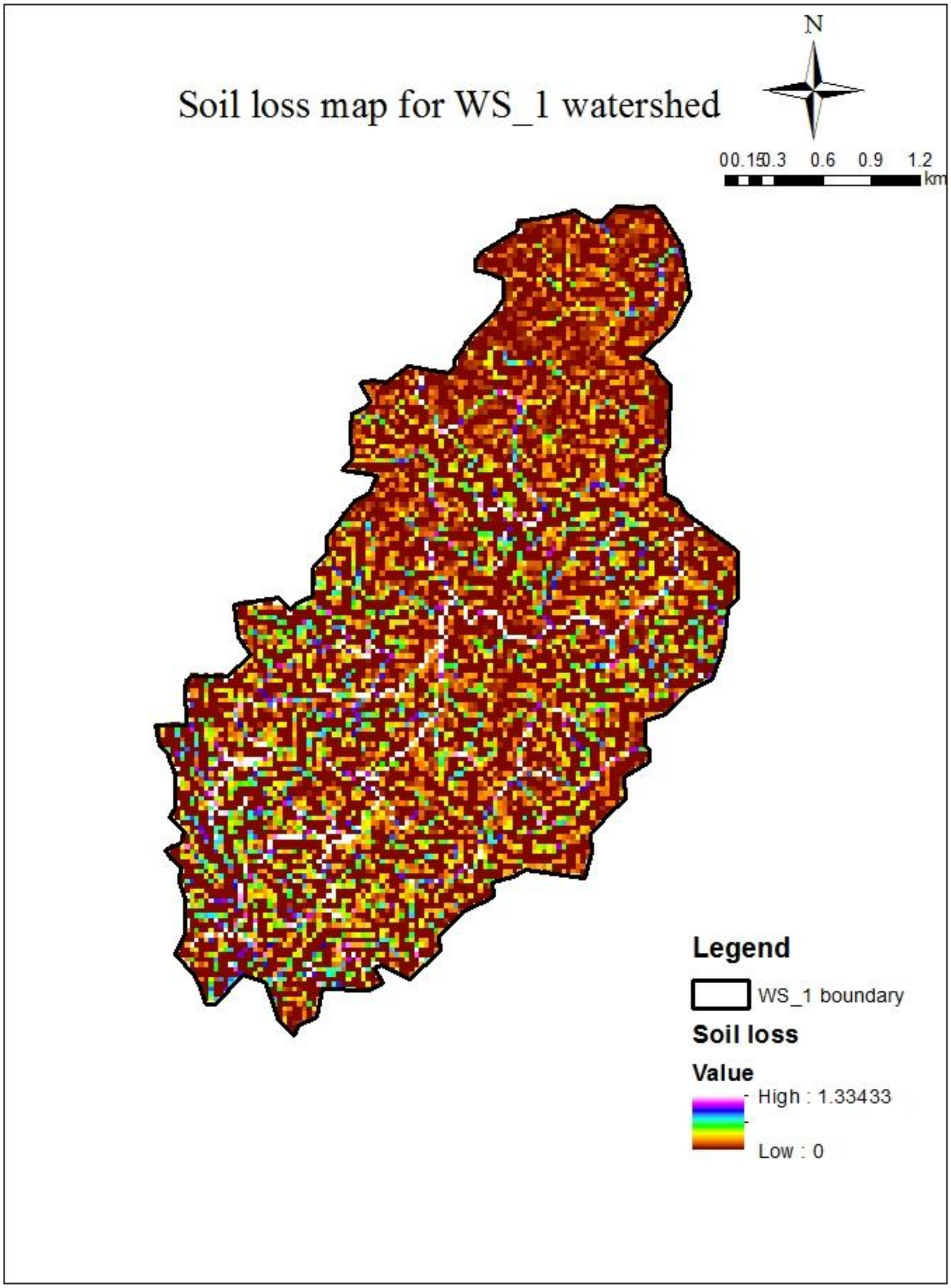


Fig.4.30 Soil loss map of WS_1 watershed

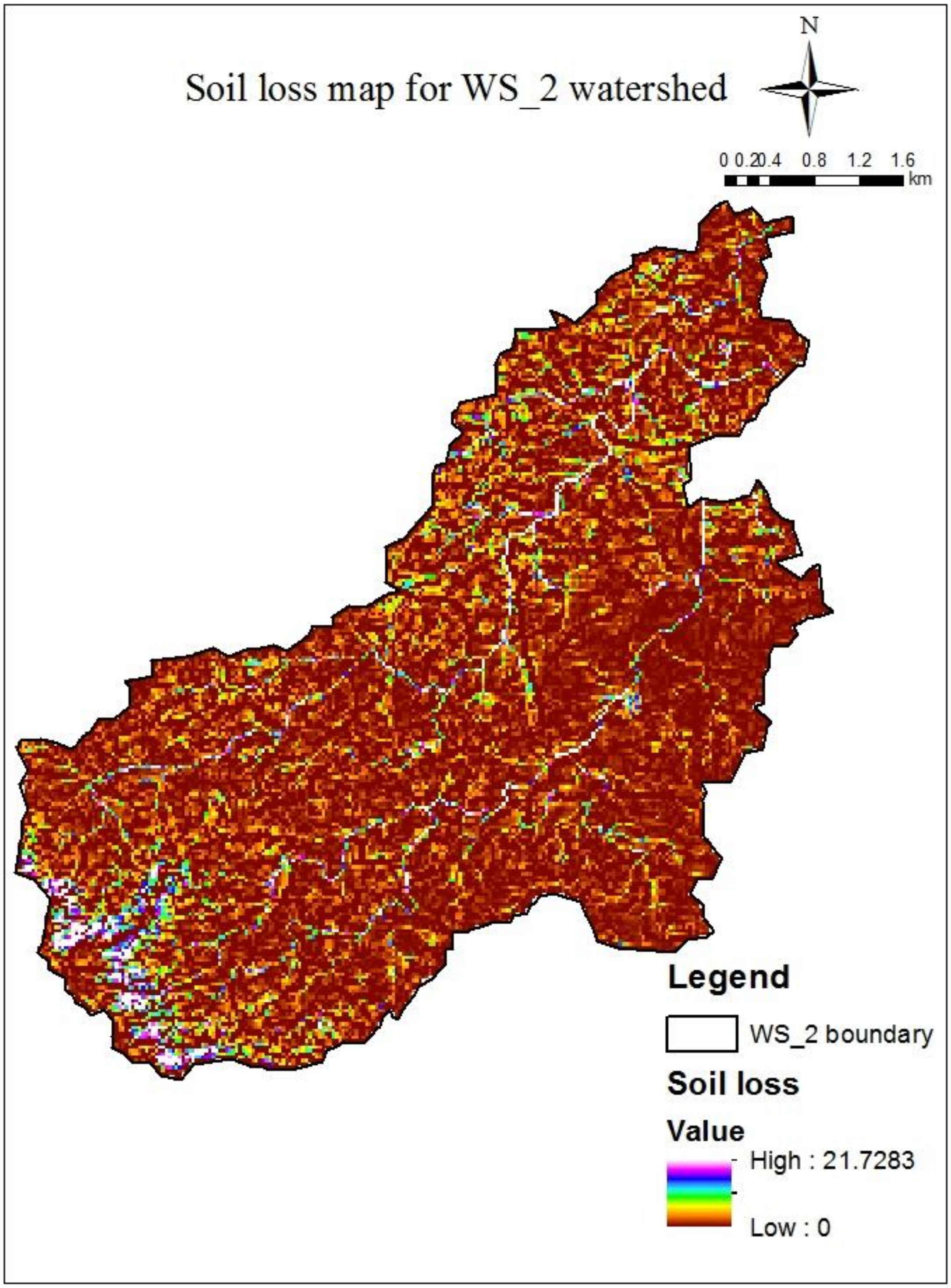


Fig.4.31 Soil loss map of WS_1 watershed

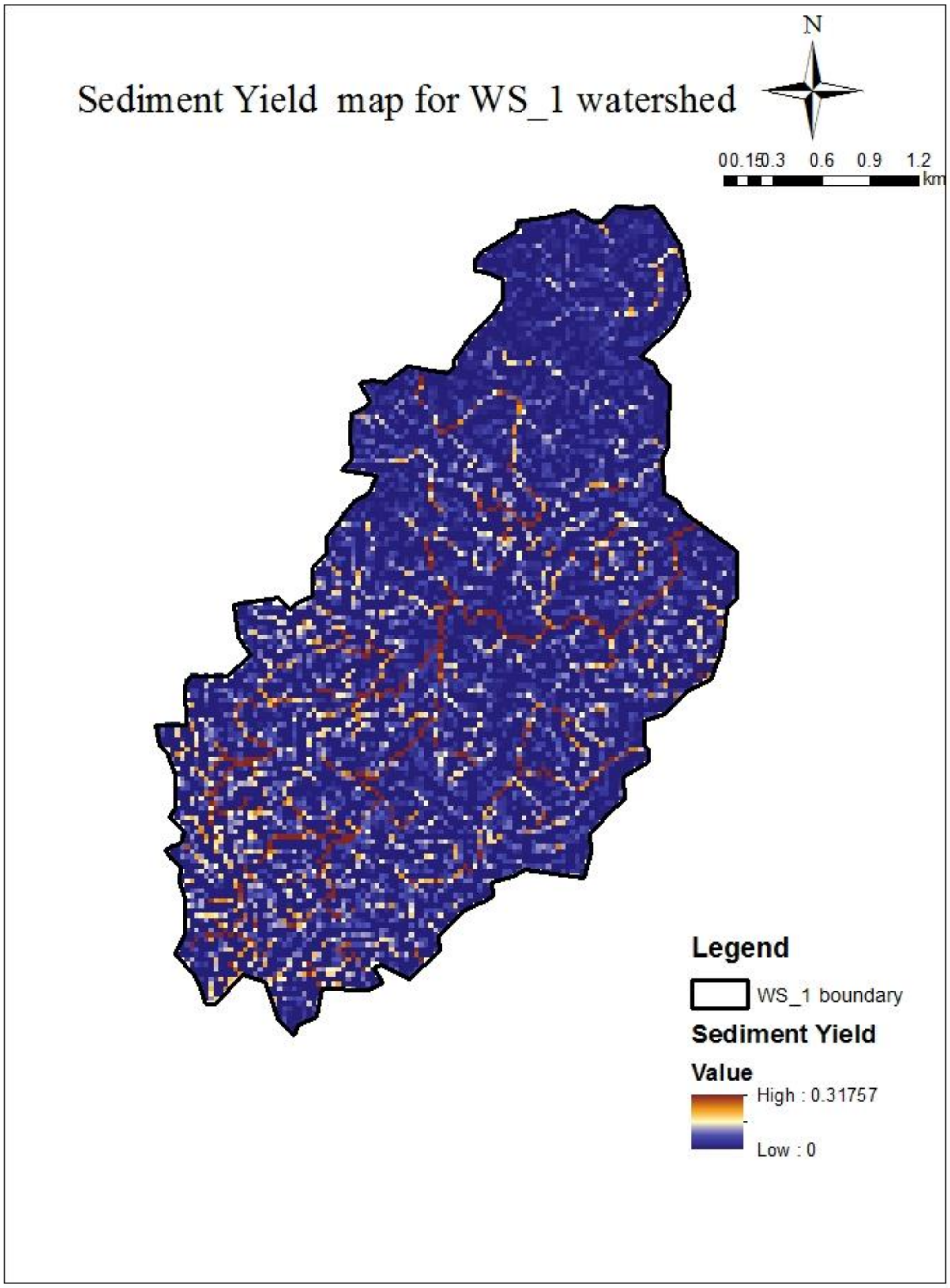


Fig.4.32 Sediment yield map of WS_1 watershed

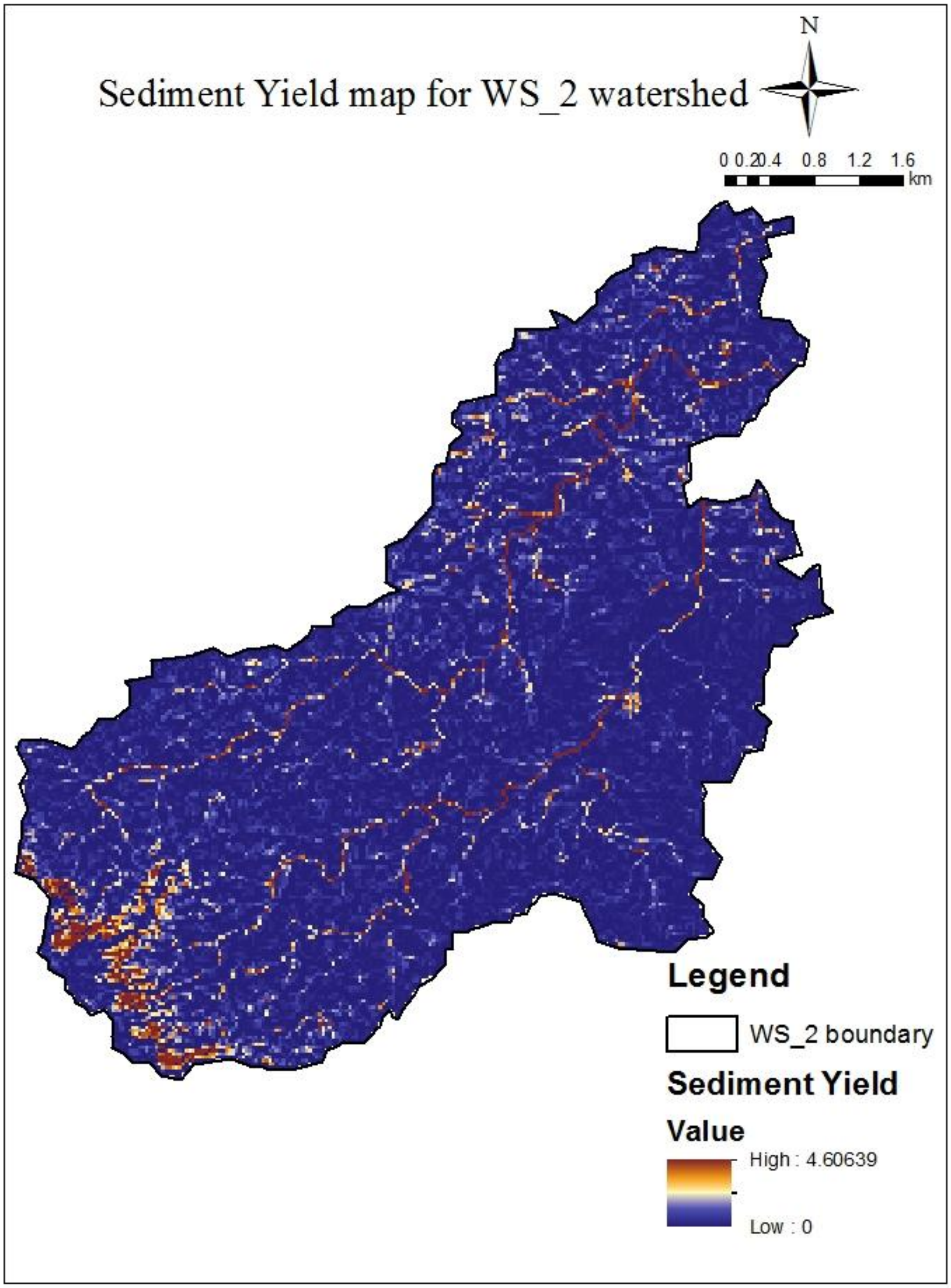


Fig.4.33 Sediment yield map of WS_2 watershed

5. SUMMARY AND CONCLUSIONS

A study was planned and conducted at Dr.Annasaheb Shinde College of Agricultural Engineering and Technology, MPKV, Rahuri with the objective of estimation of runoff for watershed using SCS-CN and estimation of soil erosion for watershed using RUSLE. Remote sensing and GIS techniques were used for fulfillment of this study. For this study MPKV Central Campus (East) watersheds were selected which was located at Rahuri tehsil, Ahmednagar district of Maharashtra.

5.1 Summary of Results

The land use/land cover map for the MPKV Central Campus (East) watersheds has been classified into six categories viz. Waterbodies, Settlements, Horticulture plantation, Cultivable Land, Barren land, Cultivable fallow land. Total geographical area covered under east watersheds (WS_1 and WS_2) had been found to be 3909.03 ha.

In 2017, for WS_1 Land use land cover pattern of M.P.K.V. central campus east watersheds revealed that majority of land was under Barren land class (439.2 ha,43.66 %) followed by cultivated land (404.1 ha , 40.17%) followed by cultivable fallow land (92.25 ha, 9.17 per cent), horticulture plantation (43.02 ha, 4.27 per cent), settlement (24.48 ha, 0.28 per cent) and water bodies (2.88 ha, 0.28 per cent).It is inference that almost 85 per cent of the WS_1 land was covered by major two classes barren land class and cultivated land which are most vulnerable for flood condition.

For WS_2 watershed in year 2017, land use land cover map revealed that majority of land was under barren land class (1573.92 ha, 54.32 %) followed by cultivated land (817.74 ha, 28.22%) followed by horticulture plantation (231.48 ha, 7.99 per cent), cultivable fallow land (201.06 ha, 6.94 per cent), settlement (63.63 ha, 2.1 per cent) and water bodies (9.27 ha, 0.31 per cent).

Weighted Curve Number calculated for the WS_1 was 80.59 and for WS_2 81.86 by Arc GIS 10.2.2. Slope adjusted CN calculated for WS_1 was 80.77 and for WS_2 was 81.92. Soil retention for WS_1 was calculated 60.47 mm and for WS_2 soil retention was 56.05 mm. Runoff depths were also calculated by using the empirical formula. For WS_1 watershed runoff depth was 169.52 mm 180.25 mm for WS_2.

For WS_1 Rainfall erosivity index ranged from 242.51 to 245.43 MJ mm ha^{-1} $h^{-1}year^{-1}$ and for WS_2 it is 244.75 to 251.74 MJ mm ha^{-1} $h^{-1}year^{-1}$. Soil erodibility index is calculated for the study area by using soil erodibility map prepared for the MPKV, Rahuri by using interpolation technique in Spatial Analyst Tool and it is in the range For WS_1 watershed, K factor ranged from 0.1 to 0.24 t h MJ^{-1} mm^{-1} and 0.03 to 0.24 t h MJ^{-1} mm^{-1} for WS_2.

Slope length and slope gradient values gives LS factor. For WS_1 watershed, LS factor ranged from 0 to 0.13 and for WS_2, LS-factor ranged from 0 to 1.31. NDVI ranged from -0.02 to 0.50 for WS_1 and -0.06 to 0.54 for WS_2. By using regression model Crop management factor (C factor) map generated which indicates that the C factor ranged from 0.24 to 0.51 for WS_1 and 0.22 to 0.53 for WS_2. Conservation Practices factor (P) map is generated by using slope map and it ranges from 0.55 to 1.00. For WS_1 P factor calculated was 0.55 to 0.9 and for WS_2 watershed P factor ranges from 0.55 to 1.0.

Soil loss for WS_1 watershed was ranged from 0 to 1.3 t ha^{-1} $year^{-1}$ and for WS_2 watershed it ranged from 0 to 21.72 t ha^{-1} $year^{-1}$.Sediment delivery ratio calculated for WS_1 was 0.238 and for WS_2 0.212. Sediment yield ranged from 0 to 0.273 t ha^{-1} $year^{-1}$ for WS_1 watershed and 0 to 4.6 t ha^{-1} t ha^{-1} $year^{-1}$ for WS_2 watershed.

5.2 Conclusions

Based on results of the study, conclusions obtained area as follows:

- The annual runoff in the MPKV Central Campus (East) watershed WS_1 for the year 2017 was 169.52 mm amounting 26.57 per cent of the annual rainfall received 638mm.
- The annual runoff in the MPKV Central Campus (East) watershed WS_2 for the year 2017 was 180.25 mm amounting 28.21 per cent of the annual rainfall received 638mm.
- Sediment yield calculated for the WS_1 watershed it ranges from 0 to 0.273 t ha^{-1} $year^{-1}$ and from WS_2 watershed sediment yield ranges from 0 to 4.6 t ha^{-1} year.
- The estimated runoff of can be utilized for optimum design of the soil and water conservation structures
- The estimated runoff and sediment yield before development of MPKV Central Campus (East) watersheds can be used for comparison or impact assessment of soil and water conservation measures adopted for the development of the watershed.

6. LITERATURE CITED

Amutha, R. and Porchelvan, P., 2009. Estimation of surface runoff in Malattar sub-watershed using SCS-CN method. *Journal of the Indian Society of Remote Sensing*, *37*(2), p.291.

Anonymous. 1972. National Engineering Handbook, Section 4, Hydrology, SCS. *United State Department of Agriculture, Washington, DC.*

Arekhi, S., Niazi, Y. and Amiri, F., 2010. Spatial distribution of soil loss and sediment yield based on SATEEC GIS system and remote sensing (case study, Ilam Dam watershed-lower part, Iran). *World Applied Sciences Journal*, 9(8), pp.860-872.

Arekhi, S., Bolourani, A.D., Shabani, A., Fathizad, H. and Ahamdy-Asbchin, S., 2012. Mapping soil erosion and sediment yield susceptibility using RUSLE, remote sensing and GIS (Case study: Cham Gardalan Watershed, Iran). *Advances in Environmental Biology*, 6(1), pp.109-124.

Atawoo, M.A. and Heerasing, J.M., 1998, March. Estimation of soil erodibility and erosivity of rainfall patterns in Mauritius. In *Second Annual Meeting of Agricultural Scientists* ,p. 219.

Atre, A.A., Damale, A.S. and Bangal, G.B., 1997. Estimation of Erosion Index at Rahuri (Maharashtra). *Journal of Maharashtra Agricultural Universities*, *22*(2), pp.221-222.

Chandrmohan, T. and Durbude, D.G., 2001. Estimation of runoff using small watershed models. *Hydrology Journal*, 24(2), pp.45-53.

Chattopadhyay, G.S. and Choudhury, S., 2006. Application of GIS and remote sensing for watershed development project–a case study, Map India 2006.

Chow, V. T., D. K. Maidment and Mays, L.W., 2002. Applied Hydrology . McGraw-

Hill Book Company, New York, USA.

Chowdary, V.M., Ramakrishnan, D., Srivastava, Y.K., Chandran, V. and Jeyaram, A., 2009. Integrated water resource development plan for sustainable management of Mayurakshi watershed, India using remote sensing and GIS. *Water resources management*, *23*(8), pp.1581-1602.

Dabral, P.P., Baithuri, N. and Pandey, A., 2008. Soil erosion assessment in a hilly catchment of North Eastern India using USLE, GIS and remote sensing. *Water Resources Management, 22*(12), pp.1783-1798.

Dhawale, A.W., 2013. Runoff estimation for Darewadi watershed using RS and GIS. *International Journal of Recent Technology and Engineering*, 1(6), pp.46-50.

De Jong, S.M., 1994. Application of Reflective Remote Sensing for Land Degradation Studies in a Mediterranean Environment (Utrecht: Netherlands Geographical Studies, University of Utrecht).

Ebrahimian, M., See, L.F., Ismail, M.H. and Malek, I.A., 2009. Application of natural resources conservation service–curve number method for runoff estimation with GIS in the Kardeh watershed, Iran. *European Journal of scientific research*, *34*(4), pp.575-590.

Elangovan, A.B. and Seetharaman, R., 2011. Estimating Rainfall Erosivity of the Revised Universal Soil Loss Equation from daily rainfall depth in Krishanagiri Watershed region of Tamil Nadu, India. In *International Conference on Environmental and Computer Science* 19, pp. 48-52.

Ferro, V. and Minacapilli, M., 1995. Sediment delivery processes at basin scale. *Hydrological Sciences Journal*, 40(6), pp.703-717.

Ferro, V. 1997. Futher remarks on a distributed approach to sediment delivery. *Hydrological Science Journal*, 42(5): 633-647.

Ferro, V., Porto, P. and Tusa, G., 1998. Testing a distributed approach for modelling sediment delivery. *Hydrological Sciences Journal*, 43(3), pp.425-442.

Garde, R.J. and Kothyari, U.C., 1987. Flood estimation using regional flood frequency analysis. *Hydraul. Eng. Rep. No. HYD-8702, Civ. Eng. Dep., University of Roorkee, Roorkee*.

Geena, G.B. and Ballukraya, P.N., 2011. Estimation of runoff for Red hills watershed using SCS method and GIS. *Indian Journal of Science and Technology*, *4*(8), pp.899-902.

Gitas, I.Z., Douros, K., Minakou, C., Silleos, G.N. and Karydas, C.G., 2009. Multi-temporal soil erosion risk assessment in N. Chalkidiki using a modified USLE raster model. *EARSeL eProceedings*, 8(1), pp.40-52.

Guptaa, P. and Panigrahya, S., 2008. Geo-spatial modeling of runoff of large land mass: analysis, approach and results for major river basins of India. *Proceedings of the international archives of the photogrammetry, remote sensing and spatial information sciences*, 37, pp.63-68.

Haan, C.T., Barfield, B.J. and Hayes, J.C., 1994. *Design hydrology and sedimentology for small catchments*. Academic Press, New York.

Haregeweyn, N., Tsunekawa, A., Poesen, J., Tsubo, M., Meshesha, D.T., Fenta, A.A., Nyssen, J. and Adgo, E., 2017. Comprehensive assessment of soil erosion risk for better land use planning in river basins: Case study of the Upper Blue Nile River. *Science of the total environment*, *574*, pp.95-108.

http://glcf.umiacs.umd.edu/index.shtml

http://www.mahaagri.gov.in

http://www.gov.on.ca/OMAFRA/english/engineer/facts/00-001.htm

Huang, C.H., Wells, L.K. and Norton, L.D., 1999. Sediment transport capacity and erosion processes: Model concepts and reality. *Earth Surface Processes and Landforms: The Journal of the British Geomorphological Research Group*, 24(6), pp.503-516.

Huang, M., Gallichand, J., Wang, Z. and Goulet, M., 2006. A modification to the Soil Conservation Service curve number method for steep slopes in the Loess Plateau of China. *Hydrological processes*, 20(3), pp.579-589.

Hjelmfelt Jr, A.T., 1991. Investigation of curve number procedure. *Journal of Hydraulic Engineering*, 117(6), pp.725-737.

Jain, M.K. and Kothyari, U.C., 2000. Estimation of soil erosion and sediment yield using GIS. *Hydrological Sciences Journal*, 45(5), pp.771-786.

Jasrotia, A.S., Dhiman, S.D. and Aggarwal, S.P., 2002. Rainfall-runoff and soil erosion modeling using Remote Sensing and GIS technique—a case study of tons watershed. *Journal of the Indian Society of Remote Sensing*, 30(3), pp.167-180.

Jennings, D. 2001. Surface water delineation for Moundsville. Spatial Analysis for Resource Management.

http://www.nrsc.wvu.edu/rm493591/fall2001/students/jennings/revised.htm,May,2003.

Jenson, J. R. 1996. Introductory Digital Image Processing: A Remote Sensing Perspective, 2nd Edition, Prentice Hall, New Jersey.

Johnson, L. E. 2009. Geographic Information Systems in Water Resources Engineering. CRC Press, New York.

Kamaludin, H., Lihan, T., Ali Rahman, Z., Mustapha, M.A., Idris, W.M.R. and Rahim, S.A., 2013. Integration of remote sensing, RUSLE and GIS to model potential soil loss and sediment yield (SY). *Hydrology and Earth System Sciences Discussions*, 10(4), pp.4567-4596.

Karaburun, A., 2010. Estimation of C factor for soil erosion modeling using NDVI in Buyukcekmece watershed. *Ozean journal of applied sciences*, 3(1), pp.77-85.

Karydas, C.G., Sekuloska, T. and Silleos, G.N., 2009. Quantification and site-specification of the support practice factor when mapping soil erosion risk associated with olive plantations in the Mediterranean island of Crete. *Environmental Monitoring and Assessment*, 149(1-4), pp.19-28.

Kefi, M., Yoshino, K., Setiawan, Y., Zayani, K. and Boufaroua, M., 2011. Assessment of the effects of vegetation on soil erosion risk by water: a case of study of the Batta watershed in Tunisia. *Environmental earth sciences*, 64(3), pp.707-719.

Kothyari, U.C. and Jain, S.K., 1997. Sediment yield estimation using GIS. *Hydrological sciences journal*, 42(6), pp.833-843.

Kouli, M., Soupios, P. and Vallianatos, F., 2009. Soil erosion prediction using the revised universal soil loss equation (RUSLE) in a GIS framework, Chania, Northwestern Crete, Greece. *Environmental Geology*, 57(3), pp.483-497.

Kudoli, A.B., Oak R.A. (2015) *Runoff estimation by using GIS based technique and its comparison with different methods—a case study on Sangli Micro Watershed*. Int J Emerg Res Manag Technol 4(5):2278–9359.

Kulkarni, A.A., Aggarwal, S.P. and Das, K.K., 2004. Estimation of Surface Runoff using Rainfall–Runoff Modeling Of Warasgaon Dam Catchment. In: *Map India Conference*, New Delhi, India.

Lillesand, T.M., Kiefer, R.W. and Chipman, J.W., 1987. Concepts and foundations of remote sensing. *Remote Sensing and Image Interpretation. John Wiley, New York*, pp.1-84.

Lu, D., Li, G., Valladares, G.S. and Batistella, M., 2004. Mapping soil erosion risk in Rondonia, Brazilian Amazonia: using RUSLE, remote sensing and GIS. *Land Degradation & Development*, 15(5), pp.499-512.

Mamata, S. and Satapathy, D.P., 2017. *International Journal of Emerging Research in Management &Technology ISSN: 2278-9359*, 6(12).

Mather, P. M. 1999. Computer Processing of Remotely Sensed Images: *An Introduction*, 2nd Edition, John Wiley and Sons, West Sussex.

McCool, D.K., Brown, L.C., Foster, G.R., Mutchler, C.K. and Meyer, L.D., 1987. Revised slope steepness factor for the Universal Soil Loss Equation. *Transactions of the ASAE*, 30(5), pp.1387-1396.

McCool, D. K., G. R. Foster, K.G. Renard, D. C .Yoder and G. A. Weesies.,1995. Revised Universal Soil Loss Equation. Department of Defense/Interagency Workshop on Technologies to Address Soil Erosion on Department of Defense Lands San Antonio, TX.

Melesse, A.M. and Shih, S.F., 2002. Spatially distributed storm runoff depth estimation using Landsat images and GIS. *Computers and Electronics in Agriculture*, 37(1-3), pp.173-183.

Meyer, L.D. and Wischmeier, W.H., 1969. Mathematical simulation of the process of soil erosion by water. *Transactions of the ASAE*, 12(6), pp.754-0758.

Mishra, S.K., Pandey, R.P., Jain, M.K. and Singh, V.P., 2007. A rain duration and modified AMC-dependent SCS-CN procedure for long duration rainfall-runoff events. *Water resources management*, 22(7), pp.861-876.

Mishra, S.K. and Singh, V.P., 2002. SCS-CN-based hydrologic simulation package. *Mathematical models in small watershed hydrology and applications*, 2841, pp.391-464.

Mockus, V., 1964. SCS National Engineering Handbook. US GPO: Washington.

Moore, I.D. and Wilson, J.P., 1992. Length-slope factors for the Revised Universal Soil Loss Equation: Simplified method of estimation. *Journal of soil and water conservation*, 47(5), pp.423-428.

Morgan, R. P. C. 1986. Soil Erosion and Conservation, Longman Group Limited. 63 -74.

Morgan, R. P. C. 1994. Soil erosion and conservation. Slisoe College, Cranfield university, Slisoe.

Murmu, S. and Biswas, S., 2012. Application of Remote Sensing and GIS Technique in Runoff Estimation of a Catchment using SCS model. In *Proceedings of the Regional Conference of the International Network of Women Engineers & Scientists (Inwes), New Delhi, India*.

Nayak, T.R. and Jaiswal, R.K., 2003. Rainfall-runoff modelling using satellite data and GIS for Bebas river in Madhya Pradesh. *Journal of the Institution of Engineers. India. Civil Engineering Division*, 84(mai), pp.47-50..

NBSS and LUP. 1995. Soils of Maharashtra for Optimising Land Use. National Bureau Soil Survey Publication 54, Soils of India Series 5.

Nohegar, A., Bodaghi, M., Kamali, A., Ghashghaee, N. and Ghaemi, S., 2013. Application of Remote Sensing Techniques and GIS for Estimating the Runoff of Sikhuran Watershed. In *International Symposium on Advances in Science and Technology, Bandar–Abbas, Iran*.

Nohegar, A., Heydarzadeh, M. and Malekian, A., 2013. Assessment of severity of droughts using geostatistics method (case study: Southern Iran). *Desert*, 18(1), pp.79-87.

NRSA.1989. Manual of Nationwide Land Use Mapping using Satellite Imagery, Part I, National Remote Sensing Agency, Hyderabad.

Pal, B. and Samanta, S., 2011. Estimation of soil loss using remote sensing and geographic information system techniques (Case study of Kaliaghai River basin, Purba & Paschim Medinipur District, West Bengal, India). *Indian journal of Science and technology*, 4(10), pp.1202-1207.

Pandey, A. P., V. M . Dabral and B. C. Chowdary 2006. Estimation of runoff for agricultural watershed using SCS curve number and geographic information system. http://www.gisdevelopment.net

Ponce, V.M. and Hawkins, R.H., 1996. Runoff curve number: Has it reached maturity?. *Journal of hydrologic engineering*, 1(1), pp.11-19.

Pradhan, R., Pradhan, M.P., Ghose, M.K., Agarwal, V.S. and Agarwal, S., 2010. Estimation of rainfall-runoff using remote sensing and GIS in and around Singtam, East Sikkim. *International journal of Geomatics and geosciences*, 1(3), p.466.

Prasannakumar, V., Shiny, R., Geetha, N. and Vijith, H., 2011. Spatial prediction of soil erosion risk by remote sensing, GIS and RUSLE approach: a case study of Siruvani river watershed in Attapady valley, Kerala, India. *Environmental Earth Sciences, 64*(4), pp.965-972..

Ram Babu, BL. Dhyani and N. Kumar. 2004. Assessment of erodibility status and refined Iso-Erodant Map of India. *Indian Journal of Soil Conservation*. 32(2),pp.171-177.

Ramakrishnan, D., Bandyopadhyay, A. and Kusuma, K.N., 2009. SCS-CN and GIS-based approach for identifying potential water harvesting sites in the Kali Watershed, Mahi River Basin, India. *Journal of Earth System Science*, 118(4), pp.355-368.

Ramana Rao, K.V. and Bhattacharya, A.K., 1997. Runoff estimation by curve number method-case studies.

Rao, K.V., A. K. Bhattacharya and K. Mishra.1996. Runoff estimation by curve number method-case studies. Journal of Soil and Water Conservation. 40,pp.1-7.

Renard, K.G., Foster, G.R., Weesies, G.A. and Porter, J.P., 1991. RUSLE: Revised universal soil loss equation. *Journal of soil and Water Conservation*, 46(1), pp.30-33.

Renard, K.G., Foster, G.R., Weesies, G.A., McCool, D.K. and Yoder, D.C., 1997. Agriculture handbook. *US Department of Agriculture*.

Renard, K.G., 1997. Predicting soil erosion by water: a guide to conservation planning with the revised universal soil loss equation (RUSLE).

Rockström, J. and Barron, J., 2007. Water productivity in rainfed systems: overview of challenges and analysis of opportunities in water scarcity prone savannahs. *Irrigation Science*, 25(3), pp.299-311.¨

Rojas-Gonzalez, A. M., 2008. Soil erosion calculation using Remote sensing and GIS in Rio Grade De Arecibo watershed, Puerto Rico. *American Society of Photogrametry and Remote Sensing (ASPRS).* Annual Conference. Portland Oregon.

Römkens, M.J.M., Prasad, S.N. and Gerits, J.J.P., 1997. Soil erosion modes of sealing soils: a phenomenological study. *Soil Technology*, 11(1), pp.31-41.

Saleh, N. M., M. S. AbdulMohsin and S. S. Sammer. 2011. Evaluation of Rainfall-Runoff Relationship of Hemren basin by using Remote Sensing and GIS Techniques. *European Journal of Scientific Research*. 54(2),pp. 224-244.

Samah Al-Jabari., M. A. Sharkh and A. Ziad. 2009. Estimation of runoff for agricultural watershed using SCS curve number and GIS. In: *Thirteenth International Water Technology Conference, IWTC 13 2009,* Hurghada, Egypt.

Sarangi, A., Madramootoo, C.A., Enright, P., Prasher, S.O. and Patel, R.M., 2005. Performance evaluation of ANN and geomorphology-based models for runoff and sediment yield prediction for a Canadian watershed. *Current science*, pp.2022-2033.

Sarangi, A., Bhattacharya, A.K., Singh, A.K. and Sambaiha, A., 2005, November. Performance of Geomorphologic Instantaneous Unit Hydrograph (GIUH) model for estimation of surface runoff. In *International conference on recent advances in water resources development and management, 23rd to 25th Nov.*,pp. 569-581.

Sekhar, K.R. and Rao, B.V., 2002. Evaluation of sediment yield by using remote sensing and GIS: a case study from the Phulang Vagu watershed, Nizamabad District (AP), India. *International Journal of Remote Sensing*, 23(20), pp.4499-4509.

Shahid, S. and M. Almasri. 2010. Application of GIS-based SCS- CN method in West Bank catchments, Palestine. *Water Science and Engineering*. 3(1), pp.1-4.

Sharma, T., Kiran, P.S., Singh, T.P., Trivedi, A.V. and Navalgund, R.R., 2001. Hydrologic response of a watershed to land use changes: a remote sensing and GIS approach. *International Journal of Remote Sensing*, 22(11), pp.2095-2108.

Sharma, D. and V. Kumar. 2002. Application of SCS model with GIS data base for estimation of runoff in an arid watershed. *Journal of Soil and Water Conservation*, 30 (2),pp.141-145.

Shiferaw. A. 2011. Estimating soil loss rates for soil conservation planning in the borena woreda of South wollo highlands, Ethiopia. *Journal of Sustainable Development in Africa*. 13(3), pp. 87-106.

Shinde, V., A. Sharma, K. N. Tiwari and M. Singh. 2011. Qualitative determination of soil erosion and priorization of micro-watersheds using Remote Sensing and GIS. *Journal of Indian Society of Remote Sensing*. 39(2), pp.181-192.

Stone, R. P. and D. Hilborn. 2000. Universal Soil Loss Equation(USLE). Ontario Ministry of Agricultural and Food original factsheet.

Sundar Kumar, P., M. J. Ratna Kanth Babu, T. V. Praveen and V. Venkata kumar. 2010. Analysis of the Runoff for Watershed Using SCS-CN Method and Geographic Information Systems. *International Journal of Engineering Science and Technology*. 2(8), pp.3947-3654.

Tian, Y.C., Zhou, Y.M., Wu, B.F. and Zhou, W.F., 2009. Risk assessment of water soil erosion in upper basin of Miyun Reservoir, Beijing, China. *Environmental Geology*, *57*(4), pp.937-942.

Tou, J. T. and R. C. Gonzalez.1974. Pattern recognition Principles. Reading, Massachusetts Addison-Wesley Publishing Company.

USDA-SCS. 1972. Sediment sources, yields and delivery ratios. National engineering handbook. Section 3 Sedimentation. Engineering.

USDA. 1985. *Soil Conservation Service*. National Engineering Handbook, USA.

USDA Soil Conservation Service 1986, Urban hydrology for small watersheds.

Technical Release 55, U.S. Department of Agriculture, Washington, DC.

Van der Knijff, J. M., RJA. Jones and Montanarella, L.,2000. Soil erosion risk assessment in Europe EUR 19044 EN. *Office for Official Publications of the European Communities*, Luxembourg, pp.34.

Walling, D. E. 1983. The sediment delivery problem. *Journal of Hydrology,* 65, pp.209-237.

Weber, R.M. and Dunno, G.A., 2001. Riparian vegetation mapping and image processing techniques, Hopi Indian Reservation, Arizona. *Photogramm. Eng. Remote Sens.*, 67(2), pp.179-186.

Williams, J. R. 1975. Sediment routing for agricultural watersheds. *Water Resource Bulletin,* 11,pp.965-974.

Wischmeier, W. H. and Smith, D. D., 1958. Rainfall energy and its relationship to soil loss. *Trans. AGU39(Q*), pp.285-291.

Wischmeier, W. H. 1959. A rainfall erosion index for a universal soil loss equation. *Soil Sci. Soc. Am. Proc.*,pp. 246- 249.

Wischmeier, W. H. and Smith, D. D., 1965. Predicting rainfall erosion losses from cropland east of the Rocky Mountains. Guide for selection of practices from soil and water conservation. U.S. Department of Agriculture handbook No. 537.

Wischmeier, W. H. 1971. A soil erodibility nomograph for farmland and construction sites. *Journal of Soil and Water Conservation*. 26, pp.189–193.

Wischmeier, W.H. and Smith, D.D., 1978. Predicting rainfall erosion losses-a guide to conservation planning. *Predicting rainfall erosion losses-a guide to conservation planning.* Agriculture Handbook no. 537, United States Department of Agriculture Science and Education Administration, Washington, pp.163.

Yue-Qing, X., Xiao-Mei, S., Xiang-Bin, K., Jian, P. and Yun-Long, C., 2008. Adapting the RUSLE and GIS to model soil erosion risk in a mountains karst watershed, Guizhou Province, China. *Environmental monitoring and assessment*, 141(1-3), pp.275-286.

Zade, M., Ray, S.S., Dutta, S. and Panigrahy, S., 2005. Analysis of runoff pattern for all major basins of India derived using remote sensing data. *Current science,* pp.1301-1305.

Zhou, P., Luukkanen, O., Tokola, T. and Nieminen, J., 2008. Effect of vegetation cover on soil erosion in a mountainous watershed. *Catena*, 75(3), pp.319-325.

7. APPENDICES

Appendix-A

Daily rainfall data (mm) and Antecedent Moisture Condition of Mahatma Phule Krishi Vidyapeeth central campus east watersheds for the year 2017

Month	Date	Rainfall (mm)	Preceding 5 Days rainfall	AMC Type
January	1	0.00	0.00	I
January	2	0.00	0.00	I
January	3	0.00	0.00	I
January	4	0.00	0.00	I
January	5	0.00	0.00	I
January	6	0.00	0.00	I
January	7	0.00	0.00	I
January	8	0.00	0.00	I
January	9	0.00	0.00	I
January	10	0.00	0.00	I
January	11	0.00	0.00	I
January	12	0.00	0.00	I
January	13	0.00	0.00	I
January	14	0.00	0.00	I
January	15	0.00	0.00	I
January	16	0.00	0.00	I
January	17	0.00	0.00	I
January	18	0.00	0.00	I
January	19	0.00	0.00	I
January	20	0.00	0.00	I
January	21	0.00	0.00	I
January	22	0.00	0.00	I
January	23	0.00	0.00	I
January	24	0.00	0.00	I
January	25	0.00	0.00	I
January	26	0.00	0.00	I
January	27	0.00	0.00	I
January	28	0.00	0.00	I
January	29	0.00	0.00	I
January	30	0.00	0.00	I
January	31	0.00	0.00	I
February	1	0.00	0.00	I
February	2	0.00	0.00	I
February	3	0.00	0.00	I
February	4	0.00	0.00	I
February	5	0.00	0.00	I
February	6	0.00	0.00	I
February	7	0.00	0.00	I

February	8	0.00	0.00	I
February	9	0.00	0.00	I
February	10	0.00	0.00	I
February	11	0.00	0.00	I
February	12	0.00	0.00	I
February	13	0.00	0.00	I
February	14	0.00	0.00	I
February	15	0.00	0.00	I
February	16	0.00	0.00	I
February	17	0.00	0.00	I
February	18	0.00	0.00	I
February	19	0.00	0.00	I
February	20	0.00	0.00	I
February	21	0.00	0.00	I
February	22	0.00	0.00	I
February	23	0.00	0.00	I
February	24	0.00	0.00	I
February	25	0.00	0.00	I
February	26	0.00	0.00	I
February	27	0.00	0.00	I
February	28	0.00	0.00	I
March	1	0.00	0.00	I
March	2	0.00	0.00	I
March	3	0.00	0.00	I
March	4	0.00	0.00	I
March	5	0.00	0.00	I
March	6	0.00	0.00	I
March	7	0.00	0.00	I
March	8	0.00	0.00	I
March	9	0.00	0.00	I
March	10	0.00	0.00	I
March	11	0.00	0.00	I
March	12	0.00	0.00	I
March	13	0.00	0.00	I
March	14	0.00	0.00	I
March	15	0.00	0.00	I
March	16	0.00	0.00	I
March	17	0.00	0.00	I
March	18	0.00	0.00	I
March	19	0.00	0.00	I
March	20	0.00	0.00	I
March	21	0.00	0.00	I
March	22	0.00	0.00	I
March	23	0.00	0.00	I
March	24	0.00	0.00	I
March	25	0.00	0.00	I
March	26	0.00	0.00	I
March	27	0.00	0.00	I
March	28	0.00	0.00	I

March	29	0.00	0.00	I
March	30	0.00	0.00	I
March	31	0.00	0.00	I
April	1	0.00	0.00	I
April	2	0.00	0.00	I
April	3	0.00	0.00	I
April	4	0.00	0.00	I
April	5	0.00	0.00	I
April	6	0.00	0.00	I
April	7	0.00	0.00	I
April	8	0.00	0.00	I
April	9	0.00	0.00	I
April	10	0.00	0.00	I
April	11	0.00	0.00	I
April	12	0.00	0.00	I
April	13	0.00	0.00	I
April	14	0.00	0.00	I
April	15	0.00	0.00	I
April	16	0.00	0.00	I
April	17	0.00	0.00	I
April	18	0.00	0.00	I
April	19	0.00	0.00	I
April	20	0.00	0.00	I
April	21	0.00	0.00	I
April	22	0.00	0.00	I
April	23	0.00	0.00	I
April	24	0.00	0.00	I
April	25	0.00	0.00	I
April	26	0.00	0.00	I
April	27	0.00	0.00	I
April	28	0.00	0.00	I
April	29	0.00	0.00	I
April	30	0.00	0.00	I
May	1	0.00	0.00	I
May	2	0.00	0.00	I
May	3	0.00	0.00	I
May	4	0.00	0.00	I
May	5	0.00	0.00	I
May	6	0.00	0.00	I
May	7	0.00	0.00	I
May	8	2.80	2.80	I
May	9	0.00	2.80	I
May	10	0.00	2.80	I
May	11	0.00	2.80	I
May	12	0.00	2.80	I
May	13	0.00	0.00	I
May	14	0.00	0.00	I
May	15	0.00	0.00	I
May	16	0.00	0.00	I

May	17	0.00	0.00	I
May	18	0.00	0.00	I
May	19	0.00	0.00	I
May	20	0.00	0.00	I
May	21	0.00	0.00	I
May	22	0.00	0.00	I
May	23	0.00	0.00	I
May	24	0.00	0.00	I
May	25	0.00	0.00	I
May	26	7.40	7.40	I
May	27	0.00	7.40	I
May	28	0.00	7.40	I
May	29	0.00	7.40	I
May	30	0.00	7.40	I
May	31	0.00	0.00	I
June	1	0.00	0.00	I
June	2	27.40	27.40	I
June	3	0.00	27.40	I
June	4	5.80	33.20	I
June	5	0.00	33.20	I
June	6	0.80	34.00	I
June	7	0.00	6.60	I
June	8	2.60	9.20	I
June	9	0.00	3.40	I
June	10	0.60	4.00	I
June	11	6.60	9.80	I
June	12	55.20	65.00	III
June	13	4.60	67.00	III
June	14	8.80	75.80	III
June	15	16.80	92.00	III
June	16	1.80	87.20	III
June	17	0.00	32.00	I
June	18	0.00	27.40	I
June	19	0.00	18.60	I
June	20	0.00	1.80	I
June	21	0.00	0.00	I
June	22	0.00	0.00	I
June	23	2.40	2.40	I
June	24	0.00	2.40	I
June	25	2.40	4.80	I
June	26	0.00	4.80	I
June	27	2.80	7.20	I
June	28	0.00	7.60	I
June	29	0.80	6.00	I
June	30	2.20	5.80	I
July	1	0.00	5.80	I
July	2	0.00	3.00	I
July	3	0.00	3.00	I
July	4	0.00	2.20	I

July	5	0.00	0.00	I
July	6	0.00	0.00	I
July	7	0.00	0.00	I
July	8	0.00	0.00	I
July	9	0.00	0.00	I
July	10	0.00	0.00	I
July	11	0.00	0.00	I
July	12	0.00	0.00	I
July	13	0.00	0.00	I
July	14	6.20	6.20	I
July	15	0.80	7.00	I
July	16	0.00	7.00	I
July	17	2.40	9.40	I
July	18	0.00	9.40	I
July	19	0.00	3.20	I
July	20	8.20	10.60	I
July	21	1.60	12.20	I
July	22	0.80	10.60	I
July	23	0.00	10.60	I
July	24	0.00	10.60	I
July	25	0.00	2.40	I
July	26	0.00	0.80	I
July	27	0.00	0.00	I
July	28	2.60	2.60	I
July	29	6.40	9.00	I
July	30	0.00	9.00	I
July	31	0.00	9.00	I
August	1	0.00	9.00	I
August	2	0.00	6.40	I
August	3	0.00	0.00	I
August	4	0.00	0.00	I
August	5	0.00	0.00	I
August	6	0.00	0.00	I
August	7	0.00	0.00	I
August	8	0.00	0.00	I
August	9	0.00	0.00	I
August	10	0.40	0.40	I
August	11	0.00	0.40	I
August	12	0.00	0.40	I
August	13	0.00	0.40	I
August	14	0.00	0.40	I
August	15	0.00	0.00	I
August	16	0.00	0.00	I
August	17	0.00	0.00	I
August	18	0.00	0.00	I
August	19	2.40	2.40	I
August	20	62.40	64.80	III
August	21	101.20	166.00	III
August	22	43.20	209.20	III

August	23	0.80	210.00	III
August	24	0.60	208.40	III
August	25	0.00	145.80	III
August	26	1.60	46.20	II
August	27	0.00	3.60	I
August	28	5.40	7.60	I
August	29	4.00	11.00	I
August	30	0.00	11.00	I
August	31	0.00	9.40	I
September	1	0.00	9.40	I
September	2	0.00	4.00	I
September	3	0.00	0.00	I
September	4	0.00	0.00	I
September	5	0.00	0.00	I
September	6	0.00	0.00	I
September	7	0.00	0.00	I
September	8	13.00	13.00	I
September	9	0.00	13.00	I
September	10	0.00	13.00	I
September	11	0.00	13.00	I
September	12	4.80	17.80	I
September	13	11.60	16.40	I
September	14	0.00	16.40	I
September	15	1.20	17.60	I
September	16	10.60	28.20	I
September	17	22.40	45.80	II
September	18	0.00	34.20	I
September	19	0.00	34.20	I
September	20	3.20	36.20	II
September	21	104.20	129.80	III
September	22	15.60	123.00	III
September	23	0.00	123.00	III
September	24	0.00	123.00	III
September	25	0.00	119.80	III
September	26	0.00	15.60	I
September	27	0.00	0.00	I
September	28	0.00	0.00	I
September	29	0.00	0.00	I
September	30	0.00	0.00	I
October	1	0.00	0.00	I
October	2	0.00	0.00	I
October	3	0.00	0.00	I
October	4	0.00	0.00	I
October	5	0.00	0.00	I
October	6	0.00	0.00	I
October	7	0.00	0.00	I
October	8	1.00	1.00	I
October	9	0.00	1.00	I
October	10	5.60	6.60	I

October	11	30.60	37.20	II
October	12	12.20	49.40	II
October	13	0.00	48.40	II
October	14	0.00	48.40	II
October	15	0.00	42.80	II
October	16	0.00	12.20	I
October	17	0.00	0.00	I
October	18	0.00	0.00	I
October	19	0.00	0.00	I
October	20	0.00	0.00	I
October	21	0.00	0.00	I
October	22	0.00	0.00	I
October	23	0.00	0.00	I
October	24	0.00	0.00	I
October	25	0.00	0.00	I
October	26	0.00	0.00	I
October	27	0.00	0.00	I
October	28	0.00	0.00	I
October	29	0.00	0.00	I
October	30	0.00	0.00	I
October	31	0.00	0.00	I
November	1	0.00	0.00	I
November	2	0.00	0.00	I
November	3	0.00	0.00	I
November	4	0.00	0.00	I
November	5	0.00	0.00	I
November	6	0.00	0.00	I
November	7	0.00	0.00	I
November	8	0.00	0.00	I
November	9	0.00	0.00	I
November	10	0.00	0.00	I
November	11	0.00	0.00	I
November	12	0.00	0.00	I
November	13	0.00	0.00	I
November	14	0.00	0.00	I
November	15	0.00	0.00	I
November	16	0.00	0.00	I
November	17	0.00	0.00	I
November	18	0.00	0.00	I
November	19	0.00	0.00	I
November	20	0.00	0.00	I
November	21	0.60	0.60	I
November	22	0.00	0.60	I
November	23	0.00	0.60	I
November	24	0.00	0.60	I
November	25	0.00	0.60	I
November	26	0.00	0.00	I
November	27	0.00	0.00	I
November	28	0.00	0.00	I

November	29	0.00	0.00	I
November	30	0.00	0.00	I
December	1	0.00	0.00	I
December	2	0.00	0.00	I
December	3	0.00	0.00	I
December	4	0.00	0.00	I
December	5	0.00	0.00	I
December	6	0.00	0.00	I
December	7	0.00	0.00	I
December	8	0.00	0.00	I
December	9	0.00	0.00	I
December	10	0.00	0.00	I
December	11	0.00	0.00	I
December	12	0.00	0.00	I
December	13	0.00	0.00	I
December	14	0.00	0.00	I
December	15	0.00	0.00	I
December	16	0.00	0.00	I
December	17	0.00	0.00	I
December	18	0.00	0.00	I
December	19	0.00	0.00	I
December	20	0.00	0.00	I
December	21	0.00	0.00	I
December	22	0.00	0.00	I
December	23	0.00	0.00	I
December	24	0.00	0.00	I
December	25	0.00	0.00	I
December	26	0.00	0.00	I
December	27	0.00	0.00	I
December	28	0.00	0.00	I
December	29	0.00	0.00	I
December	30	0.00	0.00	I
December	31	0.00	0.00	I
		638.80		

Appendix-B

Curve Number for Different Hydrological Soil Group with Different Land Use and Hydrologic condition

Cover			Hydrologic Soil Group			
Land Use and Land	**Treatment or**	**Hydrologic**	**A**	**B**	**C**	**D**
Fallow	Straight Row	–	77	86	91	94
Row crops	Straight Row	Poor	72	81	88	91
		Good	67	78	85	89
	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured & terraced	Poor	66	74	80	82
		Good	62	71	78	81
Small grain	Straight Row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured & terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close-seeded legumes or rotation meadow	Straight Row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured & terraced	Poor	63	73	80	83
		Good	51	67	76	80
Pasture or Range	Straight Row	Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
		Fair	25	59	75	83
		Good	6	35	70	79
Meadow (permanent)		Good	30	58	71	78
Woodlands		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads		–	59	74	82	86
Roads (dirt)*		–	72	82	87	89
Roads (hard surface)		–	74	84	90	92

*Including right of way (Source: Soil Conservation Services, 1972)

Appendix-C

Weighted CN calculation for MPKV Central Campus East watersheds

Table : Weighed CN for WS_1 watershed

WS_1				
HSG Polygon	**Area(ha)**	**CN**	**Area*CN**	**Weighted CN**
B	2.88	100	288	80.59
	24.48	74	1811.52	
	43.02	81	3484.62	
	404.1	76	30711.6	
	439.2	86	37771.2	
	92.25	76	7011	
	1005.93		81077.94	

Table: Weighed CN for WS_2 watershed

WS_2				
HSG Polygon	**Area(ha)**	**CN**	**Area*CN**	**Weighted CN**
B(1)	1231.92	81.13	99945.67	81.86
B(2)	209.34	84.35	17657.83	
D	1352.43	82.35	111372.6	
C	94.32	78.96	7447.507	
	2888.01		236423.6	

Appendix-D

Runoff Depth and Soil Moisture Retension Calculation For WS_1 and WS_2 watersheds

Month	Date	P	CN	S	Q	CN	S	Q
			WS_1			WS_2		
January	1	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	2	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	3	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	4	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	5	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	6	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	7	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	8	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	9	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	10	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	11	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	12	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	13	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	14	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	15	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	16	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	17	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	18	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	19	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	20	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	21	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	22	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	23	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	24	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	25	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	26	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	27	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	28	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	29	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	30	0.00	80.77	60.47	0.00	81.92	56.05	0.00
January	31	0.00	80.77	60.47	0.00	81.92	56.05	0.00
Februay	1	0.00	80.77	60.47	0.00	81.92	56.05	0.00
Februay	2	0.00	80.77	60.47	0.00	81.92	56.05	0.00
Februay	3	0.00	80.77	60.47	0.00	81.92	56.05	0.00
Februay	4	0.00	80.77	60.47	0.00	81.92	56.05	0.00
Februay	5	0.00	80.77	60.47	0.00	81.92	56.05	0.00
Februay	6	0.00	80.77	60.47	0.00	81.92	56.05	0.00
Februay	7	0.00	80.77	60.47	0.00	81.92	56.05	0.00
Februay	8	0.00	80.77	60.47	0.00	81.92	56.05	0.00
Februay	9	0.00	80.77	60.47	0.00	81.92	56.05	0.00
Februay	10	0.00	80.77	60.47	0.00	81.92	56.05	0.00
Februay	11	0.00	80.77	60.47	0.00	81.92	56.05	0.00

Februay	12	0.00	80.77	60.47	0.00		81.92	56.05	0.00
Februay	13	0.00	80.77	60.47	0.00		81.92	56.05	0.00
Februay	14	0.00	80.77	60.47	0.00		81.92	56.05	0.00
Februay	15	0.00	80.77	60.47	0.00		81.92	56.05	0.00
Februay	16	0.00	80.77	60.47	0.00		81.92	56.05	0.00
Februay	17	0.00	80.77	60.47	0.00		81.92	56.05	0.00
Februay	18	0.00	80.77	60.47	0.00		81.92	56.05	0.00
Februay	19	0.00	80.77	60.47	0.00		81.92	56.05	0.00
Februay	20	0.00	80.77	60.47	0.00		81.92	56.05	0.00
Februay	21	0.00	80.77	60.47	0.00		81.92	56.05	0.00
Februay	22	0.00	80.77	60.47	0.00		81.92	56.05	0.00
Februay	23	0.00	80.77	60.47	0.00		81.92	56.05	0.00
Februay	24	0.00	80.77	60.47	0.00		81.92	56.05	0.00
Februay	25	0.00	80.77	60.47	0.00		81.92	56.05	0.00
Februay	26	0.00	80.77	60.47	0.00		81.92	56.05	0.00
Februay	27	0.00	80.77	60.47	0.00		81.92	56.05	0.00
Februay	28	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	1	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	2	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	3	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	4	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	5	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	6	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	7	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	8	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	9	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	10	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	11	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	12	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	13	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	14	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	15	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	16	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	17	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	18	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	19	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	20	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	21	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	22	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	23	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	24	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	25	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	26	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	27	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	28	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	29	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	30	0.00	80.77	60.47	0.00		81.92	56.05	0.00
March	31	0.00	80.77	60.47	0.00		81.92	56.05	0.00

April	1	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	2	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	3	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	4	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	5	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	6	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	7	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	8	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	9	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	10	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	11	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	12	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	13	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	14	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	15	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	16	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	17	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	18	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	19	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	20	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	21	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	22	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	23	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	24	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	25	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	26	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	27	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	28	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	29	0.00	80.77	60.47	0.00		81.92	56.05	0.00
April	30	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	1	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	2	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	3	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	4	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	5	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	6	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	7	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	8	2.80	80.77	60.47	0.00		81.92	56.05	0.00
May	9	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	10	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	11	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	12	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	13	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	14	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	15	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	16	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	17	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	18	0.00	80.77	60.47	0.00		81.92	56.05	0.00

May	19	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	20	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	21	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	22	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	23	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	24	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	25	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	26	7.40	80.77	60.47	0.00		81.92	56.05	0.00
May	27	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	28	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	29	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	30	0.00	80.77	60.47	0.00		81.92	56.05	0.00
May	31	0.00	80.77	60.47	0.00		81.92	56.05	0.00
June	1	0.00	80.77	60.47	0.00		81.92	56.05	0.00
June	2	27.40	80.77	60.47	3.09		81.92	56.05	3.63
June	3	0.00	80.77	60.47	0.00		81.92	56.05	0.00
June	4	5.80	80.77	60.47	0.00		81.92	56.05	0.00
June	5	0.00	80.77	60.47	0.00		81.92	56.05	0.00
June	6	0.80	80.77	60.47	0.00		81.92	56.05	0.00
June	7	0.00	80.77	60.47	0.00		81.92	56.05	0.00
June	8	2.60	80.77	60.47	0.00		81.92	56.05	0.00
June	9	0.00	80.77	60.47	0.00		81.92	56.05	0.00
June	10	0.60	80.77	60.47	0.00		81.92	56.05	0.00
June	11	6.60	80.77	60.47	0.00		81.92	56.05	0.00
June	12	55.20	80.77	60.47	17.94		81.92	56.05	19.34
June	13	4.60	80.77	60.47	0.00		81.92	56.05	0.00
June	14	8.80	80.77	60.47	0.00		81.92	56.05	0.00
June	15	16.80	80.77	60.47	0.34		81.92	56.05	0.51
June	16	1.80	80.77	60.47	0.00		81.92	56.05	0.00
June	17	0.00	80.77	60.47	0.00		81.92	56.05	0.00
June	18	0.00	80.77	60.47	0.00		81.92	56.05	0.00
June	19	0.00	80.77	60.47	0.00		81.92	56.05	0.00
June	20	0.00	80.77	60.47	0.00		81.92	56.05	0.00
June	21	0.00	80.77	60.47	0.00		81.92	56.05	0.00
June	22	0.00	80.77	60.47	0.00		81.92	56.05	0.00
June	23	2.40	80.77	60.47	0.00		81.92	56.05	0.00
June	24	0.00	80.77	60.47	0.00		81.92	56.05	0.00
June	25	2.40	80.77	60.47	0.00		81.92	56.05	0.00
June	26	0.00	80.77	60.47	0.00		81.92	56.05	0.00
June	27	2.80	80.77	60.47	0.00		81.92	56.05	0.00
June	28	0.00	80.77	60.47	0.00		81.92	56.05	0.00
June	29	0.80	80.77	60.47	0.00		81.92	56.05	0.00
June	30	2.20	80.77	60.47	0.00		81.92	56.05	0.00
July	1	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	2	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	3	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	4	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	5	0.00	80.77	60.47	0.00		81.92	56.05	0.00

July	6	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	7	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	8	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	9	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	10	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	11	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	12	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	13	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	14	6.20	80.77	60.47	0.00		81.92	56.05	0.00
July	15	0.80	80.77	60.47	0.00		81.92	56.05	0.00
July	16	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	17	2.40	80.77	60.47	0.00		81.92	56.05	0.00
July	18	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	19	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	20	8.20	80.77	60.47	0.00		81.92	56.05	0.00
July	21	1.60	80.77	60.47	0.00		81.92	56.05	0.00
July	22	0.80	80.77	60.47	0.00		81.92	56.05	0.00
July	23	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	24	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	25	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	26	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	27	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	28	2.60	80.77	60.47	0.00		81.92	56.05	0.00
July	29	6.40	80.77	60.47	0.00		81.92	56.05	0.00
July	30	0.00	80.77	60.47	0.00		81.92	56.05	0.00
July	31	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	1	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	2	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	3	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	4	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	5	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	6	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	7	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	8	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	9	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	10	0.40	80.77	60.47	0.00		81.92	56.05	0.00
August	11	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	12	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	13	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	14	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	15	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	16	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	17	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	18	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	19	2.40	80.77	60.47	0.00		81.92	56.05	0.00
August	20	62.40	80.77	60.47	22.85		81.92	56.05	24.44
August	21	101.20	80.77	60.47	53.08		81.92	56.05	55.45
August	22	43.20	80.77	60.47	10.57		81.92	56.05	11.62

August	23	0.80	80.77	60.47	0.00		81.92	56.05	0.00
August	24	0.60	80.77	60.47	0.00		81.92	56.05	0.00
August	25	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	26	1.60	80.77	60.47	0.00		81.92	56.05	0.00
August	27	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	28	5.40	80.77	60.47	0.00		81.92	56.05	0.00
August	29	4.00	80.77	60.47	0.00		81.92	56.05	0.00
August	30	0.00	80.77	60.47	0.00		81.92	56.05	0.00
August	31	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	1	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	2	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	3	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	4	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	5	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	6	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	7	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	8	13.00	80.77	60.47	0.01		81.92	56.05	0.06
September	9	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	10	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	11	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	12	4.80	80.77	60.47	0.00		81.92	56.05	0.00
September	13	11.60	80.77	60.47	0.00		81.92	56.05	0.00
September	14	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	15	1.20	80.77	60.47	0.00		81.92	56.05	0.00
September	16	10.60	80.77	60.47	0.00		81.92	56.05	0.00
September	17	22.40	80.77	60.47	1.50		81.92	56.05	1.86
September	18	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	19	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	20	3.20	80.77	60.47	0.00		81.92	56.05	0.00
September	21	104.20	80.77	60.47	55.60		81.92	56.05	58.02
September	22	15.60	80.77	60.47	0.19		81.92	56.05	0.32
September	23	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	24	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	25	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	26	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	27	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	28	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	29	0.00	80.77	60.47	0.00		81.92	56.05	0.00
September	30	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	1	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	2	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	3	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	4	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	5	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	6	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	7	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	8	1.00	80.77	60.47	0.00		81.92	56.05	0.00
October	9	0.00	80.77	60.47	0.00		81.92	56.05	0.00

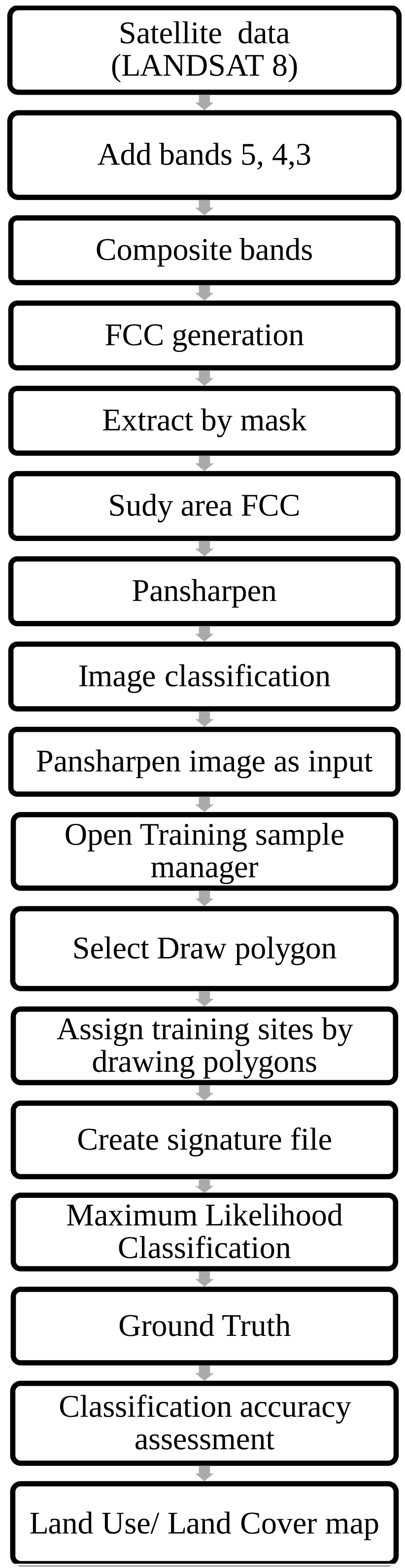
October	10	5.60	80.77	60.47	0.00		81.92	56.05	0.00
October	11	30.60	80.77	60.47	4.34		81.92	56.05	4.98
October	12	12.20	80.77	60.47	0.00		81.92	56.05	0.02
October	13	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	14	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	15	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	16	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	17	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	18	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	19	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	20	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	21	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	22	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	23	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	24	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	25	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	26	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	27	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	28	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	29	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	30	0.00	80.77	60.47	0.00		81.92	56.05	0.00
October	31	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	1	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	2	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	3	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	4	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	5	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	6	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	7	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	8	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	9	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	10	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	11	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	12	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	13	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	14	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	15	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	16	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	17	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	18	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	19	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	20	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	21	0.60	80.77	60.47	0.00		81.92	56.05	0.00
November	22	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	23	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	24	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	25	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	26	0.00	80.77	60.47	0.00		81.92	56.05	0.00

November	27	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	28	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	29	0.00	80.77	60.47	0.00		81.92	56.05	0.00
November	30	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	1	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	2	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	3	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	4	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	5	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	6	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	7	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	8	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	9	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	10	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	11	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	12	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	13	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	14	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	15	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	16	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	17	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	18	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	19	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	20	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	21	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	22	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	23	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	24	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	25	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	26	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	27	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	28	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	29	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	30	0.00	80.77	60.47	0.00		81.92	56.05	0.00
December	31	0.00	80.77	60.47	0.00		81.92	56.05	0.00
		638.80			169.52				180.25

Appendix E

Flow charts

1. Procedure for Land Use and Land Cover map



2. Procedure for preparation of Hydrologic Soil Group Map

Add soil map prapared by NBSS& LUP, Nagpur

↓

Add Study area boundary shapefile

↓

Extract By mask

↓

Soil map of study area

↓

Compare attributes of map with HSG properties

↓

Add field as HSG

↓

Assign HSG by comparing attributes of soil map and HSG properties

3. Procedure for Rainfall Erosivity Factor Map

Prepare Excel sheet of latitude and longitude of rainguage station and their respective rainfall depth

↓

Open ArcMap window

↓

File

↓

Add XY data

↓

Select Excel sheet as input data

↓

X field - Latitude Y field- Longitude, Z field- Rainfall depth

↓

Assign UTM coordinate System

↓

Right click on Sheet 1$ event file - Data- Export Data - Ok

↓

Spatial Analyst Tool

↓

Interpolation

↓

IDW

↓

Export output file as input and rainfall as Z value

Environmental settings-Processing extent-Same as Display

↓

Raster Analysis-Select Cell size and Mask the study area -OK

↓

Interpolated rain.image is generated

↓

Raster Calculator

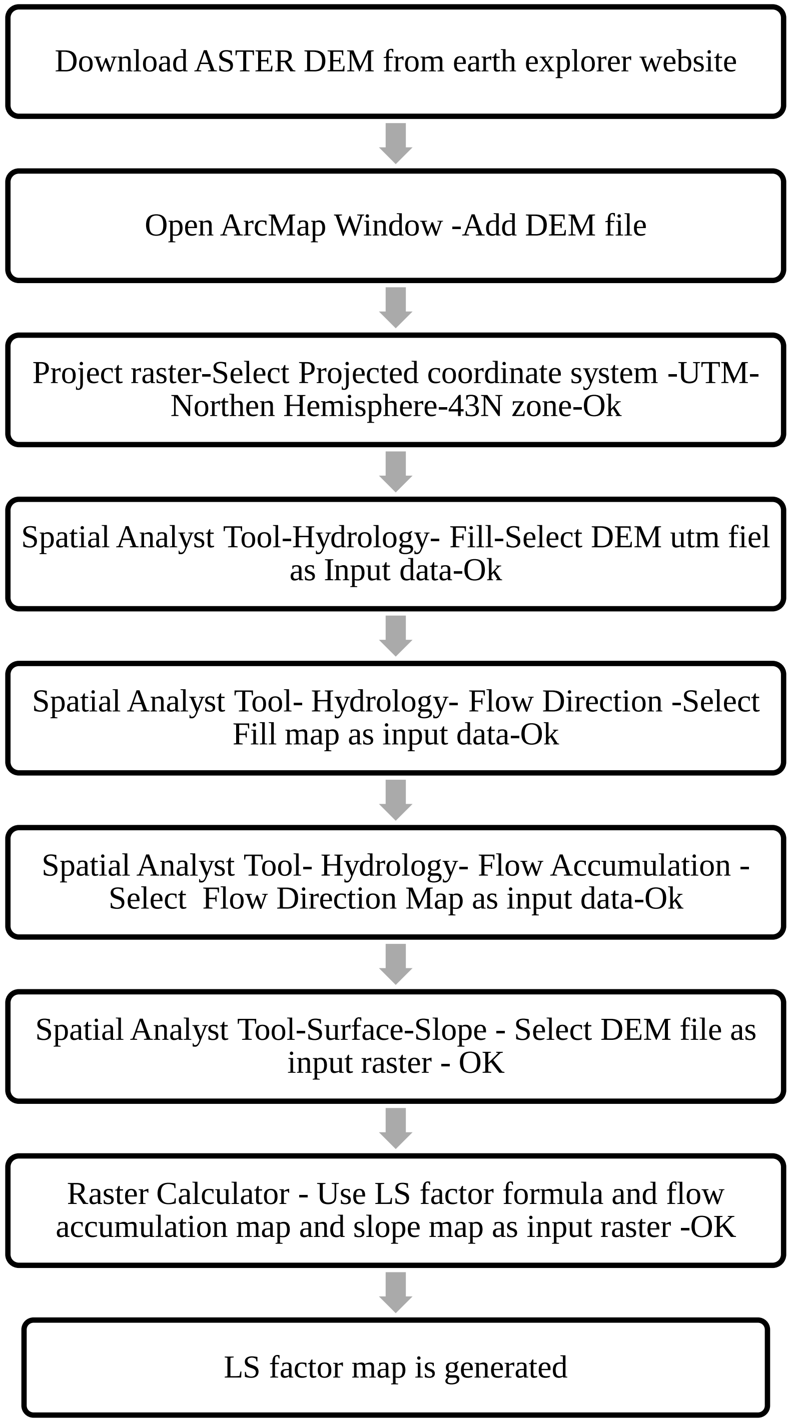
↓

R factor Formula

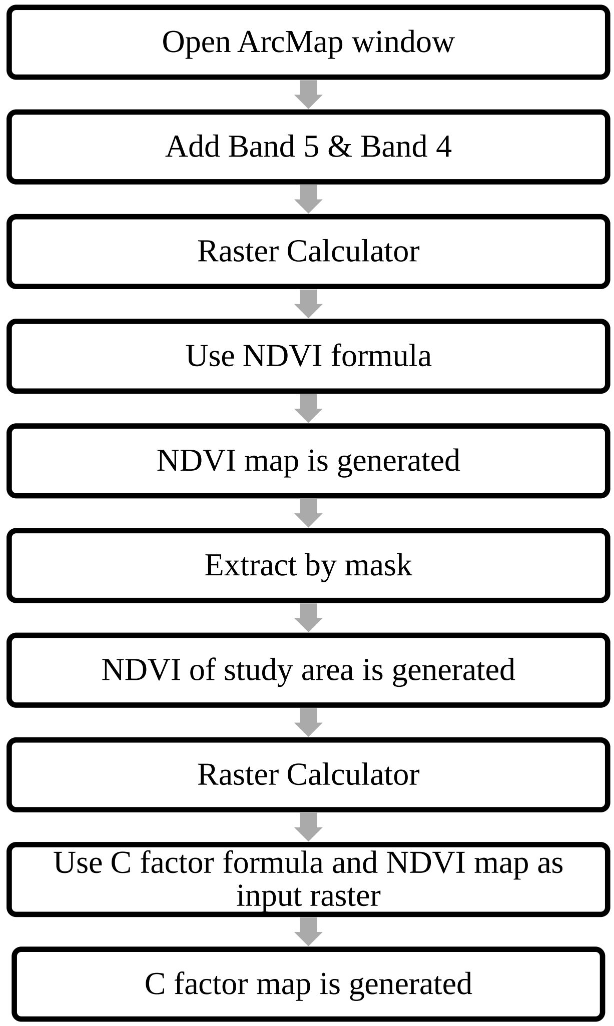
↓

R-Factor map is generated

4. Procedure for Calculation of LS-Factor



5. Procedure for calculation of C- factor



6. Procedure for Calculation of P-factor

Open ArcMap window

↓

Add DEM file

↓

Spatial Analyst Tool

↓

Surface

↓

Slope

↓

Slope map of study area is generated

↓

Spatial Analyst Tool -Reclass- Reclassify

↓

Reclassify slope according to Shin1999 table

↓

Open attribute table -Add field - P factor

↓

Assign P factor in attribute table according to Shin1999 table

8. VITA

Name	:	Miss Pradnya Dattatraya Thombare B.Tech.(Agriculture Engineering)
Personal	:	Daughter of Mrs. Mandakini and Mr. Dattatraya Shankar Thombare Born on 9^{th} April, 1995 at Ambale , Tal-Shirur, Dist- Pune
Educational details	:	
Primary	:	Z.P.Primary school, Amabale, Tal-Shirur, Dist-Pune
Secondary	:	Passed in 2010 from Vidyadham Prashala Shirur, Tal-Shirur, Dist-Pune with First class with Distinction (95.45%)
Higher Secondary	:	Passed in 2012 from Vidyadham Junior College of Science, Shirur, Tal-Shirur, Dist_Pune with first Class with Distinction (90.83%)
Graduation	:	Received Bachelor of Technology (Agriculture Engineering) Degree in June 2016 from Dr.ASCAET, MPKV, Rahuri with First Class (81.4%)
Address	:	1332/3, Spinal Plaza, Ashwini hospital, Near Gujarmala, Shirur, Tal-Shirur, Dist-Pune
Contact	:	Email: pradnyathomabre84@gmail.com
	:	Mob.No. 9421736356