# Impact Assessment of Land Use Changes and Rainfall patterns on Koyna River Catchment Hydrology

**A Project Report**

*Submitted in partial fulfillment of the requirements for the award of the degree*

*of*

**BACHELOR OF TECHNOLOGY**

*in*

**CIVIL ENGINEERING**

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# CERTIFICATE

It is hereby certified that the work which is being presented in the B.Tech. Major Project Report entitled "Impact Assessment of Land Use Changes and Rainfall Patterns on Koyna River Catchment Hydrology", in partial fulfillment of the requirements for the award of the **Bachelor of Technology in Civil Engineering** and submitted to the **School of Mechanical and Civil Engineering of MIT Academy of Engineering, Alandi(D), Pune of MIT Academy of Engineering, Alandi(D), Pune** is an authentic record of work carried out during an Academic Year 2022-2023, under the supervision of **Mr. Nikhil Bhalerao**, **School of Mechanical and Civil Engineering.**

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# Abstract

Due to an ever growing water demand, increased human interventions in natural systems and the need for sustainable future planning, studying response of a hydro-logical system to the surrounding changes has become important. The inter-relationships between human, hydro-meteorological and natural factors with water is complex. changes in land use due to unplanned urbanization can have a severe effect on hydrology of the region. Watershed, a geographically dynamic unit area that contributes runoff to a common point has been accepted as a basic unit for planning and implementation of the protective, curative and amelioration programmes.

Koyna River in Satara district of Maharashtra state in India is well-known for being home to the 'Koyna dam', the second largest completed hydro-electric plant in India. Due to the emerging changes and updated capabilities of GIS and Data capturing techniques, acquisition and creation of more accurate data is possible today. Computational capabilities of hydro-logical modeling softwares allow for use of multiple data for analysis. This has brought computer models closer to reality. They can help in quantifying the effect of desired factors on a catchment over the years. The affecting factors assessed in the present study are land use changes, soil, rainfall and its patterns. This is done by giving data as input to HEC1 model to run the simulation. Results can hugely benefit in the decision making and future planning of the region.

# Acknowledgment

We express our gratitude towards our respected project guide Mr. Nikhil V. Bhalerao for his constant encouragement and valuable guidance during the execution of this project work. His exceptional knowledge and experience in the project domain and his valuable instructions have helped us in every stage of the project. We also want to express our gratitude towards the respected school dean, Dr. Shyam Shukla for his continuous support. We would be failing in our duty if we do not thank all the concerned staff members for their inputs and the department of civil engineering as a whole for its evergreen co-operation.

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# Chapter 1

# Introduction

## 1.1 Introduction

Water is one of the essential components of environment and requires proper planning and management to achieve its sustainable utilization. Due to Global advances and the standards of living there is growing dependency on water resources. In addition to climate change, land use change is one of the human driven factors altering the quality and quantity of both surface and groundwater. Urbanization without proper planning has a severe effect on the hydrology of any region. It changes rainfall-runoff pattern in turn affecting the hydrology of a nearby river. This inter-relation stays true for an entire catchment and various studies and simulations have found many changes in a catchment severely affecting its hydrology.

Koyna River - known as the lifeline of Maharashtra is one such river with a catchment larger than 900 Sq-Km. Due to its favorable regional characteristics, along with being a home to the second largest Hydro-Power plant in India with the capacity of 1,960 MV, it is also able to sustain and provide balance in the vast surrounding forest ecosystems in the Koyna wildlife sanctuary.

Just as the wide area is depend on the Koyna, the hydrology of Koyna is sensitive to the changes in the catchment, like land cover, land use, rainfall, climate, soil. There is a need to assess those changes based on the past data and plan for the measures to be taken in the future. Today there is a huge study being done on the inter-dependencies of these kind to use them to avoid future threats as well as plan for sustainable developments.

While many parameters and approaches are considered for these studies based on the area, we have used the constantly updating technologies of today's like Remote sensing, GIS and hydro-logical modelling system software to simulate the changes throughout the 20 years with relatively more accurate data than other studies done on the similar regions. Some have assessed the effect of rainfall, but very little study has been done on the combined effect of the both, hydro-meteorological and human driven parameters as well as using models like HEC-1 and HEC HMS. Also the results available today are of inadequate accuracy due to outdated technologies used then, while we've used authorized data from government agencies, softwares of the latest computation capabilities, and have considered the latest study period. Hence we believe that this study will get us to acquire more accurate, more recent and more authentic data on the minute inter-dependencies between the Koyna river hydrology and the affecting surrounding parameters.

Figure 1.1: Koyna Reservoir

## 1.2 Background

Today, despite knowing various solutions to the environmental problems, there is lack of optimized plans of implementation. Problems of water can only be solved by learning from the examples of the past and implementing it to plan for the future. It is well known that human settlements have caused the disruption of multitudes of and natural processes. In fact water scarcity is one of the major problems we face today. Cities are seen being flooded due to lack of proper urban planning that is now difficult to undo. Hence, only knowing what human factors affect water systems is not enough. We cannot completely stop the exploitation of resources, it only can be retrained, and has to be given an alternative. Causes have to be analyzed through past data to properly plan future changes to minimize their effect on ecosystem.

## 1.3 Project Idea

The data we've got through this project, at its best can help plan and sustain the ecosystem as well as human settlements on the vast surrounding of the Koyna. It can drive the authority to take necessary actions against the factors assessed that are seen to be harmfully affecting the river ecosystem and provoke them to come up with the necessary solutions to maintain Koyna's hydrology and surrounding ecosystems. The work involves the use of technologies like Remote sensing and GIS for the acquisition and pre-processing of the data used and hydro-logical simulation software that is very rarely used. This guarantees for more authentic results that can prove to be an asset in the decision making.

## 1.4 Motivation

Project revolves around the age old domains of environmental and water resource, but involves the use of modern technologies like RS, GIS and Hydro logical Modelling. These can be used to solve many similar problem statements owing to their diverse applications. This project for us is a noble work as it solves the problem regarding the basic need of mankind, which in itself has been the motivation enough to take up, plan and carry out this project.

## 1.5 Project Challenges

Today, despite knowing various solutions to the environmental problems, there is a lack of proper implementation due to the lack of proper optimized planning. Problems of hydrology and water can only be solved by learning from the examples of the past and implementing it to plan for the future. It is well known that human settlements have caused the disruption of multitudes of natural processes. Hydrology is not an exception. In fact water scarcity is one of the major problems we face today. Cities are seen being flooded only due to lack of proper urban planning that is now difficult to undo. Hence, only knowing what human factors affect water systems is not enough. We cannot completely stop the exploitation of resources. It only can be optimized or be given an alternative. The challenges we faced: Being from a civil engineering background, most of the concepts in GIS and the computational hydrology were entirely unknown, which led us to learn everything anew. WMS is a software very rarely talked about, with limited learning resources, as well as semi-automatic classification didn't give adequate accuracy, all of which had us experiment and learn with multiple trials and errors.

## 1.6 Proposed Solution

The effect of the affecting factors can be known by analysis of past data using simulation offered by HEC1 model. On giving adequate and accurate input data, the run model can give insights that otherwise would be lost in the vast collection of data. The data we've got through this project, at its best can help plan and sustain the ecosystem as well as human settlements on the vast surrounding of the Koyna bank. This can also drive the authority to take necessary actions against the factors assessed that are seen to be harmfully affecting the river ecosystem and also in some ways provoke them to come up with the necessary solutions to maintain Koyna's hydrology and surrounding ecosystems.

## 1.7 Major Contribution

Even though the model such as we have implemented have been implemented before, the data used for such models have been of inadequate accuracy. Also the data is usually only used for the model without analysing separately to make it more ready to use for further studies. while we have chosen the accurate alternative to the satellite data used in most of the works, and authentic data sources like government authorities. Hence just as much as the results of the model,the data is presented in such a way that it can directly be used for further studies of the region.

Not much of the study is done on the upstream part of the Koyna river as the changes in the part are considered to be insignificant. Hence very less authentic and recent data of the region was present. We've have tried our best to acquire and analyse whatever possible data.

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# Chapter 2

# Literature Review

1. Nabajit Hazarika and others have analysed the river dynamics along with land-use in an active floodplain of a large tropical river (brahmaputra floodplain). Analyses of river dynamics show frequent and large-scale changes experienced in the floodplains of the study region. Change in land- use pattern in association with river dynamics can be effectively used as an indicator of evaluating socio-economic impact of riverine hazards on human beings.[1]

2. Deepak Khare and colleagues created a land use/land cover map from satellite imagery, a drainage network, and the development of a database using a geographic information system (GIS), and runoff generation with the model to estimate the impact of landuse change on run-off. Surface runoff increased by 5% in ten years, from 1990 to 2000, due to changes in land use. This study has aided in determining potential run-off change due to changing land use, on the basis of which various measures and plans, such as conjunctive use of water, developing irrigation projects, and so on, can be implemented, all of which are heavily dependent on the land use pattern.[2]

3. S. S. Panhalkar* and others have done the Generation of LULC map and flood risk map validated with long-term inundation maps and Generation of flood risk index(FRI) Considering: land cover and topographic, social (population density) and geomorphological parameters and to identify potential flood risk areas. Importance

of RS and GIS in hazard management. 7.47% area of the study region falls in high risk zone and 21% area in moderate risk zone. Overall accuracy of AHP method is quite higher with 79.36% as compared to ranking and rating methods used for weighing.[3]

4. D. D. Alexakis, M. G. Grillakis, and 5 others [2014] used a hydrological model to simulate runoff processes in a catchment area, quantifying the sensitivity of the distributed hydrological model to land use, and predicting the future land use/land cover (LULC) map using CA-Markov chain analysis. The critical role of the phenomenon of urban sprawl and the significant change in LULC in the increase of runoff rate Multi-temporal remote sensing data in hydrological models can effectively support risk assessment, sustainable development, and general management decisions before and after flood events. The application of CA-Markov provided an indication of the potential impact of future land use change on flood vulnerability.[4]

5. Griet Heuvelmans and others(2) split-sample test and predicted the land use impact on catchment hydrology , checked the validity of derived parameter values which are assumed to be identical for the new land and also the crop and management characteristics that are adapted to the land use under study by evaluating the transfer-ability of the main controlling parameters of the semi- distributed SWAT model in a step-wise fashion. The transfer of parameter estimates between catchments with different environmental conditions, may be problematic especially for the simulation of low flows. The hypothetical land use scenario induces new environmental conditions affecting model parameters other than the strictly land use related ones.[5]

6. P.D.Wagner and others(2) analysed the past land use changes between 1989 and 2009 and their impacts on the water balance in the Mula and Mutha Rivers catchment upstream of Pune region in Maharashtra To identify the land use changes from three Rivers catchment multi-temporal land use classifications for the cropping years. To use the hydro-logic SWAT (Soil and Water Assessment tool) model to assess im-

pacts on runoff and evapo-transpiration. They found out that an increase of urban area from 5.1 % to 10.1 % and cropland from 9.7 % to 13.5 % of the catchment area during the 20-year period were identified. At the sub-basin scale urbanisation led to an increase of the water yield by up to 7.6 %, and a similar decrease of evapo-transpiration, whereas the increase of cropland resulted in an increase of evapo-transpiration by up to 5.9 %.[6]

7. Praveen Kumar Mallupattu and others(2) studied the area's substantial rapid development during the past decades in terms of urbanisation, industrialization, and population increase. And they detected and quantified the LU/LC in Tirupati urban area. LU/LC changes were significant during the period from 1976 to 2003. There is significant expansion of built-up area noticed. On the other hand there is decrease in agricultural area, water spread area, and forest areas.[7]

8. P.E.Zope and others(2) estimated the change in Land use between 1966 and 2009 using the topo-sheets and satellite images for the Poisar River catchment in Mumbai, India. The major causes of urban floods include increase in precipitation due to climate change effect, drastic change in land use–land cover (LULC) and related hydrological impacts. Effect of urbanisation is a prominent reason for an increase in the flood peak discharge and lag time reduction. Rapid infrastructural development of the area has caused the reclamation of the natural places used earlier as retention or detention ponds to satisfy the need of urban dwellers.[8]

9. Aman Srivastava and Pennan Chinnasamy acquired Rainfall data and Spatio-temporal data(RS and GIS) of IIT Bombay campus, Land use classification ( and area of each land cover), Soil conservation service- curve number (SCS- CN), Runoff and WCN estimation for each year, Establishing relation between LULC and hydro-ecological balance. Results are rather positive, attributing to the green campus approach of IITB. Maximum-likelihood algorithm could be employed to detect the land-use classifications for future studies. Generating simulated scenarios to predict

future behaviours of the rainfall-runoff process within changing trends of LULC using advanced hydrological models can be future scope. Better differentiation between vegetation cover, barren land, and the forest (cover) required.[9]

10. Pradeep kumar naik and others(3) have done the Classification of the water resources of the Koyna River basin and assessed the suitability for drinking and irrigation purposes. Highest annual average rainfall is recorded at Mahabaleshwar (6,024 mm) in the north, whereas the lowest is received at Karad (745 mm) in the east the probability of the occurrence of normal rainfall. Analysis has been done for 187 water samples from different sources and analyzed the piper's diagram. Both surface water and groundwater are fit for drinking and domestic purposes as per the criteria prescribed by the Bureau of Indian Standards.[10]

11. Sambhaji Shinde and others(3) investigated the spatio-temporal variability of 40-year(1970–2010) in the discharge of the Krishna and Koyna River channels at Karad and Varunji gauging stations. Calculation of mean decadal discharge(MDQ), standard deviation (SD), Mean annual discharge (MAQ), coefficient of variation (CV) and Pearson correlation coefficient (R), and variance (R2). highest discharge variability ( of 61.2%) was at the Varunji (Koyna) station and minimum (51.0%) at the Karad (Krishna) station. Low rainfall variation from the actual mean in the Krishna(457) and high in the Koyna (1050) basins. The MAQ for both the channels was low during 2001–2002 and maximum during 2006–2007. MDQ of the Krishna River was found higher as compared to the Koyna River. At the Karad station, the discharge variability was highest between 2000 and 2010, whereas at the Varunji station, it was lowest between 1970 and 1980.[11]

12. Piyush Yadav and Shailesh Deshpande identified impervious surface increment, green cover loss, and natural drainage loss using detailed accounts from LULC changes take place in Pune city.The LANDSAT 7 image classification accuracy ranges from minimum 84.3% to maximum 91.04% with an average accuracy of 87.52 % for

14 years. The classification result shows that there is a prominent increase in the impervious surfaces: a jump of 13.74% from 11.67% in 2001 to 25.41% in 2014. The increase in impervious surface has resulted in loss of urban vegetation (grass, tress cover etc.), agricultural land, and large open areas from 87.54% to 73.27% with a total loss of 14.27%.[12]

13. Groundwater discharges and recharges from various sources for the water years 1988-89 and 1992-93 (May to May of the following year) have been estimated by pradeep k naik and Arun aWasthi for the Koyna River basin. Groundwater draught by wells for domestic, stock, and irrigation needs is estimated to be 16.50 MCM per year, with natural losses from the groundwater system totaling 38 MCM (35 MCM baseflow + 3 MCM spring flow) per year, of which 7 MCM is already being directly pumped from Koyna River tributaries for irrigation needs.[13]

14. Bansode T. M. and Konnur B. A. studied and analyzed the land use patterns and changes of Koyana river basin using remote sensing and GIS. They also collected and analyzed the multi spectral satellite data of LANDSAT for mapping and monitor land use changes occurred during 2005. Because it is regarded as a crucial component for comprehending the planet and its entire system, mapping land use is significant for many management and planning operations. The current study demonstrates how effectively land use classification and its analysis of change in the study region in 2005 may be accomplished utilising remote sensing and GIS technology. According to the findings, there are three types of land usage in total: forest land, non-agricultural land, and cultivable land. The quality of the input datasets, the classification methods, the algorithm, etc. are likely to have an impact on the classification outcomes. For the selection, planning, and implementation of land use schemes to fulfil the needs of the community, information about land use and land cover and potential uses for them is crucial.[**?**]

15. Pratik S. Matkar and Abhijit M. Zende identified land cover/land use change and

assessed change dynamics at various spatial and temporal scales. Satara district was chosen as a study area because it is a rapidly growing area, in order to quantify the LU/LC pattern for the year 2012. The National LU/LC classification developed by NRSC ISRO divides the study area's land into five types of Levels. Scrub land is the major LU/LC category in the Satara area, covering 6238.91 km2 (59.56%), followed by agricultural land, Natural Vegetation, Fallow land, and water bodies, each contributing 2724.5475 km2 (26.0115)%, 995.125 km2 (9.49%), 327.8675 km2 (3.12%), and 188.55 km2 (1.80%) of the total geographical area. The study concludes that in the Satara district area, scrub land contributed the most (59.56%), while water bodies contributed the least (1.80%), and it also identifies the driving forces that have a significant impact on the urban ecosystem. Population growth, demand for forest products, demand for locally produced food, and global issues such as higher energy prices and climate change could be attributed to the driving forces for the resulting spatial extent of these land use or land cover classes and their changes in this study area. Furthermore, future climate change may affect where humans live and how they use land for various purposes.[14]

16. Tarate Suryakant Bajirao and others(2) have determined the impacts of LULC on Koyna river basin hydrology. Study Span-1999-2015: Percentage increase/decrease was found in land classes. Increased: Deep water, rocky land/ hard surface area. Decreased: Agricultural land, hilly land. Converted: Agricultural land into Hard surface and Scrub land, Thick forest into Scrub or open forest. Disappearance of high vegetation coverage (HVC) with an increase in low vegetation coverage (LVC) and medium vegetation coverage (MVC) seen. Cause for most of the change: natural and anthropogenic activities.[15]

17. Wakjira Takala Dibaba and others(2) have assessed the LULC, climate change and their combined effect on finchaa catchment hydrology. The impacts of land use changes on hydro-logical components like surface runoff, ground water, water yield were seen over time span. For this, CA-Marcov model was used. Sensitivity Analysis, Calibration and Validation were done to assess the performance of the hydro-logical

model. Also by projecting climate change, temperature and rainfall was assessed. And finally the combined effect of both climate changes and Land use changes were assessed.[16]

## 2.1 Related work And State of the Art

- For preparation of the land use data, most of the similar works, that is both- those restricted to land use change study as well as those going for its use in hydro-logical or similar models, have used satellite imagery owing to its ease of access. They use either Landsat or Sentinel's imagery, for being freely available, or purchase superior quality of satellite imageries if more accuracy is expected. It has become a common methodology.
- Soil data is mostly taken from FAO or similar websites. It contains the dataset of the entire globe.
- Various models are run today harnessing the present high computational capabilities. They are the simulation of the reality and help in achieving diverse objectives like water resource management, flood assessment, hydro-geological studies, urban water planning, etc. Though no model can be an exact replica of the reality, they are enough for getting objective specific results and are widely being used for taking sustainable decisions.

## 2.2 Limitation of State of the Art techniques

- The satellite data freely available is not accurate enough to distinguish the sub classes like those under the vegetation class. They have to be identified by land surveying, which still cannot guarantee consistency in the accuracy. Many also opt for high quality premium imageries, but they are over-priced owing to the details they show.

- FAO database is good for a few countries that have finer soil data available and open for use, but the soil data of India is much coarser on FAO database, which is far from the resolution that the hydro-logical studies demand.
- When going for hydro-logical modeling, the emphasis while concluding is only led on either the results of the worked out model, while the change in land use data used over the year for the model is not separately manually analyzed. Though this allows for keeping the topic of the discussion focused, loses a valuable insight about the land use changes through years impacting the hydro-logical processes. The data can also be kept as a record of the land use change.

## 2.3 Discussion

Studies similar to ours are rarely carried out on dam upstream areas, and if done on catchments as large as the Koyna's are restricted to a single cause and effect factor. We've considered multiple factors, and chosen a simple model that helped getting direct relation of the land use, soil and precipitation with the hydro logical system. Instead of satellite imageries that for the free data lacks accuracy while the data of required accuracy is overpriced, we've used data pre-classified by NRSC. NRSC is a reputed Indian institute involved in remote sensing. This ensures the authenticity and accuracy of the data.
But the data is in raster format, we had to manually digitize it, and raster layers only of 5 year intervals: 2005, 2010 and 2015 are available for use, hence all the study period itself was fixed accordingly.
Similar ways, we've used raster data given by government authorities, of relatively finer resolution but requiring manual digitization over the FAO for its readily available soil's vector data, with much coarser soil types.

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# Chapter 3

# Problem Definition and Scope

## 3.1 Problem statement

1. Land use land cover changes are hugely affecting hydrology of the Koyna river catchment.
2. Just as the surrounding forest ecosystems, rainfall patterns, human settlements, run-off-infiltration are sensitive to the behavior of Koyna, the vice versa is true.
3. Very little authentic and recent data is available about the effects of land use changes and rainfall patterns on the entire dam Koyna catchment upstream the dam. Decision making and future planning cannot be done based on inadequate, inaccurate, or out- dated study data.

## 3.2 Goals and Objectives

1. To prepare Land Use classification and land use change data for the Koyna River Catchment.
2. To develop a rainfall-runoff model of the catchment.
3. To analyze hydro-meteorological data of the catchment.
4. To analyze the combined effect of change in land use and rainfall patterns on the catchment hydrology.

## 3.3 Scope and Major Constraints

### 3.3.1 Scope

- Results of the land use change detection will remain as a tool for future planning of the region. Land is classified for recent years and is more reliable due to the manual classification opted over the satellite based semi-automatic classification.
- Assessment of the factors like rainfall, soil and hydrology throughout the years requires collecting the data from various government authorities.The actual work of analysis and decision making thus takes time. We've made the work for future studies easier by collecting the data and putting it into the best way to also be readily available for insights and useful decision making.
- We've established direct inter-relations between rainfall and hydrology; land use and hydrology; soil and hydrology, while most of the projects either focus on the running of the model or relation between only one of the factors.

### 3.3.2 Major Constraints

- NRCS layers of the years between 2005 and 2010, 2010 and 2015 are not available. Hence the change over the 5 years directly only could be assessed.
- Large part of the Koyna reservoir land is maintained in the form of 'Koyna Wildlife Sanctuary'. This land remains unchanged, hence no significant and drastic changes are seen in forest and agriculture.
- Computer models are only the predicted replicas of the reality, hence never give near-accurate results. Studies in Hydrology and meteorology requires consideration of multitude of factors for the model to be close to accurate. One cannot predict what factor might impact in what intensity due to natures unpredictable behaviours.

## 3.4 Expected Outcomes

1. The accurate spatial and attribute data of land use classes in Koyna River catchment for year 2005, 2010 and 2015.

2. The helpful conclusions drawn from the land use changes in mentioned 10 years spans.

3. High accuracy data from year 2005 to 2015 of the following factors considered:

i. Land use

ii. Soil Texture

iii.Daily Rainfall

iv. Daily dam inflow and outflow

4. The running HEC1 model with acceptable accuracy that helps establishing interrelations between the factors considered.

# Chapter 4

# Project Requirements

## 4.1 Software Requirements for Project completion:

### 4.1.1 QGIS

Also known as Quantum GIS is a free and open-source cross-platform desktop geographic information system (GIS) application that supports viewing, editing, and analysis of geospatial data. QGIS works as a geographic information system (GIS) software, allowing users to analyze and edit spatial information. It supports both-raster and vector layers, multiple formats of raster images, and can geo-reference images. With various ready to install plugins available, it can be used in a wide variety of applications, hence is used across various domains.

QGIS was used by us for:

- Watershed delineation and
- Land use classification

### 4.1.2 WMS(Watershed Modelling Systems, by Aquaveo)

It is all-in-one water solution software that provides an interface to support industry standard hydro-logical models like:

- HEC1
- HEC HMS

- Rational Method
- National Stream Statistics Modeling
- MODRAT Modeling
- Spatial Hydrology - HMS MOD Clark and GSSHA Modeling
- Hydraulics and Floodplain Modeling
- Storm Drain / Sanitary Sewer Modeling
- Water Distribution Modeling
- Water Quality Modeling

It provides good support as well as processing tools for GIS data, and requires extensive CPU and RAM for computing.

We've used the software to:
- Delineate watershed
- Input and format data as required for HEC1 model.
- Calculate SCS Curve Number
- Create and analyze Rainfall Runoff(HEC1) Model

## 4.2 Considered Stakeholder Expectations

It is expected that the results be showcased in a format globally viewable and easily interpretable for a non-technical people. The model alone is not the final result, but the conclusions drawn from the results of the simulation have to be stated and the results be showcased in an authentic and easily readable formats like non-verbal visualizations.

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# Chapter 5

# Methodology/ Approach/ Techniques

## 5.1 Flow Chart

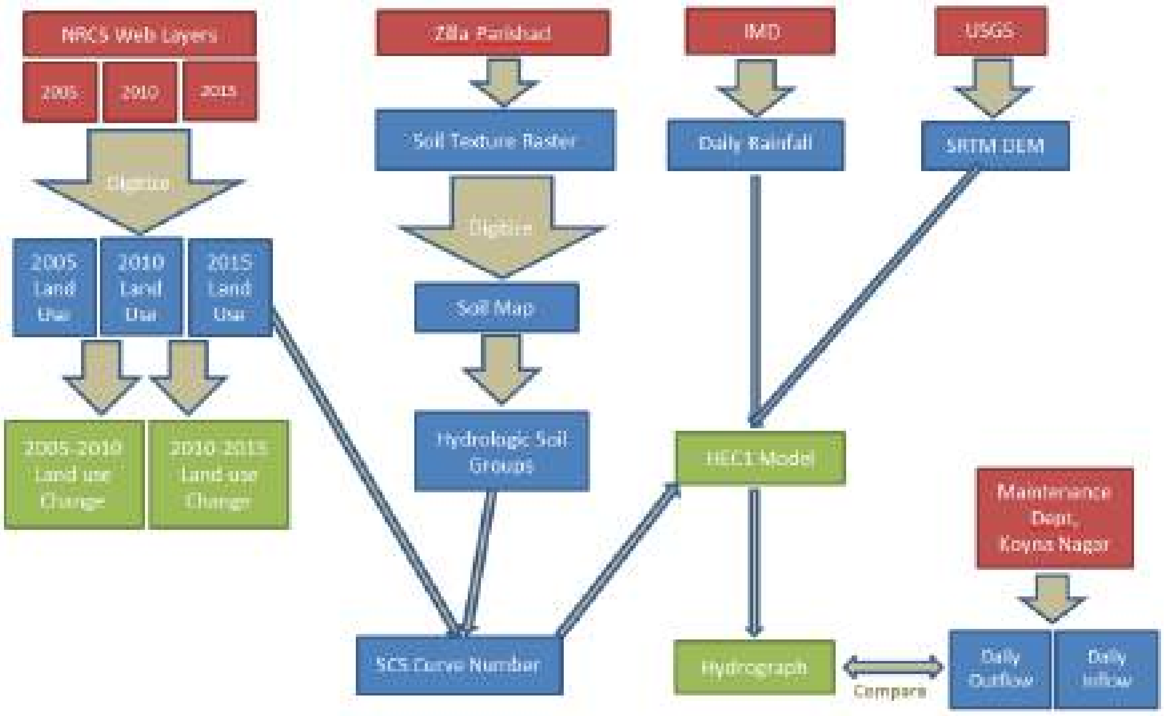



Figure 5.1: Flow Chart

## 5.2 Approach

The goal was to assess the impact of land use on hydrology of certain region, but also in the process, create an authentic data that could be useful for decision making. The land use data required for hydro-logical model could also be used for assessing change through years, and create land use change data for 10 years. Study year was suggested by one of the personnel in WRD. It was suggested Dam upstream area be taken because the downstream is already studied by many.

- Area of Interest: Koyna River Catchment.
- Study Period: 10 years [2005 to 2015]

Sequentially the following steps were followed:

**A. Preparation of data for Hydro-logical Model:**

1. NRCS raster data was manually digitized for change assessment and as an input to hydro-logical model.
2. Daily rainfall data from 2000 to 2020 was obtained from Indian Meteorological Department, Pune.
3. Soil Texture Raster of Satara district of a finest resolution was obtained.
4. Daily inflow and outflow of Koyna Dam was obtained from Irrigation Department, Pune.

**B. Change detection:**

Digitized land use class data of year 2000, 2005 and 2015 was analyzed to assess change in land use between each of the 5 years span.

**C.Hydro-logical Modeling:**

HEC1 model was run in WMS Software inputting the collected data

# Chapter 6

# Implementation

## 6.1 Study Area

Area of interest was the catchment to the Koyna River's dam upstream portion. The area was recommended by a representative from Water Resource Department,Pune owing to the fact that due to conserved lands and forests changes are not drastic in the area, and very less data about change in hydrology and land use is available. The river starts at Mahabaleshwar at an elevation of 579. It is a major tributary to Krishna and home to the largest hydro-electric power plant in India.

Figure 6.1: Region of Interest

## 6.2 Catchment Delineation

Hydro-logical studies cannot be directly carried out considering any area and boundary of a choice. They have to be carried out considering a catchment boundary for a particular outlet. As the Koyna dam is the point where all of the river's upstream water and the streams contributing to the river finally meet, we delineated the region based considering the DAM as an outlet. Catchment areas are practically nothing but the result of differences in ground elevations. The area where all of the precipitation that happens finally meets the defined outlet point is the catchment area. The region right beyond the catchment boundary has to have an opposite aspect as the boundary has to be essentially a ridge that leads the water to flow at its either sides, one of which comes under the selected catchment and the other in the neighboring catchment. Hence the input for the software is nothing but the elevation values at definite points, and an outlet point. Elevation is extracted from the Digital elevation model, while the outlet point vector is defined by us. Employing step by step algorithms in the form of different functions in plugins available in QGIS, we got the drainage network and based on the same, the delineated catchment area.

- DEM used is **1 Arc Sec SRTM DEM** from *https://earthexplorer.usgs.gov/*
- DEM had to be pre-processed before using.
- Pre-processing done on raw DEM involved:

1. Clipping to an Area of interest
2. Re-projecting to proper projection system
3. Filling sinks

- Strahler order of a desired value should be defined according to the precision desired. In the present study, all the strahler values of value 2 and above were allowed. This helped for a precise drainage network creation.
- After defining an outlet point, its coordinates were used in an upslope area plugin to delineate the catchment area- to obtain a shapefile acting as a boundary to the catchment.

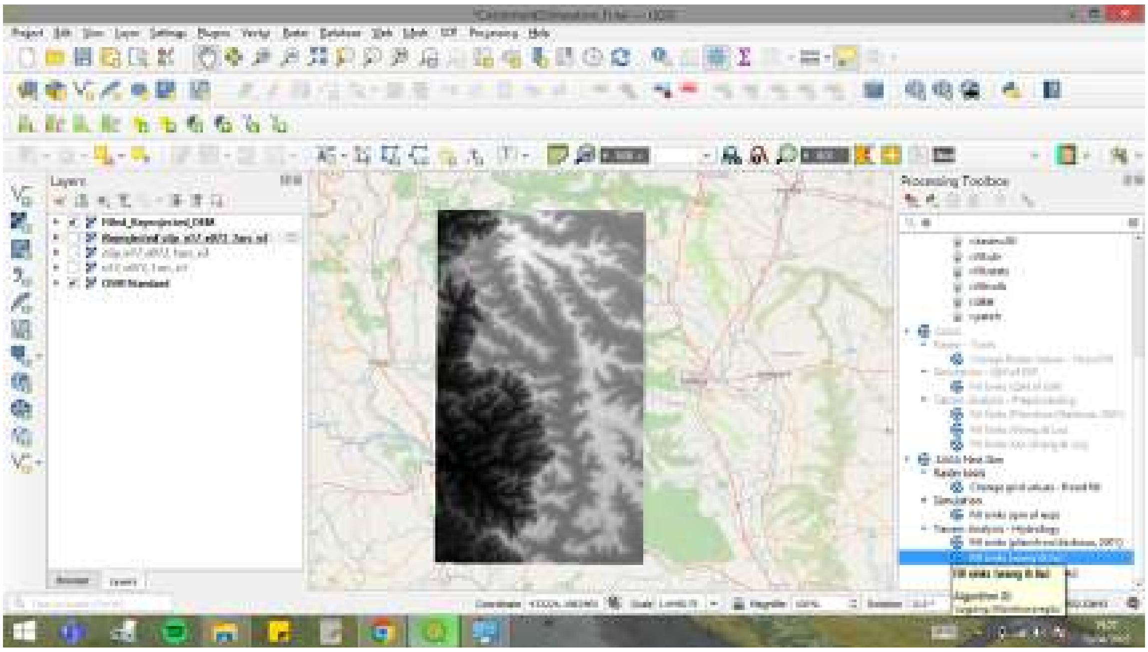


Figure 6.2: Imported DEM pre-processed in QGIS

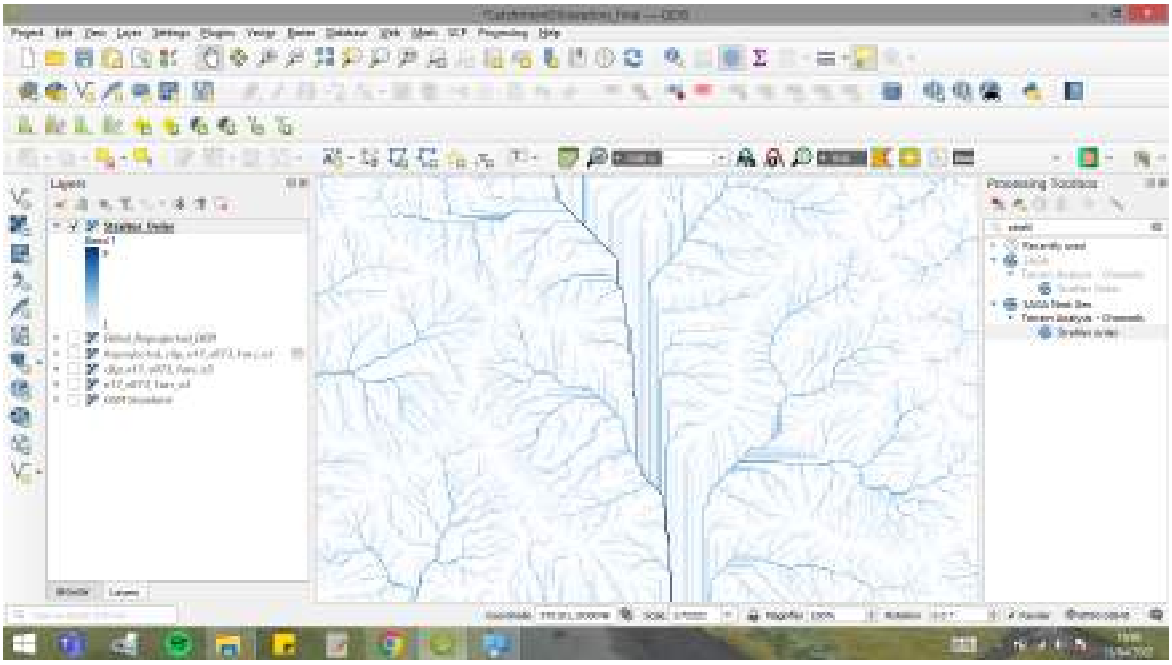


Figure 6.3: Strahler Order

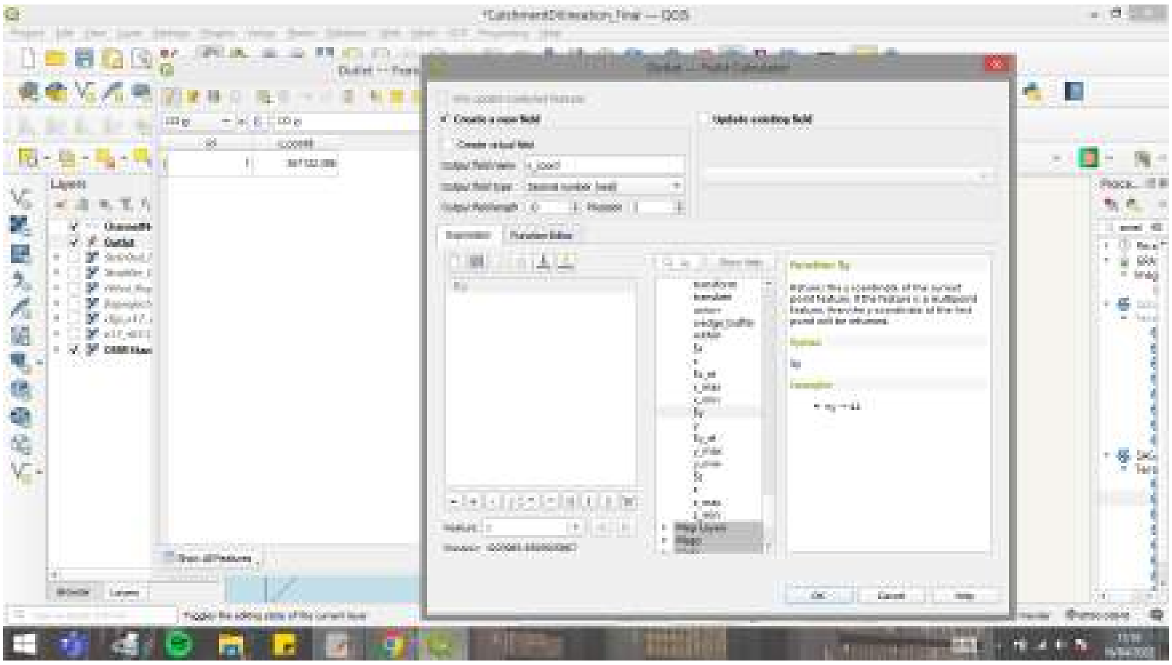


Figure 6.4: Outlet Point

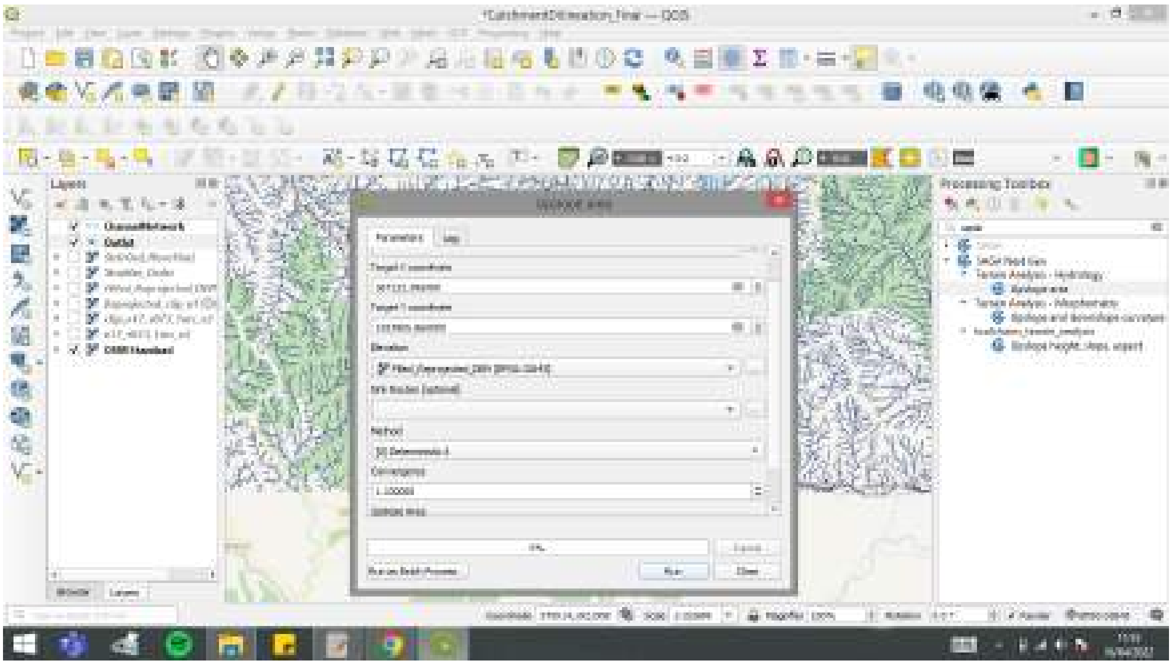


Figure 6.5: Up-slope area plugin for Catchment delineation

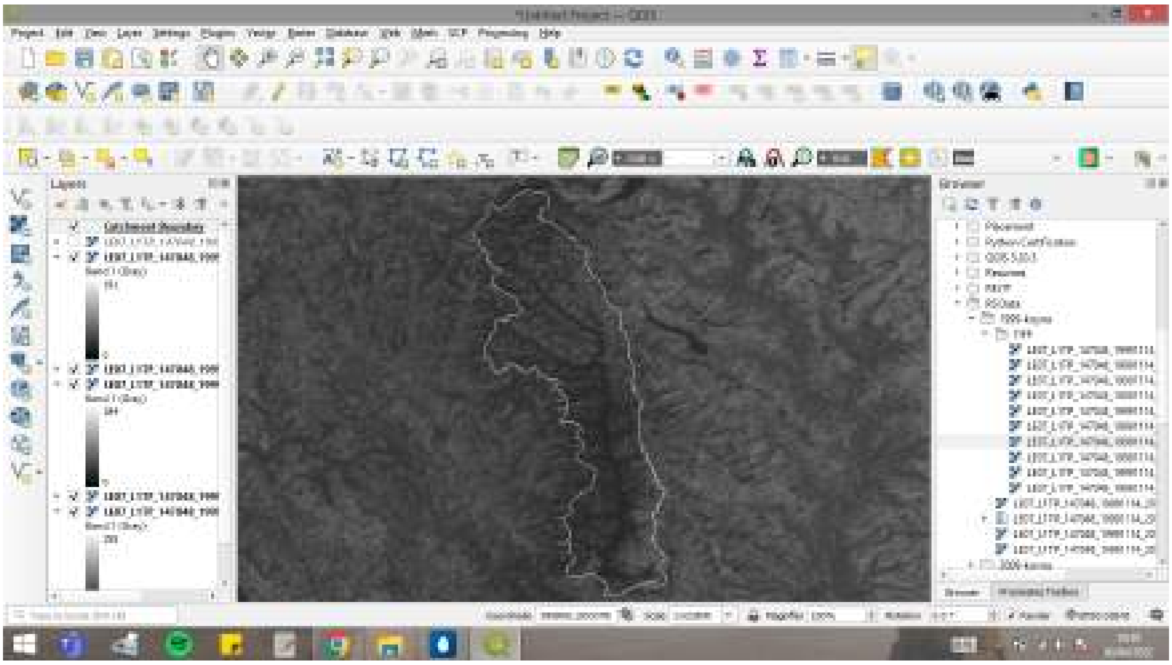


Figure 6.6: Obtained shape-file layer of catchment boundary

This catchment acts as a spatial boundary for all the further data and processes. Following are the features of the catchment:

- **Catchment Area: 902 sq-km**
- **Elevation range: 609 to 1402 m**
- **Water coverage: 92 sq km**
- **Outlet: Koyna Dam**
- **Delineation done using: QGIS**

## 6.3 Land Use Classification and Change Analysis

### 6.3.1 Experimented Approach: Semi-Automatic Classification

The conventional and more opted for approach was tried that involved classification using satellite imagery.

The classification was done separately on each year's spectral bands. None of the versions of Landsat satellite sensors has been active throughout the chosen 20 years (1999-2019). The years chosen during this approach were not the years chosen for the finalized one and for each year following data was used:

**1. 1999:** Landsat 7 [(Enhanced Thematic Mapper Plus (ETM+)]

**2. 2000:** Landsat 5 [Thematic Mapper (TM) ]

**3. 2019:** Landsat 8 [Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)]

Each of the three satellite data is not merely an images but a bandset- the collection of images of different spectrums or bands.

Classification was employed on the bandset collection of each year, using 'SCP(semi-automatic classification plugin)'.

Bandsets had to be preprocessed, which involved:

1. Clipping with the vector file created
2. Atmospheric and other corrections

Then the classification algorithm was run selecting the number of classes of choice and classified image was obtained. These two steps were repeated for two other years.

The algorithm classifies an image(here satellite) based on the differences and the similarities in pixel values. EM radiation values captured in a pixel representing built-up area is different from that of the pixel that has captured agriculture. While the there is relative closeness in the values of two pixels that have captured agricultural land. The software classifies as the image in as many clusters as we want. The re-classification has to be done based on the acquired results.

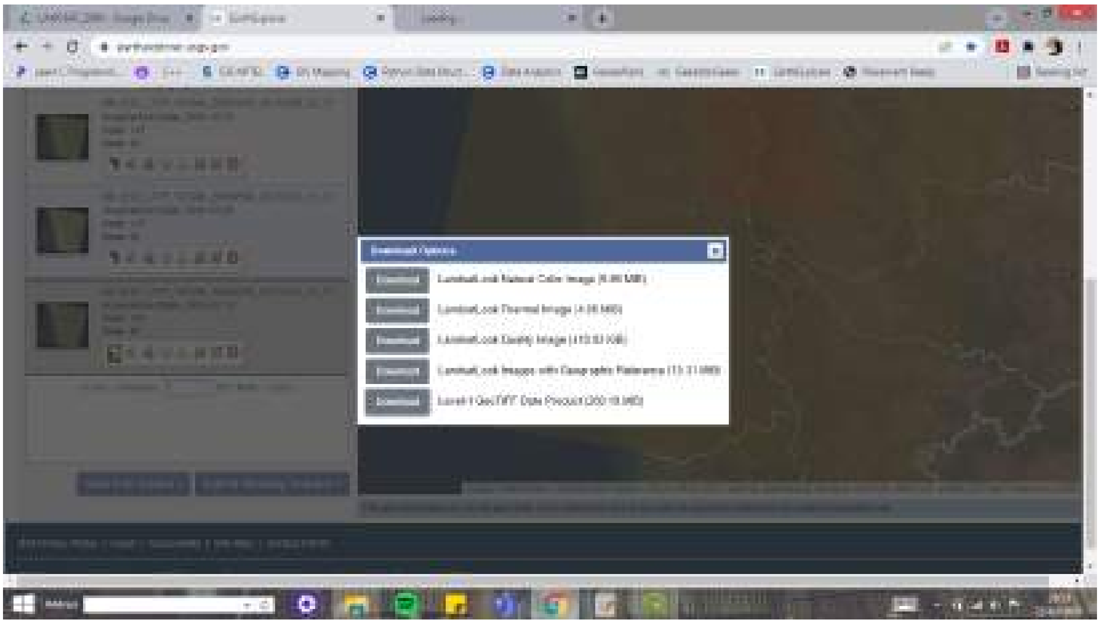


Figure 6.7: Satellite image downloading for one of the years (1999, landsat 7)

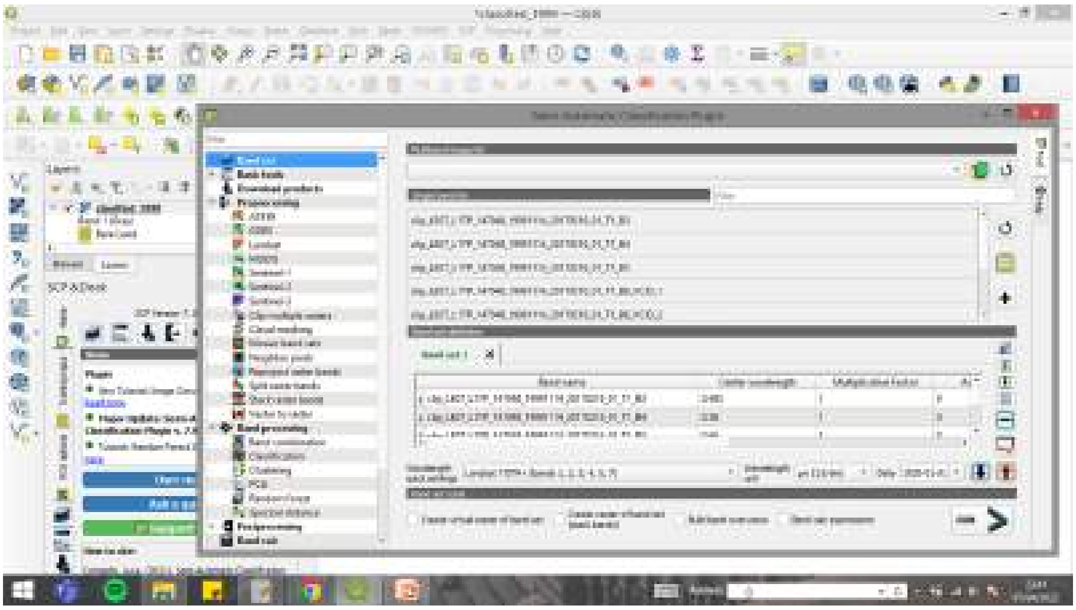
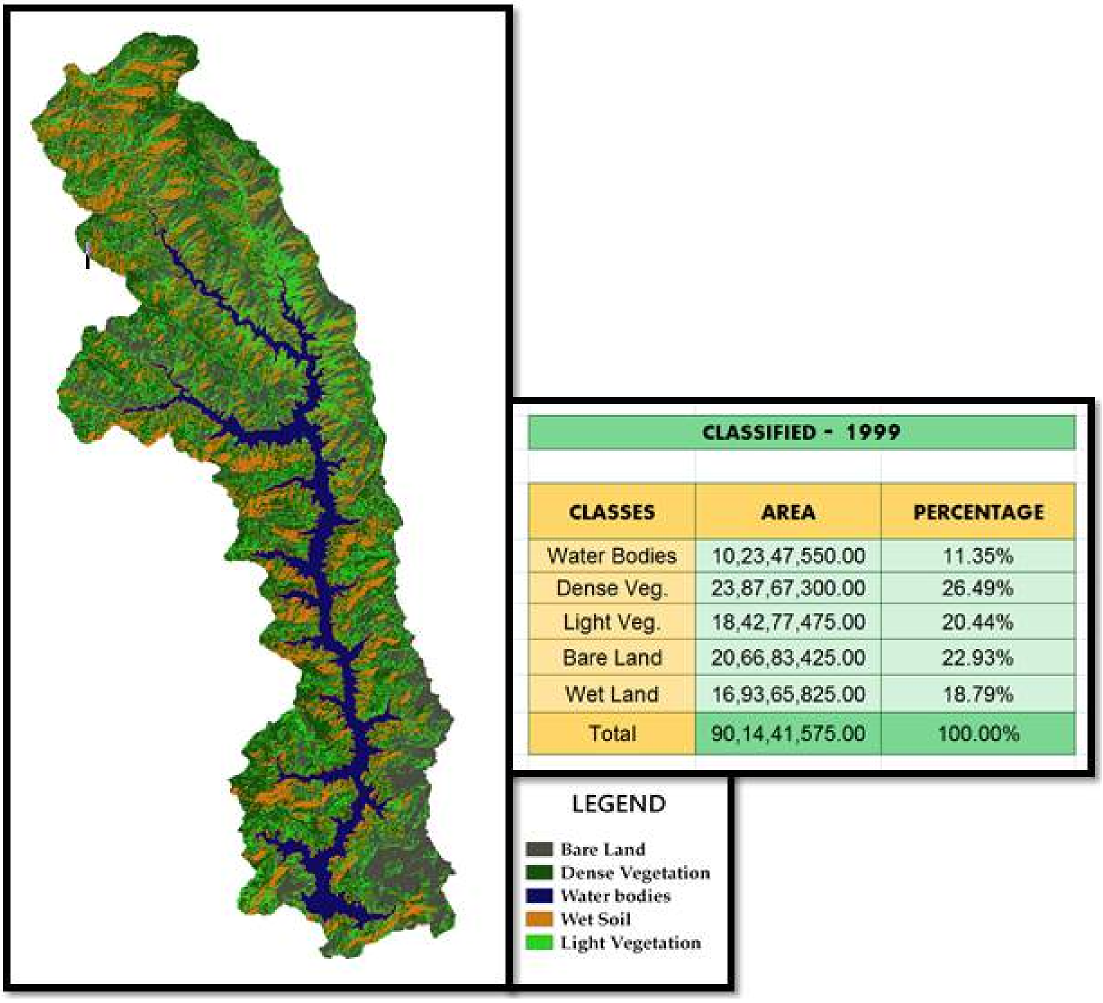


Figure 6.8: Semi-Automatic Classification Plugin

**Results of Land-use Classification done using Clustering:**

***1999:***

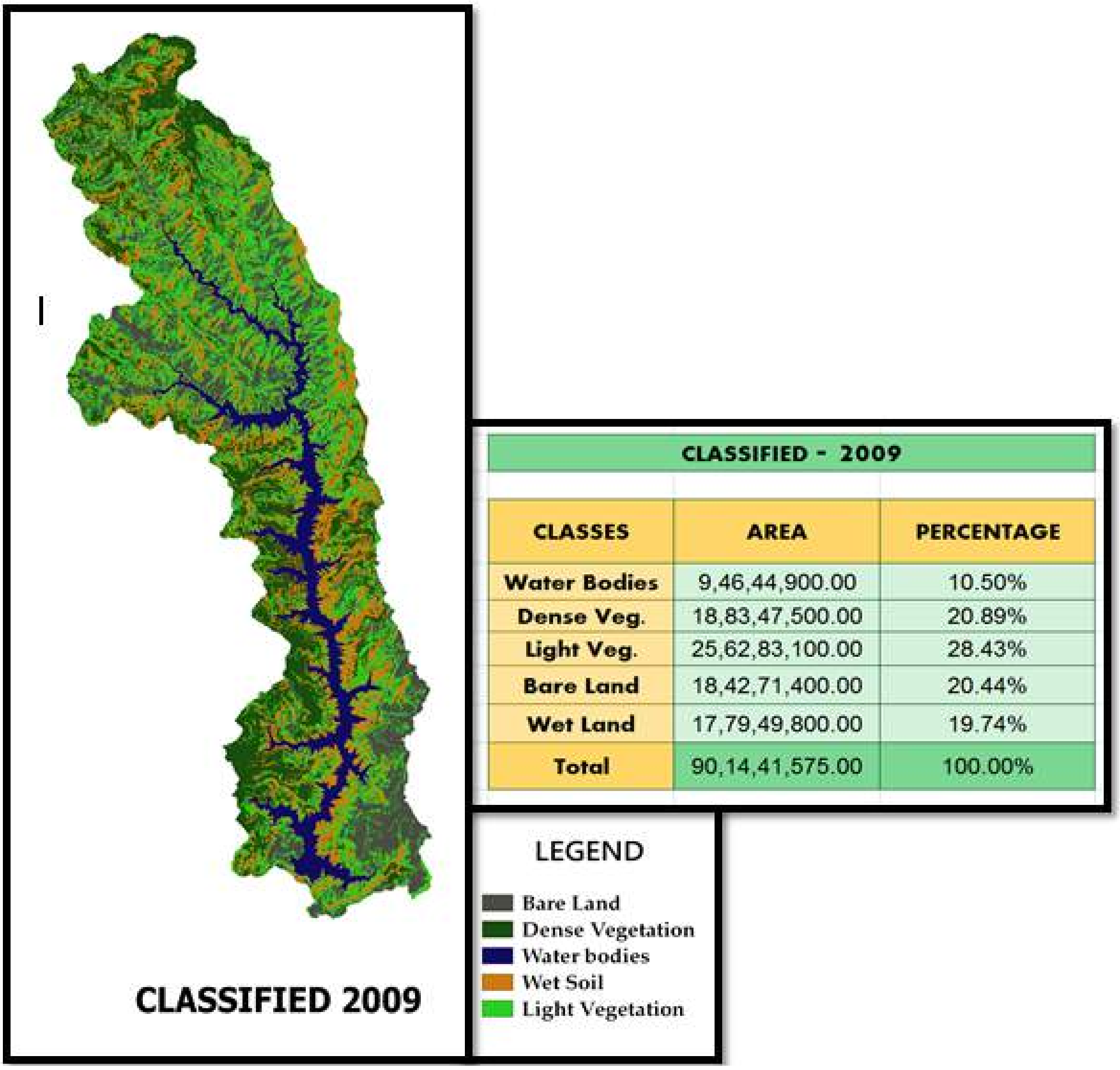


| CLASSIFIED - 1999 | | |
|---|---|---|
| CLASSES | AREA | PERCENTAGE |
| Water Bodies | 10,23,47,550.00 | 11.35% |
| Dense Veg. | 23,87,67,300.00 | 26.49% |
| Light Veg. | 18,42,77,475.00 | 20.44% |
| Bare Land | 20,66,83,425.00 | 22.93% |
| Wet Land | 16,93,65,825.00 | 18.79% |
| Total | 90,14,41,575.00 | 100.00% |



Figure 6.9: Output: 1999, Land Classification

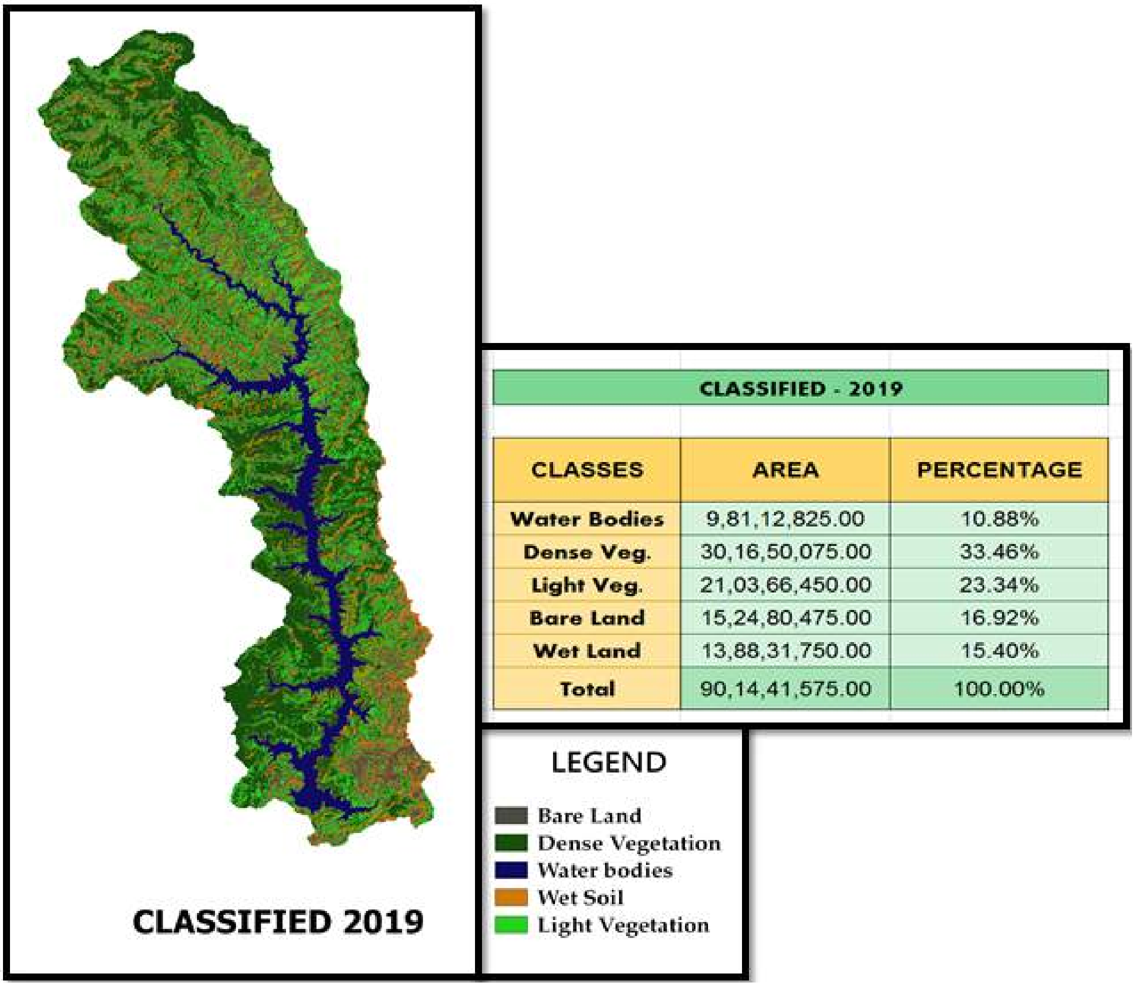
*2009:*




| CLASSIFIED - 2009 | | |
|---|---|---|
| CLASSES | AREA | PERCENTAGE |
| Water Bodies | 9,46,44,900.00 | 10.50% |
| Dense Veg. | 18,83,47,500.00 | 20.89% |
| Light Veg. | 25,62,83,100.00 | 28.43% |
| Bare Land | 18,42,71,400.00 | 20.44% |
| Wet Land | 17,79,49,800.00 | 19.74% |
| Total | 90,14,41,575.00 | 100.00% |

Figure 6.10: Output: 2009, Land Classification

***2019:***




| CLASSIFIED - 2019 | | |
|---|---|---|
| CLASSES | AREA | PERCENTAGE |
| Water Bodies | 9,81,12,825.00 | 10.88% |
| Dense Veg. | 30,16,50,075.00 | 33.46% |
| Light Veg. | 21,03,66,450.00 | 23.34% |
| Bare Land | 15,24,80,475.00 | 16.92% |
| Wet Land | 13,88,31,750.00 | 15.40% |
| Total | 90,14,41,575.00 | 100.00% |

Figure 6.11: Output: 2019, Land Classification

Having distinguished each of the year's land use into classes, software is able to quantify the area of each class and the change in the area of a same class in maps of two different years.

The number of classes produced by the software are not always equal to the number desired by us, hence by visual inspection, comparison with satellite images, we had to regroup the classes into the desired number, and then calculate the area of each class, the change in the area, and the percentage change.

**Results of Change Analysis:**

**LULC change from 1999 to 2009**

| Classes | 1999 | 2009 |
|---|---|---|
| Water Bodies | 11.35% | 10.50% |
| Dense Veg. | 26.49% | 20.89% |
| Light Veg. | 20.44% | 28.43% |
| Bare Land | 22.93% | 20.44% |
| Wet Land | 18.79% | 19.74% |

Figure 6.12: Land Use Change 1999 to 2009

**LULC change from 2009 to 2019**

| Classes | 2009 | 2019 |
|---|---|---|
| Water Bodies | 10.50% | 10.88% |
| Dense Veg. | 20.89% | 33.46% |
| Light Veg. | 28.43% | 23.34% |
| Bare Land | 20.44% | 16.92% |
| Wet Land | 19.74% | 15.40% |

Figure 6.13: Land Use Change 2009 to 2019

The results of the change detection obtained with this method were of a largely inadequate accuracy. Hence the results of this method were discarded to be replaced by the other.

### 6.3.2 Final Approach: NRCS Layer Digitization

The reasons of choosing this approach over the previous one:

1. Achieve superior accuracy(of about 80-90%)

2. Increase the number of classes

The reason this approach is much better for an accurate classification is that it

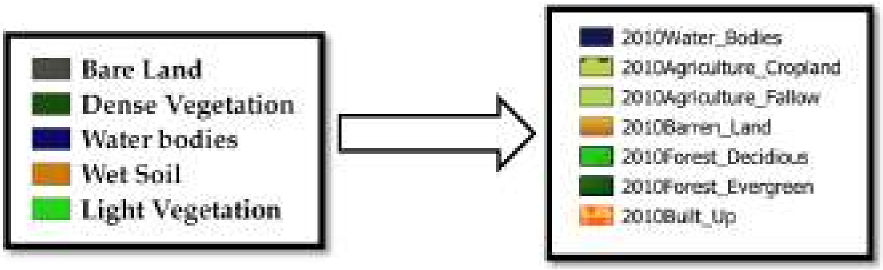



Figure 6.14: Increased classes with new approach

involves using the data pre-classified by NRSC which is a reputed organization in remote sensing. They provide number of ready-made layers with finer accuracy which is otherwise difficult to achieve for individuals using free satellite images. But because they are only available in the form of web layer, they cannot be processed through any automated process or algorithm. Hence they have to be manually digitized to obtain a vector form. Vector form has to be obtained in order to attach attributes to it like area, land use name, or any. This is done by manually drawing polygons that cover each class. Polygons drawn over each land use class are saved in a separate file with a format called 'shapefile'(.shp).

Also due to the involvement of this approach, based on the provision of layers by NRSC, the study period for entire work was re-framed as **2005 to 2015**

**Details of the web layer used:**

Web Map Service (WMS) URL: *https://bhuvan-vec2.nrsc.gov.in/bhuvan/wms*

version: 1.1.1

layer - lulc:MH_LULC50K_0506

lulc:MH_LULC50K_1011

lulc:MH_LULC50K_1516

matrixSet- "EPSG:4326"

layerExtent : 72.643,15.606,80.898,22.027

format: "image/png"

The layer is web map layer means it cannot be downloaded. A single URL contains number of layer depicting number of maps that can imported into GIS softwares.

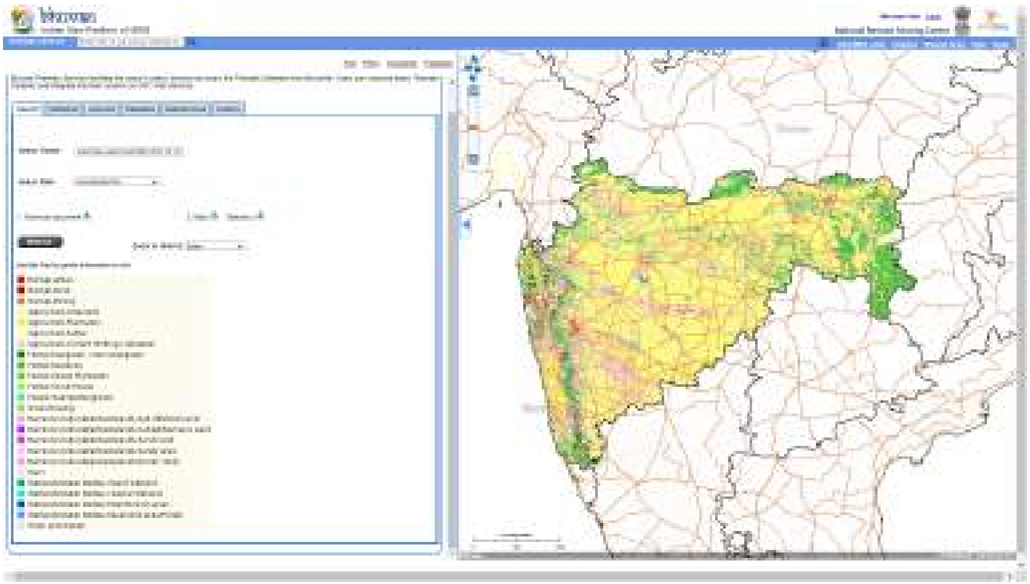


Figure 6.15: land use layer on NRCS Portal

After manually digitizing land use raster web layer using spatial digitizing tools in QGIS, the polygons were merged.

**Merging polygons, Why and How:** Originally after digitization, each polygon of the same class being spatially and geometrically different than the other, is assigned the attribute values separately. By merging, all the polygons of the same land use class were assigned singly the land use attribute value and the area of each polygon summed up to form a total area that was assigned to the single merged record of the land use class. Doing this for each land use class of each year, we created the LULC map and attribute data for year 2000, 2010, 2015.

**The classes considered and digitized were:**

1) Water Bodies
2) Built-up
3) Deciduous Forest
4) Evergreen Forest
5) Agricultural Cropland
6) Agricultural Fallow
7) Barren Land

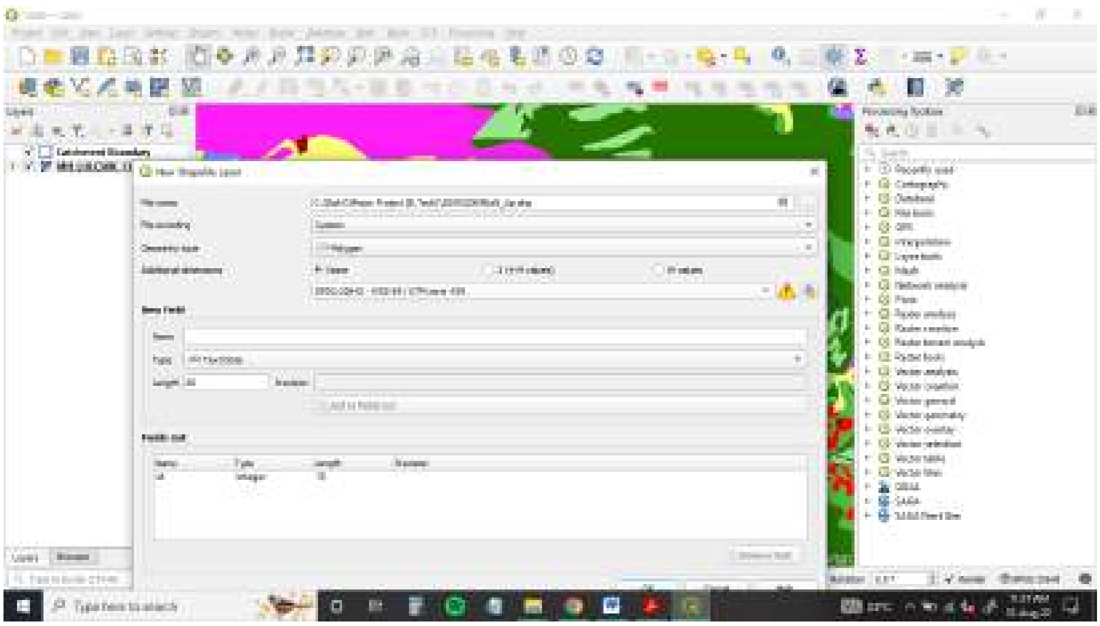


Figure 6.16: Creating shapefile of one of the land uses

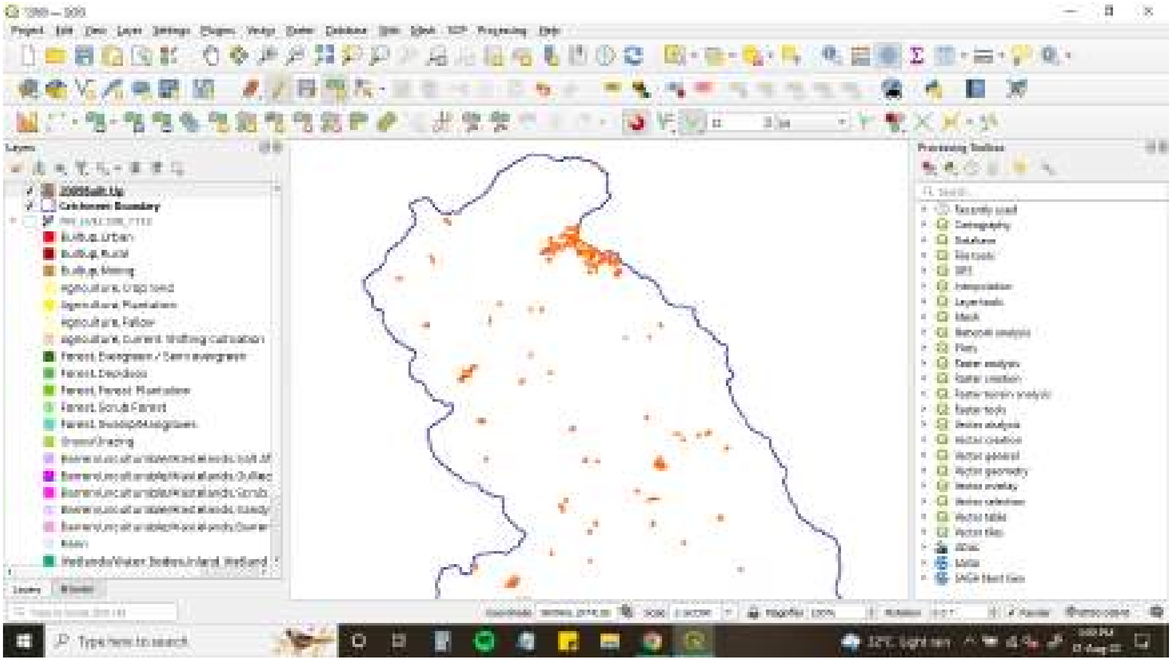


Figure 6.17: Digitization: Intermediate stage

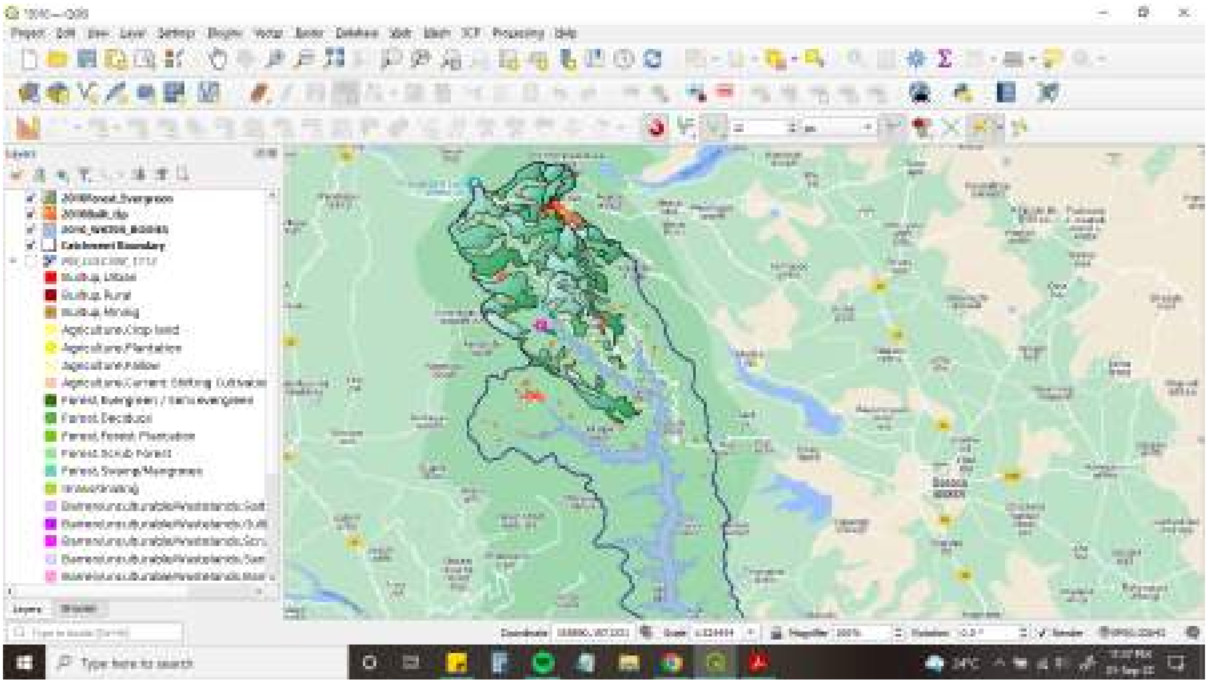


Figure 6.18: Digitization: Intermediate stage

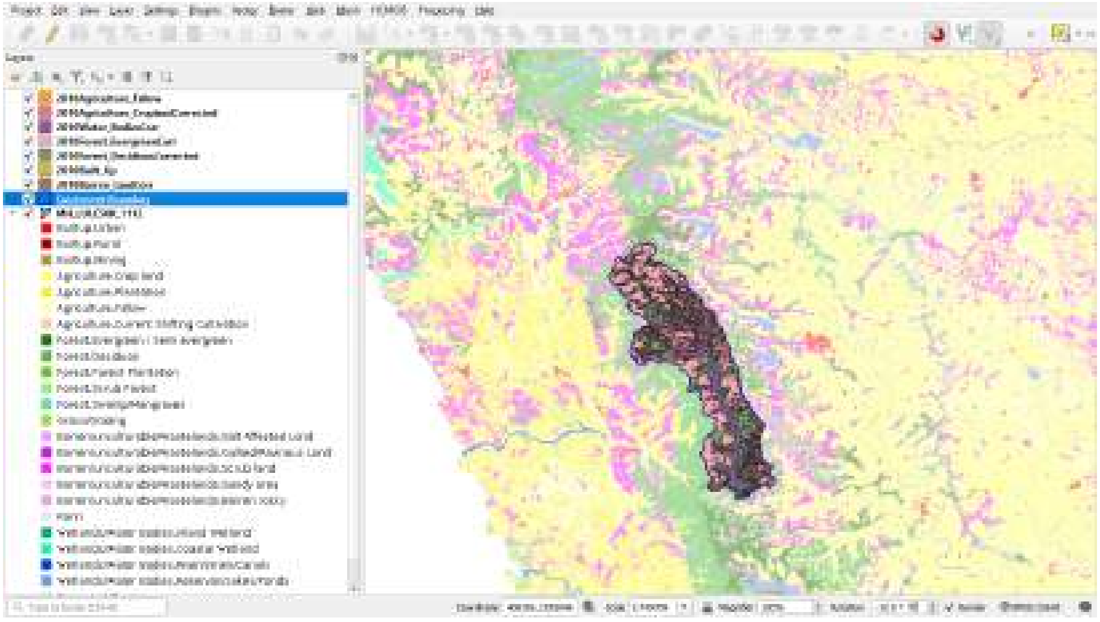


Figure 6.19: Completed Land use digitization over the referred NRCS web layer

### 6.3.3 Output of the Final Land Use Classification

**A. Maps:**

***Year 2005:***

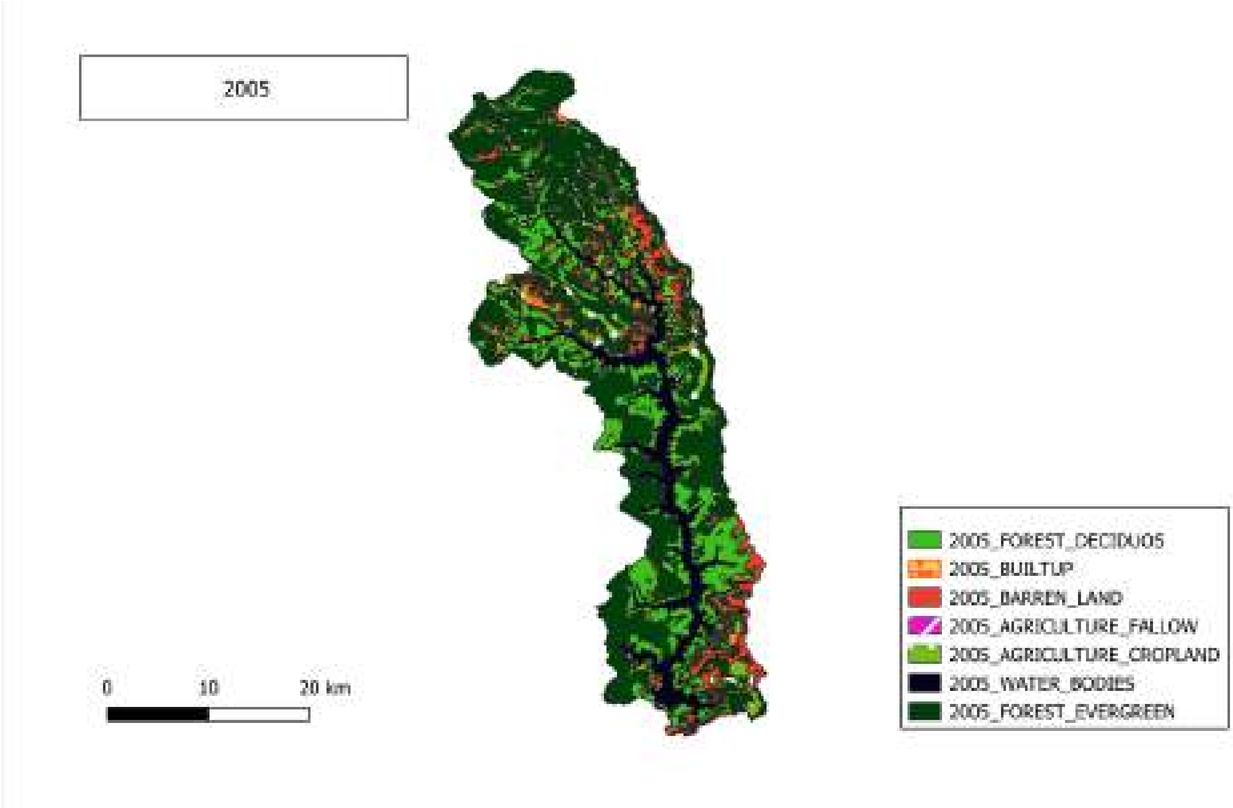



Figure 6.20: Land use: 2005

***Year 2010:***

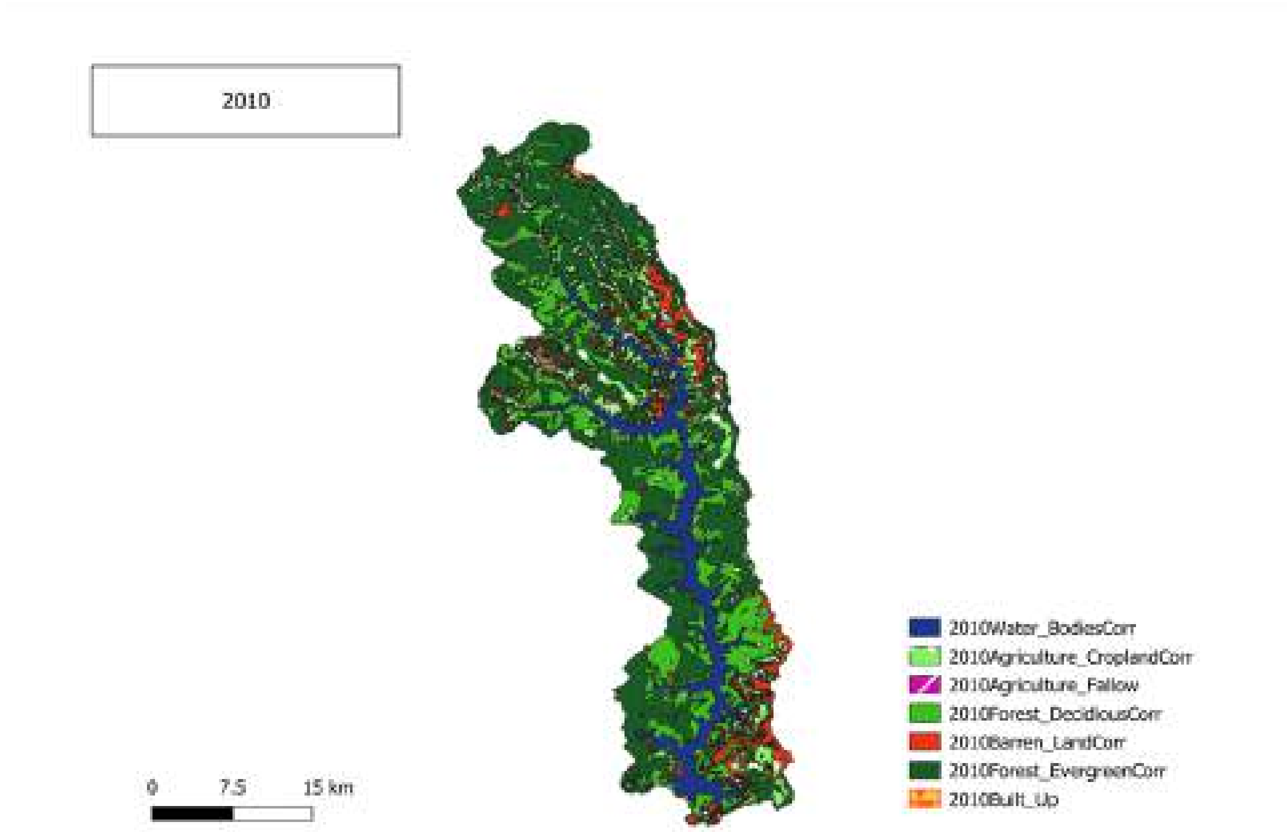



Figure 6.21: Land use: 2010

***Year 2015:***

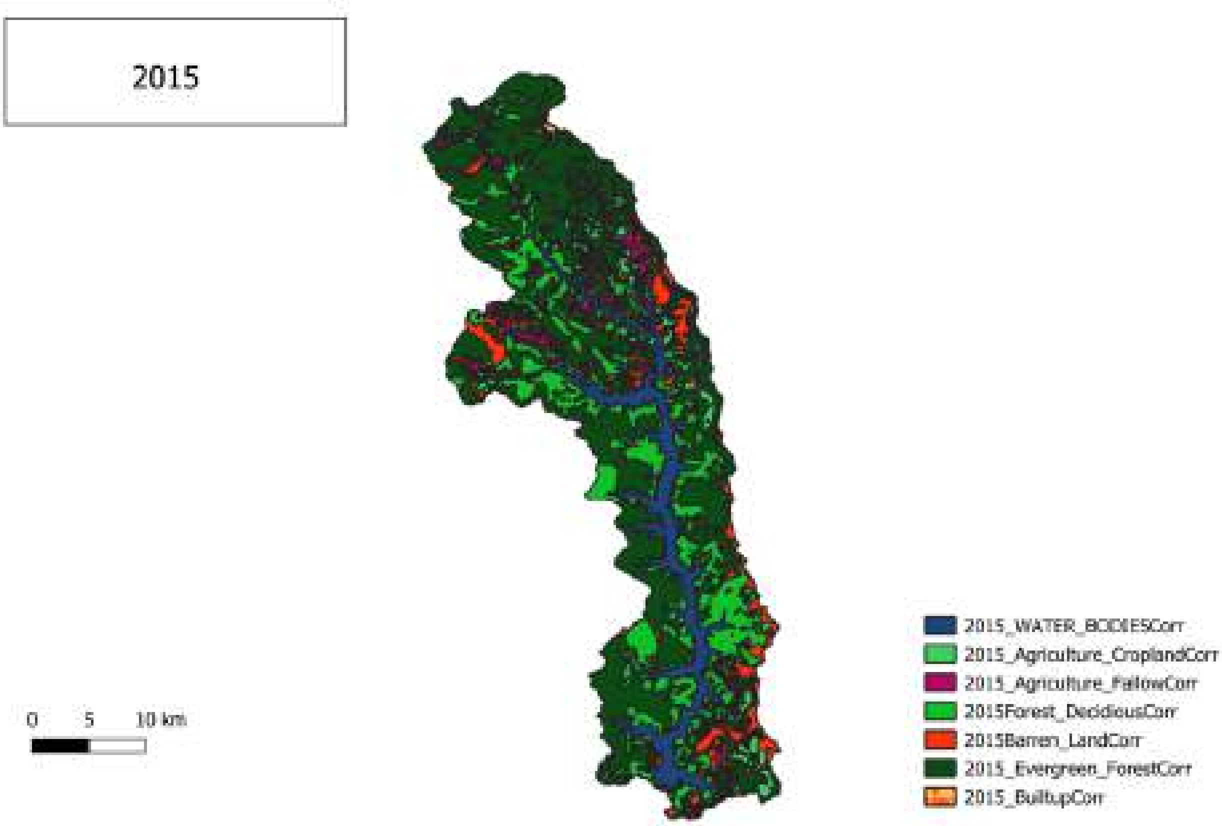



Figure 6.22: Land use: 2015

**B. The Area Attribute:**

| 2005 CLASSIFICATION | |
|---|---|
| CLASS | AREA (Sq.km) |
| AGRICULTURE_CROPLAND | 106.23 |
| AGRICULTURE_FALLOW | 1.27 |
| BARREN_LAND | 82.17 |
| BUILT_UP_AREA | 7.43 |
| FOREST_EVERGREEN | 344.93 |
| FOREST_DECIDUOUS | 256.50 |
| WATER_BODIES | 106.71 |
| | 905.25 |

Figure 6.23: Land use Areas: 2005

| 2010 CLASSIFICATION | |
|---|---|
| CLASS | AREA (Sq.km) |
| AGRICULTURE_CROPLAND | 104.60 |
| AGRICULTURE_FALLOW | 1.78 |
| BARREN_LAND | 76.77 |
| BUILT_UP_AREA | 7.44 |
| FOREST_EVERGREEN | 333.29 |
| FOREST_DECIDUOUS | 274.94 |
| WATER_BODIES | 106.44 |
| | 905.25 |

Figure 6.24: Land use Areas: 2010

| 2015 CLASSIFICATION | |
|---|---|
| CLASS | AREA (Sq.km) |
| AGRICULTURE_CROPLAND | 100.64 |
| AGRICULTURE_FALLOW | 2.79 |
| BARREN_LAND | 70.52 |
| BUILT_UP_AREA | 6.15 |
| FOREST_EVERGREEN | 335.74 |
| FOREST_DECIDUOUS | 283.32 |
| WATER_BODIES | 106.08 |
| | 905.25 |

Figure 6.25: Land use Areas: 2015

### 6.3.4 Land use change analysis

Land use change assessment was one of the two primary goals of classifying land, hydro-logical model being the other one. Having manually digitized land use raster and after merging, having calculated area of each class of each year- year 2000, 2010 and 2015 using QGIS's field calculator, we could easily calculate the difference in the area in km$\hat{2}$ of each classes.

The change in areas of each class of the classified classes in two 5 year intervals were acquired. Hence this data can be used for diverse applications. One of the demerits of not going for automatic land use change provided by SCP is not getting the data about the area of each class getting converted into all the other. But the quantity of area decreased or increased of each land use can be further used to find a trend of each class, abrupt changes and finding causes if done considering 1 year interval. Still we could represent the data to know the percentage change of each land use class and the entire catchment land use happened for in the both 5 year intervals as well as the whole 10 year interval from 2005 to 2015.

**A. Primary output of the final land use change calculations:**

| Changes from 2005 to 2010 | |
|---|---|
| **CLASS** | **AREA Increased/Decreased (Sq.Km)** |
| AGRICULTURE_CROPLAND | -1.64 |
| AGRICULTURE_FALLOW | 0.51 |
| BARREN_LAND | -5.40 |
| BUILT_UP_AREA | 0.01 |
| FOREST_EVERGREEN | -11.64 |
| FOREST_DECIDUOUS | 18.43 |
| WATER_BODIES | -0.27 |
| Total Land Area Changed | 42.07 |

Figure 6.26: Land use Change: 2005 to 2010

| Changes from 2010 to 2015 | |
|---|---|
| **CLASS** | **AREA Increased/Decreased (Sq.Km)** |
| AGRICULTURE_CROPLAND | -3.95 |
| AGRICULTURE_FALLOW | 1.01 |
| BARREN_LAND | -6.24 |
| BUILT_UP_AREA | -1.29 |
| FOREST_EVERGREEN | 2.45 |
| FOREST_DECIDUOUS | 8.39 |
| WATER_BODIES | -0.35 |
| Total Land Area Changed | 134.26 |

Figure 6.27: Land use Change: 2010 to 2015

| Changes from 2005 to 2015 | |
|---|---|
| CLASS | AREA Increased/Decreased (Sq.Km) |
| AGRICULTURE_CROPLAND | -5.59 |
| AGRICULTURE_FALLOW | 1.52 |
| BARREN_LAND | -11.65 |
| BUILT_UP_AREA | -1.28 |
| FOREST_EVERGREEN | -9.20 |
| FOREST_DECIDUOUS | 26.82 |
| WATER_BODIES | -0.62 |
| Total Land Area Changed | 157.31 |

Figure 6.28: Land use Change: 2005 to 2015

| Change in Percent of Total Area | |
|---|---|
| Year Interval | Percent of the Catchment Area Changed |
| 2005 to 2010 | 4.65 % |
| 2010 to 2015 | 14.83 % |
| 2005 to 2015 | 17.38 % |

Figure 6.29: The Percent of total land use changed

## 6.4 Data Collection

### 6.4.1 Rainfall

Precipitation is a major factor that is responsible for the accumulation of water in catchment. Since Hydro-logical model represents the quantity and the when and where of the water that runs off and the water that infiltrates, initial quantity of this water is assumed to be directly dependent on the amount of the rainfall. While many other factors like wind, temperature, humidity can affect the quantity of water present at any time in the catchment, rainfall pattern is the major factor, and can give the accuracy enough required for the comparative studies of our kind.

Rainfall value in catchment studies is taken either according to the number of spatially distributed rain gauges, by considering rainfall recorded by each of the gauge inside the catchment boundary and spatially distributing the rainfall by weighted average or interpolation, or lesser accurate- by taking the lump value, that is the average of the rainfall recorded by all the rain gauges at a time irrespective of the spatial distribution.

The temporal resolution of the rainfall required for the model was 24 hrs, that is the **data for each day from 1st January 2000 to 31st December 2015**, which is a huge data.

The data openly available is only up to the frequency of yearly and monthly form. Many opt for grid based data by NASA. But this data is based on the sensing of the satellites and computations done. This data cannot be used for studies of small areas, as there is inconsistency of accuracy throughout the globe. Hence the rainfall recorded by ground based gauges are only to be relied upon.

An authentic and reliable source of the data recorded by gauges physically in India for daily rainfall is the **Indian Meteorological Department**. But the daily record of data isn't for personal use freely. However, for project studies, the daily data can be acquired on an institutional level stating the purpose, on the condition that it not be used for a purpose other than that stated and accepted by IMD. The daily data was thus acquired from IMD's data supply portal: *https://dsp.imdpune.gov.in/*

| YEAR | MONTH | MAHABALESHWAR | MEDHA | PATAN | KOYNA CATCHMENT (Average, mm) |
|---|---|---|---|---|---|
| 2005 | 1 | 3.900 | 13.000 | 0.000 | 5.633 |
| 2005 | 2 | 1.400 | 0.000 | 0.000 | 0.467 |
| 2005 | 3 | 0.000 | 3.000 | 0.000 | 1.000 |
| 2005 | 4 | 66.200 | 44.100 | 51.000 | 53.767 |
| 2005 | 5 | 11.800 | 0.000 | 0.000 | 3.933 |
| 2005 | 6 | 1354.000 | 614.600 | 636.800 | 868.467 |
| 2005 | 7 | 3031.800 | 875.400 | 1101.700 | 1669.633 |
| 2005 | 8 | 2610.800 | 646.600 | 880.200 | 1379.200 |
| 2005 | 9 | 1428.600 | 461.400 | 474.400 | 788.133 |
| 2005 | 10 | 202.500 | 114.800 | 106.800 | 141.367 |
| 2005 | 11 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2005 | 12 | 0.000 | 0.000 | 0.000 | 0.000 |

Figure 6.30: Daily Rainfall Value: 2005

| YEAR | MONTH | MAHABALESHWAR | MEDHA | PATAN | KOYNA CATCHMENT (Average, mm) |
|---|---|---|---|---|---|
| 2010 | 1 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2010 | 2 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2010 | 3 | 5.100 | 0.000 | 0.000 | 1.700 |
| 2010 | 4 | 6.100 | 2.100 | 0.000 | 2.733 |
| 2010 | 5 | 48.800 | 24.600 | 0.000 | 24.467 |
| 2010 | 6 | 565.700 | 263.800 | 342.800 | 390.767 |
| 2010 | 7 | 1949.500 | 624.400 | 553.000 | 1042.300 |
| 2010 | 8 | 1038.600 | 314.000 | 241.000 | 531.200 |
| 2010 | 9 | 701.000 | 220.000 | 306.000 | 409.000 |
| 2010 | 10 | 92.400 | 107.600 | 80.000 | 93.333 |
| 2010 | 11 | 85.600 | 61.400 | 77.000 | 74.667 |
| 2010 | 12 | 0.200 | 0.000 | 0.000 | 0.067 |

Figure 6.31: Daily Rainfall Value: 2010

| YEAR | MONTH | MAHABALESHWAR | MEDHA | PATAN | KOYNA CATCHMENT (Average, mm) |
|---|---|---|---|---|---|
| 2015 | 1 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2015 | 2 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2015 | 3 | 74.000 | 44.100 | 50.800 | 56.300 |
| 2015 | 4 | 69.600 | 8.600 | 18.700 | 32.300 |
| 2015 | 5 | 121.300 | 58.300 | 34.600 | 71.400 |
| 2015 | 6 | 1440.500 | 657.500 | 383.400 | 827.133 |
| 2015 | 7 | 1068.100 | 217.900 | 171.800 | 485.933 |
| 2015 | 8 | 972.200 | 84.900 | 106.700 | 387.933 |
| 2015 | 9 | 359.900 | 114.400 | 79.700 | 184.667 |
| 2015 | 10 | 210.500 | 102.600 | 78.600 | 130.567 |
| 2015 | 11 | 25.600 | 53.200 | 0.000 | 26.267 |
| 2015 | 12 | 0.000 | 0.000 | 0.000 | 0.000 |

Figure 6.32: Daily Rainfall Value: 2015

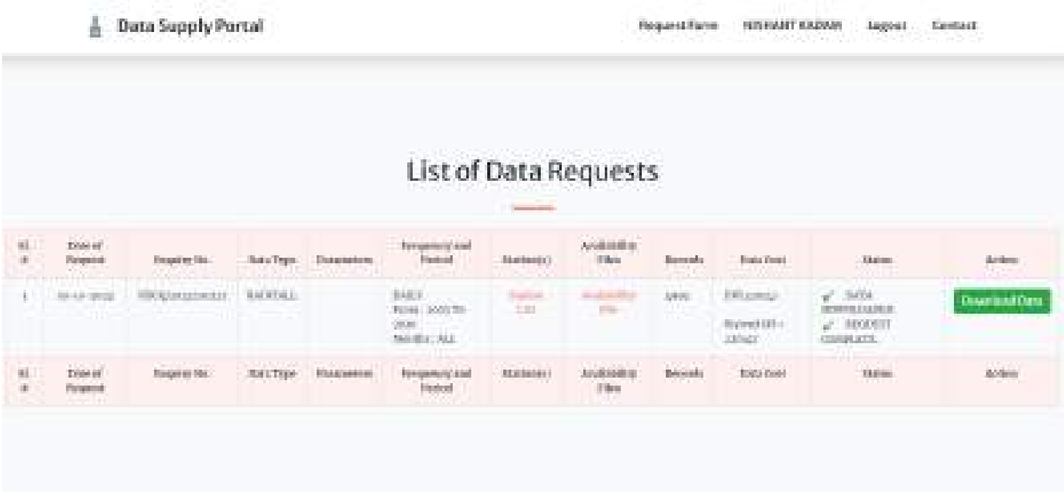



Figure 6.33: Data Request at IMD Data Portal

### 6.4.2 Soil Texture

The value of infiltration and runoff of the water, that is- what quantity of the water that accumulates on the ground due to rainfall will run towards the slope and what quantity will infiltrate into the ground at any particular place depends on the soil type of that place. Thus the data about the soil types present throughout the catchment with was an important requirement. Generally, soil data is downloaded from FAO(Food and Agriculture Organization of United State) Soils Portal. The resolution provided by FAO for our study area is much coarser, as it hardly only distinguishes land in 2 soil types. Hence a local source was opted for the data, and we could get a high resolution map of Satara district's soil texture. Just as the land use, shape-files of each soil type was required. Hence following two steps were followed:

**1) Geo-referencing the soil texture map:**

Using various GCPs like Dams, Road intersections, district administrative boundary shape-file, etc., the map was geo-referenced.

**2) Digitizing the soil texture map**:

Map was manually digitized to create a vector form of the data with the attribute of soil type and area of each type. For the 15 years of our study span, Soil types are assumed to remain same, just as most of the studies have done as the changes in soil even in a decade with respect to an area as large as 902 sq.km. are negligible.

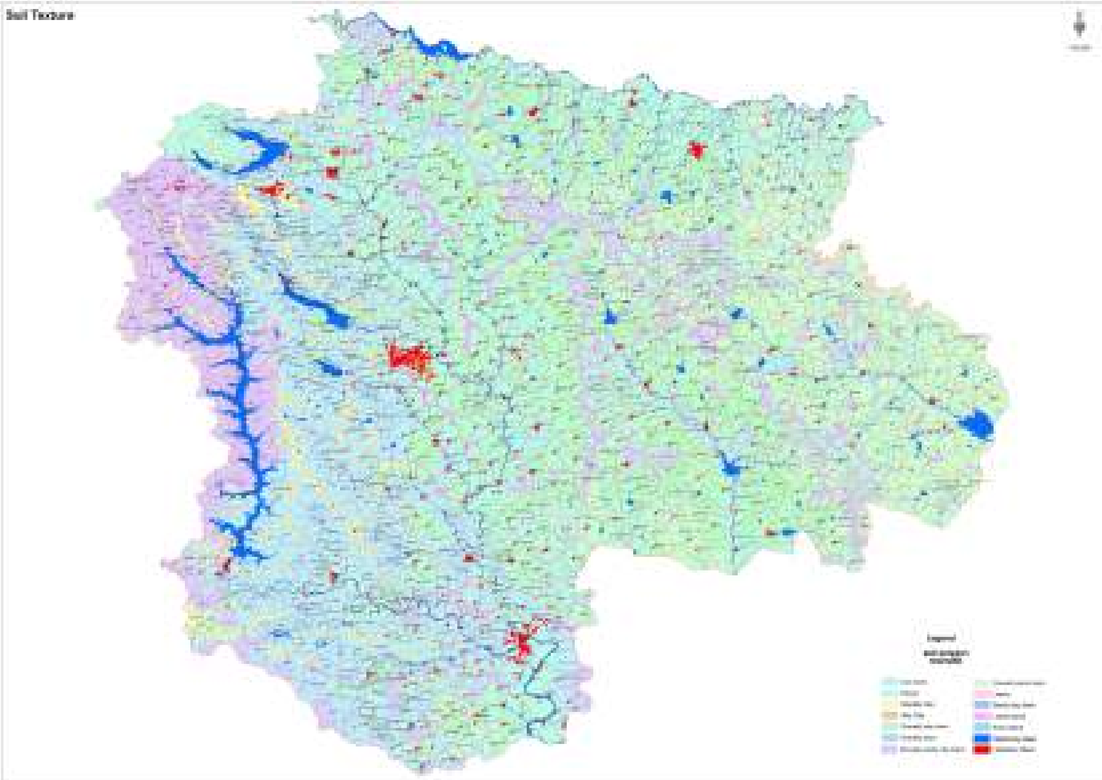



Figure 6.34: Soil Texture Map

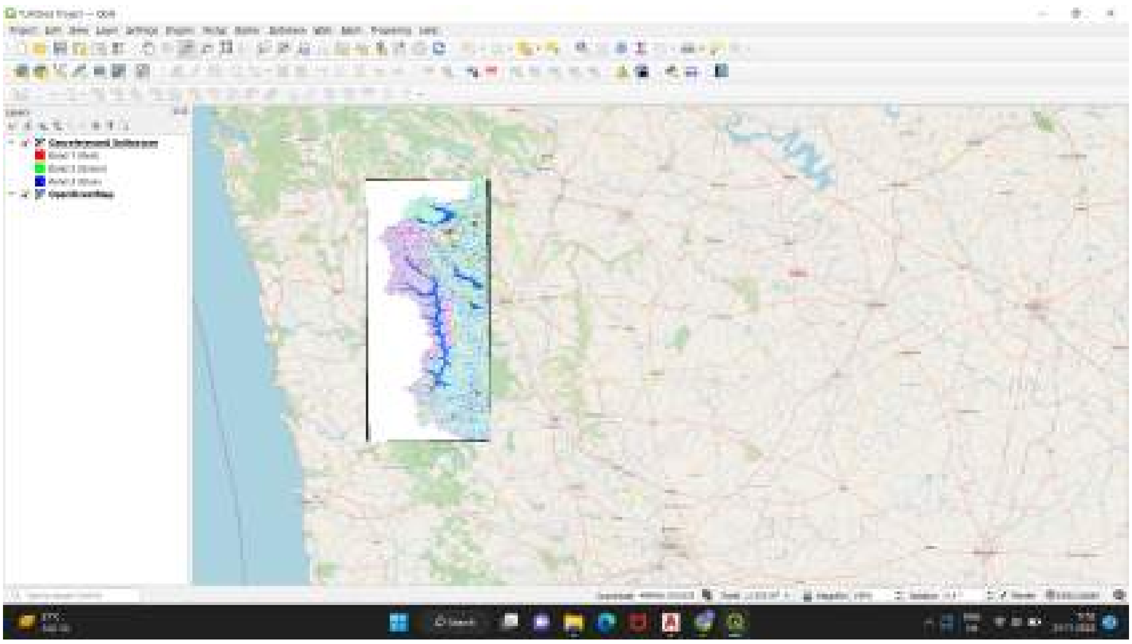


Figure 6.35: Geo-referenced Soil Map

The raster contained all the soil types available in the Satara district, while only the types present inside the catchment area as well as those that can be mapped to SCS Curve number were to be digitized.

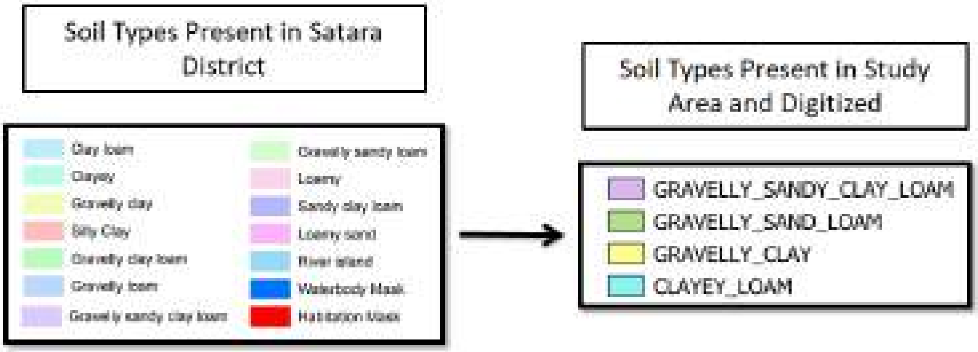



Figure 6.36: Digitized Soil Classes out of the total classes mentioned in raster

**3)Mapping Soil Texture to Standard Hydro-logical Soil Groups:**

Soil types can be called by different names based on the study they are used for or the location on globe. The use of this data in view of hydrological modelling is to prepare a CN Grid. This grid is a combination of land use and soil to calculate an output in a form of a value of each grid. This value is called as CN number and depicts the amount of water that infiltrates or runs off. There are 4 standard classes considered for this namely A, B, C and D. These are called hydro-logical soil groups. Based on the standards, the digitized soil types were mapped into these hydro-logical soil groups(HYSG).

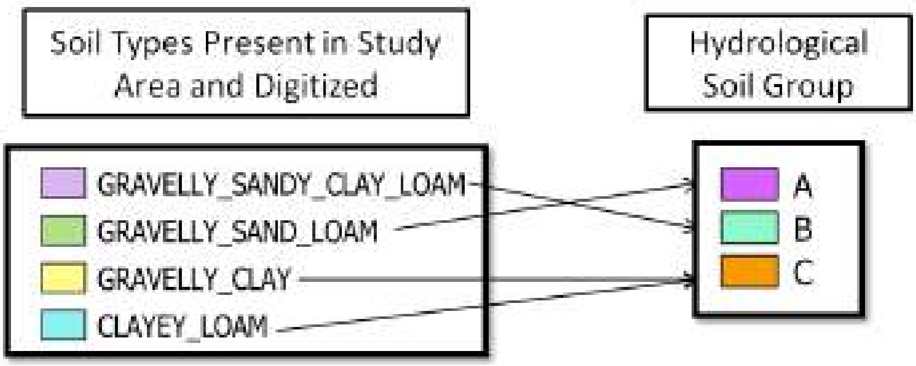



Figure 6.37: HYSG mapped to the digitized soil types

**4)Results of the Digitized Soil:**

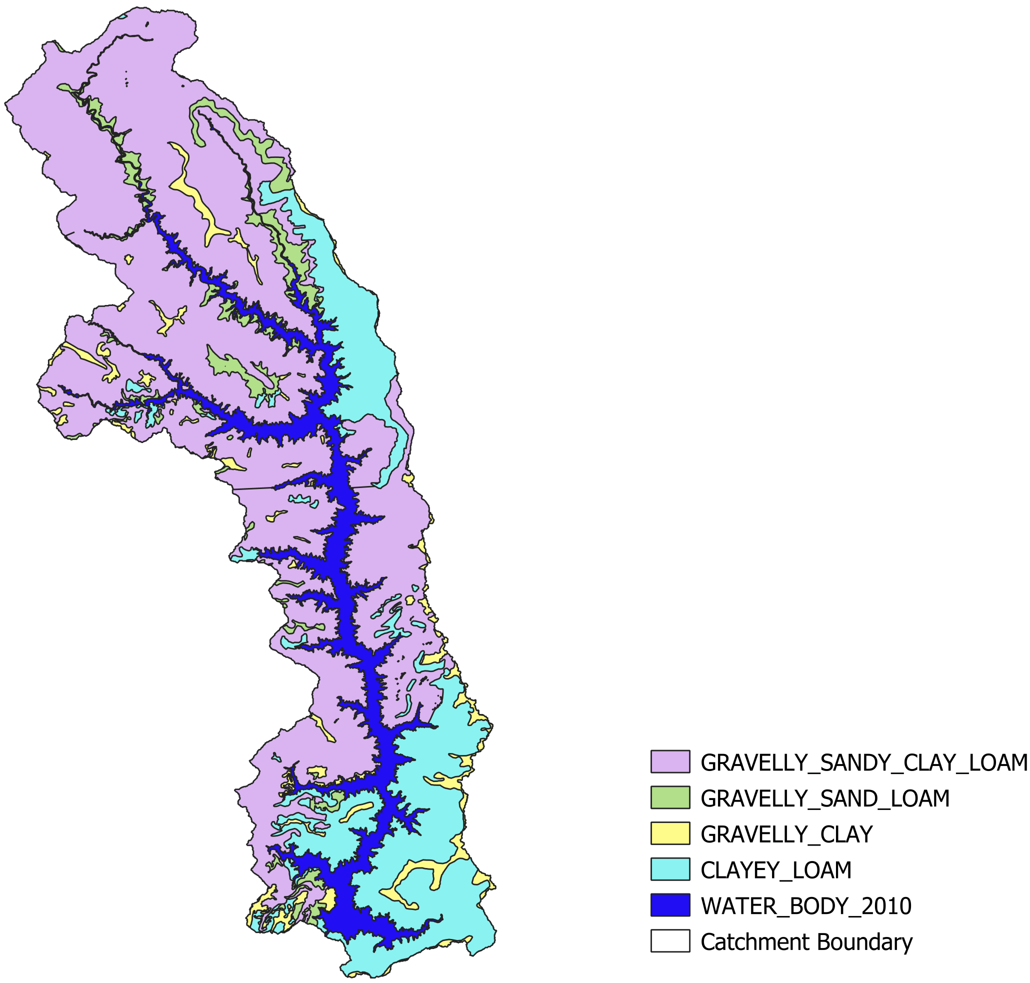



Figure 6.38: Soil type map of the catchment

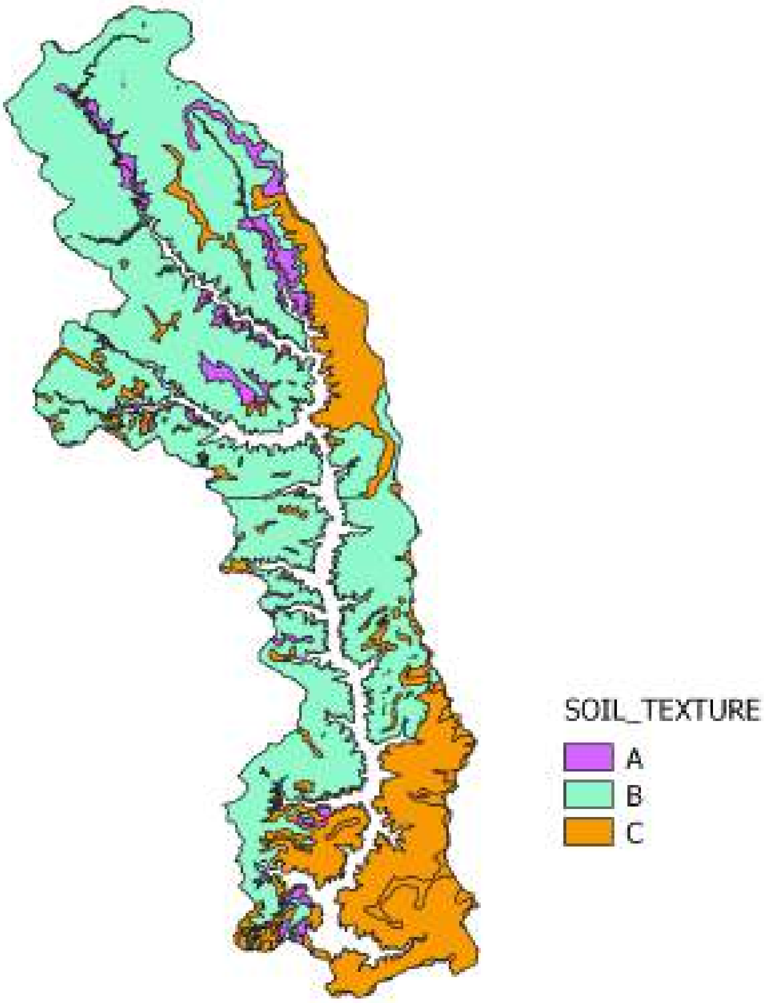



Figure 6.39: Hydro-logical Soil Group Map of Catchment

| id | SOIL TYPE | HSG | AREA (Sq.Km) |
|---|---|---|---|
| 1 | CLAYEY_LOAM | C | 175.41 |
| 2 | GRAVELLY_CLAY | C | 40.276 |
| 3 | GRAVELLY_SAND_LOAM | A | 40.849 |
| 4 | GRAVELLY_SANDY_CLAY_LOAM | B | 533.959 |

Figure 6.40: Area covered by each Soil Type

### 6.4.3 Inflow-Outflow

The volume of water present at different stages in a river is recorded by measuring water level at a particular frequency(monthly, daily, etc). This data has been proven helpful in reservoir analysis of different kinds, water resource and distribution planning, evaluation of urban flood risk, etc. We had proposed a model iterating daily with daily rainfall input. Hence the data of inflow and outflow was also required of that of each day. The data source for this data can depend on the authority of the river or basin. It is generally available with the authority directly responsible for working on the particular river/catchment. It can also be available in departments like irrigation or agriculture. For Koyna, on having requested the data to the number of such authorities, we could get it from the **Koyna Dam Maintenance Subdivision, Koynanagar** by the help from and enquiry at **Basin Simulation Division, Pune**.

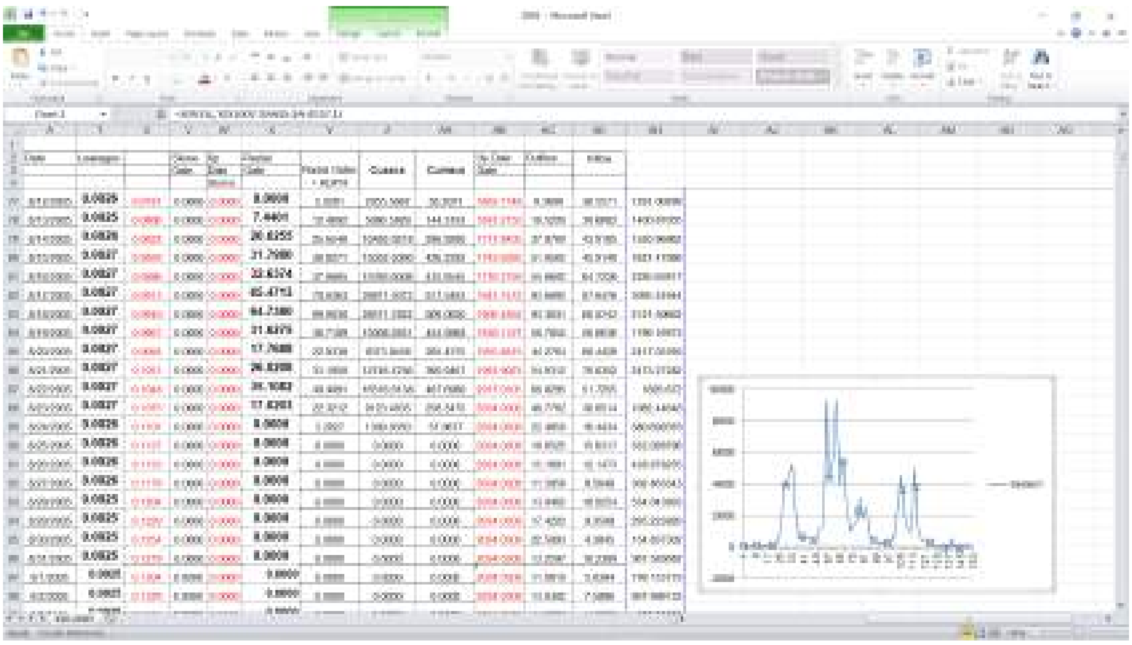


Figure 6.41: Real hydro-graph prepared out of inflow-outflow data

## 6.5 Hydro-logical modelling

A model is a small scale imitation of reality made to simplify real large scale processes in order to study them. Hydro-logical processes have been modelled since the development of a method for computing the time of concentration and the rational method for computing peak discharge by *Mulvany* in 1850. The models have been of various kinds through time- small scale physical models, mathematical analogues and the latest one- the computer models. Hydrology is a natural process, so with it comes the nature's unpredictable nature, uncertainty and complexity. Computer models understand the data we input. This data is the available records of the reality, it is the parameters that are responsible for the hydro-logical processes and behaviors, and through mathematics and algorithms the machine computes the data to run a simulation of the reality. Hydrology is also sensitive to region, so there is no best model. One has to choose a model based on an understanding of what parameters have to be considered for a particular region.

The model we had chosen to implement on Koyna river catchment is HEC-1. It has been for a long time an industry-standard in hydro-logic analysis. It was developed by the Hydro-logic Engineering Centre in California. After an introduction of HEC-HMS, a much upgraded version of HEC with a real interface and features that harness latest computation powers, HEC has become quite primitive for full scale analytical studies in hydrology. Moreover HEC only considers a single storm event and is a lumped parameter model, but as making it relatively less preferable for strict hydro-logic analysis. But as we were more focused on only analysing the effect of the change in land use, soil and rainfall on the hydrology, HEC-1 had the features enough to acquire the necessary results.

It simulates the effect of precipitation on surface-runoff with a basin. This includes various parameters other than precipitation that affect the surface run-off, that is snow melt, losses, etc. There are number of options to choose for inputing precipitation data: Basin Average, Gage, Hypothetical storm, no precipitation and Probable Maximum Precipitation, while various methods to choose from for computing losses-like uniform, exponential, green ampt, holtan and SCS curve number. It gives stream flow hydro-graphs at any location in the river basin.
Using HEC program is free for use, but due to lack of user-friendly interface, we chose to use the program through an all in one interface provided by WMS- Watershed modelling systems. This software provides an user friendly interface while working with HEC.

Following is the data required for HEC-1 modelling in WMS:

**1)DEM**

**2)Land Use**

**3)Soil types**

**4)Precipitation**

**The following sections cover the step-by-step processes we've carried out to run the model:**

### 6.5.1 Catchment Delineation:

Though catchment was delineated in QGIS already, and it was according to that boundary that the data was created/acquired, WMS requires that the delineation be done into it for the actual processes in running the model. This is because it has a systematic and step-by-step approach of executing processes. This is done by listing sequentially all the steps to go through to run the model at the end, and one has to follow the steps(not all are mandatory) to reach the end. This is one reason why WMS interface makes HEC easier.

The same DEM used in QGIS was used for delineation in WMS, i.e. 1 arc second SRTM DEM. The stream network was generated using TOPAZ and the outlet point was defined. It was important that the boundary generated from this delineation process be same as the one generated in QGIS to use all the land use and soil data created without changes. Hence the outlet shape-file and boundary shape-file generated in QGIS was imported in WMS to refer and pin outlet at the same location. Thus the delineated area was acquired ready for further processes.

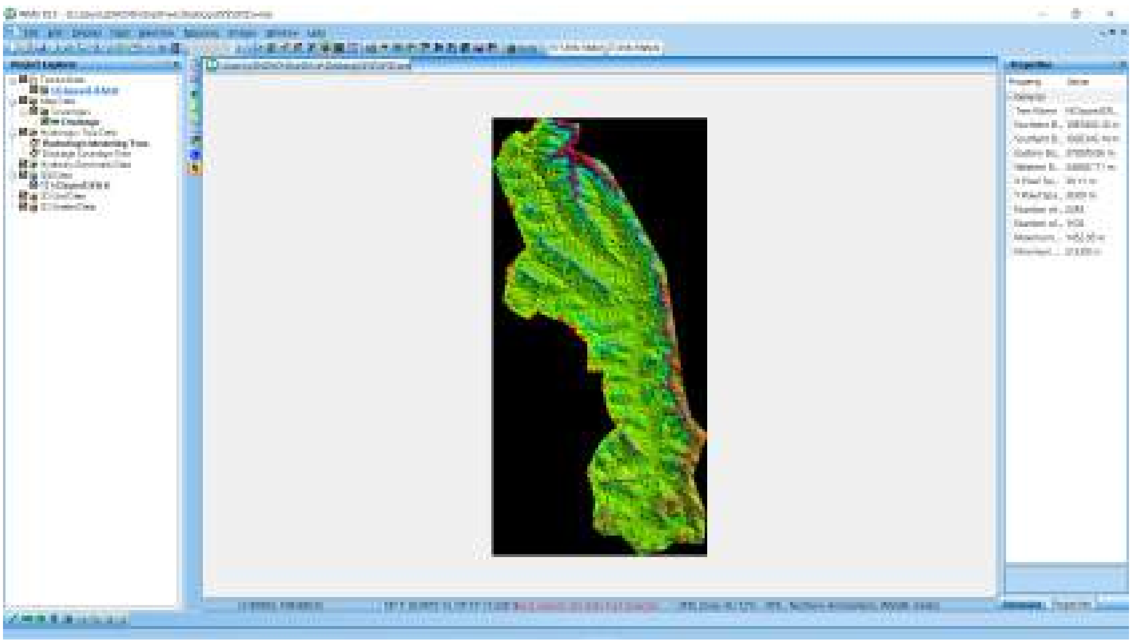


Figure 6.42: DEM Imported in WMS

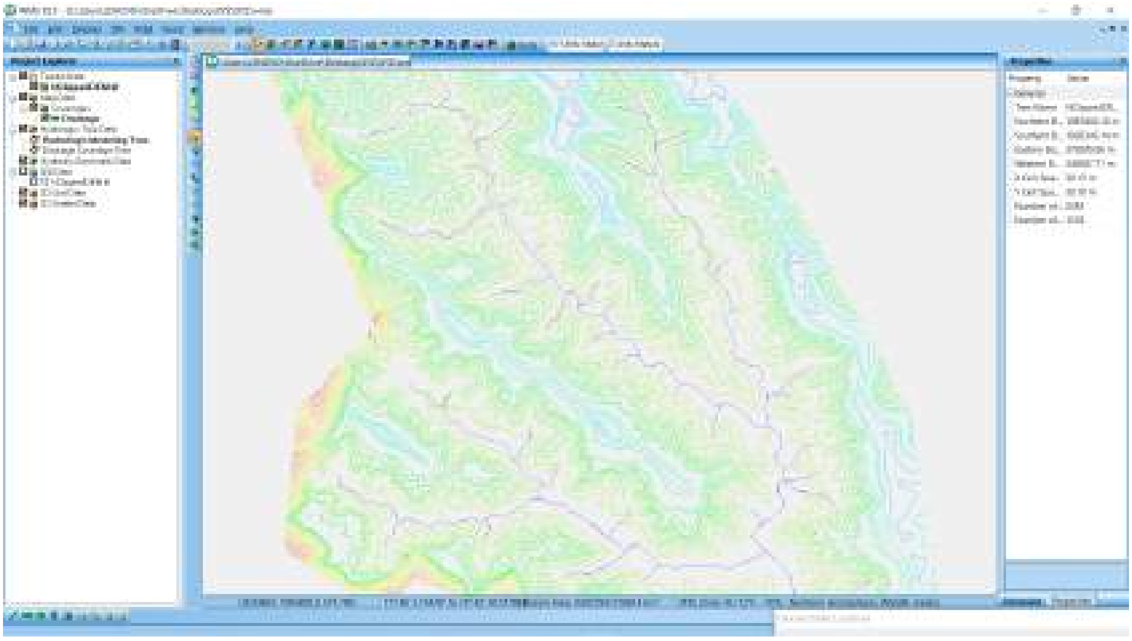


Figure 6.43: Generated stream network

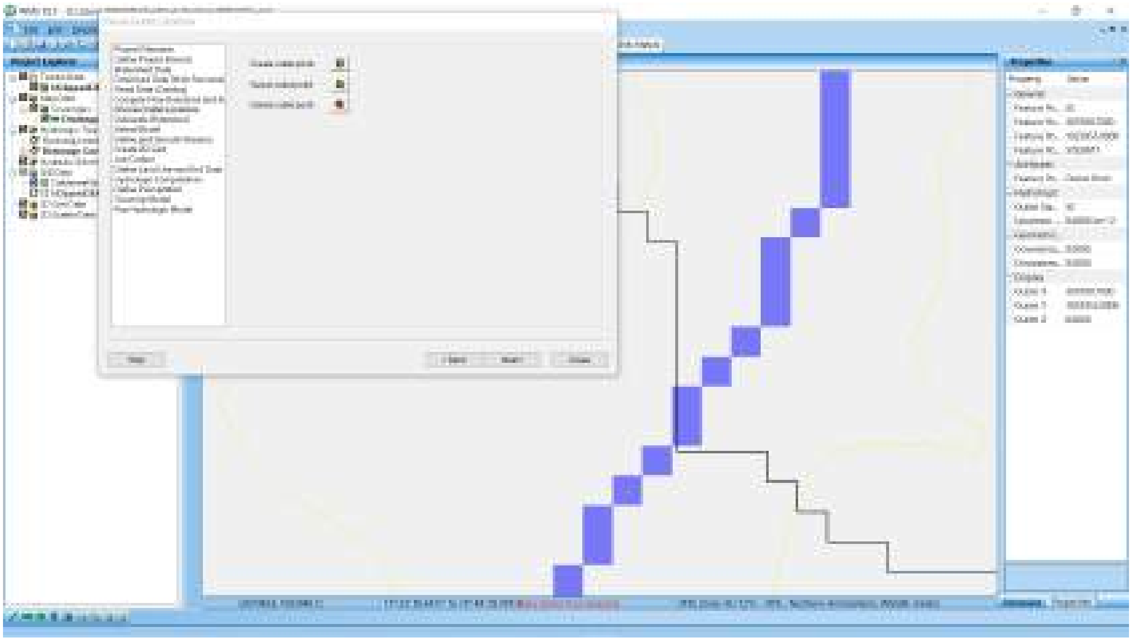


Figure 6.44: Defining Outlet

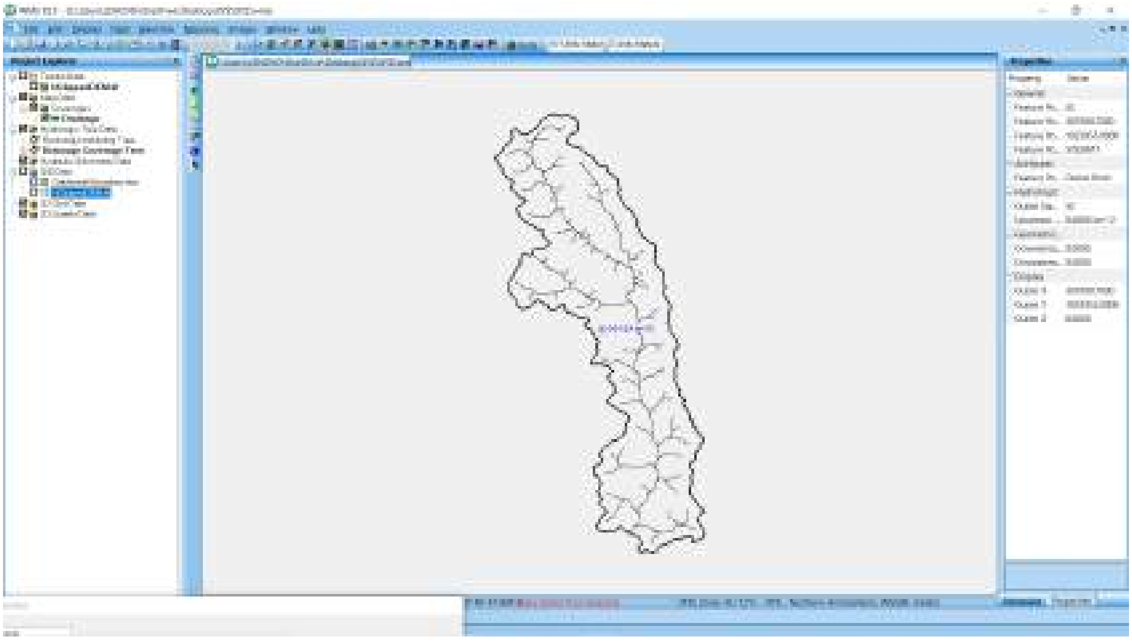


Figure 6.45: The acquired catchment boundary

### 6.5.2 Choosing the model and configuring:

Firstly after delineation HEC-1 was chosen in the 'Select model' tab, followed by a few pre-processing jobs like smoothing the stream in 'define and smooth streams' tab to control how detailed or abstract the stream follows the actual stream. Fig 6.43 shows the stream network exactly following the stream grid. Then grid size was set for the 2d grid that will be generated for the computation. It was kept as 30.134 m. These steps command the resolution that the data inputted will be divided into, and the computation time. The last configuration is that of setting the job control. This steps ask to enter the date and time of starting and ending of the simulation. It is with this date in mind that all of the data is entered in coming steps.

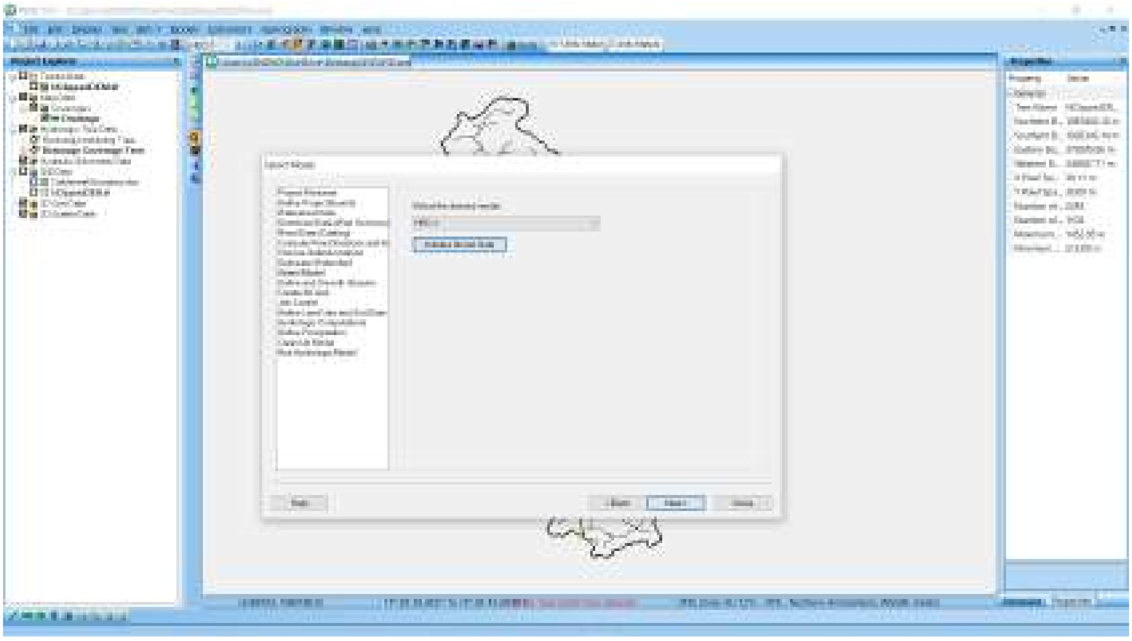


Figure 6.46: Choosing HEC-1 as a model

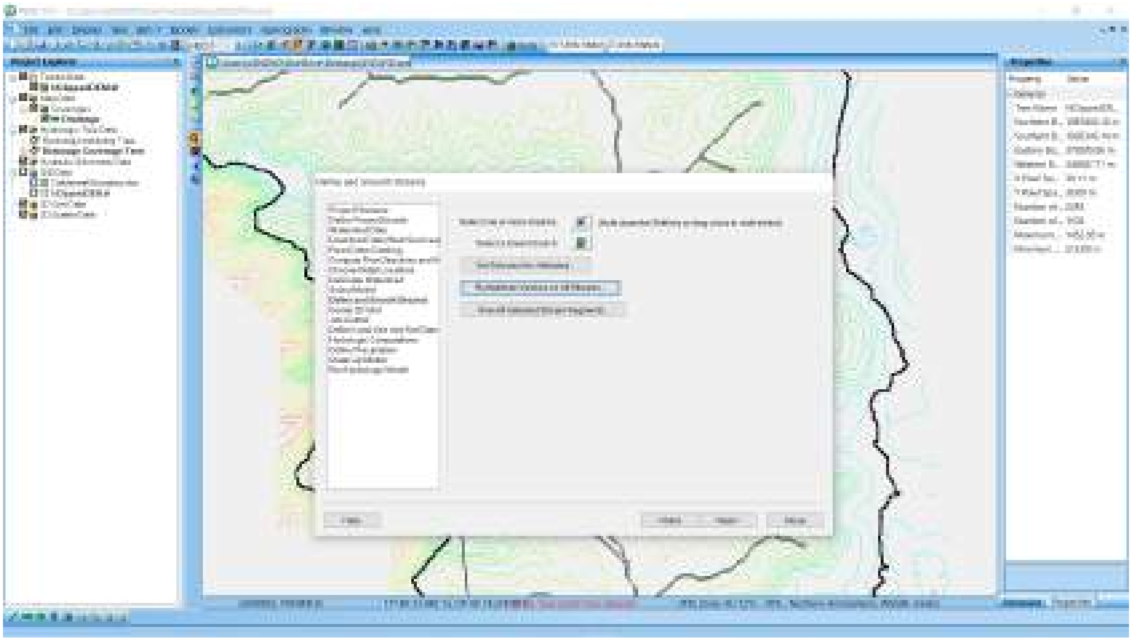


Figure 6.47: Smoothing streams

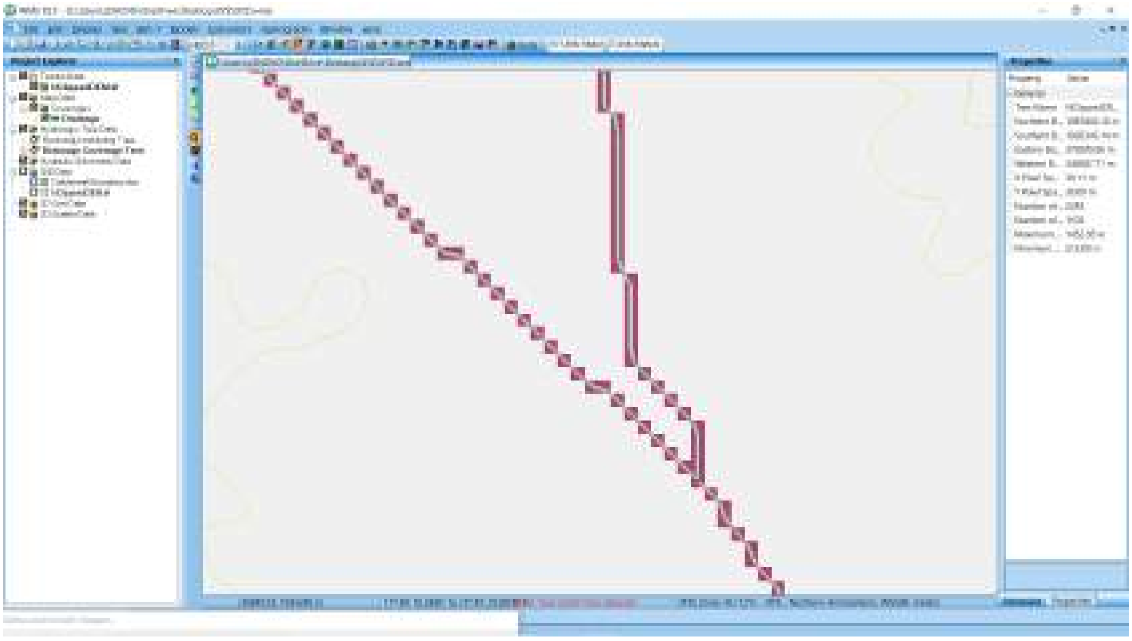


Figure 6.48: Smoothed stream network

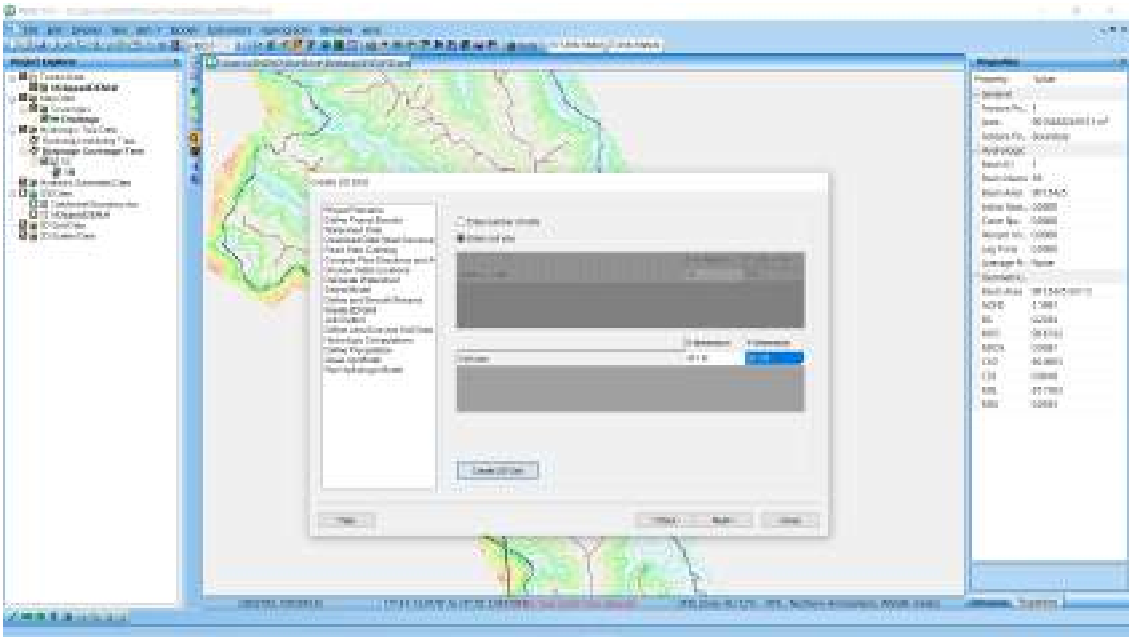


Figure 6.49: Entering cell size for 2D grid

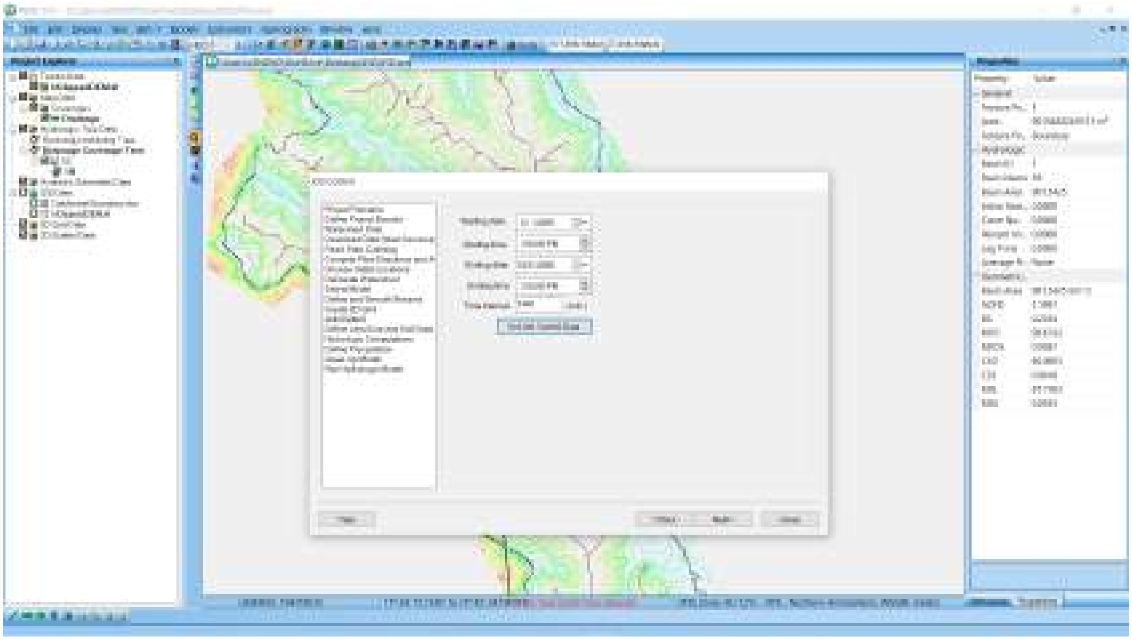


Figure 6.50: Setting job controls for the model

### 6.5.3 Importing land use and soil data:

Land use and soil are the two parameters that significantly affect run-off and infiltration, and WMS provides a tab to import the shape-file data of the both before using it's attribute values.

In the tab 'Define Land use and Soil Data', shape-files of land use of one of the 3 years in our study- year 2005 was uploaded. This shape-file contained all the land use shape features of 2005 merged in one with an attribute table having a separate record of each. We've to mention in 'Type' that it's 'Land Use'.

The same is done with the soil data, except that the same soil data is used for all the 3 years(2005, 2010 and 2020), specifying the 'Type' as 'Soil Type'. The coverage for clipping this shape-file data is kept as is default- Drainage.

After importing the shape-files, their attributes have to be mapped with the standard attributes set by WMS to understand what is what. This is done using 'GIS feature to object wizard'. Firstly land use is mapped, assigning an unique Id, and mapping Id to each record, each of one land use class and land use name attribute in the shape-file is mapped to 'layer' attribute named as 'land use'. This is where the data is actually read by WMS and hence the errors if any are shown and have to be resolved. The same for soil- an unique id and mapping id is attached, soil type class in soil texture digitized shape-file is mapped to 'layer' attribute named as 'texture', and HSG soil type attribute is mapped to 'SCS Soil type' in WMS. This is again followed by removing the errors pointed out by the software. Thus the land use and soil type coverage is set.

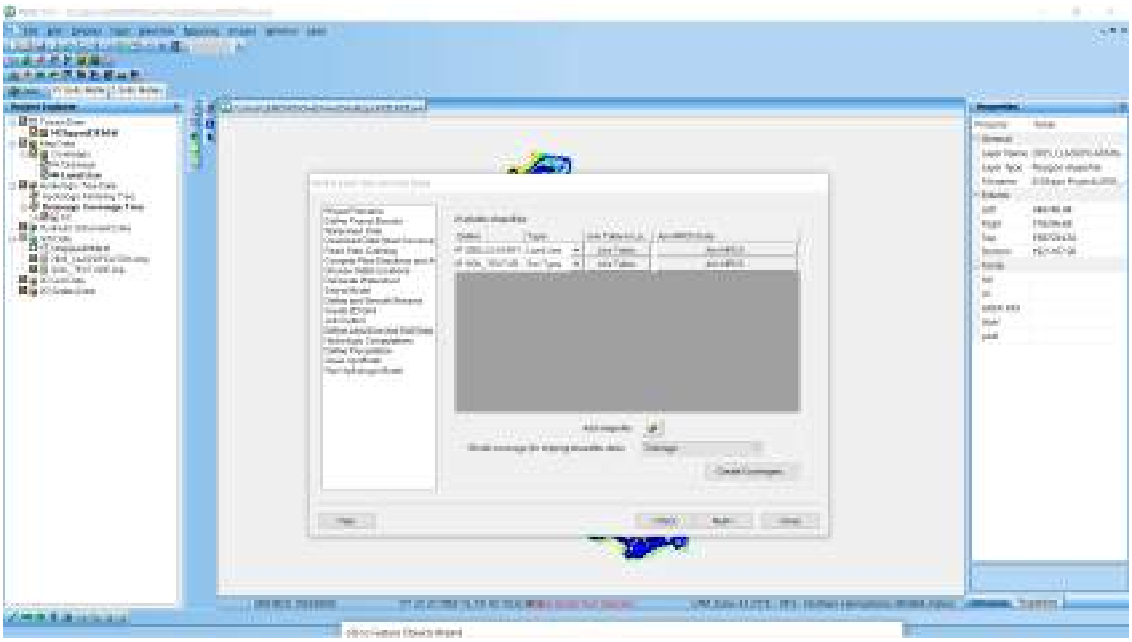


Figure 6.51: Importing Land use and soil type shape-files

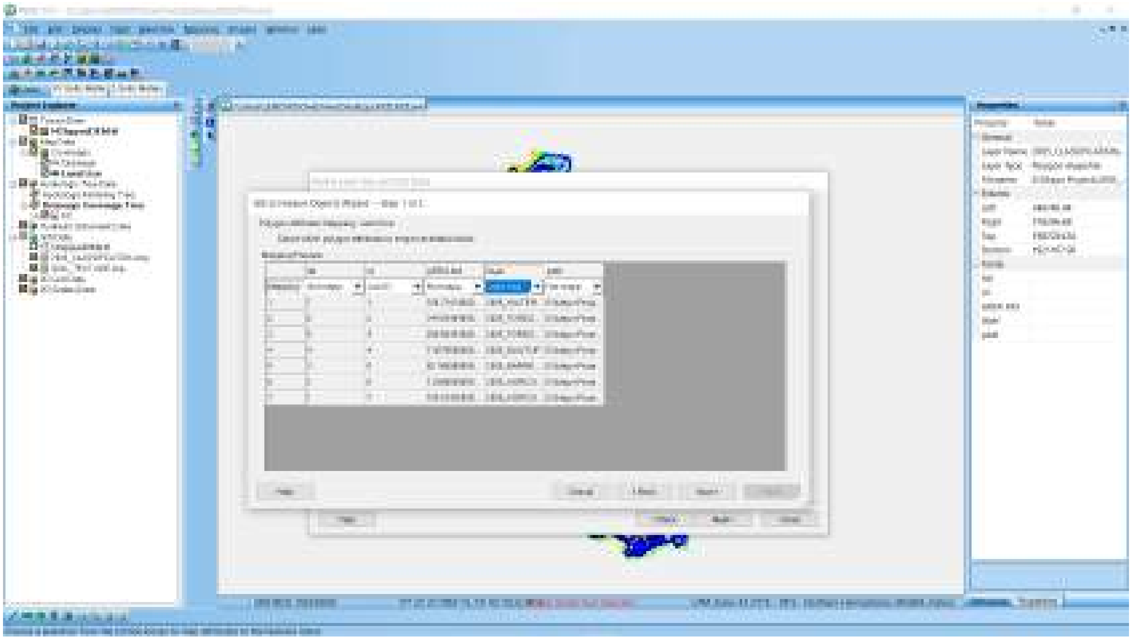


Figure 6.52: Polygons attributes mapping: Land Use

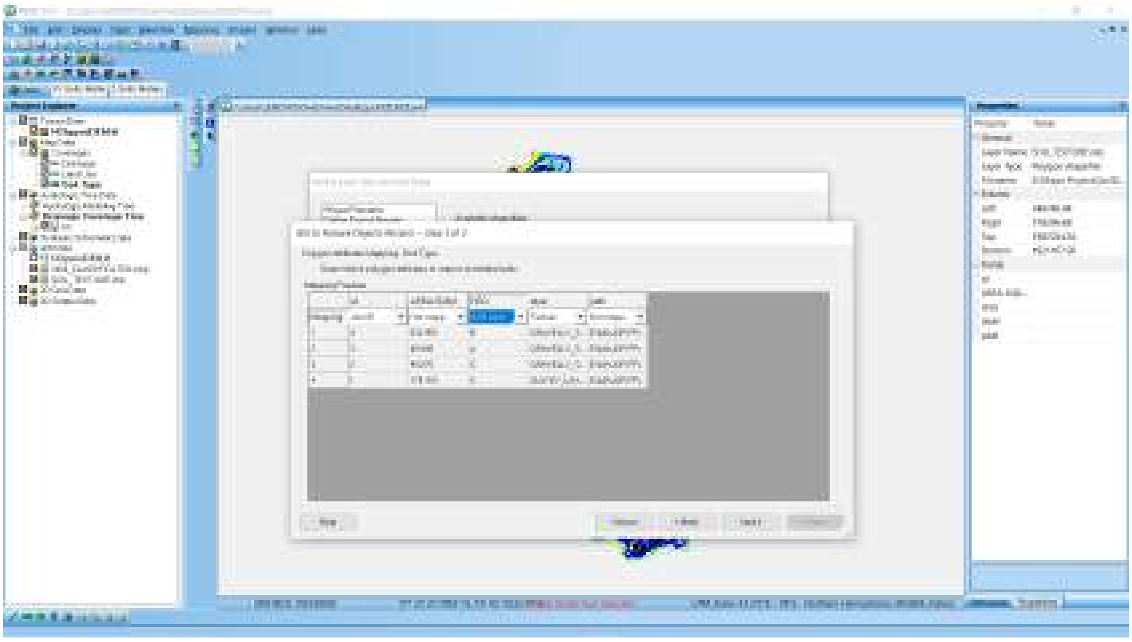


Figure 6.53: Polygons attributes mapping: Soil Type

### 6.5.4 Computing SCS curve number:

Developed by USDA Natural Resources Conservation Service, from an empirical analysis of runoff from catchments and hill-slopes by the USDA, is widely used to approximately estimate the direct runoff from a rainfall event in a particular region. It is a standard numeric value based on the following:

1. Hydro-logic Soil Group
2. Land use
3. Treatment and Hydro-logic Condition

Hence, using the land use and soil coverage created, as through the coverage, that software could read the attributes of the both, and curve number(CN) for each of the combinations between land use class and hydrological soil group could be assigned. The values for each combination were taken from standard tables, and a .txt file of a table containing CN values for the respective combinations of the considered land use and hydrologic soil group was created as per WMS standards and imported. Also the soil coverage and land use coverage was mapped to the respective field. This finally gave a report of CN values- 'CN Report'. These values were thus detected and assigned spatially to the grids with respect to the combination they contained.

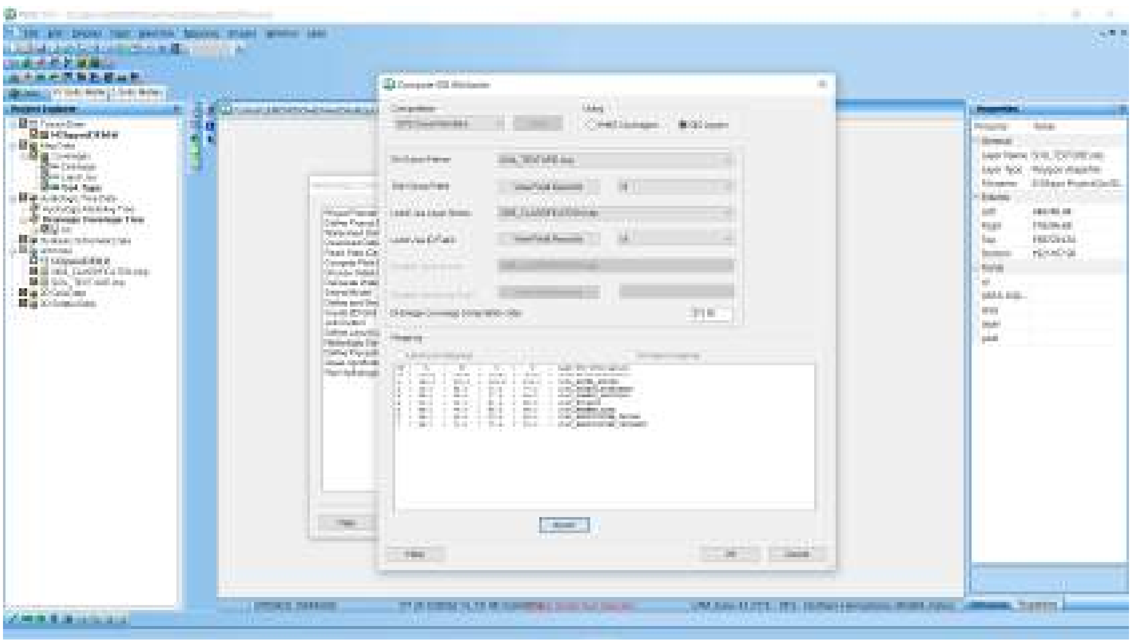


Figure 6.54: Assigning Coverage and Importing Respective CN values

Runoff Curve Number Report
(Generated by WMS)

Sat Oct 22 17:25:09 2022

Runoff Curve Number Report for Basin 1B

| HSG | Land Use Description | CN | Area km^2 | Product CN x A |
|---|---|---|---|---|
| C | 2005_FOREST_EVERGREEN | 70 | 54.241 | 3796.901 |
| D | 2005_FOREST_EVERGREEN | 77 | 36.161 | 2784.394 |
| C | 2005_FOREST_DECIDUOS | 77 | 26.234 | 2020.051 |
| D | 2005_FOREST_DECIDUOS | 83 | 36.870 | 3060.210 |
| D | 2005_BUILTUP | 86 | 2.482 | 213.421 |
| D | 2005_AGRICULTURE_CROPLAND | 81 | 58.141 | 4709.434 |
| D | 2005_WATER_BODIES | 100 | 1.418 | 141.808 |
| D | 2005_BARREN_LAND | 89 | 9.572 | 851.910 |
| C | 2005_BARREN_LAND | 86 | 41.124 | 3536.684 |
| D | 2005_AGRICULTURE_FALLOW | 80 | 0.709 | 56.723 |
| B | 2005_FOREST_DECIDUOS | 66 | 238.237 | 15723.638 |
| B | 2005_FOREST_EVERGREEN | 55 | 118.055 | 6493.020 |
| C | 2005_AGRICULTURE_CROPLAND | 78 | 13.472 | 1050.795 |
| B | 2005_BUILTUP | 72 | 4.254 | 306.305 |
| B | 2005_AGRICULTURE_CROPLAND | 71 | 117.700 | 8356.728 |
| C | 2005_BUILTUP | 81 | 1.418 | 114.864 |
| B | 2005_BARREN_LAND | 79 | 136.844 | 10810.710 |
| B | 2005_WATER_BODIES | 100 | 3.545 | 354.519 |
| C | 2005_AGRICULTURE_FALLOW | 74 | 0.355 | 26.234 |
| B | 2005_AGRICULTURE_FALLOW | 61 | 0.709 | 43.251 |

CN (Weighted) = Total Product \ Total Area
71.4904

Figure 6.55: CN Report for 2005

### 6.5.5 Defining Precipitation and Loss method:

Finally the precipitation was inputted taking the average rainfall value of year 2005 from the daily rainfall data acquired from the Indian Meteorological Department. Hence. 'Basin Average(PB)' was the format of input chosen.

In loss method, SCS Curve number was chosen, which would use the values acquired in the previous section.

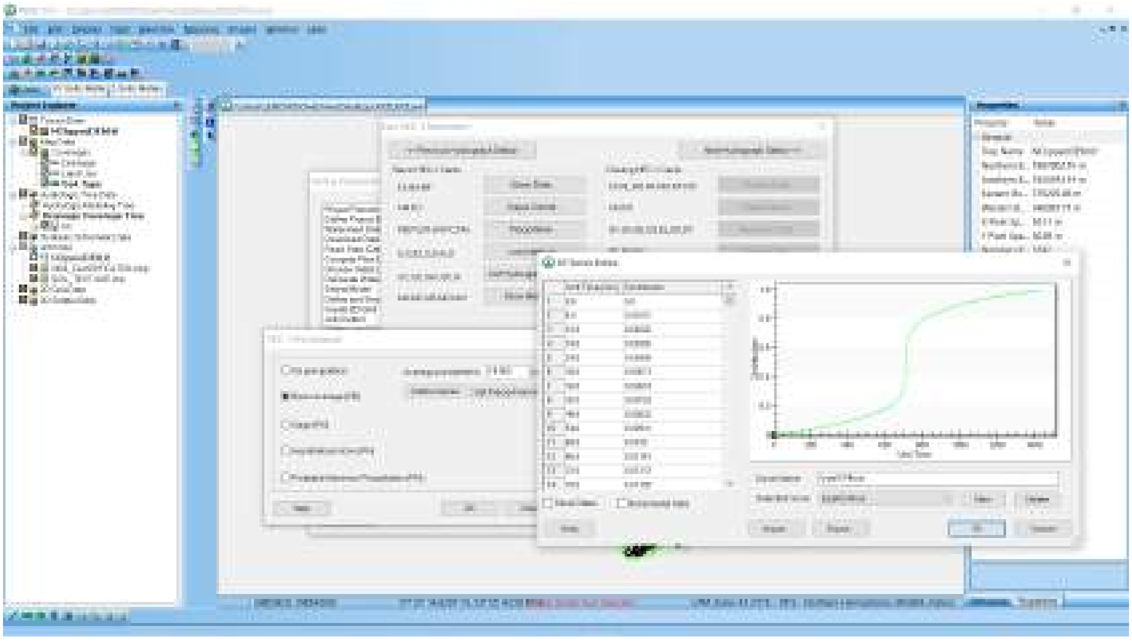


Figure 6.56: Assigning the Precipitation Values

Figure 6.57: Choosing SCS curve number as the loss method

### 6.5.6 Running the model:

Having assigning the data required for the year 2005, as a final step, the model was run. The process from section 6.5.2 to 6.5.6 was repeated for the year 2010 and year 2015 using their respective data.

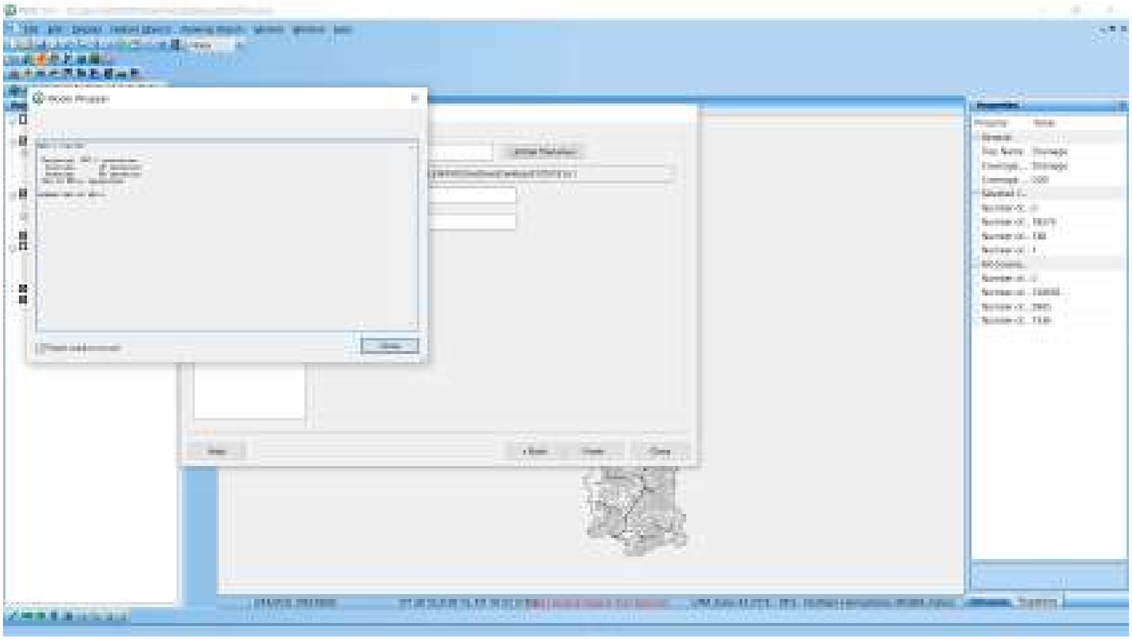


Figure 6.58: Model set to run

# Chapter 7

# Results Analysis

## 7.1 Land Use Classification:

**Percentage contribution of each class:**

For all of the years roughly, most of the land is seen to be covered with the forest area with coverage more than 60%, while the least coverage is that of the fallow agricultural land, with less than 1% of the total catchment area.
Built-up is very negligible with only about 1% coverage, while barren land has up to 8% to 9% of the contribution. Area covered by the cultivated agriculture land is seen to be equal to the area of water body, i.e. 11 to 12%.
On a broad perspective this trend does not significantly change, but the trend in whatever relatively major and minor changes have happened, is still insightful.

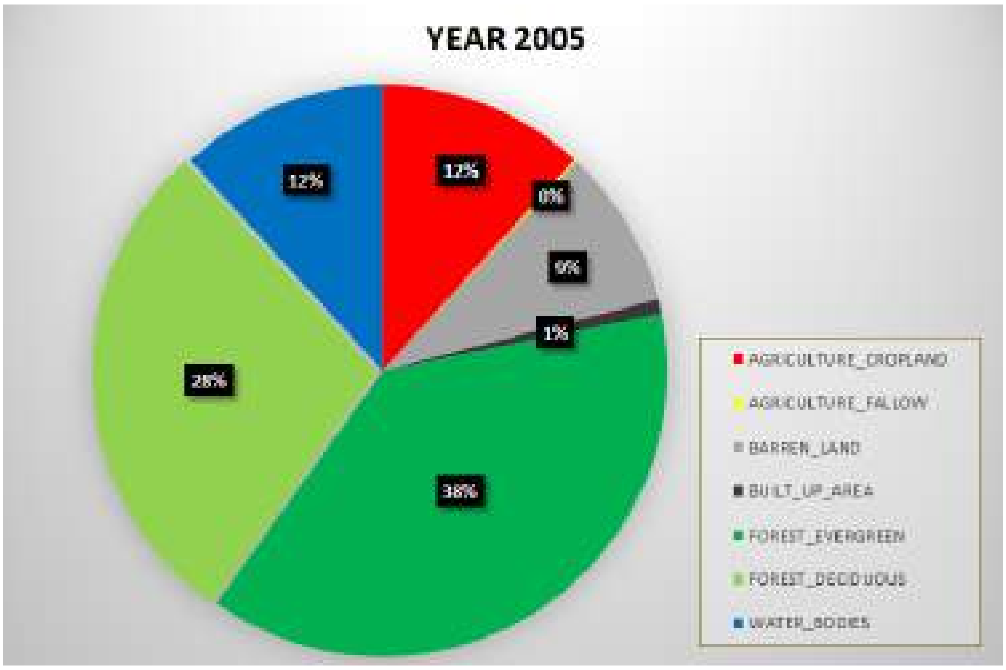



Figure 7.1: Percent of each land use class, 2005

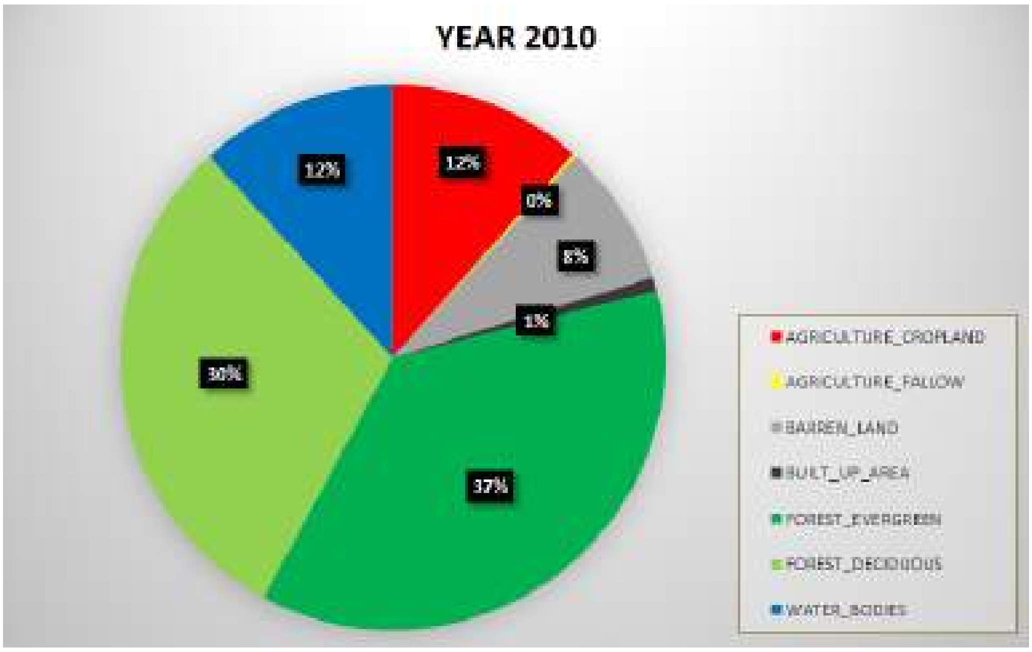



Figure 7.2: Percent of each land use class, Year 2010

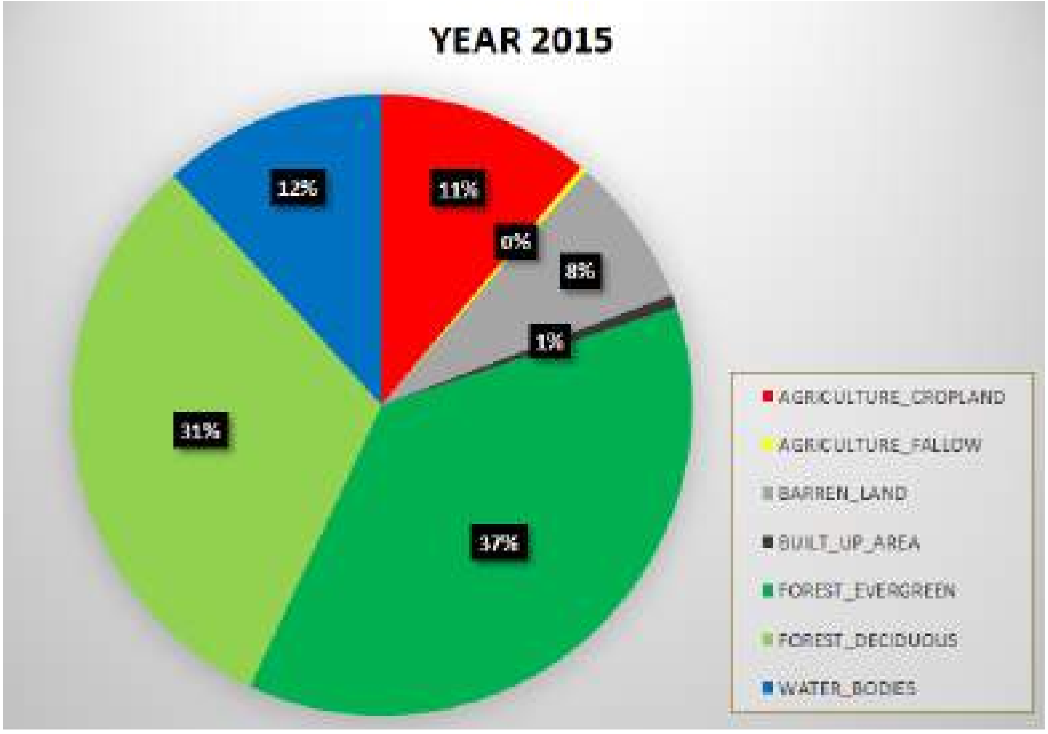



Figure 7.3: Percent of each land use class, Year 2010

## 7.2 Land use Change

**A. Land use analysis of each class separately:**

For most of the classes there is either a increase or a decrease through 15 years. The only significant increment is in deciduous forest, more significant from 2005 to 2010 interval than from 2010 to 2015, while though very insignificant, fallow agriculture is also seen to have increased. Decrement is seen in cultivated agriculture with 2 sq.km from 2005 to 2010 while of 4 sq.km till 2015. Barren land shows the same decrease of 6 Sq.Km during the both 5 year intervals between 2005 and 2015. A significant decrease is in evergreen forest from 2005 to 2010, that is of 10 sq.km which has again shown an increase of 2 sq.km from 2010 to 2015. Change in built-up is very insignificant owing to its already lesser percent of coverage in catchment. Its change from 2005 to 2010 can be considered as almost absolutely null.

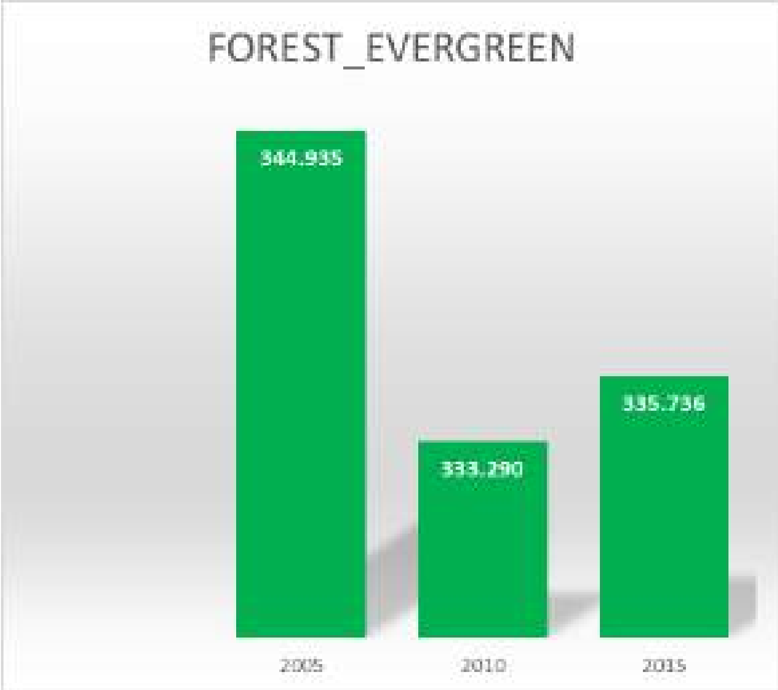



Figure 7.4: Changes through years in Area of Evergreen Forest


Figure 7.5: Changes through years in area of Deciduous Forest

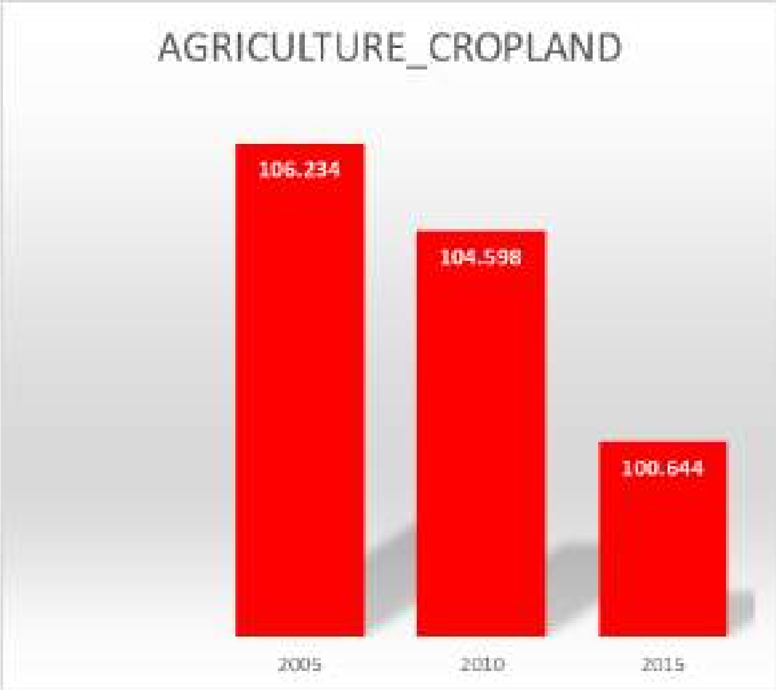



Figure 7.6: Changes through years in area of Agricultural Cropland

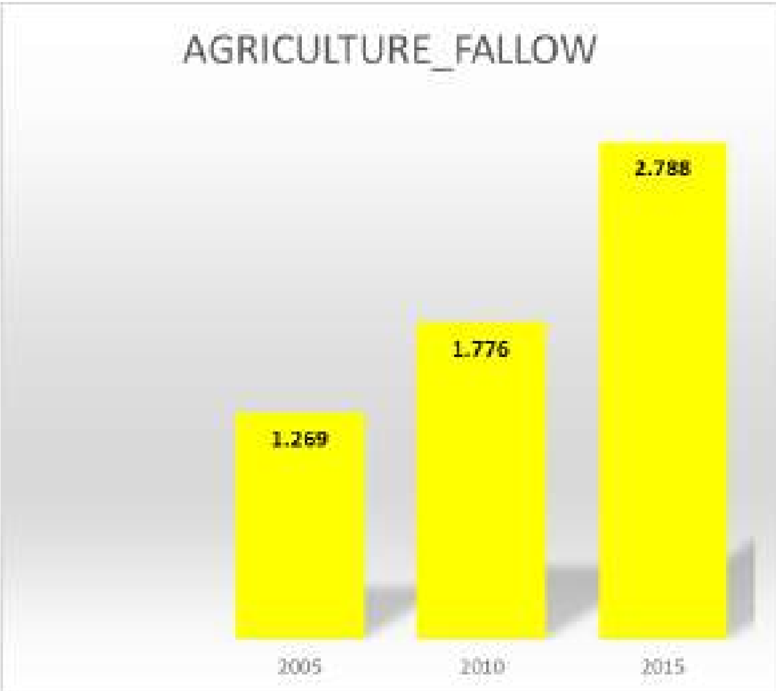



Figure 7.7: Changes through years in area of Fallow agriculture

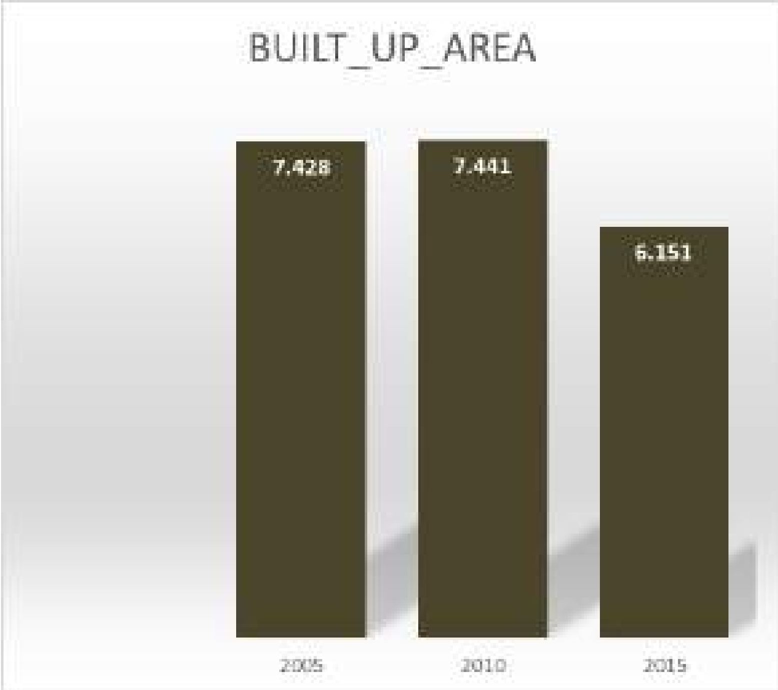



Figure 7.8: Changes through years in area of Built-up


Figure 7.9: Changes through years in area of Barren Land

**B. Increase or decrease in land use areas during 5 year intervals:**

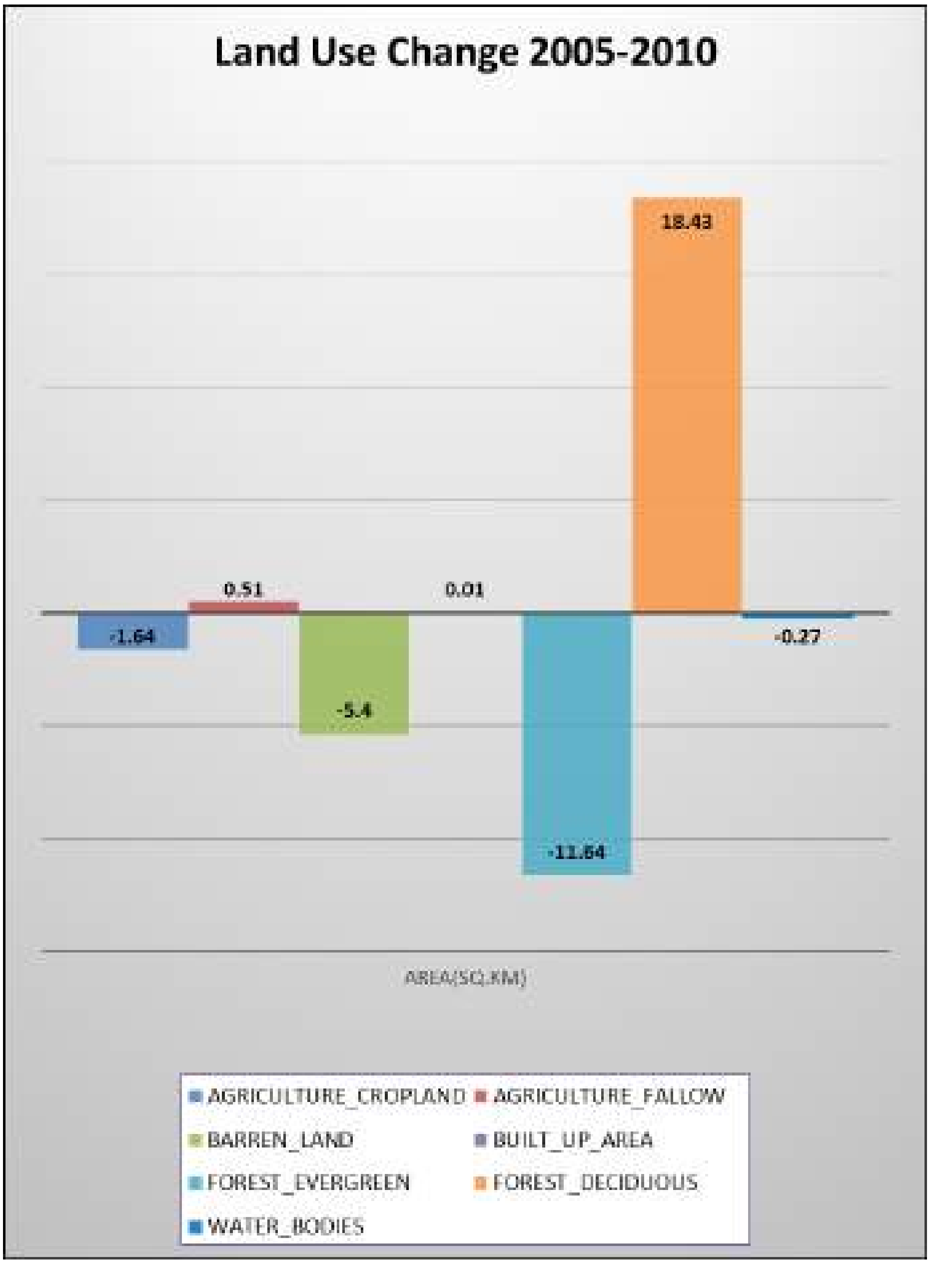



Figure 7.10: Increase/Decrease in land use from 2005 to 2010

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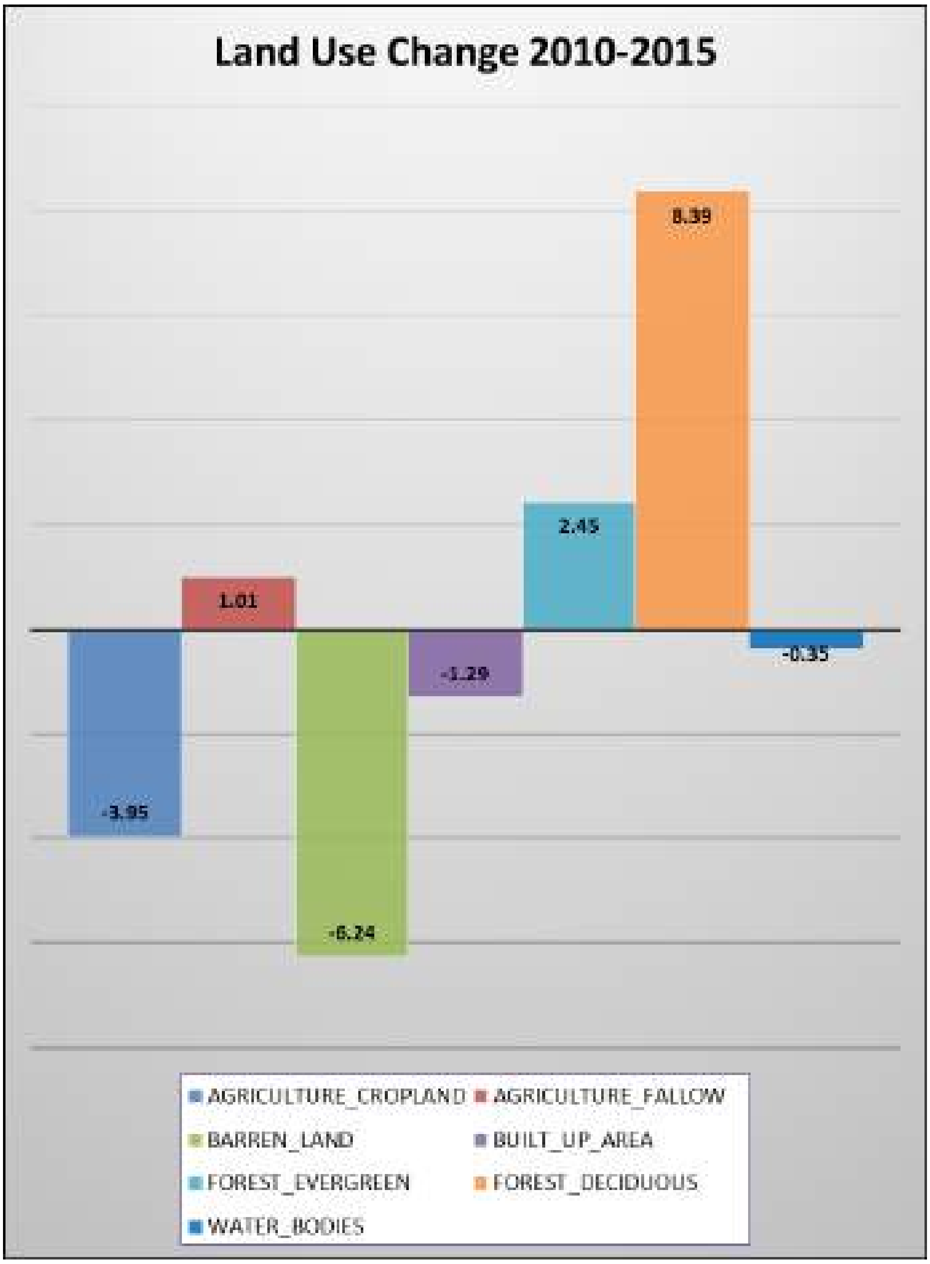


Figure 7.11: Increase/Decrease in land use from 2010 to 2015

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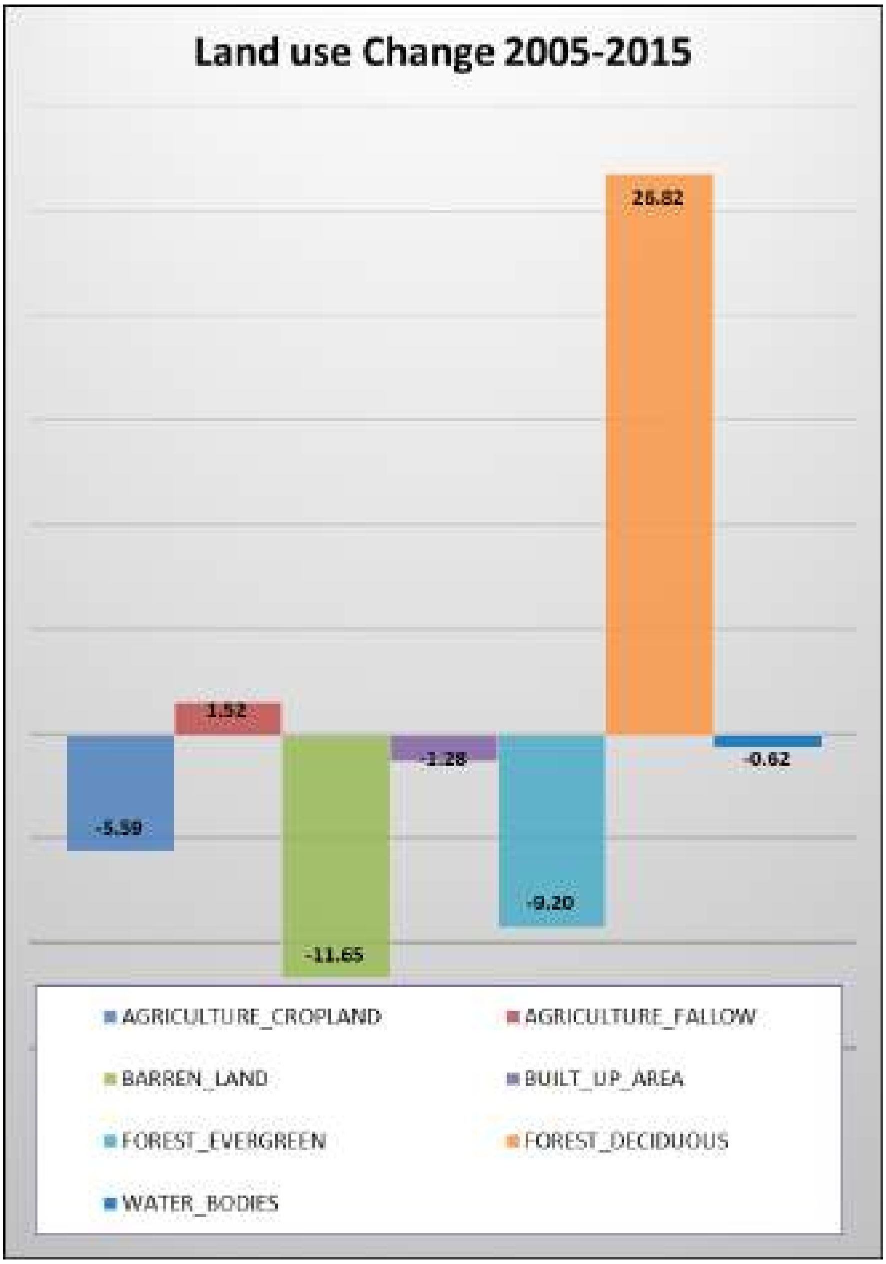


Figure 7.12: Increase/Decrease in land use from 2005 to 2015

## 7.3 Soil type Classification:

These are the soil types in the catchment at a broader perspective, and can be divided into multiple sub-types still significant for various studies. But the ones that hydro-logical studies are concerned with are only considered here. With more than 60% coverage, gravelly sandy clay loam covers most of the land, followed by clayey loam with 22%. The least coverage is of gravelly sandy loam and gravelly clay, both contributing 5%. Hence it can be inferred that about 95% of the land is a loam soil, with the least contribution of a gravelly sand loam.

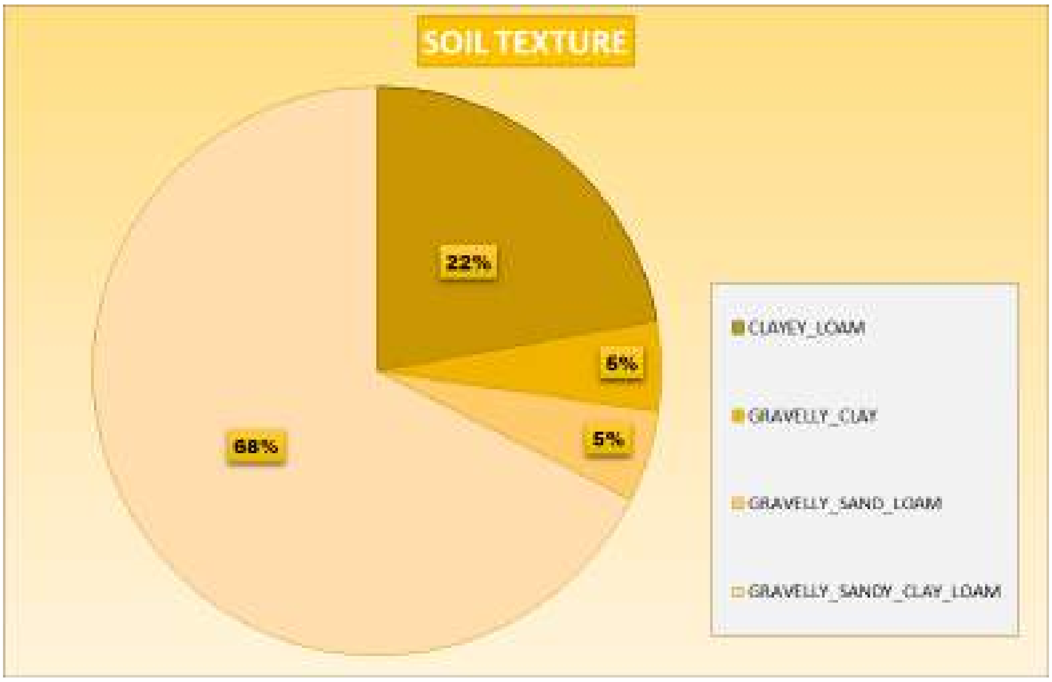


Figure 7.13: Percent of each soil type present in catchment

## 7.4 Rainfall:

The daily rainfall data was acquired from the IMD, for all years from 2005 to 2020. Along with having used this data as an input to the the hydro-logical model, it is presented in the form of yearly and monthly averages in the following charts. Along with the temporal average, spatial average was also taken, as the daily data received from IMD was for each rain gauge stations in the Satara district. Out of them, all the values of the 3 stations that fell into the catchment: Mahabaleshwar, Medha and Patan were considered. Taking an average of each station value, again the monthly and yearly average was taken.

**How is this different from the common rainfall data found anywhere?**

A rainfall data available anywhere is either pre-averaged or from any sources with undefined knowledge of the calculations done. This is the data calculated from daily rainfall taken from the most reliable source. Also other available data generally represents a rainfall of an area under a particular station, or of all the stations under a common authority which gives an average representing rainfall value of the whole district, or a similar region, but this data acts as a rainfall value of a hydro-logical unit - the catchment area of koyna. Hence it can be used to asses the trends that strictly represent that of Koyna's upstream catchment, and can be used to study an effect cause relationships in the catchment, and take decisions.

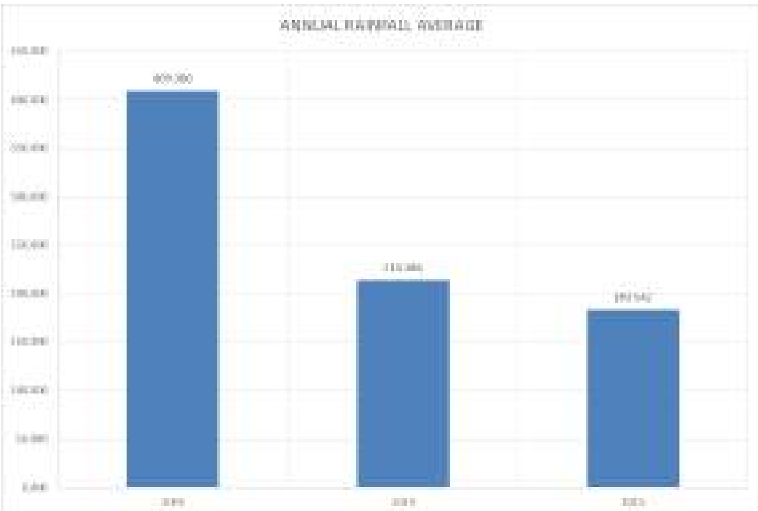


Figure 7.14: Average values established out of daily rainfall

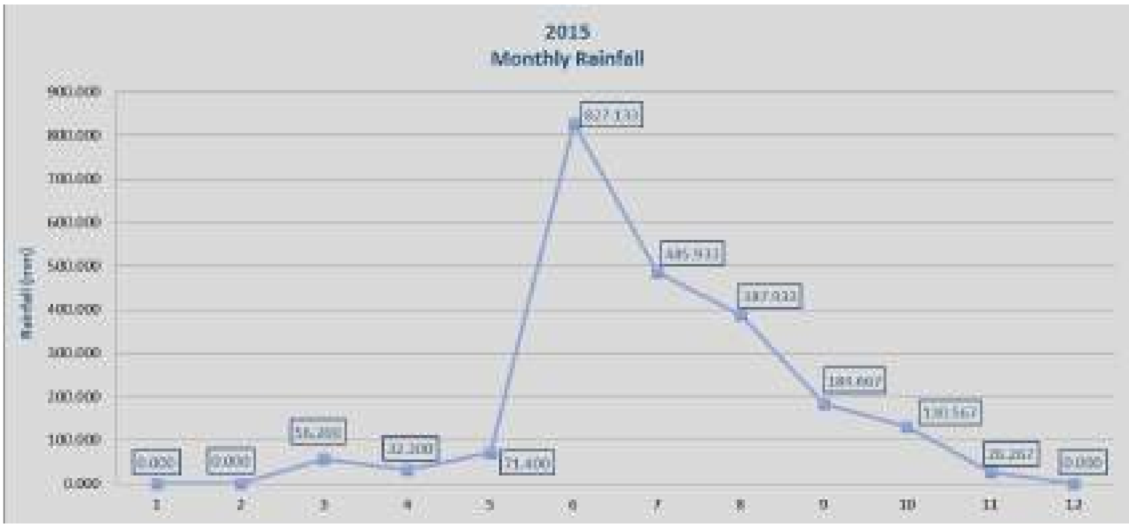


Figure 7.15: Monthly Rainfall Variations, 2005

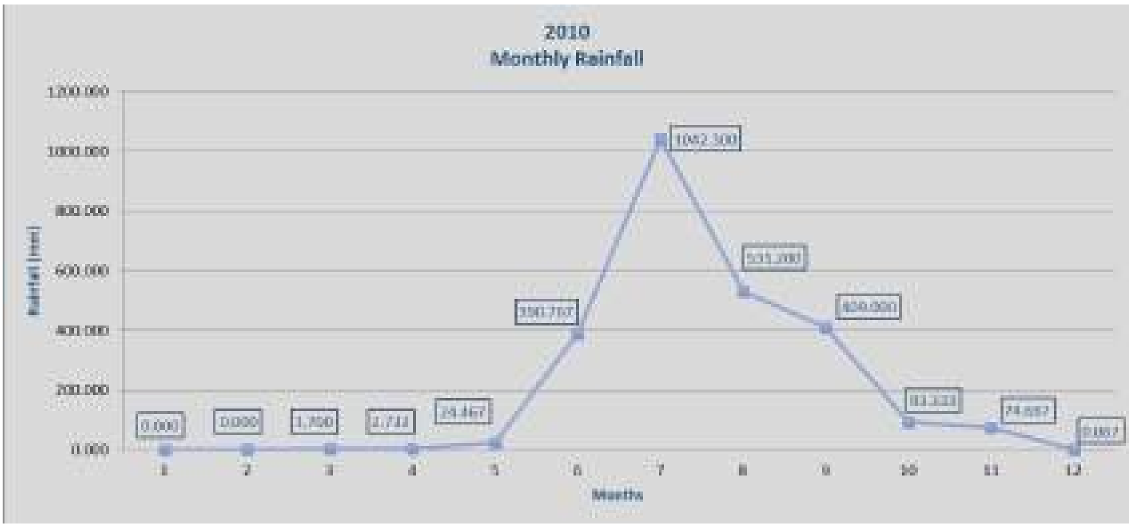


Figure 7.16: Monthly Rainfall Variations, 2010


Figure 7.17: Monthly Rainfall Variations, 2015

## 7.5 Hydro-logical Model:

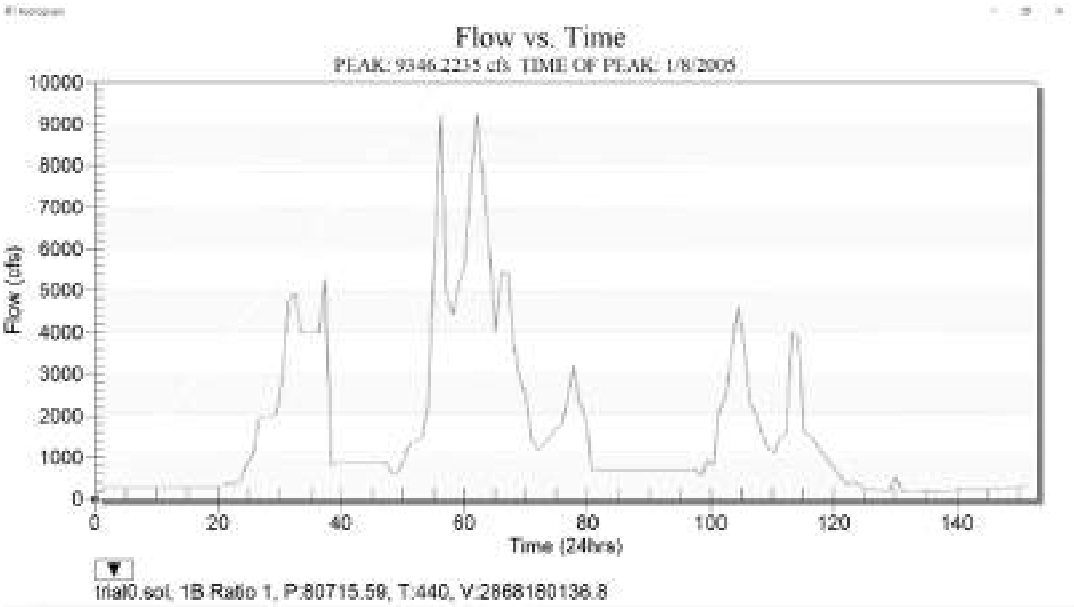


Figure 7.18: Modelled Hydro-graph: 2005

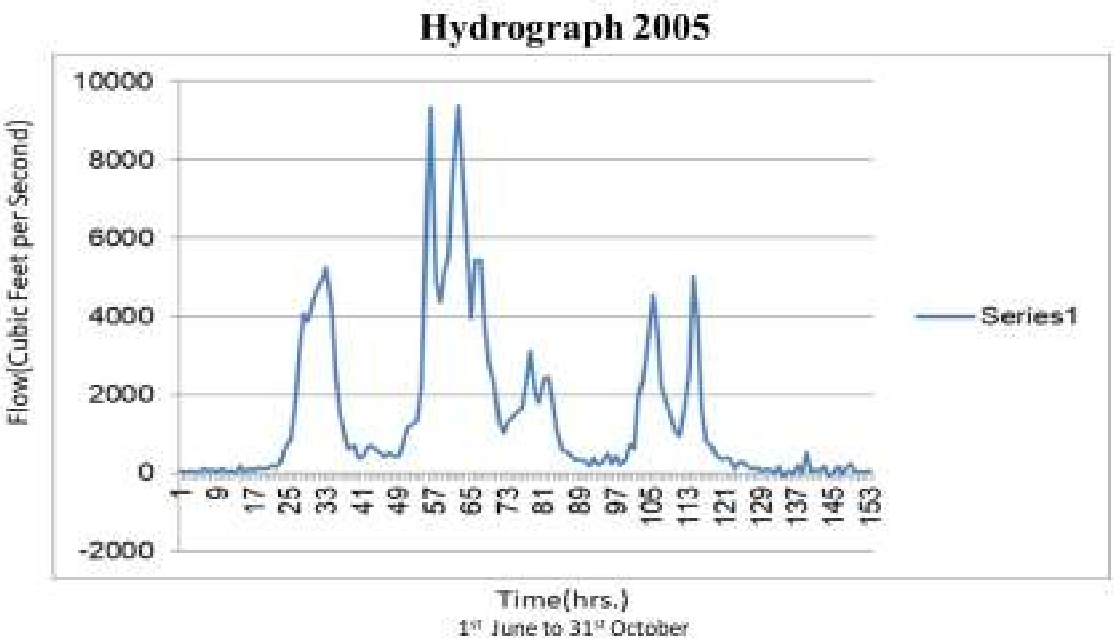


Figure 7.19: Real Hydro-graph: 2005

# Chapter 8

# Conclusion & Future Work

As per the objectives were set of establishing the inter-relationship between the factors that affect Koyna River Catchment hydrology, the factors that could be finally successfully assessed were: Land use, Soil and Rainfall. Not only were they used for hydro-logical modelling to run the model and get the hydro-graph, they were used as a data to analyse and interpret their trend through the study period. The study period was 15 years, and the study boundary was defined by us exclusively. Hence the land use class data was created for the year 2005, 2010 and 2015 using NRCS web layers making the results more reliable than the commonly produced automatic classification using satellites. Using the same, land use changes from 2005 to 2010 and 2010 to 2015 were assessed. Data of the soil types that concern hydrology was created and analysed along with using it for the hydro-logical model. The curve number value was generated using the land-use and soil data. Daily rainfall data from IMD was used as a precipitation input for the model, while the rainfall patterns yearly and monthly were also analysed. The inflow and outflow received from Koyna river authority was used to create the real hydro-graph data for comparison.

Hence even though the interpretations regarding the model run were not exactly put owing to the highly different standards opted for modelling, the prime objective of creating a readily available data that can help assess the impact the assessed factors have had on the catchment hydrology was successfully met. Hence while some of the data can directly be used for positive decision making, some can be indirectly used for further studies/analysis.

- Following is the **future work** to be done or can be done based on the data and results acquired from the current work:

1) Due to the use of manual digitization, though the accuracy could be highly improved and land use increase and decrease could be quantified in terms of area, the data about what class changed into what wasn't created, hence with the help of GIS softwares, it can be done using the data currently created.
2) Only the average annual rainfall data out of the acquired daily data was used for modelling. As far as the objective of creating a model data out of a data, it was enough, but a much finer models can be prepared in the future using the data acquired.
3) A much deeper interpretation of the results of the hydro-graph run is required. Also the interpretations of the comparison of the real hydro-graph created and the modelled hydro-graph obtained should be made.
4) The CN grid data created, for each of the respective 3 years can be compared and analysed.
5) The data and the procedure mentioned can together help in various further study over the same catchment.

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# Appendices

# Appendix A

# Photographs

Figure A.1: Visit to Indian Meteorological Department

Figure A.2: Discussion with the Guide

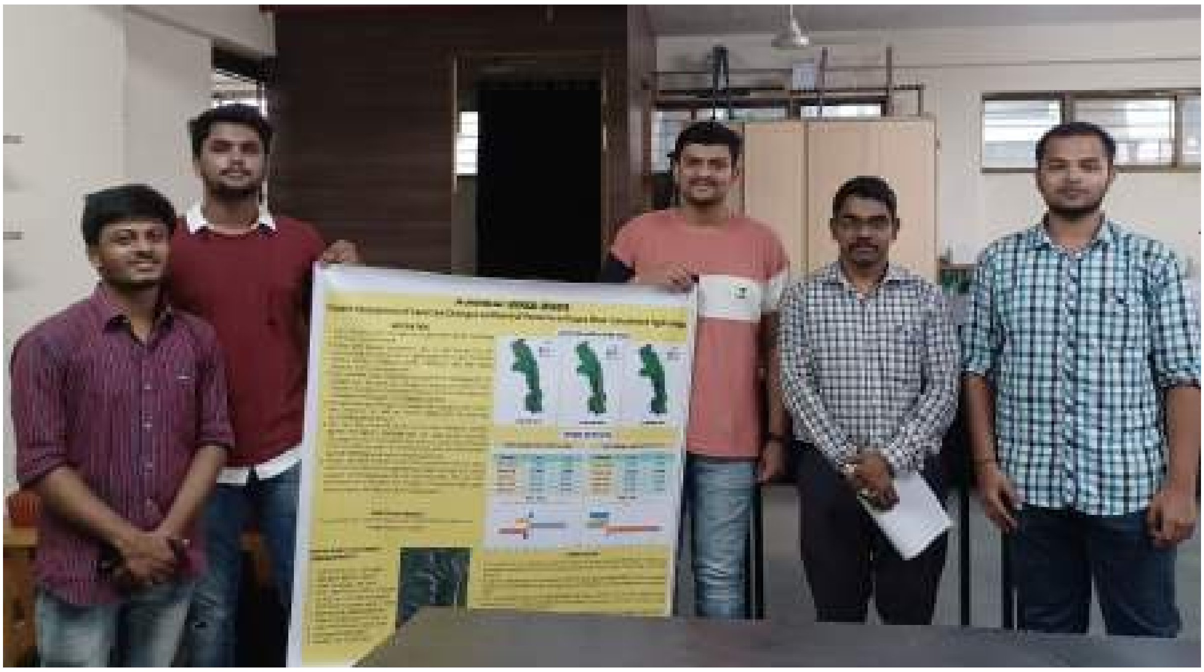

Figure A.3: Project Poster Presentation

## Appendix B

# Project Team Photo with Advisor

Figure B.1: The team's photo with the project advisor