CHARACTERISATION OF RIVER KOSI IN THE MONSOON 2010-12

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Civil Engineering

By
Kunal.|109CE0032

Department of Civil Engineering
National Institute of Technology Rourkela

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Under the supreme guidance of Prof. Ramakar Jha

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CERTIFICATE

This is to certify that the project entitled**, Characterization of river Kosi in the monsoon of 2010-12** submitted by **Kunal** is partially completed thesis for fulfillment of the requirement for the award of Bachelor of Technology Degree in Civil Engineering at National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter in the report has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Date:

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I also thank my friends who directly or indirectly helped me in my project work and completion of the report.

Last but not the least I would like to thank my parents who taught me the values of hard work. I would like to share this moment of joy with my mother and father. They rendered me constant support during the whole tenure of stay at NIT Rourkela.

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ABSTRACT

Climatic change, unplanned land use pattern, deforestation, socio-economic change and human intervention are affecting the hydrology of Kosi river basin .In the absence of proper flood management, potential threat of flood damages is increasing in every extreme flood event. The existing structural counter measures in the basin will not be sufficient against probable extreme floods. So, it is necessary to develop non-structural counter measures. The methodology in this study is to develop non-structural counter measures for downstream reach of Kosi river basin so that losses and damages due to flood disaster could be minimized with the simultaneous application of structural as well as non-structural measures. This paper presents the results of statistical analysis as well as model analysis based on Kosi river basin data procured from Central Water Commission office, Patna and TRMM website in order to develop the relationship between various hydrological parameters like rainfall, soil moisture, runoff and hence to develop flood forecasting model using simple statistical tools (least square methods of best fit technique)and doing inundation analysis using maps available in NRSC website for last three years during monsoon. The results found are satisfactory and can be used for flood forecasting and hence bring down the effect of the menace both in terms of life and property.

CHAPTER~ 01

INTRODUCTION

1.1 General:

The main hazards repeatedly occurring and causing heavy losses in terms of lives and properties in India are floods, landslides, avalanches, hailstorms, windstorms, lightning strikes, earthquakes, fire, and epidemics. The overall impacts caused by water-induced disasters such as floods, landslides, and avalanches are the most severe. One of the most important river, known for recurrent flooding events is Kosi, sometimes also known as sorrow of Bihar. Kosi has been area of interest for researchers from long back as it has an ever changing course and was estimated to be 120 km in span of 250 years to west (Diwakar, 1959; Gole & Chitale, 1966).Many different logics have applied to put up a reason for shift as well as solutions for it. However, now this is not a problem as enbankment has been made along the river which keep it controlled. But in the August 2008, due to breach in the embankment caused heavy flooding and almost affected over 2.3 million people in the northern part of Bihar (a state in India).

Study shows that though river has been embanked but is vulnerable to flooding event as Climatic change, unplanned land use pattern, deforestation, socio-economic change and human intervention are affecting the hydrology of Kosi river basin. In the absence of proper flood management, extent of flood damages is increasing in every extreme flood events. The existing structural counter measures in the basin will not be sufficient against probable extreme floods. So, it is necessary to develop non-structural counter measures. The methodology in this study is to characterize hydrological parameters i.e rainfall and runoff of the basin (using least square method as well as ANN) and then develop non-structural counter measures for downstream reach of Kosi river basin so that losses and damages due to flood disaster could be minimized with the simultaneous application of structural as well as non-structural measures. This paper presents the results of statistical analysis as well as inundation analysis based on Kosi river basin data which includes soil moisture, inundated area, and water level as various gauge sites. The developed results will be useful for community level people to prepare themselves during extreme flood events to save their lives and properties as a part of flood disaster management approach.

CHAPTER ~02

LITERATURE REVIEW

The literature review presented here has been basically related to Inundation in a chronological order.

(Smith, 1997) worked with active and passive remote sensing to estimate water surface area, stage and discharge. Methods for mapping surface area are by far the best developed. More recently, improvements in satellite orbital precision and the increasing availability of multi-temporal satellite data have enabled the estimation of river stage and discharge from space. While these techniques are largely in their infancy and not yet used operationally, three general approaches have emerged: (1) direct measurement of water surface level from radar altimeter waveform data; (2) determination of water surface elevations at their point of contact with the land surface using high-resolution satellite imagery and topographic data; and (3) correlation of satellite-derived water surface areas with ground measurements of stage or discharge. It should be noted that river flow velocity cannot be directly measured from space. Satellite estimates of discharge therefore require the use of ground-based empirical relationships between discharge and inundation area or stage.

(Batesa and De Roo, 2000) proposed a raster based flood inundation simulation where we describe the development and testing of a simple physically-based flood inundation model, LISFLOOD-FP, capable of being integrated with newly available high resolution raster-based Digital Elevation Models. This new scheme is an extension of the LISFLOOD catchment model (De Roo et al.,1999a) and is specifically designed for channel and floodplain hydraulic routing problems.

(Xihua Yang and Bengt Rystedt, 2002**)** developed an integrated methodology for flood prediction using geographic information system (GIS) and hydrodynamic modelling and to obtain flood information for flood emergency planning. The feasibility of simulating a flood event along a river channel is explored in areas near residential development in Eskilstuna community, Sweden.

(Kothyari 2004**)** described a technique of Artificial Neural Networks (ANN) and a concept is introduced on the use of ANN for estimation of hydrological parameters from un gauged catchments. A regression-based model was coupled with the ANN by Kothyari (2004) for the estimation of the mean annual flood. The model was first derived for the estimation of Q by making use of the independent variables. The output of such an auxiliary model, along with the other variables, was considered as input to the ANN model that was termed as the substantive model.

(Overton, 2005) produce a floodplain inundation model for the 600 km long and 1–5 km wide portion of the River Murray in South Australia from the New South Wales border to Lake Alexandrina. The model was developed using a Geographical Information System (GIS), remote sensing and hydrological modelling. Flood inundation extents were monitored from Landsat satellite imagery for a range of flows, interpolated to model flood growth patterns and linked to a hydrological model of the river. The resulting model can be analysed for flows ranging from minimum flow to a 1-in-13-year flood event for any month and weir configuration and has been independently tested using aerial photography to an accuracy of approximately 15% underestimate. The results have proven the approach for determining flood inundation over a large area at approximately one-tenth of the cost of detailed elevation and hydrodynamic modelling. The GIS model allows prediction of impacts on infrastructure, wetlands and floodplain vegetation, allowing quantitative analysis of flood extent to be used as an input into the management decision process.

(Knebl et al 2005) developed a framework for regional scale flood modeling that integrates NEXRAD Level III rainfall, GIS, and a hydrological model (HEC-HMS/RAS). The San Antonio River Basin (about 4000 square miles, 10,000 km2) in Central Texas, USA, is the domain of the study because it is a region subject to frequent occurrences of severe flash flooding. A major flood in the summer of 2002 is chosen as a case to examine the modeling framework. The model consists of a rainfall–runoff model (HEC-HMS) that converts precipitation excess to overland flow and channel runoff, as well as a hydraulic model (HEC-RAS) that models unsteady state flow through the river channel network based on the HEC-HMS-derived hydrographs. HEC-HMS is run on a 4!4 km grid in the domain, a resolution consistent with the resolution of NEXRAD rainfall taken from the local river authority. Watershed parameters are calibrated manually to produce a good simulation of discharge at 12 subbasins. With the calibrated discharge, HEC-RAS is capable of producing floodplain polygons that are comparable to the satellite imagery. The modeling framework presented in this study incorporates a portion of the recently developed GIS tool named Map to Map that has been created on a local scale and extends it to a regional scale. The results of this research will benefit future modeling efforts by providing a tool for hydrological forecasts of flooding on a regional scale.

(Overton et al 2006) developed a model using a Geographical Information System (GIS), remote sensing and hydrological modeling. Floodplain inundation extents were detected from satellite imagery for a range of flows and interpolated to model flood growth patterns. The RiM-FIM predicts the extent of flooding on the River Murray floodplain from a range of river flows and weir levels. It is useful for predicting the extent of inundation on the River Murray floodplain (~606,000 ha) including the flow regimes of wetlands and floodplain vegetation. It allows for spatial and quantitative analysis of the flood extents to be usedas an input into the management decision process.

(Pappenberger et al 2007) ran a sensitivity analysis of a one-dimensional flood inundation model (HEC-RAS) on the River Alzette, Luxembourg. He applied five different methods (Sobol, Kullback–Leibler entropy, Morris, regionalised sensitivity analysis and regression) and the outcomes on selected examples compared. It is demonstrated that the different methods lead to completely different ranking of importance of the parameter factors and that it is impossible to draw firm conclusions about the relative sensitivity of different factors. Moreover, the uncertainty inherent in the sensitivity methods is highlighted.

(Fuagara et al 2008) worked with the application of flood modelling that integrates hydraulic modelling (MIKE 11 hydrodynamic model) and geographic information systems (GIS) for urban floodplain inundation. The Kuala Lumpur city is the domain of the study; it is the most densely populated area in the country. The form of flooding frequently experienced in the study area is the flash flood and it can happen several times each year. In this study the flood plain and river geometry of Klang river basin is developed using MIKE 11 hydrodynamic model oriented GIS. The river network system is incorporated in the DEM for hydrodynamic modeling of water level and discharge of 100-year return period storm design. 3D-GIS and spatial analytical techniques together with hydraulic data processing are performed on ArcView GIS platform to enhance the visualization and display techniques for visual presentation and generation of flood inundation maps.

(Manohar Kumar SAH, 2009) did an inundation analysis and flood forecasting Tinau river basin (Nepal) using hydrological analysis that is statistical co-relation development using trend analysis, and inundation analysis using one dimensional hydrodynamic numerical model HEC RAS.

(Bhola and Singh, 2010) did rainfall – runoff modeling for river Kosi using SCS-CN and ANN method and compared the results and found that the performance comparison of both the models is made with coefficient of determination (R2) which is coming to be 0.82 in case of SCS-CN method and 0.89 in case of ANN.

(Nasrizal et al 2010) worked with a 3D hydrodynamic flood simulation study which utilizes the Geographic Information System (GIS) where a Digital Elevation Model (DEM) of Damansara Catchment was developed and integrated into a flood model using InfoWorks River Simulation (RS) program to simulate the flooding event on 26th February 2006. Existing Damansara River profile was collected through hydrographic surveying activity. The 3D flood model was calibrated and validated successfully. The computer simulation results produced an updated flood inundation map which is essential to put up a master plan for flood mitigation.

(Yarrakula et al 2010) conducted hydrodynamic modeling of Subarnarekha river to develop a flood forecasting model. Digital Elevation Model (DEM) of study area was prepared using high resolution CARTOSAT-1 imageries and river cross sectional nodes were extracted from DEM. Remote sensing and GIS tools were used for transforming from CARTOSAT-1 stereo images, inundation and damage areas. Results of hydrodynamic model of flood year 1997 matched quite well with those measured by CWC. Assessment of damage due to flooding of agriculture land, habitats, dense forest, mixed vegetation, scrubs, plantation, water bodies and barren land for 1997 were determined and elaborated.

(Lincoln1 and Zogg2, 2011) analyzed LMRFC Flood Inundation Toolset contains two methods of estimating the water surface profile. The simplest and quickest method is the Water Surface Profile From Points Tool, although it requires a high-resolution land elevation dataset that includes the elevation of the stream/river surface being evaluated. The other method, the Water Surface Profile from Cross Sections Tool, is likely to produce better results in most cases and should be used when the water surface profile is based upon information from other sources.

(Bhadra, 2011) mapped the flood inundated area using GIS for the Dikrong river basin of Arunachal Pradesh, India, corresponding to different return periods (2, 5, 25, 50, and 100 years). Further, the developed inundation maps corresponding to 25, 50, and 100 year return period floods were compared to corresponding maps developed by conventional methods as reported in the Brahmaputra Board Master Plan for Dikrong basin. It was found that, the average deviation of modelled flood inundation areas from reported map inundation areas is below 5% (4.52%). Therefore, it can be said that the modelled flood inundation areas matched satisfactorily with reported map inundation areas. Hence, GIS techniques were proved to be successful in extracting the flood inundation extent in a time and cost effective manner for the remotely located hilly basin of Dikrong, where conducting conventional surveys is very difficult.

(Kia et al 2011) developed a flood model using various flood causative factors using ANN techniques and geographic information system (GIS) to modelling and simulate flood-prone areas in the southern part of Peninsular Malaysia. The ANN model for this study was developed in MATLAB using seven flood causative factors. Relevant thematic layers (including rainfall, slope, elevation, flow accumulation, soil, land use, and geology) are generated using GIS, remote sensing data, and field surveys. To measure the performance of the model, four criteria performances, including a coefficient of determination (R2), the sum squared error, the mean square error, and the root mean square error are used. The verification results showed satisfactory agreement between the predicted and the real hydrological records.

CHAPTER~03

STUDY AREA

3.1 KOSI RIVER

The Kosi River basin is one of the largest river basin in northern India. It constitutes an area of about 61, 000 sq.km. The River Kosi is commonly known as Sapta Kosi as it comprises of seven tributary rivers namely (From west to east); Indrawati, SunKosi, Tama Kosi, Likhu, Dudh Kosi, Arun and Tamor. Out of these, three tributaries originate in Tibet, namely, Sun Kosi, Tama Kosi and Arun. Mainly, the basin of Kosi can be divided into three major river sub-basins, the SunKosi, Arun and Tamor. The Sun Kosi River is constituted of three tributaries that is, the Indarwati, Sunkhoshi, Tama Kosi, Dudh Kosi and Likhu rivers. The Kosi has an average discharge of 1564 m^3/s or55,000 cu ft/s. During floods, it sometimes increases up to 18 times the average value. The greatest recorded flood was 24,200 m^3/s(850,000 cu ft/s) on August 24, 1954. The Kosi Barrage has been designed for a peak flood of 27014 m^3/s(954,000 cu ft/s). The Kosi river has laid waste large fertile tracts during its frequent migrations and has caused extensive damage through overbank flooding and inundation. For this reason, it is famously known as “Sorrow of Bihar”.

3.1.1 SunKosi Basin

The watershed area of the SunKosi basin is about 19,000 sq. km. The SunKosi River gets originated in the mountain range east of Barhabise called Kalinchowk, and flows in west direction with steep river gradient of 1:10 to meet the BhoteKosi at Barhabise. The BhoteKosi, originates from a glacier on the south slope of Mt. Xixabangma Feng, in the southern part of the Himalayan range in the Tibetan plateau. The catchment area at the confluence point is about 2,375 km2 of which about 2000 sq. km lies in Tibet. The average gradient in the upper reach is 1:8, while in the lower reach it is about 1:31. The SunKosi flows in a south-east direction up to Dolalghat, the confluence point of the SunKosi with the Indrawati River, with an average gradient of 1:130. The Indrawati River, one of the main tributaries of the SunKosi River, originates in the Himalayan range and flows in a south, south-east direction to meet with the River SunKosi at Dolalghat. The average gradient of this river is about 1:34 in the upper reach and 1:194 in the lower reach. The total catchment area of the Indrawati at the confluence with the SunKosi River is about 1,175 sq. km. The SunKosi River, after the confluence with Indrawati River, flows in a south-east direction up to Tribeni with an average gradient of 1:450. The TamaKosi River, which originates in the southern part of the Tibetan Plateau of China, flows in a southerly direction through the Rolwalin Himalayan range and enters Nepal. Within Nepal, the river flows in a southern direction through the mountainous and hilly areas with an average gradient of 1:20 in the upper reach and 1:110 in the lower reach to meet with SunKosi River at Khurkot. The TamaKosi River has total drainage area of 4,190 sq. km at Khurkot. About 40 km downstream of Khurkot, the SunKosi River joins with the Likhu Khol

The Likhu Khola originates in the mountain range and flows in the south direction to meet the SunKosi River. The average gradient of Likhu Khola is about 1:54. Its drainage area at the confluence point with the SunKosi is 1,070 sq. Km. The SunKosi River after the confluence with Likhu Khola, meets with the DudhKosi at about 25 km downstream. The DudhKosi originates in the Khumbu and Nojumpa Glaciers located on the southern slopes of the Mahalangur Himalaya range and flows directly from north to south resulting in a rapid river gradient. The average gradient is about 1:30 in the upper reach and 1:250 in the lower reach. The total drainage area of the river (at the confluence with the SunKosi River) is about 4,140 km2. The SunKosi River flows in a south-eastern direction to meet the Arun and Tamur Rivers to form the SaptaKosi at Tribeni. The total length of the river is 330 km. The gradient of the SunKosi River is approximately 1:210 throughout the entire length of its course in Nepal.

3.1.2 Arun River Basin

The Arun River has its origin in a glacier on the northern slope of Mt. Xixabangma Feng (El.8012m), part of the Himalyan range in the southern part of the Tibetan highland. The river is called Pengqu in Tibet. It flows along the Himalyan range in upper reaches for a distance of about 280 km and then makes a very sharp turn to the southwest at the junction with its tributary, (the Yenuzangbu River Tibet), forming a big bend. The Arun then flows in the southward direction crossing the Himalyan range into Nepal. It continues to flow in south direction and joins the SaptaKosi (Kosi) River at Tribeni. The total length of the river is almost equal to 510 km and the total drainage area is about 36,000 sq.km, from which almost 25,310 sq. km lies in Tibet. In Tibet it has a slope of 1:130 and 1:630 in upper and lower reach, respectively. When it enters in Nepal it has a steep gradient in the range of 1:30 to 1:50 in upper reach. In the middle and lower reach of Nepal, it has a slope of 1: 96 and 1:300 to 1: 400 respectively.

3.1.3 Tamur River Basin

The river has its origin in the High Himalayas. Near its origin the Tamur is called Medalung Khola. Before it becomes Tamur River, it is joined by a large khola called Yangma Khola. The northern boundary of the Tamur catchment lies in high Himalayas and hence delineates the border between Nepal and Tibet. Similarly the eastern boundary lies in the High Himalayas and delineates the border between Nepal and India. Kanchanjanga (at an elevation of 8586m) the world‘s third highest peak is in this basin. In addition, there are 13 other major peaks in the basin, ranging from 5938 m (Ganbul on northern border of Nepal with Tibet) to 7902 m (Kambachen inside Nepal).

FIGURE A: Kosi river basin map from FMIS website

In the present report the rainfall data of the years 2010, 2011, 2012 have been taken from TRMM website, which is the mean rainfall for the lower river basin.

Rainfall data are considered only for monsoon period i.e. from June to October for the year so total 100 data sets are used and discharge for the 2 stations for the years (2010,2011,2012) is considered, two discharge stations are

1) Barahkshetra, India
2) Bhimnagar, India

Among which Barahkshetra lies in the upstream hilly areas of Himalaya and Bhimnagar in downstream relatively planner area.

The rainfall and discharge data were collected from the Water Resources Department, Govt. of Bihar and then scaled. The data has been modified because the discharge data of River Ganga and its tributaries are confidential and may not be made public.

The Kosi basin is an alluvial which has been studied in detail by remote sensing techniques. The Kosi's alluvial fan has fertile soil and abundant groundwater in a part of the world where agricultural land is in acutely limited supply in relation to population. The basin area of river Kosi lies in hydrological soil group C with two type of moisture content i.e AMC II and AMC III, as the precipitation data considered is for the monsoon season.

CHAPTER~04

METHODOLOGY

4.1 Data collection :

This part of the paper contains the type of data collection, method of data collection and the sources of data. However whatever data used in here in the analysis is free of cost and available in the official website of different agencies. Following are the data with their type and sources:

Data	Date Type	Source
Rainfall	Gauge station	TRMM
Water Level	Gauge station	CWC
Inundated area	Satellite	NRSC
Soil Moisture	Satellite	NOAA

4.2 Data rendering :

This part of the paper deals with the way to use the collected data. As the characterization of the river is required, hence the inter-relation of the stations in terms of effects has to be known for various parameters. Moreover establishment of equations is also required so as to have continuous data and if it is not available, that is, if reading of certain date is not taken due same problems at gauging station, it can be estimated. Following are steps under taken:

4.2.1 Statistical Analysis:

a) Least Square Method:

The Method of Least Squares is a procedure to determine the best fit line to data. The method easily generalizes to find the best fit of the form

$$y = a_1 f_1(x) + \ldots + c_K f_K(x);$$

b) Artificial neural network (ANN)

The relationship of rainfall-runoff is known to be highly non-linear and complex. The rainfall-runoff relationship is one of the most complex hydrologic phenomena to comprehend due to the tremendous spatial and temporal variability of watershed characteristics and precipitation patterns, and the number of variables involved in the modeling of the physical processes. Hydrologists are often confronted with problems of prediction and estimation of runoff, precipitation, contaminant concentrations, water stages, and so on. Although many watersheds have been gauged to provide continuous records of stream flow, hydrologists are often faced with situations where little or no information is available. In such instances, simulation models are often used to generate synthetic flows. The available rainfall-runoff models are HEC-HMS, MIKE-11, SWMM, etc. These models are useful for the hydrologic and hydraulic engineering planning and design as well as water resources management; e.g., hydropower generation, flood protection and irrigation. The existing popular model is considered as not flexible and they require many parameters. Obviously, the models have their own weaknesses. Therefore, in view of the importance of the relationship between rainfall-runoff, the present study was undertaken in order to develop rainfall-runoff models that can be used to provide reliable and accurate estimates of runoff.

ANN models have been used successfully to model complex non-linear input output relationships in an extremely interdisciplinary field. The natural behavior of hydrological processes is appropriate for the application of ANN method. In terms of hydrologic applications, this modeling tool is still in its nascent stages. Several studies indicate that ANN have proven to be potentially useful tools in hydrological modeling such as for modeling of rainfall-runoff processes flow prediction, water quality predictions, operation of reservoir system groundwater reclamation problems etc. The objective of the present study is to develop rainfall-runoff models using ANN methods.

An ANN can be defined as ‗a data processing system consisting of a large number of simple, highly interconnected processing elements (artificial neurons) in an architecture inspired by the structure of the cerebral cortex of the brain‘. The ANN tries to mimic the functioning of the human brain, which contains billions of neurons and their interconnections. Two types of neural network architectures, namely multilayer perceptron (MLP) and radial basis function (RBF) network are implemented. The architecture of an ANN is designed by weights between neurons, a transfer function that controls the generation of output in a neuron, and learning laws that define the relative importance of weights for input to a neuron. The objective of ANN is to process the information in a way that is previously trained, to generate satisfactory results. Neural network can learn from experience, generalize from previous examples to new ones, and abstract essential characteristics from inputs containing irrelevant data. The main control parameters of ANN model are interneuron connection strengths also known as weights and the biases. In all cases, the output layer had only one neuron, that is, the runoff.

4.2.2 Inundation Analysis:

Under this section, one can utilize either specifically available software or else can go for combination of software easily available. But the most important part is generation of inundation map which, in this study has been used from already available inundation maps in NRSC website. Then the map is digitized to know the value of area so that it can be used for developing relation with other parameters like rainfall, soil moisture and water level. The relation development is emphasized as carrying out simulation for inundated area each time is difficult and more than that parameters used for co-relation development are those which can be easily measured like water level, rainfall etc.

The relation development can either be done by least square method or by neural network method and further checked for various combination of regression like linear regression, normal distribution or Gaussian distribution and hence the accuracy can be increased.

CHAPTER~05

RESULTS AND DISCUSSIONS

5.1 Statistical Analysis:

Set 1:Rainfall correlated with modified discharge using least square method with combinations of same day, 1 day lag and 2 days lag for the monsoon period of 2010- 12.

I. Bhimnagar

a) 2010:

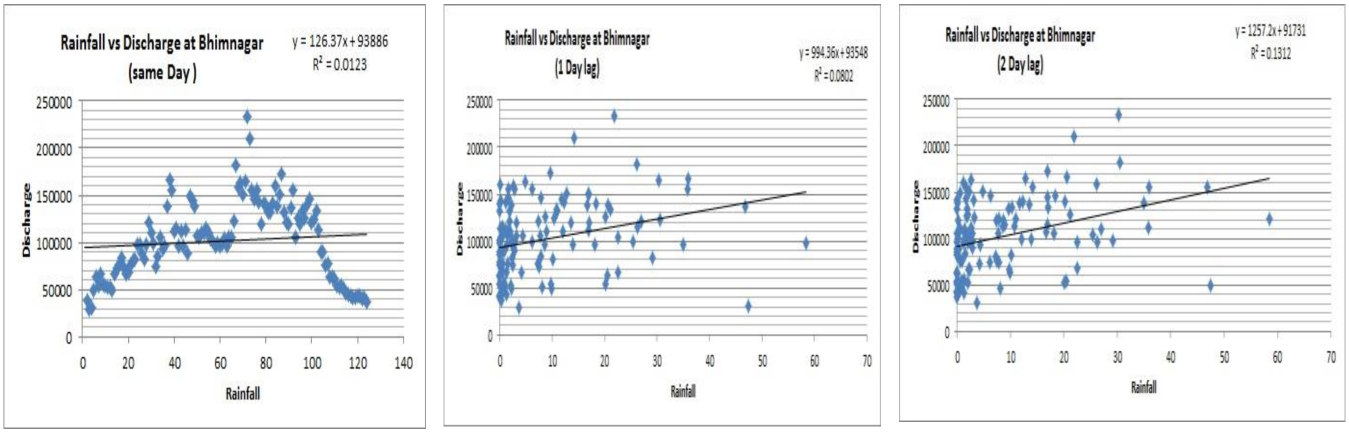

Figure 1: Rainfall-Runoff co-relation at Bhimnagar in the year of 2010 for combination of same day, 1 day lag and 2 days lag using least square method.

b) 2011

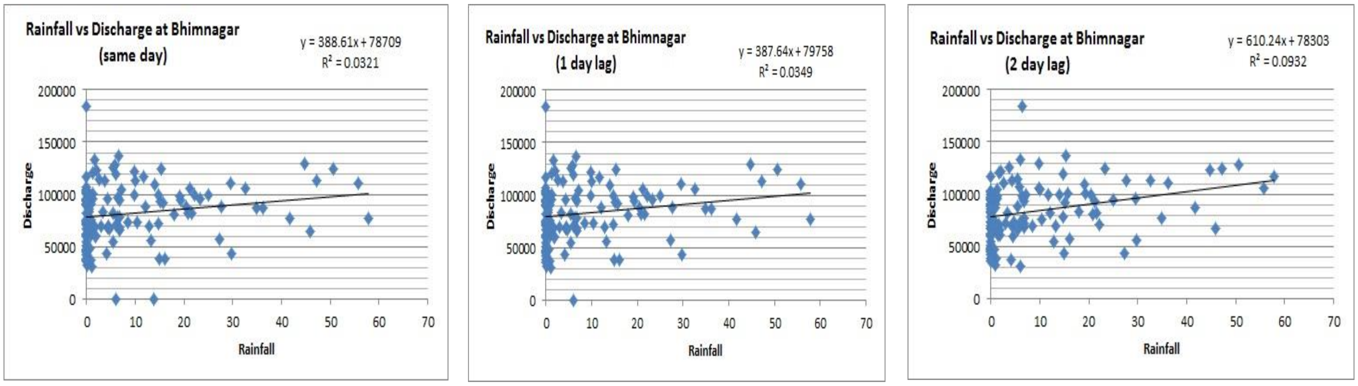

Figure 2: Rainfall-Runoff co-relation at Bhimnagar in the year of 2011 for combination of same day, 1 day lag and 2 days lag using least square method.

c) 2012

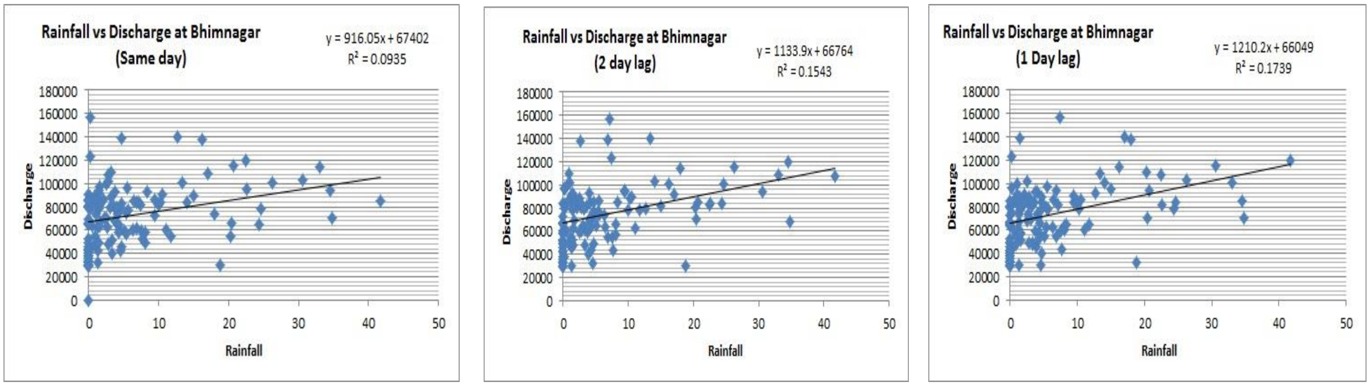

Figure 3: Rainfall-Runoff co-relation at Bhimnagar in the year of 2012 for combination of same day, 1 day lag and 2 days lag using least square method.

II Barahkshetra:

a) 2010

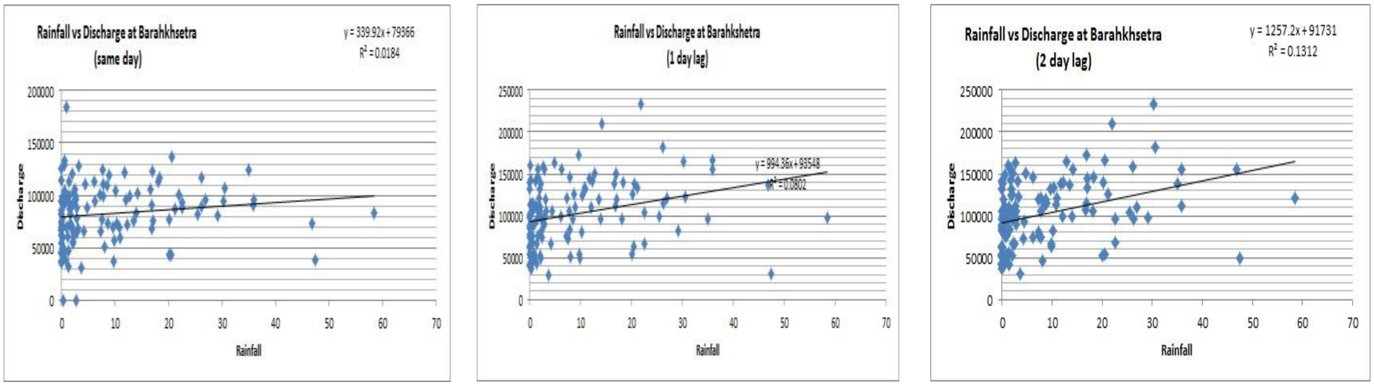

Figure 4: Rainfall-Runoff co-relation at Barahkshetra in the year of 2010 for combination of same day, 1 day lag and 2 days lag using least square method.

b) 2011

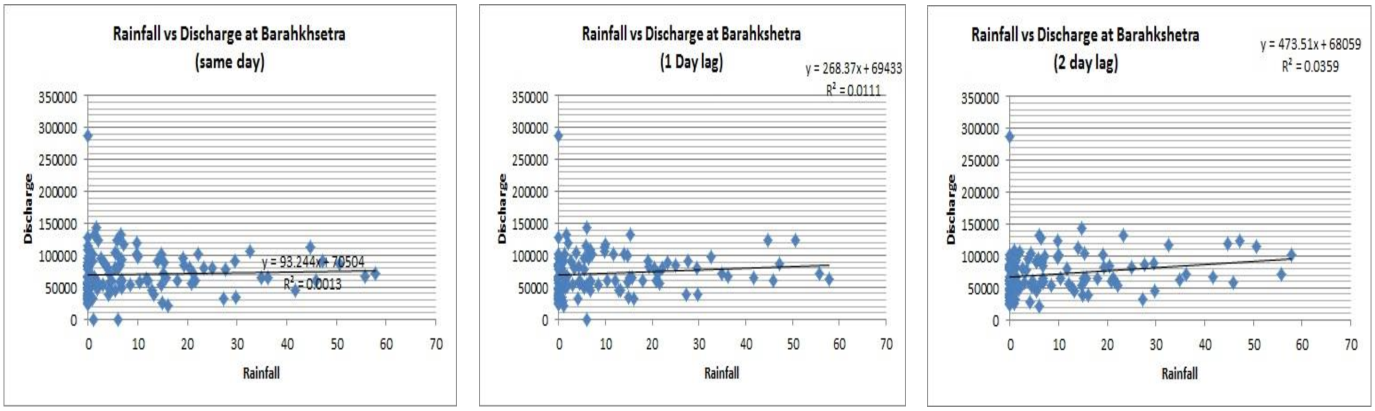

Figure 5: Rainfall-Runoff co-relation at Barahkshetra in the year of 2011 for combination of same day, 1 day lag and 2 days lag using least square method.

c) 2012

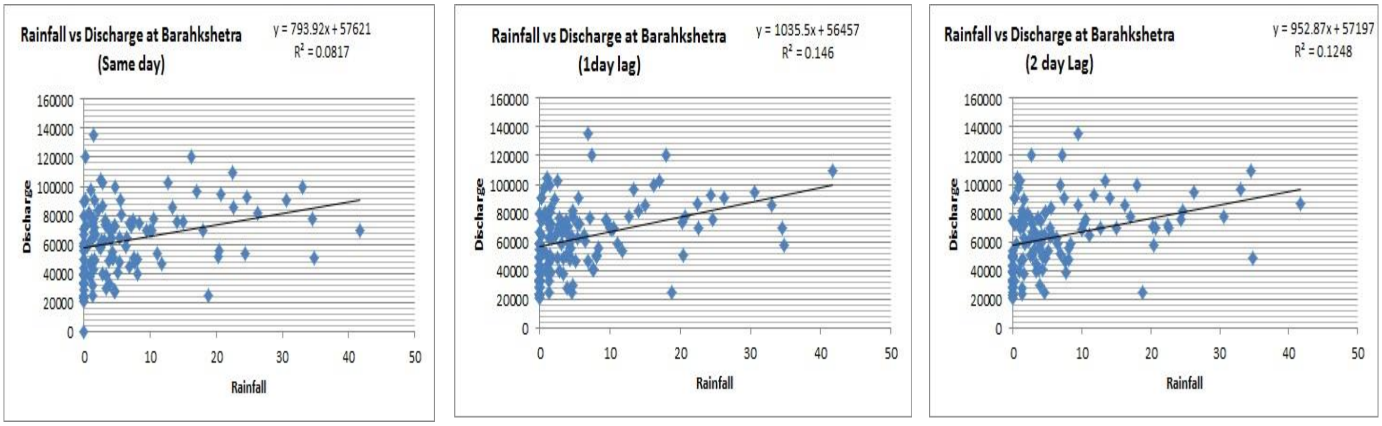

Figure 6: Rainfall-Runoff co-relation at Barahkshetra in the year of 2012 for combination of same day, 1 day lag and 2 days lag

In the above analysis, that is for the set 1 results, it can been that there is no good result as the raw data of rainfall and modified discharge is directly co-related without taking any consideration of the basin characteristics like topology, soil moisture etc, but anyways it gets better with the combination of one day and two days which means that there is a lag in time pointing towards the time taken by water to constitute stream flow. However the results can't be used which prompted to use some model analysis and hence ANN is chosen as it is universal, in the sense that it doesn't take into consideration of a particular basin rather it can be used for all the basins irrespective of its characteristics.

Set 2: Using ANN model runoff was generated and compared with modified discharge using different input/combination of inputs for various combinations like same day, 1 day lag and 2 days lag.

I. Rainfall as input

A) 2010

a) Bhimnagar

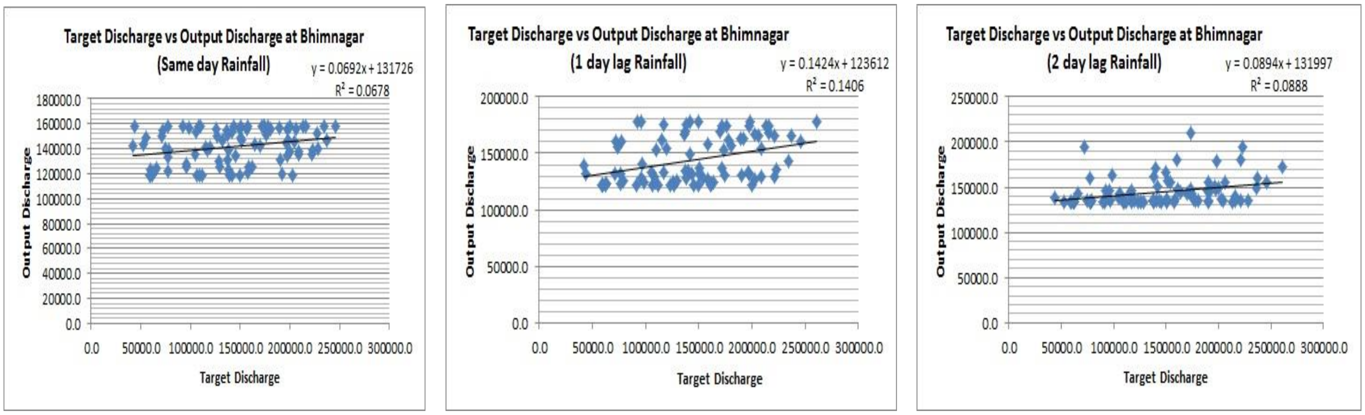

Figure 7: Rainfall-Runoff co-relation at Bhimnagar in the year of 2010 for combination of same day, 1 day lag and 2 days lag using ANN rainfall is single input.

b) Barahkshetra:

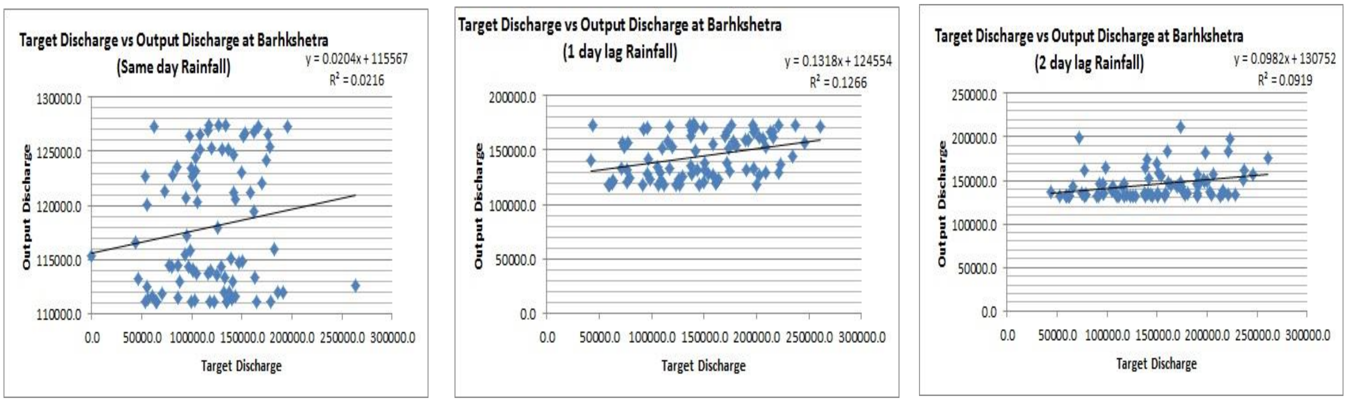

Figure 8: Rainfall-Runoff co-relation at Barahkshetra in the year of 2010 for combination of same day, 1 day lag and 2 days lag using ANN rainfall is single input.

B) 2011

a) Bhimnagar

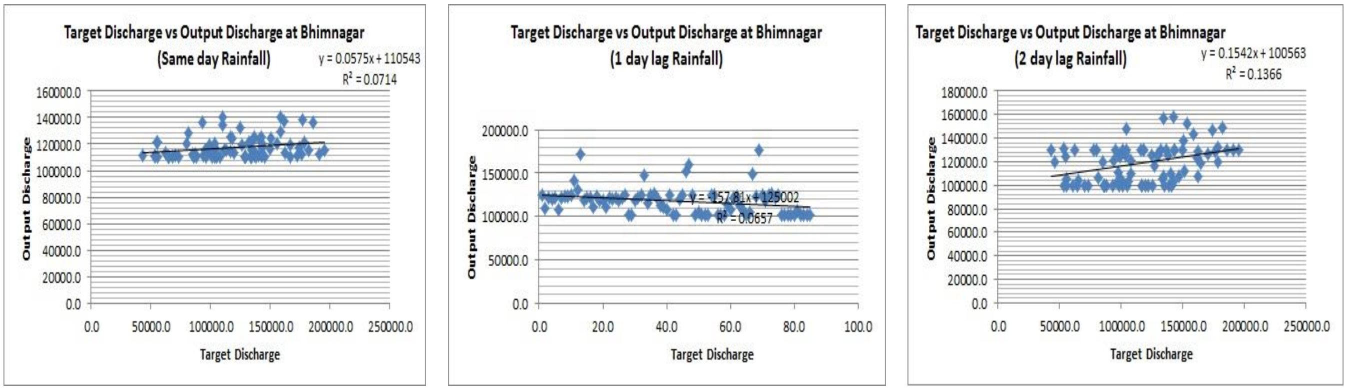

Figure 9: Rainfall-Runoff co-relation at Bhimnagar in the year of 2011 for combination of same day, 1 day lag and 2 days lag using ANN rainfall is single input.

b) Barahkshetra

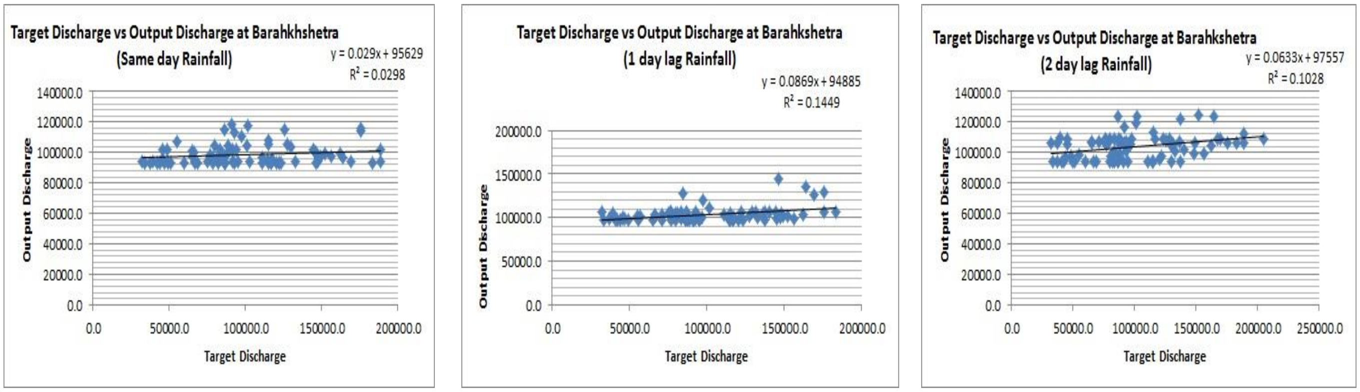

Figure 10: Rainfall-Runoff co-relation at Barahkhsetra in the year of 2011 for combination of same day, 1 day lag and 2 days lag using ANN rainfall is single input.

2012

a) Bhimnagar

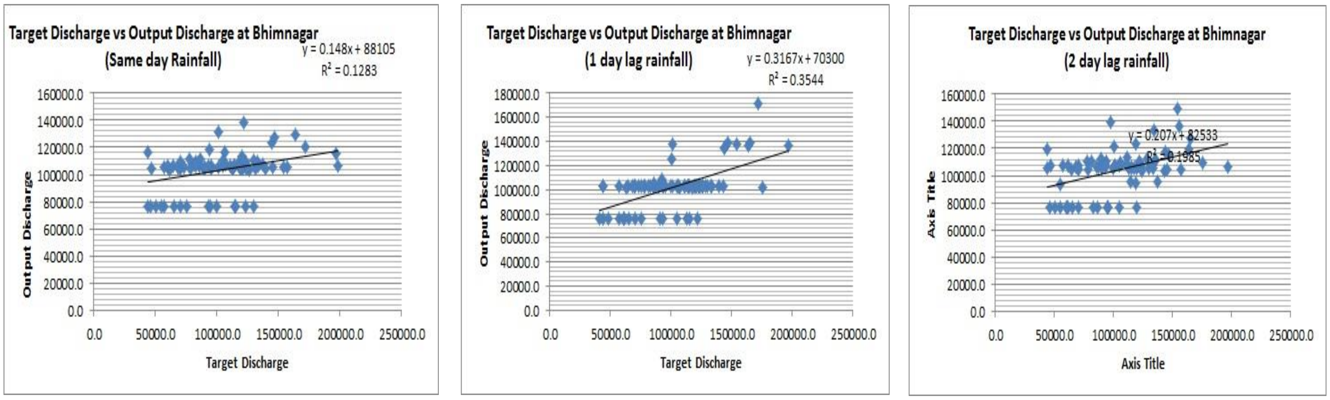

Figure 11: Rainfall-Runoff co-relation at Bhimnagar in the year of 2012 for combination of same day, 1 day lag and 2 days lag using ANN rainfall is single input.

b) Barahkshetra

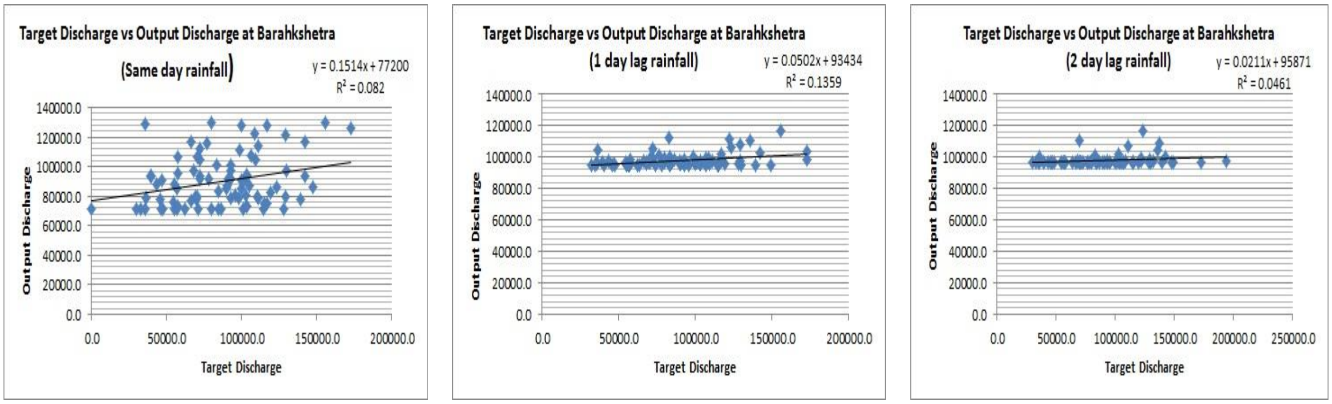

Figure 12: Rainfall-Runoff co-relation at Bhimnagar in the year of 2010 for combination of same day, 1 day lag and 2 days lag using ANN rainfall is single input.

The results in above subset are somewhat satisfactory but not to the mark because it is somewhat difficult to directly co-relate rainfall-runoff. It is required to use some model which is particularly useful for a certain basin with more parameters known. But one thing which can be ascertained is that precipitation takes almost one day to join the stream as the best results are for one day lag. Now other part of characterization is to known how much time water from upstream takes to reach the downstream station, hence it is required to develop a downward discharge relation for river.

II. Modified Discharge at Barahkshetra as Input and output generated is discharge at Bhimnagar that is downward discharge.

a) 2010

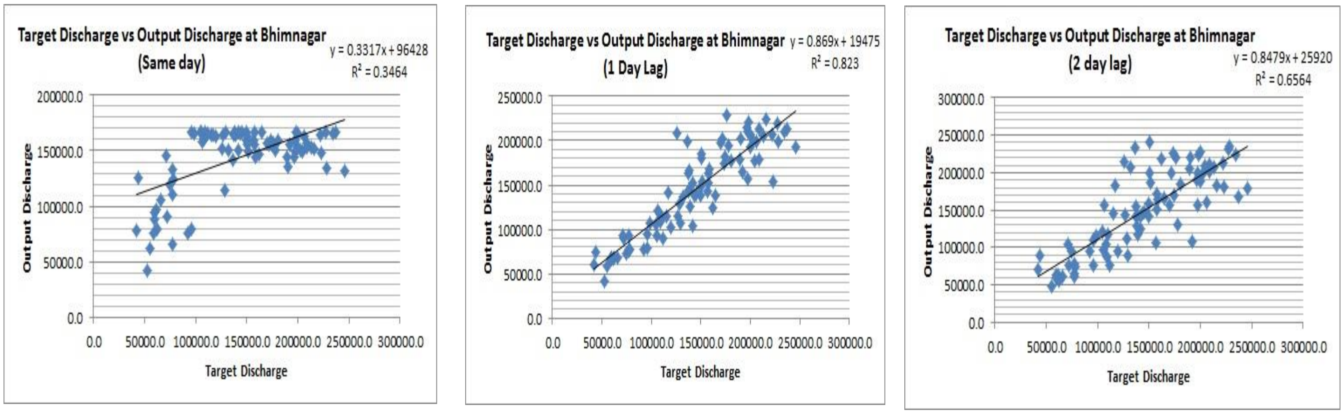

Figure 13: Rainfall-Runoff co-relation at Bhimnagar in the year of 2010 for combination of same day, 1 day lag and 2 days lag using ANN using discharge at upstream is input.

a) 2011

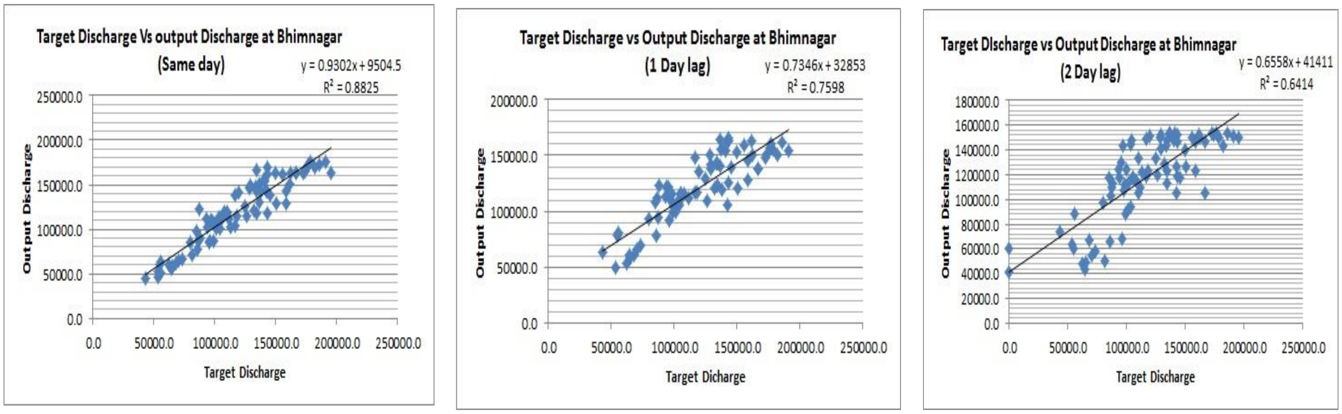

Figure 14: Rainfall-Runoff co-relation at Bhimnagar in the year of 2011 for combination of same day, 1 day lag and 2 days lag using ANN using discharge at upstream is input.

c) 2012

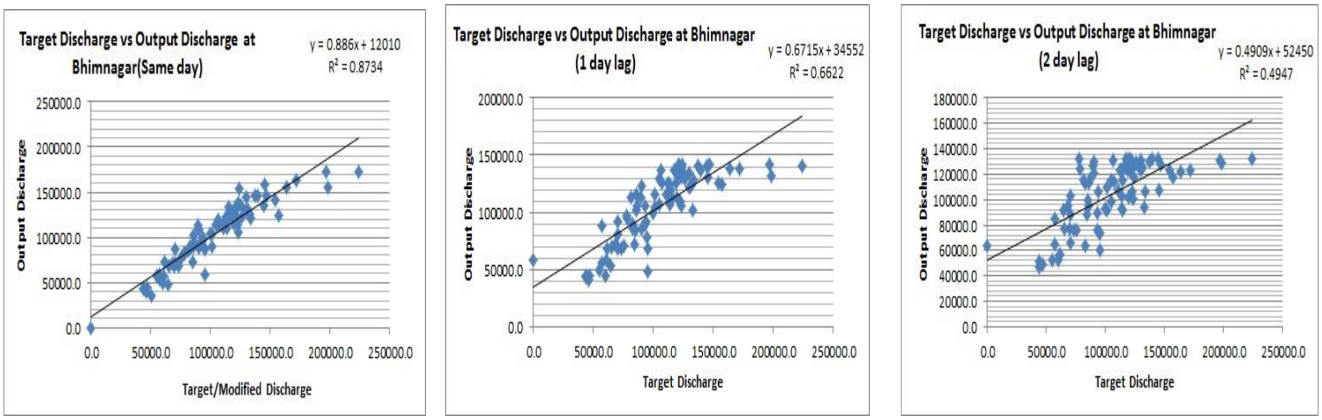

Figure 15: Rainfall-Runoff co-relation at Bhimnagar in the year of 2012 for combination of same day, 1 day lag and 2 days lag using ANN using discharge at upstream is input.

The results in above subset show very good co-relation and hence can be used for estimating the discharge at Bhimnagar if the data is missing. Moreover, one more thing comes out is that it takes less than 24 hours to reach water from Barahkhsetra to Bhimnagar and this can be easily verified by the elevation analysis of the area which shows a very steep slope and hence the velocity of water is very high. Now to increase accuracy of analysis one more combination is used that is used that is previous days rainfall and the discharge at upstream.

III. Rainfall as well as Discharge at Barahkshetra as Input and Output generated is Discharge at Bhimnagar

a) 2010

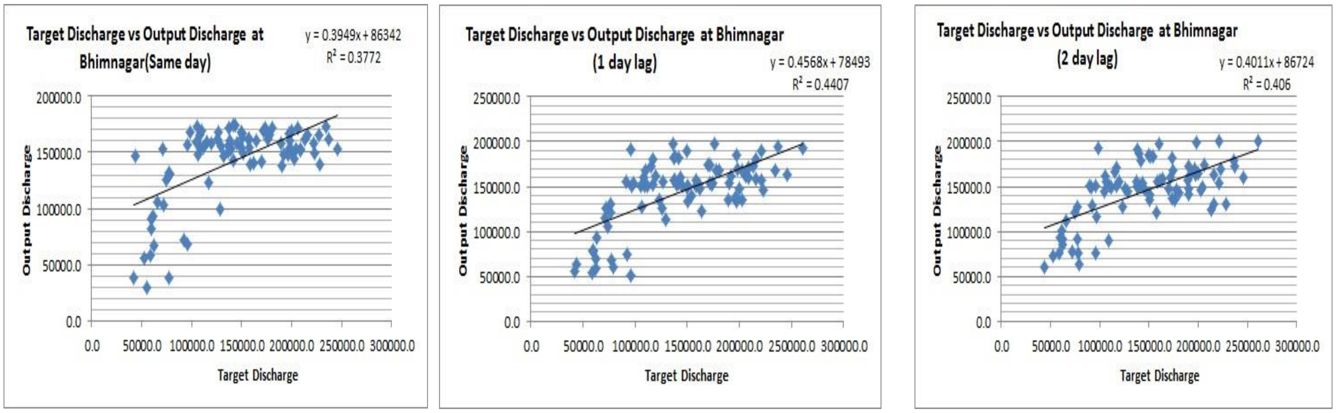

Figure 16: Rainfall-Runoff co-relation at Bhimnagar in the year of 2010 for combination of same day, 1 day lag and 2 days lag using ANN using discharge at upstream as well as rainfall is input

b) 2011 :

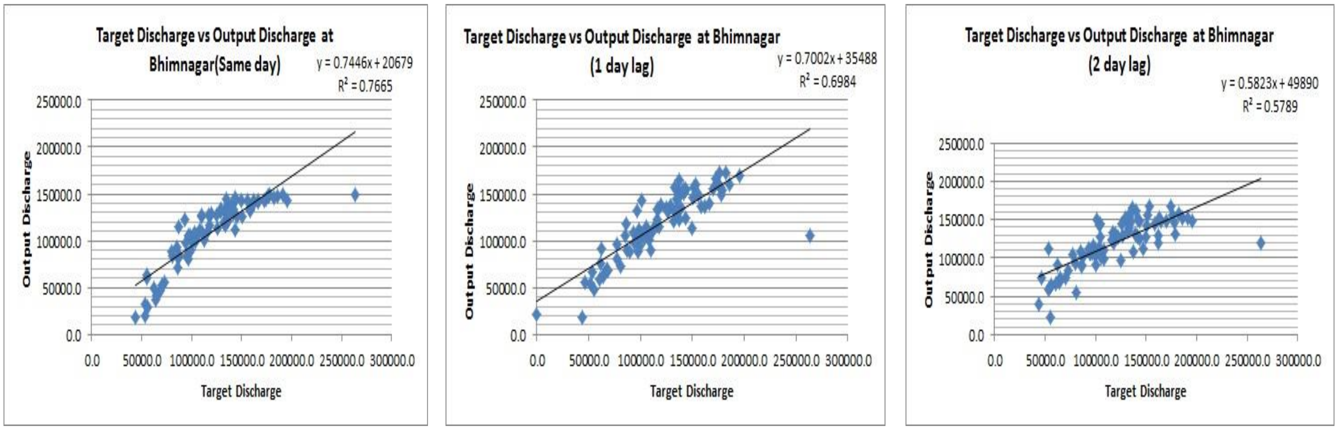

Figure 17: Rainfall-Runoff co-relation at Bhimnagar in the year of 2011 for combination of same day, 1 day lag and 2 days lag using ANN using discharge at upstream as well as rainfall is input

c) 2012:

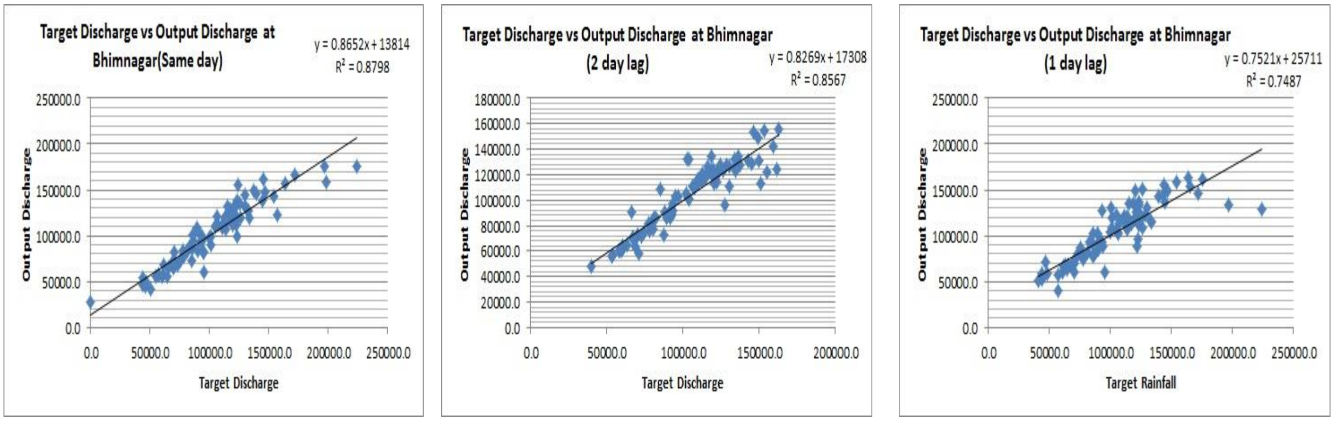

Figure 18: Rainfall-Runoff co-relation at Bhimnagar in the year of 2010 for combination of same day, 1 day lag and 2 days lag using ANN using discharge at upstream as well as rainfall is input

The results in this section are even better as more information is provided and hence this combination is most suitable for forecasting the level of discharge at any point.

5.2 Inundation Analysis:

Set 1: Inundation Map Area Digitized:

a) 2010:

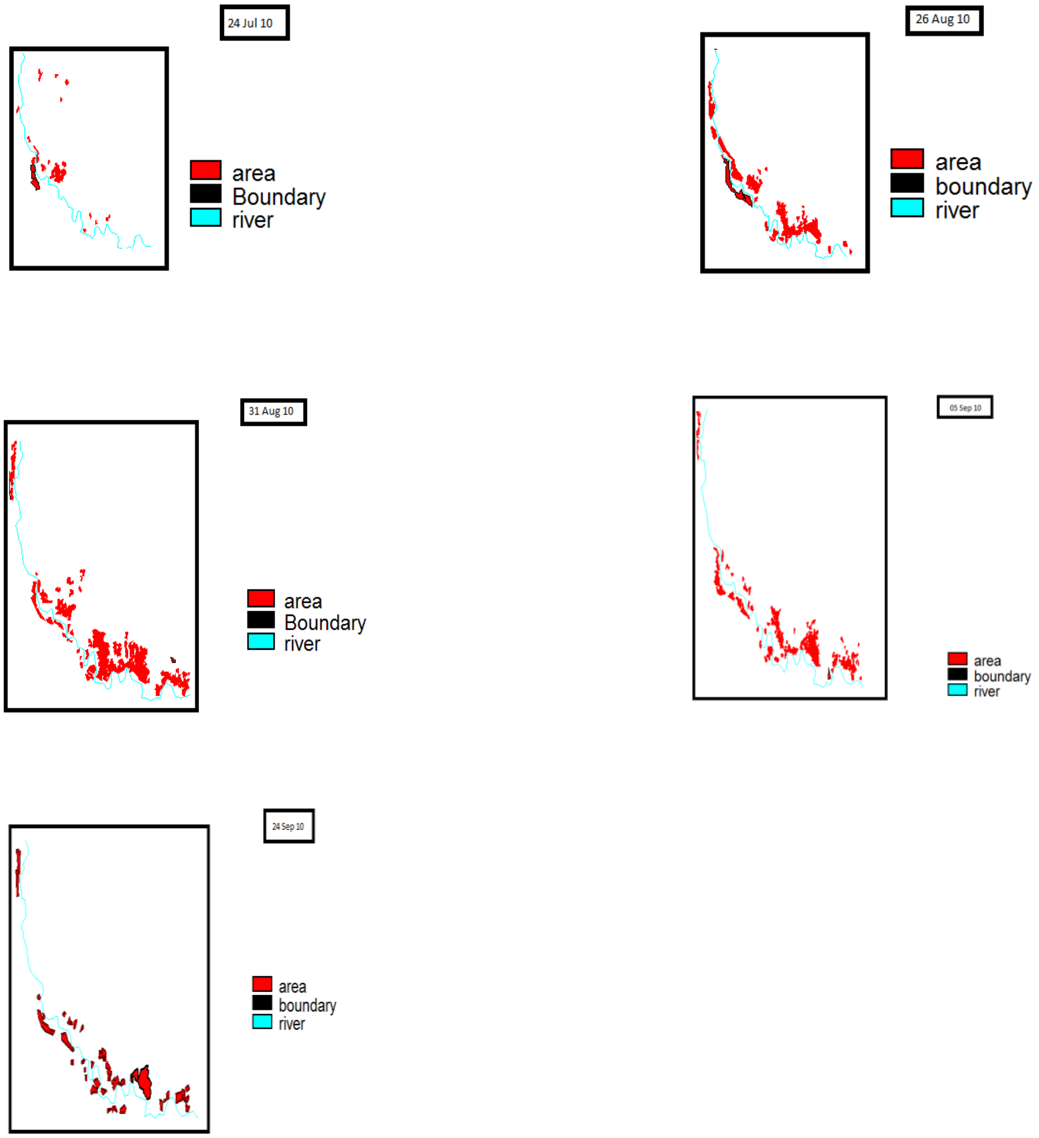

Figure 19: Inundated area drawn by ILWIS for the year 2010 for different dates.

b) 2011

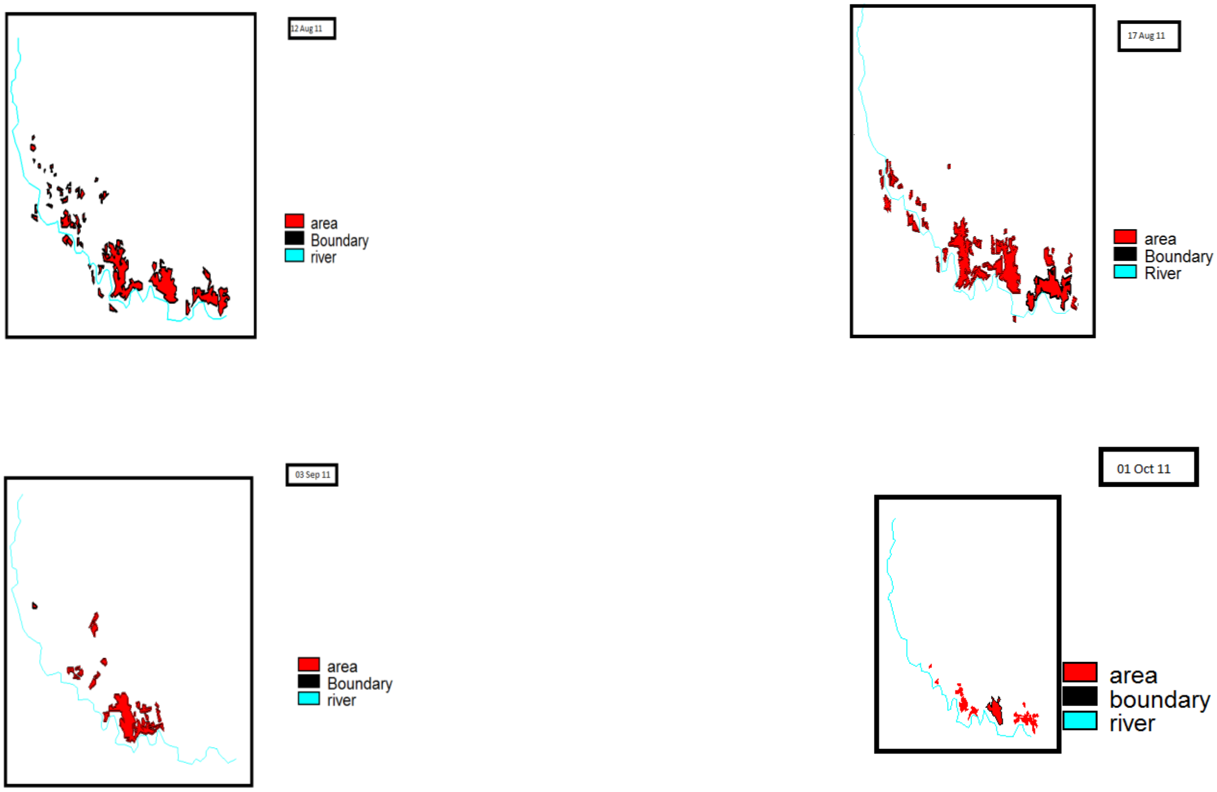

Figure 20: Inundated area drawn by ILWIS for the year 2011 for different dates.

c) 2012

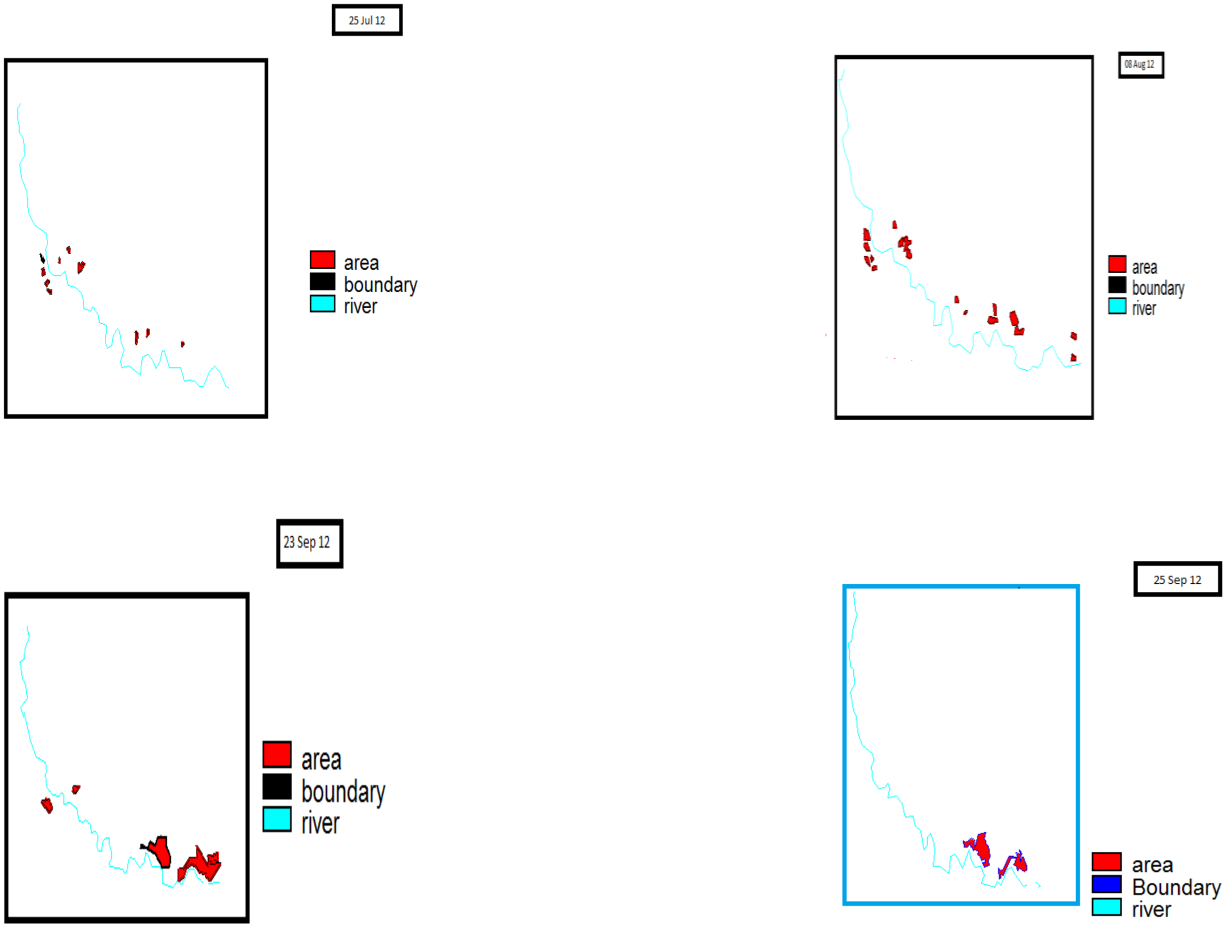

Figure 21: Inundated area drawn by ILWIS for the year 2012 for different dates.

In the above maps shown, it can be seen that inundated area lies mainly in the eastern side of river which is due to the smaller streams that do not join the mainstream rather flow under gravity due human intervention, climatic change and the elevation and the inundated area on west side may be taken as the seepage through the embankment that controls the river. Moreover, some of the dates has zero inundation though there was rainfall recorded on that day which means that soil moisture is very low and hence no inundation can be produced.

SET 1: Co-relation between inundated area and parameters that is rainfall, soil moisture and water level:

a) With rainfall:

	Same Day Rainfall			One Day Lag Rainfall		
INUNDATED AREA	2010	2011	2012	2010	2011	2012
	.025	.136	.298	.013	.001	.002

Table 1: Co-relation coefficients of inundated area vs rainfall of same day and one day lag

b) With Soil moisture:

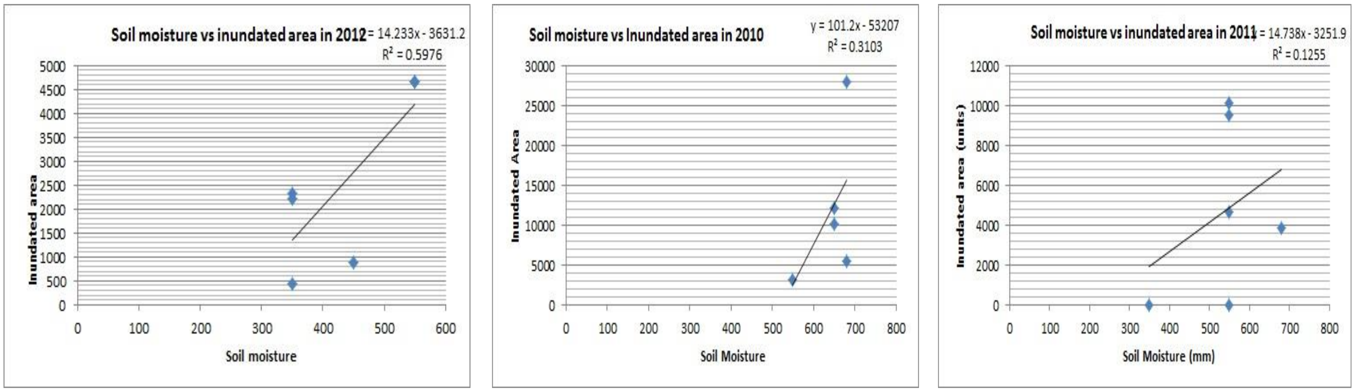

Figure 22 : Soil Moisture- Inundated area for years of 2010, 2011, 2012

c) With Water Level:

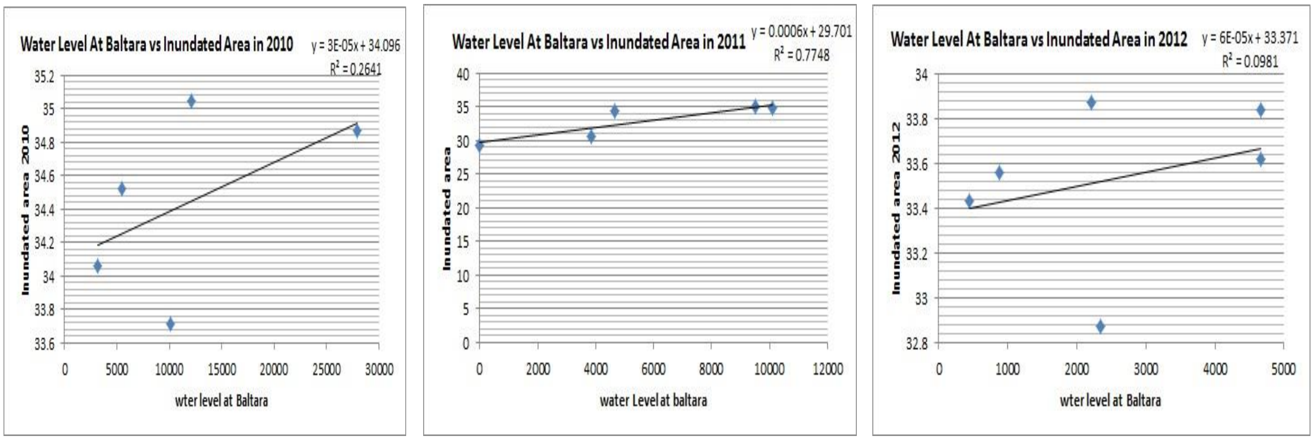

Figure 23: Water Level at Baltara- Inundated area for years of 2010,2011,2012

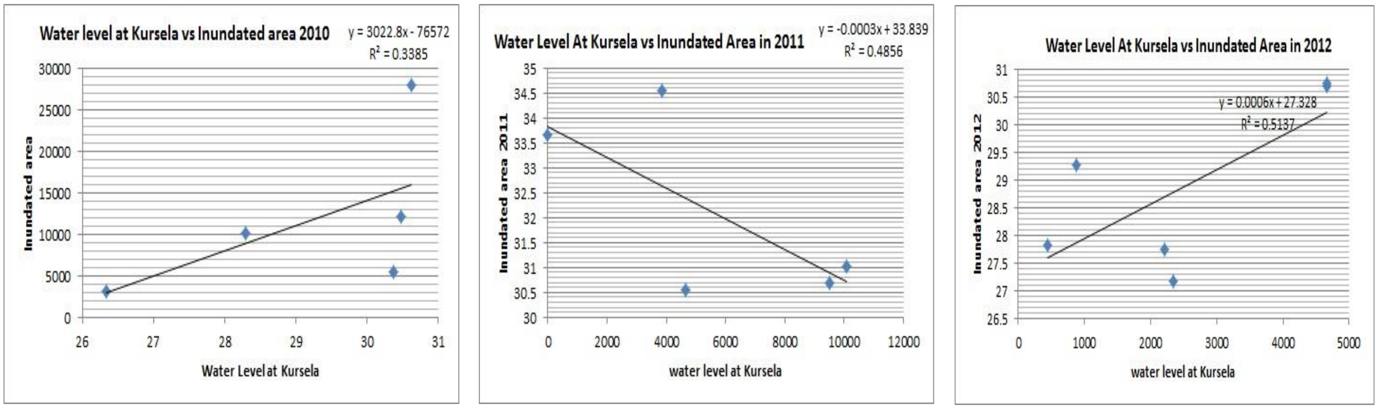

Figure 24: Water Level at Kursela- Inundated area for years of 2010, 2011, 2012

In this set of results, it is seen that there is no good co-relation of rainfall-inundated area for any of the year and it is so because it is very difficult to model the inundated area with only one parameter known and that too with rainfall which has large range of temporal and spatial variation. Further when inundated area is co-related with soil moisture it showed good results and because inundated area is almost a linear variation with soil moisture i.e the intake capacity of the soil. But this can be modified if done with ANN. The last part of the is most important as water level can be easily measured at any station. Moreover, the station chosen is in lower reach so results are satisfactory and can be directly used in the field.

CHAPTER~06

CONCLUSIONS

Following are the conclusions drawn from the study:

- Simple linear regression between rainfall and modified discharge for raw data didn't show good correlation but gets better with combination of 1 day lag and 2 day lag.
- Using ANN :

a) When rainfall was the only input, output discharge for both the discharge stations showed unsatisfactory co-relation with target discharge.

b) When discharge at Barahkshetra was the input, the co-relation was fairly good. Best co-relation co-efficient for different year:

In 2010, it was for 1 day lag: 0.82

In 2011, it was for same day: 0.88

In 2012, it was for same day: 0.87

c) When discharge at Barahkshetra as well as rainfall was input, co-relation co-efficient was fairly good. Best co-relation co-efficient for various year under considerations:

In 2010, it was for 1 day lag: 0.44

In 2011, it was for same day: 0.76

In 2012, same day: .87

- Co-relation between inundated areas was not good with rainfall and soil moisture as it was done through least square method but with water level at Kursela and Baltara, it got better.

In 2010, with water level at Kursela: 0.34

In 2011, with water level at Baltara: 0.78

In 2012 with water level at Kursela: 0.51

CHAPTER~07

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