Development of a SWAT Model to Investigate the Impact of Hydroclimate and Land Uses on Water Quantity and Quality in the 'Mathavanga' River, Bangladesh.

By

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EXECUTIVE SUMMARY

To determine the nitrogen load and surface-overflow runoff of the chosen watershed region, a project on the ‘Mathavanga’ River was investigated. We utilized ArcGIS and ArcSWAT modeling software to obtain information on the nitrogen load and current and projected surface-overflow load for the project's chosen watershed region. ArcGIS-ArcSWAT was used to process the spatial and temporal data. MS Excel was used to compare actual data with simulated data from software and display graphs. By altering the curve number, manual calibration was carried out. Data from the 2021 observed surface flood and the 2051 predicted surface overflow were compared in a comparison graphic. For the year 2021, we implemented a vegetative strip as a natural way to lower nitrogen burden. In August, the busiest month for farming, we were able to lower nitrogen load by roughly 15% thanks to the vegetative filter strip. The projection of future surface overflow data also indicated that, after 30 years, there will be a considerable reduction in surface overflow load.

Part A

Project Concept and Description

1.1 Project Introduction

According to information gathered from long-term ecosystem monitoring and research stations located all around the world, changes in climate, such as precipitation and temperature, can have a major impact on the quantity and quality of surface waters. During storms, snowmelt, hot weather spells, or droughts, water quality can deteriorate. It may result in water quality issues that the ecosystem is unable to cope. The elements governing water quality in an ecosystem are vulnerable to climate change. The Earth's temperature is rising daily as a result of the greenhouse effect. The typical climate situation is changing globally as a result of this, and ongoing climate stress will increase the frequency with which ecosystem thresholds will be surpassed. Water bodies will suffer as a result of this.Even now, we have a living example of this. Around the world, droughts are extending and getting worse. The intensification of tropical storms is caused by the increase in ocean water temperature. Chemical, physical, and biological components in watersheds are altered by changes in land use. As a result, the quality of nearby surface waters changes. The impression of water-quality changes arising from climatic changes can be complicated by human-caused changes such as the usage of chemical fertilizers, pesticides, and waste disposal, which can both ameliorate and exacerbate climate change. We require a tool to predict future scenarios and develop a solution to lessen the detrimental effects of climate change and land usage in order to examine these implications water body We developed a hydrology and water quality model to precisely predict potential future scenarios.

In our project following objectives were achieved taking Mathavanga River in Chuadanga district as our study area:

1) Developing a hydrologic and water quality model to investigate the effect of climate change and land uses on water quantity and water quality (nitrogen load) in a waterbody.

2) Designing a nature-based solution (NbS) to reduce nitrogen load from the watersheds.

We need to know the amount of surface overflow data and chemical yields in order to estimate the future effects of climate change and land development on water bodies.SWAT is the most recent program to utilize for these activities in order to obtain data on chemical yields and surface overflow. SWAT is used in this research to forecast and assess the agricultural chemical production, in this case, nitrogen. Data on surface overflow for the present and the future was also acquired. Then, using the vegetative strip as a supply, we developed a natural solution.Then, using the vegetative strip as a supply, we developed a natural solution. Nature-based solutions (NBS) are defined as "activities to protect, sustainably manage, and restore natural or modified ecosystems that solve societal concerns effectively and adaptively, giving benefits to human well-being and biodiversity at the same time" (IUCN, International Union for Conservation of Nature, 2016).

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1.2 Literature review

Mathavanga River is a Bangladesh-India transboundary river. The river flows through Kushtia, Meherpur and Chuadanga districts of Bangladesh. This river is 121 km long, 29 m wide and 10 m deep near Darshan. The area of the river basin is 500 square kilometers. Generally, the surrounding area does not overflow the banks of this river. The river is free from tidal influence. Mathabhanga river identification number given by Bangladesh Water Development Board or 'Paubo' is river no. 76 in southwestern region. Mathabhanga is the second largest branch of Padma, the main river of Chuadanga district.Mathabhanga was the main branch of Padma from birth.About 400 years ago when the Ganges flowed through the Bhagirathi, the riverbed became filled with sand and the headwaters carried the headwaters.the Ganges from Jalangi town in Murshidabad district of West Bengal. In the past, this place was the origin of river Navganga. Navagangariver emerges as a tributary of Ganga and flows southward to Kumari village in Alamdanga. The river Kumara flows through Alamdanga, Shailkupa, Sreepur, Madhukhali, Boilmari, Maksudpur, Bhanga, Tekerhat, Rajoir and flows into the ocean estuary near Madaripur on its south-easterly course. Later, the river Kaliganga originating from Talbaria in Kushtia takes the course of the river Kumar and cuts it somewhere and proceeds towards the sea. Near Karimganj there was a canal connecting Nabanga with Bhairabriver called Jalangirkhal or khari. Navganga River flows north of Chuadanga towards

Jhenaidah, Magura region. Rennell's map shows that the Jalangiriver, a tributary of the Navaganga, flows in a south-westerly direction, cutting off the Bhairav river and falling into the Bhagirathi river. When the mouth of Navganga is filled with silt, the mouth of Hauli, the connecting canal between Navganga and Bhairav, is closed once to keep the Kumara running. When this mouth is breached by a flood, the head-broken river originates.Border River Mathavanga enters Chilmari Union of DaulatpurUpazila of Kushtia and proceeds south along the India-Bangladesh border for about 15 km. After entering Bangladesh near Kazipur, it crossed about 70 km and met Bhairav. After 25 kilometers, the Mathabhangariver entered India. At the entrance to Bangladesh, it receives water from a water table called Matmura in Gangniupazila on the right side and receives the flow of Hisna and JhanJha rivers near Khalishakunti. Open throughout the year. Ganga River is connected to this groundwater table. Mathavangariver also receives rain water in some areas of Gangniupazila in its course. During the monsoons, the Mathavanga River receives flood water from the Ganges River. But the entire flow of this river goes to India downstream of Darshan throughout the year. Mathabhangariver was connected with Kajala river by canal called Steward canal. It has a loop cut south of Khalishakundi. RaisaBeel Canal falls from Kurlgachi Union of DamurhudaUpazila on its right bank before Darshan. Damodar Bill canal of Madana Union area of the same upazila has come downstream in DarshanareBhati. DamurhudaUpazila has a river called Dari on its southern border which is connected to Damodar Bill. Chuadanga and Darshan have water level measuring stations of the Mathabhanga River. In our project, we used SWAT to come up with the nature-based solution which is the provision of a vegetative filter strip. Hydrologic and water quality modeling using SWAT was done to reach this solution with accuracy.SWAT is used to evaluate the impact of future climate change on the hydrology and water resources of the Upper Blue Nile River Basin (UBNRB). The inputs of weather data were selected by screening using two well-known downscaling models which are SDSM and LARS-WG. These inputs were screened from large scale output from one GCM or several GCM.The impacts of scenarios are simulated for future time periods, 2051 and compared with model results for the 2021 baseline period. The SWAT model is calibrated and validated on streamflow observed at Darsana and Hatboalia during the baseline period. Model performance is evaluated using standard performance parameters. All these statistical quantities indicate a good adjustment of the modeled to the observed streamflow for both the calibration and validation period. The results of the future simulations of flow and other hydrological processes in the UBNRB, using SWAT reveal that, relative to the 20th- century baseline period, the Blue Nile River streamflow declines in both the 2051 decade. These reductions range between 10% and 50%, depending mainly due to higher temperatures and lower precipitation, as predicted by the GCM's climate models.

1.3 Standards and codes of practices

To do this project, we follow some Standards and codes of practices. We develop a model with Arc-SWAT and have some statically parameter which is the coefficient of determination(R^2). We find the value of $R^2$to develop the model.Calibration procedure involved the adjustment of the SWAT parameters manually or by using SWAT-CUP so that the resulting stream flows matched the observed inflows. The validation process assesses whether the model has been properly settled, using one or more periods different of the calibration period. We also Calibrate and Validate by the SWAT Model.

1.4 Stakeholders' expectations/requirements

Farmers, the government and agricultural policymakers are stakeholders. Owing to filter stripping fishermen's health should not be impacted by this project and other benefits include improved water quality, a healthy aquatic environmental and human health protection.

1.5 Project Requirements

The stream flow seen at Darsana and Hatboalia during the baseline period is used to calibrate and validate the SWAT model. We need few things in order to complete this project. The SWAT model cannot be run without this condition. Minimum Nash-Sutcliffe Efficiency (NSE) values of 0.65 and 0.55 should be reached for the model calibration and validation, respectively. Important weather information including rainfall (mm), maximum and minimum temperatures (oC), wind speed (km/h), relative humidity (%), and solar radiation (cal/cm2) must be incorporated into the model. The model must take into account the impact of several land uses, including urban, agricultural, water, forest, and pasture. Soil types, land use, and slope classes should all be included into the Hydrologic Response Unit (HRU). At least 30 years should pass before the water quantity and quality are projected. In the busiest agricultural month the vegetative filter strip ought to be able to reduce nitrogen load by more than 15%. Additionally, the vegetative filter strip shall keep the nitrogen load within Bangladesh Standard's standard limit for inland discharge.

1.6 Project Management

Project management is the process of carrying out certain project goals in accordance with predefined parameters by using procedures, techniques, abilities, knowledge, and experience. Project management final deliverables are subject to time and budget constraint.In our project, we used the ArcSWAT model to examine how agricultural practices affect the health of the watershed as a whole in specific regions along the MathavangaRiver. We needed a lot of data to finish the project, which we had to purchase from various expensive web platforms. Additionally, we finished the project on schedule.

1.6.1 Project plan

The discipline of project planning focuses on how to complete a project within a predetermined timeframe, often with predetermined stages and resources. When the project will be finished are all addressed in the project plan, also referred to as the project management plan. It includes more than just tasks and due dates on a Gantt chart. The primary role of a project plan is to organize and control the project's execution and control phases. The following documents make up a project plan, as was already mentioned:

Project Charter: Provides a general outline of the project. It addresses a wide range of subjects, such as the project's goals, objectives, and stakeholders.

Statement of Work: This document outlines the project's goals, objectives, deliverables, milestones, and tasks.

Work Breakdown Structure: This structure breaks down the project scope into the work packages, deliverables, phases, and subprojects that will produce your ultimate deliverable.

Project Plan: The project plan document contains different sections for the scope management, quality management, risk assessment, resource management, stakeholder management, schedule management, and change management plans.

1.6.2 Risk management

Project risk management is the process of identifying, evaluating, and responding to any risks that may arise throughout the course of the project in order to keep it on track and fulfill its goals. In order to identify potential risks to the project and decide how to manage them should they materialize, risk management shouldn't only be an afterthought; it should also be a part of the planning process.Soil erosion is one of the largest problems with land degradation and the main environmental issue in Mediterranean regions. Estimating soil erosion loss in these places is frequently difficult due to the intricate interplay of multiple components, including climate, land uses, geography, and human activities. The Soil and Water Assessment Tool (SWAT) model is used in this study to predict the patterns of surface runoff generation and the hazards associated with soil erosion. The goal is to identify the most degraded sub-catchments in order to implement the necessary management intervention.

1.6.3 Required resources and budget

In our project we work with the Arc SWAT application to calibrating and validating. To run this application, we need some resources. We collect some discharge data from Water Development Board. When we apply to get the discharge data we are paying the water development board. This is the resources and budget of our project.

1.7 Impacts of the project

The study was aimed at improving the SWAT water quantity and quality models by incorporating the impacts of surface depression and employing a wet-dry calibration scheme. Surface depressions are important topographic features that influence overland flow formation and runoff processes, and hence basin response. SWAT's wetland feature was used to integrate the detected depressions into sub basins.Climate change has had marked impacts on natural systems, including water and land. This paper attempts to predict the monthly variation of nutrient load from the year 2016-2050 using a SWAT model to investigate the impact of climate change. The main climate consequences related to water resources are the increase in temperature, change in precipitation pattern, reduction in water availability and an increase in flooding. Bangladesh is home to some of the poorest people in the world, 130 million of whom earn less than $1 per day. The effects of climate change will only make the population's current issues worse. As primary contributors for the Intergovernmental Panel on Climate Change, Bangladeshi scientists have performed critical roles.

Current Climate:

Bangladesh experiences a hot, humid environment. The monsoon has the greatest influence on its climate, with pre- and post-monsoon circulations having a minor impact. The warm, humid, and unstable air carried by the south-west monsoon originates over the Indian Ocean. There is some inter-annual fluctuation in the monsoon's start and finish dates, which are typically the first week of June and the first week of October, respectively. In addition to the monsoon, the easterly trade winds are active and provide warm, comparatively dry circulation. There are four distinct seasons in Bangladesh: pre-monsoon (March to May), monsoon (June to early-October), and post-monsoon (late-October to November). The following are the seasons' basic characteristics:

• The winter months are generally colder and drier, with an average temperature that ranges from 7.2 to 12.8 C to 23.9 to 31.1 C. In the north, the lowest temperature can occasionally drop below 5degree Celsius, but frost is relatively uncommon. In winter, there is a temperature gradient from south to north. The southern districts are typically 5degree Celsius warmer than the northern districts in terms of temperature.

• From March to June, the pre-monsoon is hot with an average maximum temperature of 36.7 °C, mostly in the west for up to 10 days, a very high rate of evaporation, and irregular but occasionally severe rainfall. Occasionally, the temperature in some regions will soar to 40.6 °C or more. In April, at the start of the pre-monsoon season, the highest temperatures are recorded. With the warmer zone in the southwest and the colder zone in the northeast during the pre-monsoon season, the mean temperature gradient is directed in this way.

•The monsoon season produces intense torrential rain that is both hot and humid. The monsoon season sees around four fifths of the average yearly rainfall. In comparison to the eastern districts, the mean monsoon temperatures are greater in the western districts. Although there are occasionally colder days during and after intense downpours, the season is normally warm.

• The post-monsoon is a brief season marked by a cessation of rain and a steady drop in the minimum nighttime temperature.

Land use on Stream Water quality:

One of the main reasons for the decline in water quality is the changing land use and land cover in rapidly urbanizing areas. A precise understanding of the relationships between land use and water quality, however, remains elusive due to the heterogeneity of urban land use patterns and spatial scale effects. At regional and even global scales, human activities have significantly impacted the physical and chemical characteristics of water quality as well as the stability of aquatic ecosystems. Rapidly urbanizing areas are where human activity is most concentrated and land use is changing drastically, making them, unsurprisingly, the most typical areas for water quality degradation. Understanding and predicting how changes in land use and land cover will impact water quality at various spatial scales is one method. During the process of urbanization, the gathered population and industries have huge impacts on the original natural vegetation, soil environment, and aquatic ecosystem. The significant changes in regional land use and land cover caused by urbanization are mainly reflected in the increase of impermeable surfaces such as roads and squares. All these changes will directly impact the water quality.

1.7.1 Impacts on society

Climate change is one of the major challenges of our time and adds considerable stress to human society and the environment. Increases in air temperature, alterations in precipitation patterns and snow cover, and perhaps an increase in the frequency of flooding and droughts are the most significant changes in the climate system connected to water resources.Climate change also induces land use changes, i.e., autonomous or planned adaptation, resulting in in-direct impacts on land use and water quality. Relationships between socio-economic conditions, climate change, agricultural production, water resources, and diffuse water pollution are highly complex and require an integrated approach to assess their overall, sectoral, and dissipated impacts. Using impact modelling to investigate these interactions produces divergent conclusions and multiple uncertainties, expressing the need for a spatially distributed approach to any large-scale modelling.

Effects of Land Use Patterns on Stream Water Quality:

Climate change and land use can hugely affect society. Chaco Canyon is situated almost 150 miles to the north-east of Albuquerque, New Mexico. In 2015, the thousand-year flood event in South Carolina, USA happened. The same thing can happen if farmers start using chemical fertilizer instead of organic fertilizer without any treatment plan. It can lead to excessive nitrogen load in waterbodies, which can hamper one's health and also biodiversity.

Water Quantity and Quality Modeling:

SWAT is a process-based hydrologic model that was developed to assess the effects of land use and management on water, sediments, and pollutants in agricultural basins. Impounded water in SWAT can be replicated in a variety of ways, including ponds, marshes, depressions/potholes, and reservoirs, each with its own set of characteristics. The Hydrologic Response Unit (HRU) is the fundamental modeling unit, and it is a homogenous mix of land use, topography, and soil properties.

1.7.2 Effects on environment and sustainability

Water is the foundation of climate models and the medium for fertilizer and pollution movement. Habitats and waterbodies are important human activity sinks. Sustainable development requires establishing a balance between the permissible consequences of certain land uses and the water reliance of other land uses. A conceptual framework is offered to assist in addressing the issues associated with establishing such an equilibrium. The TILIS research will not be limited to Europe; such an approach can be used to other areas. Water's involvement in the formation of negative feedback should be clearly included into a broader framework of human interaction with land and water.When, if, and how riparian vegetation protects water quality is not always obvious. Other research has concluded that the terrain has little or no significance. Climate change is real, and we understand what is causing it and how to avoid it, but we must not lose sight of other, more serious environmental sustainability issues. In response to climate change, sustainability should not be an overarching plan that influences people's activities and duties. Even minor climatic changes are expected to have significant and catastrophic implications that will almost surely touch every part of the globe.

1.7.3 Health and safety issues

All the identified aspects in the baseline studies of the area may be related to some health and safety-related risks for the population and personnel, and impacts are expected. Impacts could be:

- Indirect emissions, increased acoustic background, climate change, water and soil pollution, as a possible direct relationship with the maintenance of environmental (ambient air, soil, and water) quality criteria, for which mitigation strategies are provided in relevant parts of this study.

Social risks are also expected to have an impact on the health and safety of people, as referred to in

- Physical relocation of homes may make it impossible to provide essential services and related amenities to everyone affected by the project, such as appropriate water supply systems, health facilities, power, and other fundamental services.
- Potential rise in accidents and injuries, including deaths, throughout the building and operational stages for a variety of causes, including road crossings and traffic movements, physical work, manual handling, escape routes and doors, electrical failures and uncontrolled flames, chemicals, toxic and combustible materials, bad air conditions, insufficient welfare facilities, and others.
- People will flock to the host site as a result of enhanced access to social amenities such as employment possibilities, notably in the civil works sector; local artists; tourism; agriculture, fishing, trading, and other fixed and seasonal vocations; and improved service delivery.

- Potential rise of waterborne illnesses such as cholera, bilharzia, blackfly, and malaria due to poor water quality or water pollution from construction and sewage sludge; solid waste production from rubbish created by construction workers.
- Sexual behavior changes that result in the spread and/or escalation of sexually transmitted illnesses and unintended pregnancies.
- Apart from waterborne infections, dust, atmospheric gaseous emissions, and air pollution that may occur when creating trenches by the operation of vehicles during the transfer of building materials and equipment, the operation of water treatment plants, exhausts from trucks and construction machinery, and human contact may cause the spread of other infectious diseases such as TB and respiratory ailments.
- Other illnesses and occupational and safety issues may emerge or worsen as a result of staff movement during the building and operation stages, as well as the agglomeration of people in settlement areas. For example, noise and vibration from heavy machinery, heavy trucks, soil stripping, trenching, pipe stringing, welding, and backfilling operations may cause a rise in acoustic and heart attack concerns. Limited building operations may have to continue 24 hours a day, increasing employees' and community members' exposure to noise.
- The mobility of snails increases the possibility of the introduction of new illnesses such as schistosomiasis.

PART-B

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2.1.1 SWAT Model Description SWAT is a long-term water quality simulation model that forecasts how management actions in watersheds affect water, sediment, and agricultural chemicals. The model is specifically tied to a particular watershed. SWAT splits a watershed into sub basins connected by a stream network and further delineates HRUs within each sub basin that consist of unique mixes of land cover and soils. The model assumes no interaction between HRUs. And these HRUs are practically all across each sub basin. HRU delineation reduces simulation computing costs by combining related soil and land use regions into a single unit. SWAT can model surface and subsurface flow, sediment formation and deposit, nutrient destiny, and landscape movement.As a physically-based distribution model that use easily available inputs and allows users to investigate long-term effects. SWAT requires a variety of information to enable its application, including topography, soil, land use, weather, and so on.

2.1.2 Digital Elevation Model:

A Digital Elevation Model, also known as a DEM, is a type of raster GIS layer. DEMs are frequently used for computations, adjustments, and additional study of a region, particularly analysis based on the elevation. We have collected our DEM from NASA Earth data search then created a mosaic DEM for our further works.

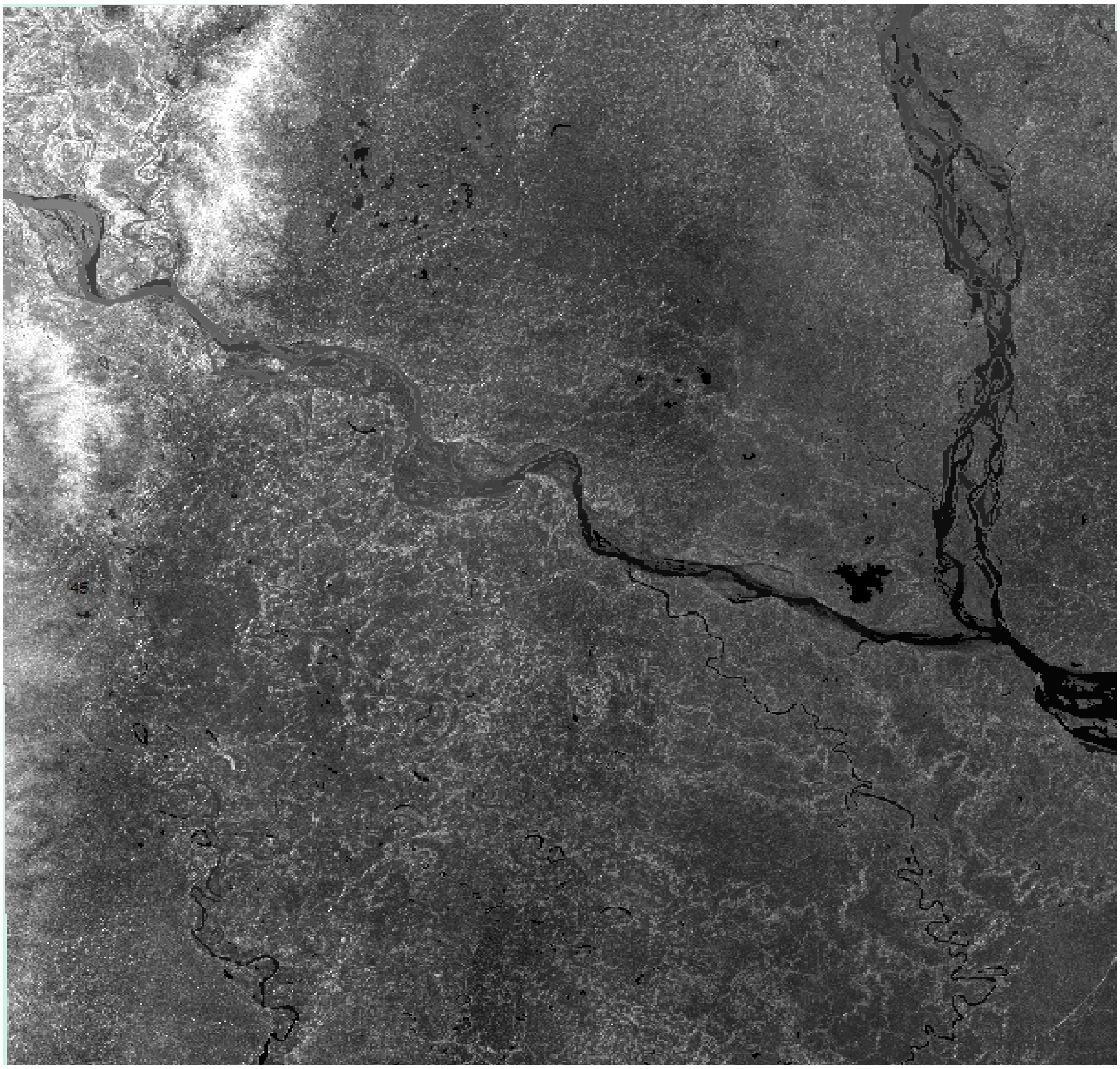

Figure: Projected DEM

2.1.3 Watershed Delineation:

Watershed delineation is a process for creating a boundary surrounding a water body or runoff outlet that represents the contributing area for a specific control point or water outlet in order to analyze the portions of the study area. The projected DEM was input for watershed delineation in the ArcSWAT. After DEM setup flow direction and accumulation with stream network of outlet was done. Manually selected the latitude and longitude of our river stations and manually selected the sub basin outlet and point source input. The sub-basin was delineated by selecting the watershed outlets. In this study, the Mathavanga river watershed was divided into 3 sub basin and number of outlets are also 3. As shown in figure each sub basin's respective area covered, length, reach, width, depth, etc. were estimated by calculating the sub-basin parameters.

Legends:

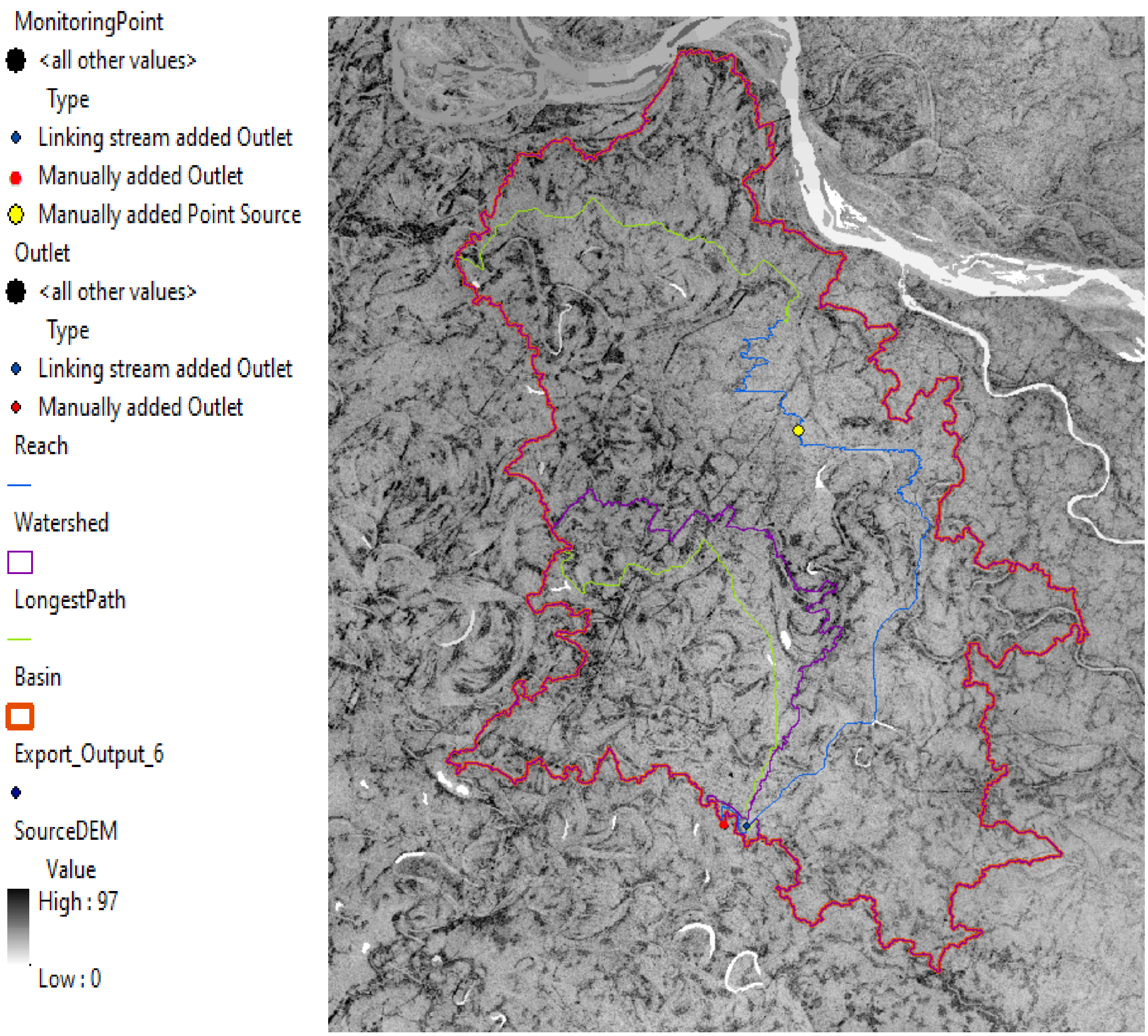

Figure: Watershed Delineation

2.1.4 Land use/Soil/Slope:

- Land use – Land use basically refers the economic and cultural activities (e.g., agricultural, residential, industrial, mining, and recreational uses) which are practiced at a given place. It represents the use of land by the human. Human activities are related with the land use. In this swat land use area, the highest part is agricultural land-row crops (AGRR) and second highest part is agricultural land-generic (AGRL). Third part is belonging to urban area which is very low.

Legends for
land use classes

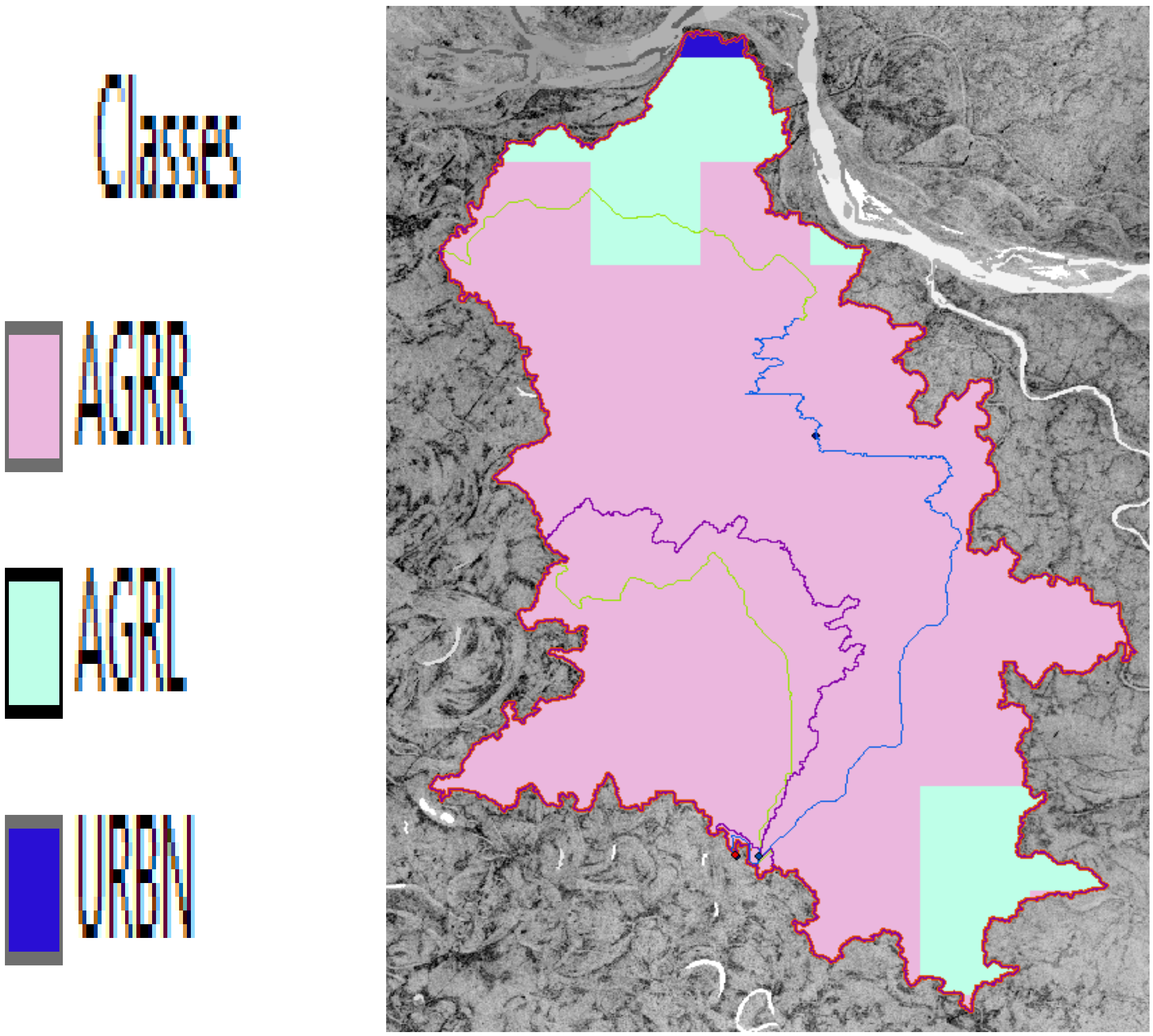

Figure: SWAT land use classes

- Soil – This soil was basically obtained as a layer file and converted to raster format after giving input for defining the soil cover and it was reclassified based on user-defined FAO soil type (SWAT- Soil). We found many layer with the color.

Legends

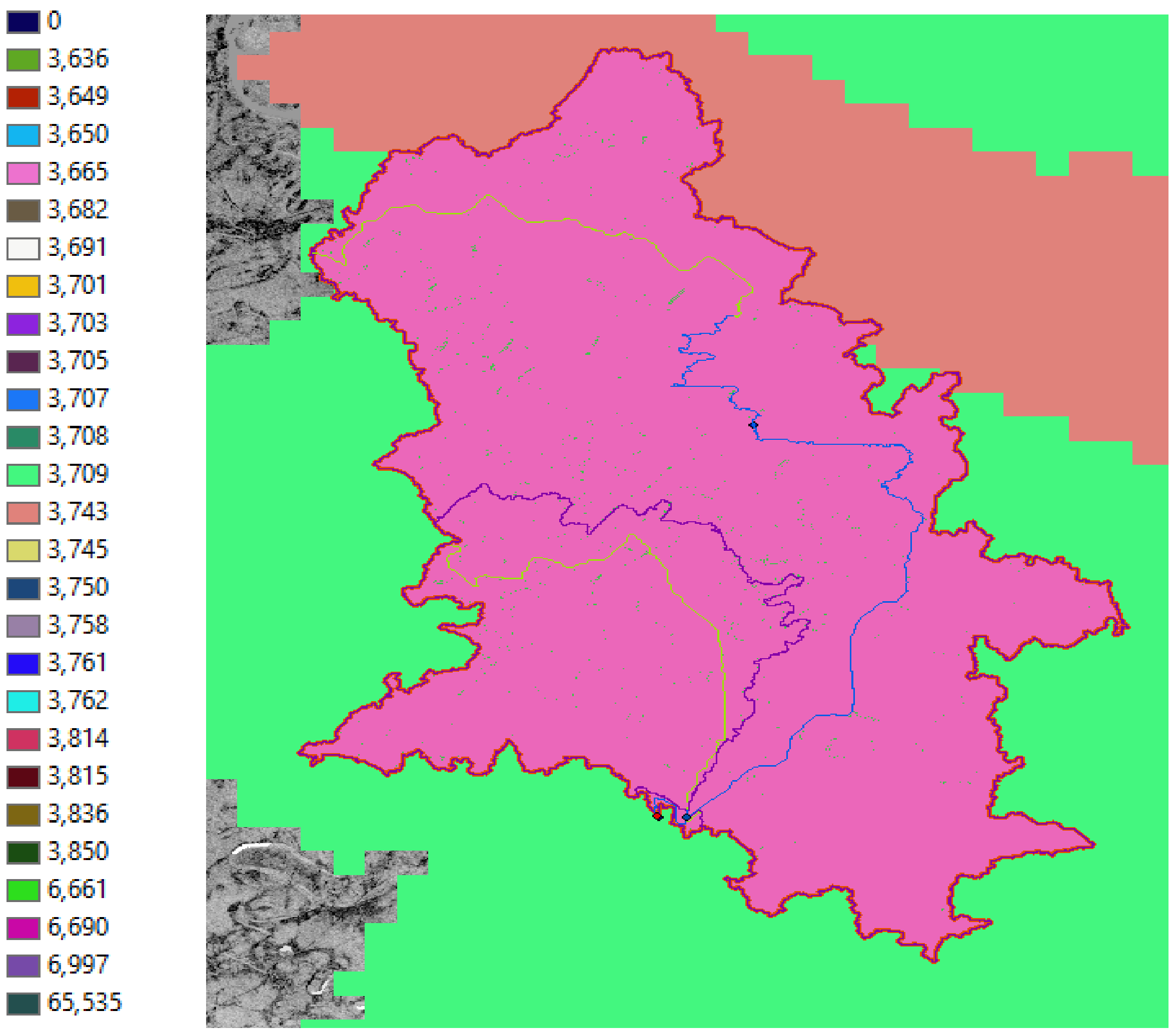

Figure: SWAT Soil

- Slope – To determine the water, nutrients and sediments movements slope measurement is very important. We have the two range for our slop layer which are 0-15 percent (lower limit) and another one is 15-9999 percent (upper limit). Most parts are covered with upper limit for our area.

Legends

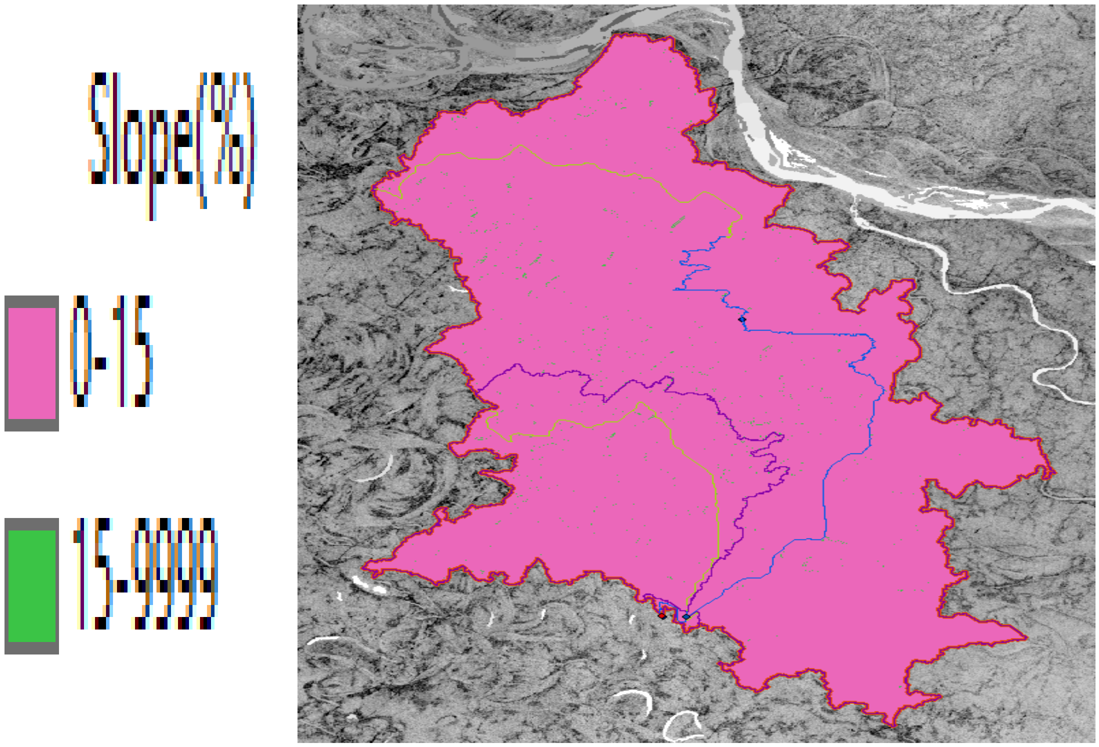

Figure:SWAT slope classes

2.1.5 HRU Analysis

Hydrological response unit (HRU) is the combination of land use, soil, and slope characteristics. The input parameters were overlaid to create the HRU feature. Here need to input the land use grid, soil grid and slope data. The outcome of importing the database provides a report in which each HRU is grouped based on the existing land use pattern and soil type.Despite the fact that modified discretization and routing beyond normal HRU routing through sub basin networks are easily available in the SWAT model framework, few research has investigated them. Other gridded hydrologic models exist, but few include the comprehensive management, plant development, and water quality algorithms that are inherent in SWAT.

2.1.6 Weather Database:

The Arc SWAT weather database imports meteorological information including rainfall (mm), maximum and lowest temperatures (oC), wind speed (km/hr), relative humidity (%), and solar radiation (cal/cm2) from the CFSR globe database which is very important. The software examined these values in accordance with the research area's corresponding latitude, longitude, and elevation, andthe input files were written automatically.

1.8 Analysis of alternate solutions

2.2.1 Model Calibration

Model calibration is a crucial step in the initial testing procedure. In general, calibration and validation are performed to make sure the parameters are being utilized to portray the research area. Using the observed data, the model was calibrated for assessing the curve number and precipitation. Calibration was carried out to improve the model's efficacy and accuracy as well as to get good coefficient values, which will improve the model's performance. For the model to transition from the predicted beginning condition to an ideal state, a warm-up time of one year was maintained. For five years (from 2016 to 2020), calibration was done on a daily time step to find the best value by adjusting the curve number. High surface is represented by a higher curve number.

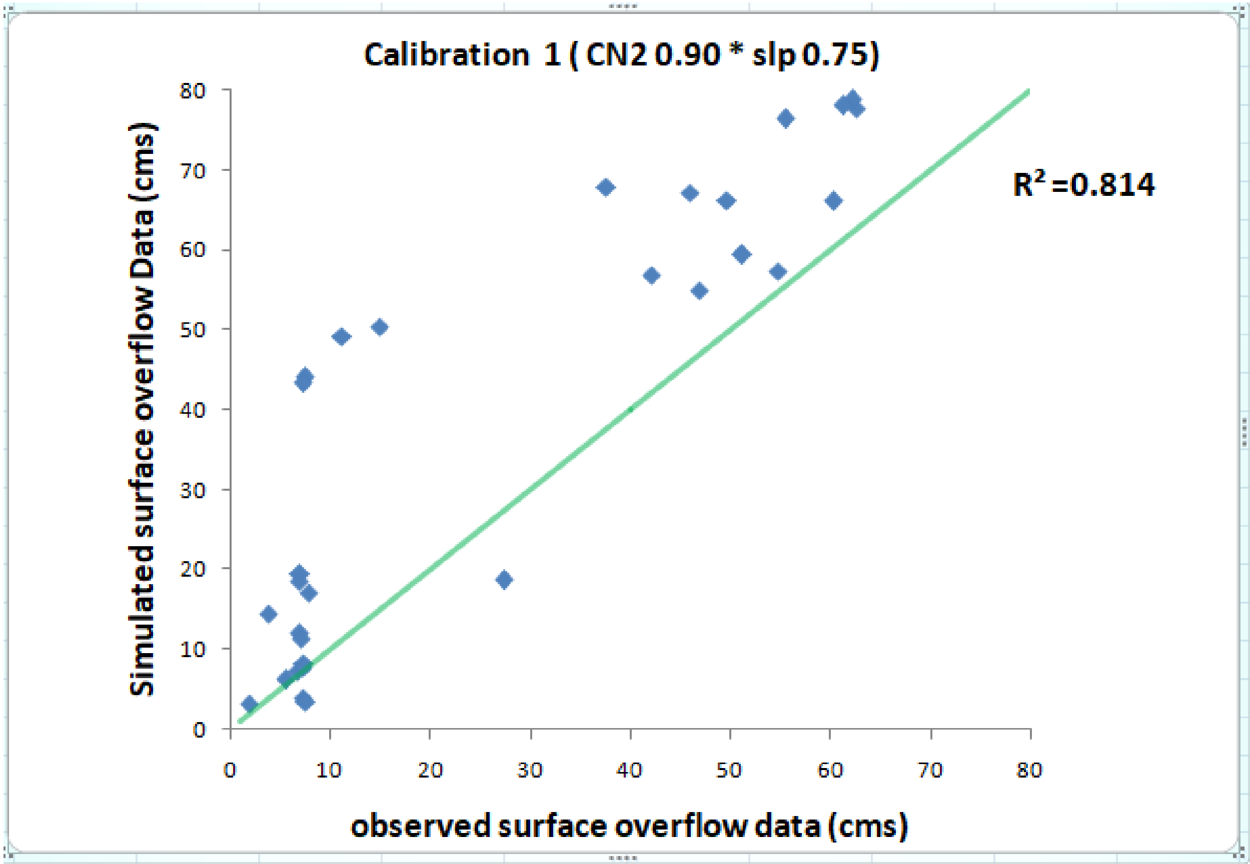

Figure 1: Scatter plot of simulated and observed flow out during the calibration period for CN 0.90 and slope 0.75

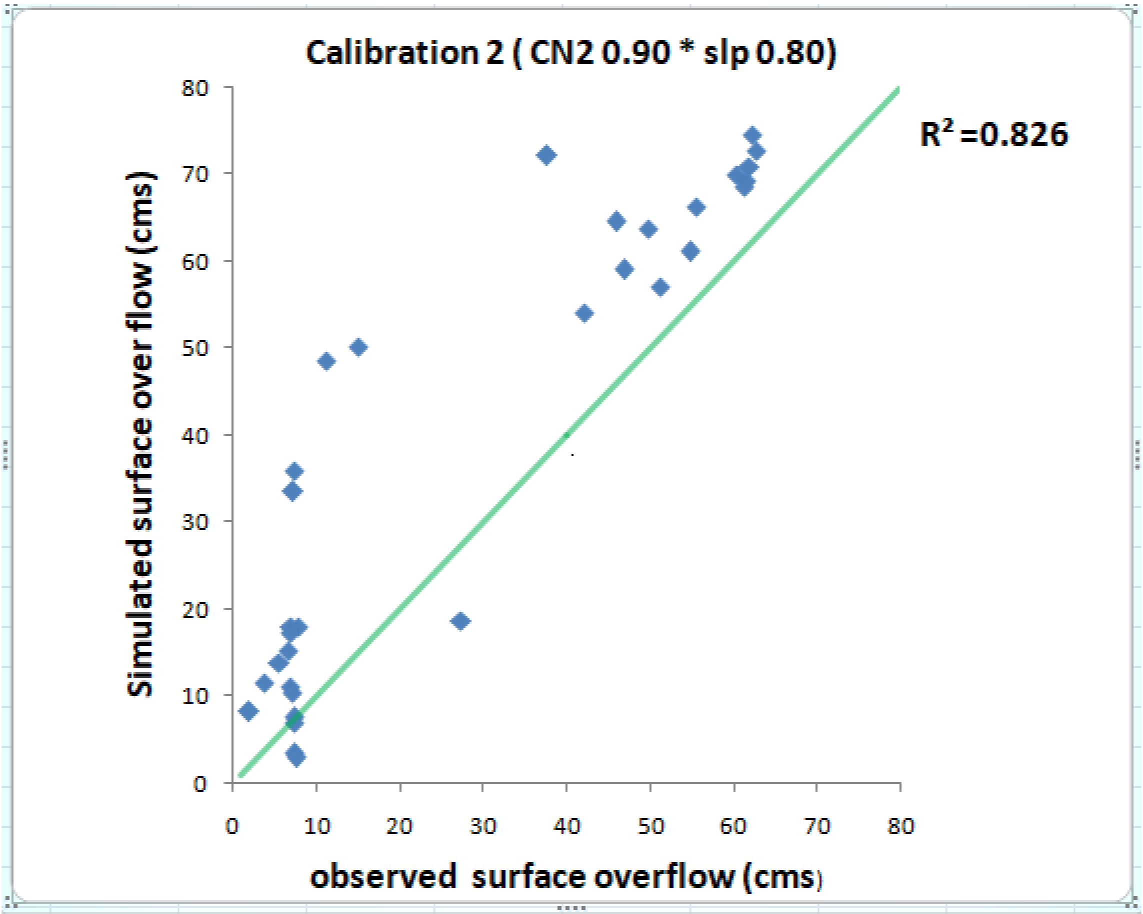

Figure 2: Scatter plot of simulated and observed flow out during the calibration period for CN 0.90 and slope 0.80

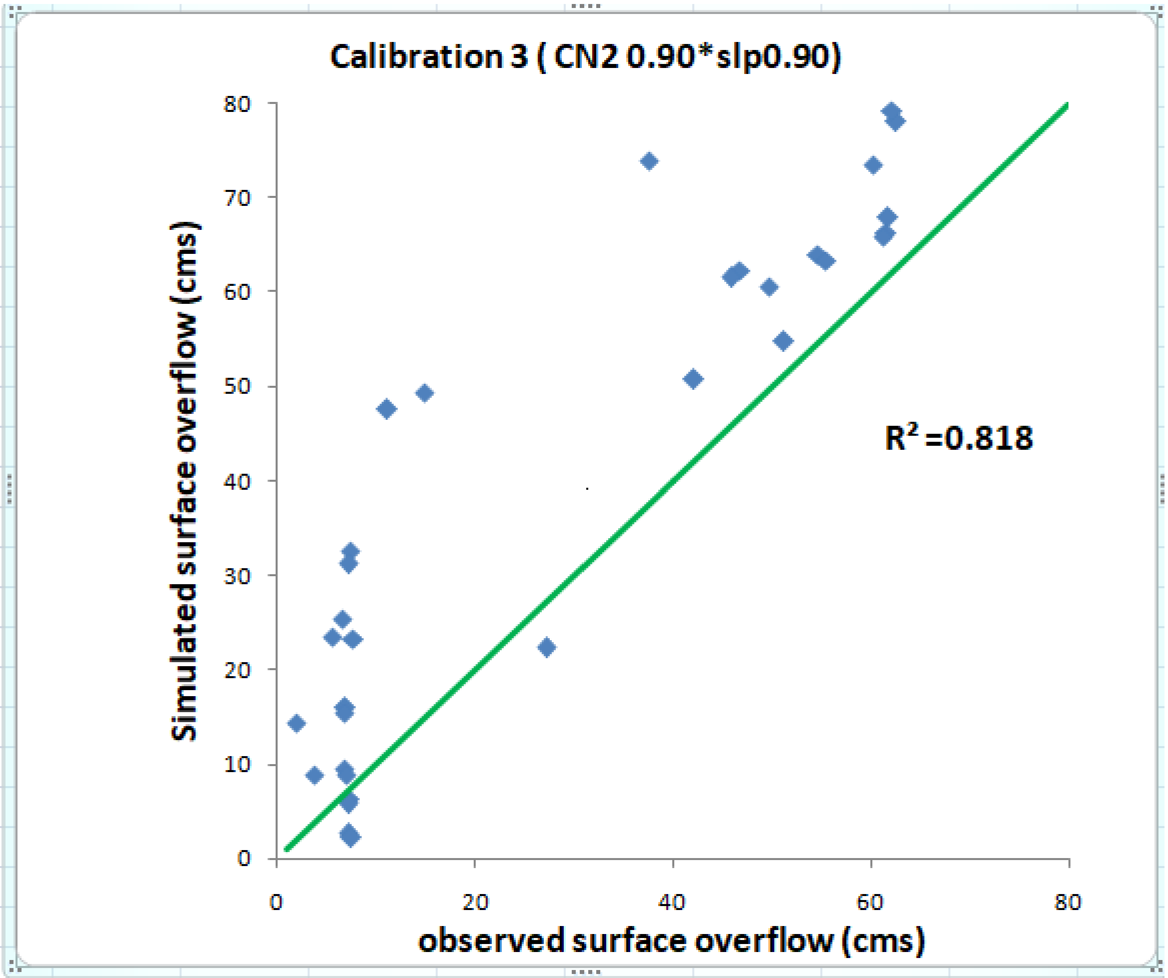

Figure 3: Scatter plot of simulated and observed flow out during the calibration period for CN 0.90 and slope 0.90

The model runs with different curve numbers and slope. Among them three simulation values give the required R^2. The best value that has been chosen is for current number 0.90 and slope 0.80 which gives the $R^2 = 0.826$. The R^2 value suggests that there was a good agreement between observed and simulated flow during this period. After the calibration of the flow, the SWAT model captured the hydrologic characteristic in the study area well and reproduced acceptable daily flow simulation.

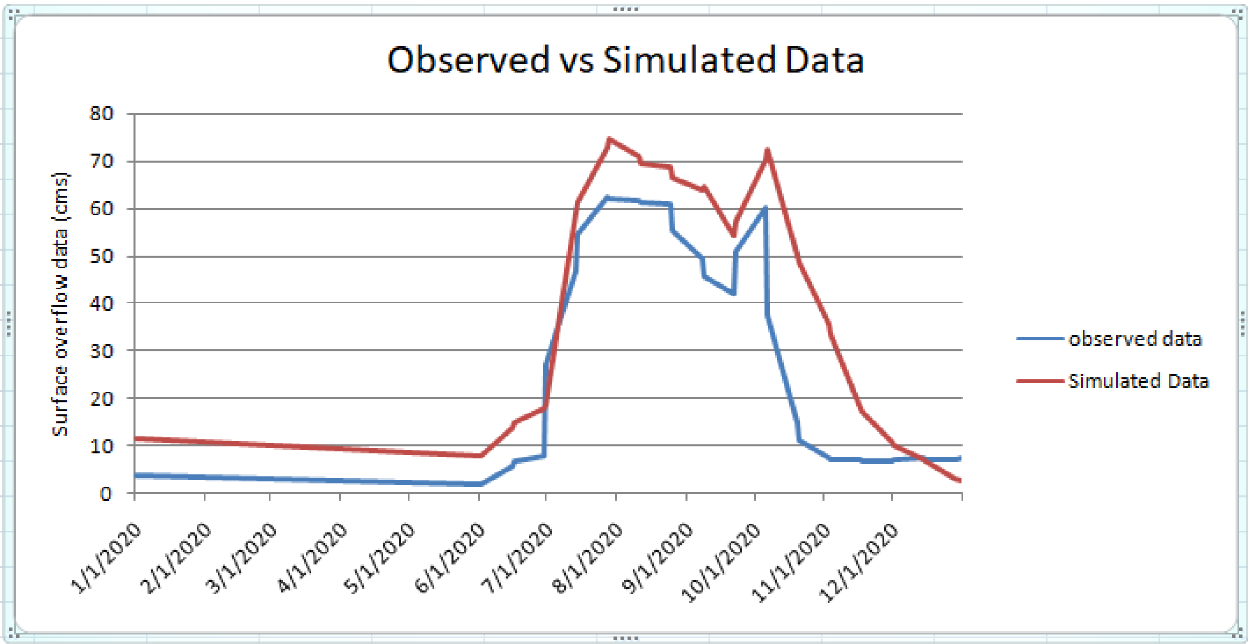

Figure: Final calibration result both observed and simulated.

In the figure shown that maximum time Simulated surface overflow result is higher than observed surface overflow.

PART-C

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2.1 Development of the prototype

A simple functional sample, model, or simulation of the real data on which the other forms are based is referred to as a prototype. The primary goal of prototyping is to confirm the dataset's design. A prototype (Validation) is produced, tested, and then revised as necessary until a workable result is obtained from which the full system may be developed. This process is known as the prototyping model.

2.2 Performance evaluation of implemented solution against design requirements

Validation of model

After developing the model, we have to validate the model. We have found out that if the model will work properly for future date simulation.

So, for validation purposes, we compared the simulated and observed data for year 2021.

Table: Surface Overflow Data Comparison of the Year 2021

Date	Observed Data(m3 /s)	Simulated Data(m3 /s)
1/1/2021	7.51	3.175
1/11/2021	7.26	1.251
1/25/2021	7.75	1.006
1/26/2021	7.88	0.9497
2/8/2021	8.01	0.1988
2/9/2021	7.7	0.1622
2/22/2021	7.39	0.108
2/23/2021	7.1	0.1061
3/8/2021	6.8	0.05527
3/9/2021	5.79	0.06436

3/22/2021	4.77	0.01332
3/23/2021	4.54	0.01385
4/5/2021	4.31	0
4/6/2021	2.87	0
4/19/2021	1.43	0
4/20/2021	1.56	0
5/3/2021	1.68	0
5/4/2021	2.91	0.004285
5/17/2021	4.14	0
5/18/2021	4.1	0
5/31/2021	4.05	1.099
6/1/2021	4.02	0.9611
6/14/2021	3.96	2.237
6/15/2021	10.05	3.554
6/28/2021	16.11	5.008
6/29/2021	16.23	6.297
7/12/2021	16.32	5.495
7/13/2021	16.91	4.417
7/24/2021	17.49	27.17
7/25/2021	31.5	26.82
8/9/2021	45.51	52.2
8/10/2021	72.33	52.31
8/23/2021	99.15	50
8/24/2021	98.46	49.94
9/6/2021	89.76	53.19
9/7/2021	70.97	52.97
9/20/2021	52.18	53.54
9/21/2021	49.92	52.22
10/4/2021	47.65	40.89
10/5/2021	29.98	41.16

10/18/2021	12.3	22.48
10/19/2021	25.11	26.54
11/1/2021	37.92	15.43
11/2/2021	22.53	15.24
11/11/2021	7.13	13.27
11/12/2021	7	13.4
11/29/2021	6.87	4.447
11/30/2021	6.86	4.236
12/13/2021	6.85	7.307
12/14/2021	6.82	6.51
12/27/2021	6.78	2.092

Here is the comparison chart for year 2021. There are many ways to validate a model. One of the techniques is R square value. When trying to validate a model, if the R square value goes more than 0.5, then we can say that the model is validated. After plotting the data, we found out that our R square value is more than 0.5. As a result, we can say that our model is now validated.

Here is the graphical representation of the model shown below :

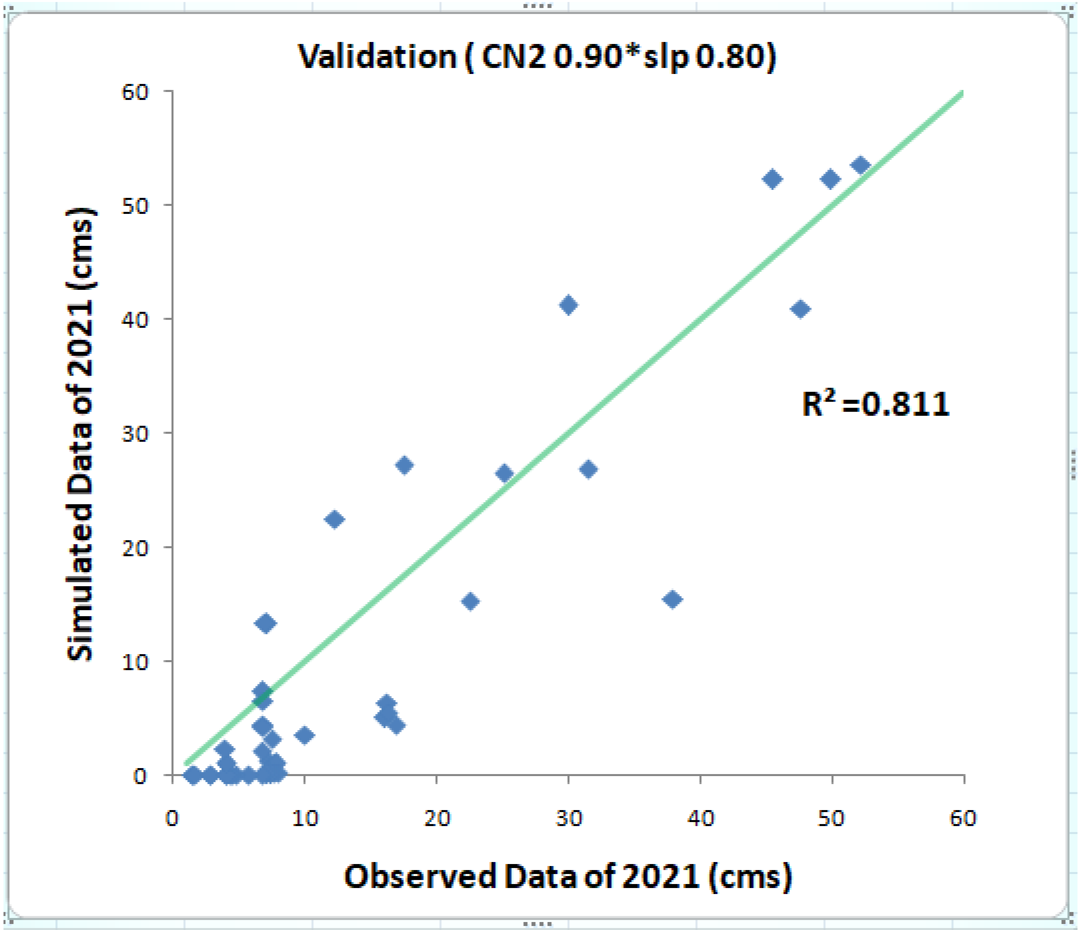


Figure 4 : Surface overflow Data comparison of year 2021

2.3 Finalization of design

The finalization of this design involved calibration analysis. We used 2021 observed vs 2021 simulated data for our calibration. As for fulfill requirement we have totally done for three times in calibration with cn 0.9 for all and slope used respectively 0.75, 0.85 and 0.90. And we got all the calibration with fulfill our requirements. After observing all the value of R^2we select more precise value. We have taken which value is near 1 and which was 0.826.

2.4 Use of modern engineering tools

A cloud-based mapping and analysis tool is ArcGIS. Use it to share and collaborate, analyze data, and create maps. Gain access to apps designed specifically for workflows, global maps and data, and field mobility tools. ArcSWAT is the most extensively utilized watershed simulation model in ARCGIS. The majority of papers are accepted in peer-reviewed journals that employ the SWAT methodology. However, it lacks information about other nations. Therefore, this model has to be configured for non-US locations basically at any place of the world.

2.5 Future flow Outcome prediction (2021-2051)

Analyzing observed surface overflow Data and total nitrogen load in 2021

Month	observed data of 2021	Total N (Kg) of 2021
January	7.58	5.62
February	7.62	0.45
March	5.72	0.07
April	2.61	0.034
May	3.36	17.48
June	7.85	1245.96
July	19.96	12497.7
August	68.53	16584.2
September	68.54	8420.7
October	29.87	4188.2
November	12.69	702.81
December	6.83	620.32

In the table , there are observed surface overflow of 12 month in 2021 and total nitrogen load of 12 month in 2021 shown .

Here is the graphical representation of observed surface overflow in 2021.

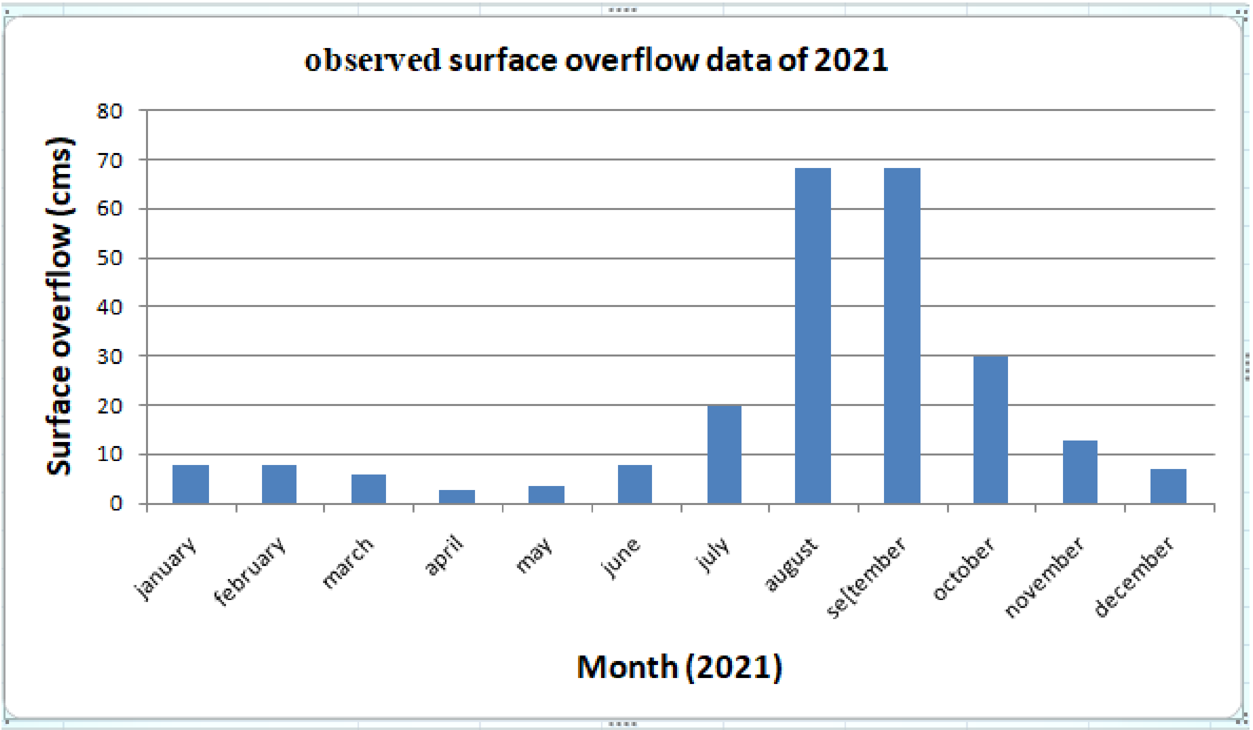
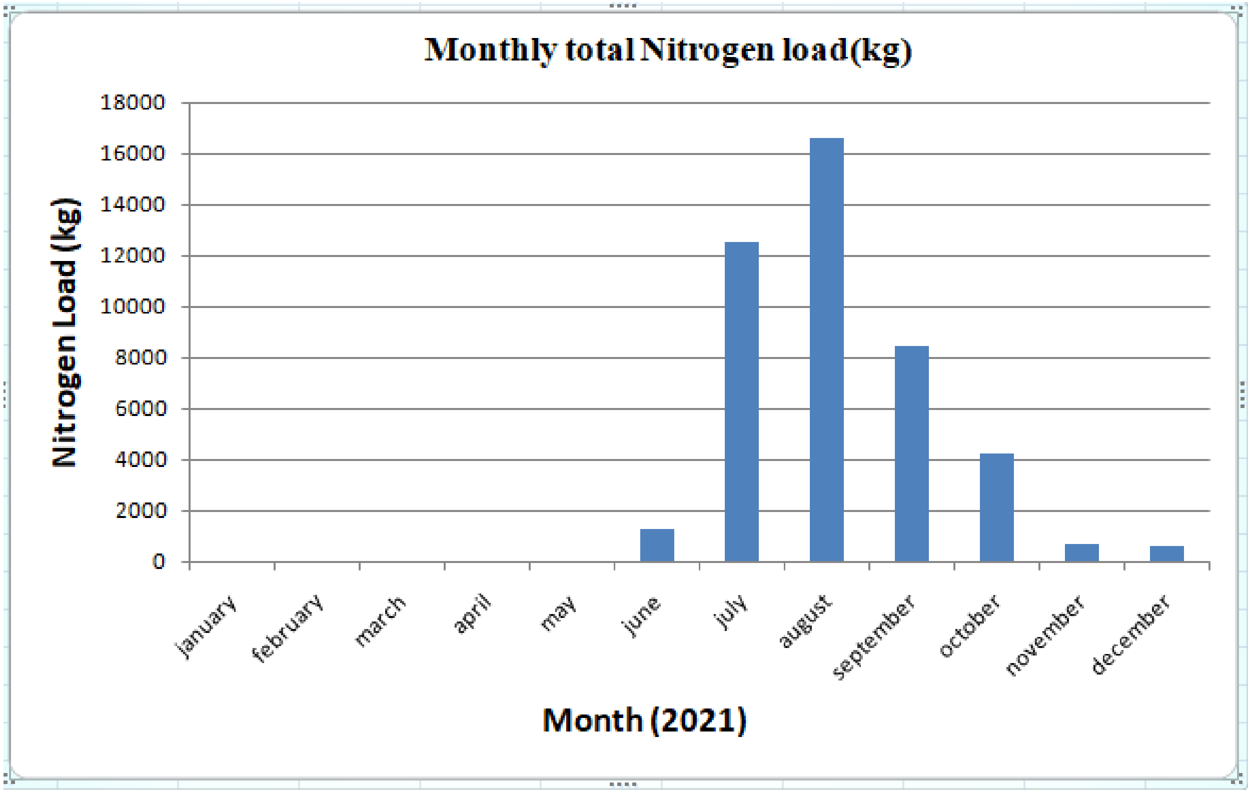


Figure : Monthly observed surface overflow data of 2021

Here is the graphical representation of total nitrogen load in 2021.



Here, observed surface overflow data is not model output. This is collected data from Bangladesh water development board. Total nitrogen load data is the output of the model . Now if we analyze the fact that when surface overflow is high, nitrogen load is also high. In the month of July, August, September and October is the time when both surface overflow and nitrogen load is high. The major reason for this scenario is because during those months there is monsoon and rainfall happens, after the precipitation nitrogen used in agricultural fields wash off and fall into rivers. That is why nitrogen load is high at that time.

Based on our model, we tried to simulate the surface overflow data for year 2010 to 2060. Then we compared the data of 2051 to the observed data for 2021. By comparing both data we get an overall overview of the changes in flow in various months. It gives us a clear picture of how the future flow outcome will change from the present scenario.

Month	observed data of 2021	Simulated data of 2051
January	7.58	0.00000754
February	7.62	0.0000111
March	5.72	0.0000254
April	2.61	8.19
May	3.36	6.98
June	7.85	5.76
July	19.96	2.5
August	68.53	10.69
September	68.54	9.81
October	29.87	13.32
November	12.69	2.57
December	6.83	0.475

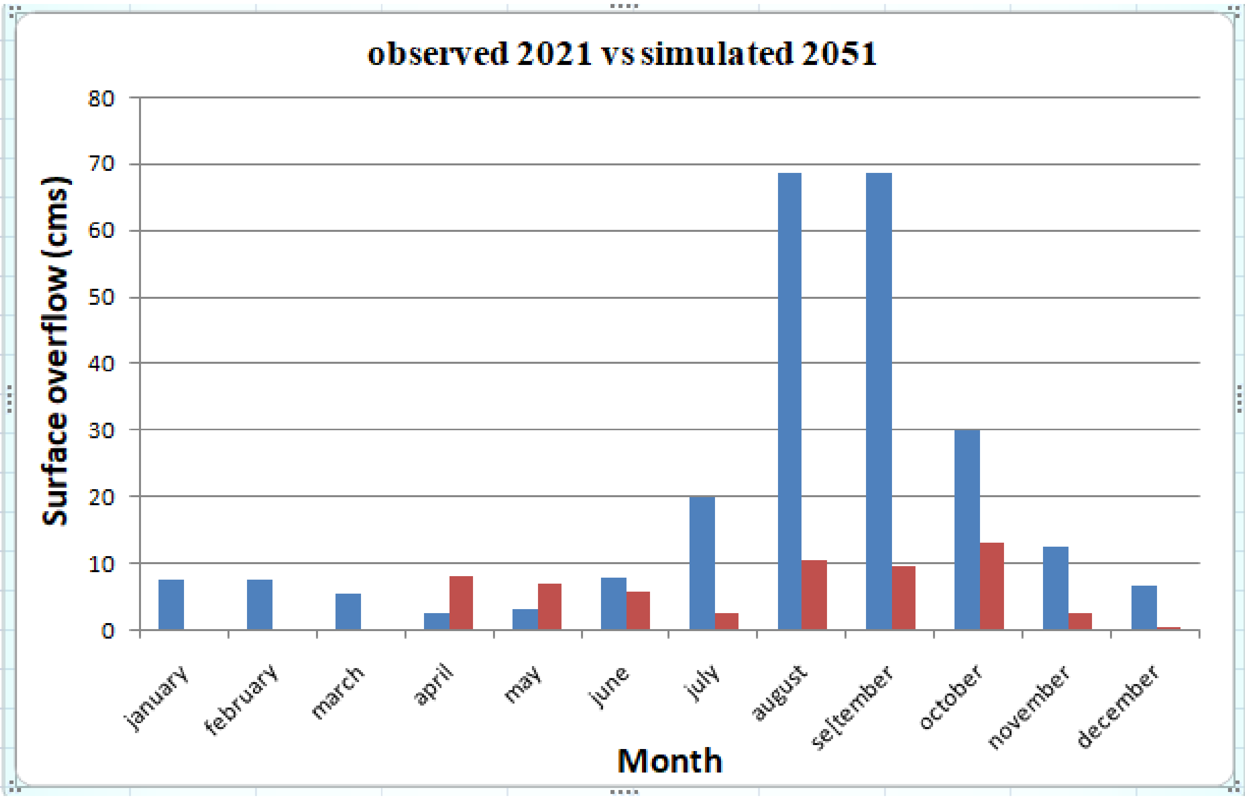


Figure : Observed Surface overflow data of 2021 vs simulated surface overflow data of 2051.

According to the figure, after 30 years the surface overflow will decrease. That may be because of climate change.

2.6 Nature Based Solution

3.6.1 Effect of Vegetative Filter Strip (VFS) for surface overflow:

Vegetative filter strips are land areas of either planted or indigenous vegetation, situated between a potential pollutant-source area and a surface-water body that receives runoff.As the water moves more slowly, some of it can seep into the soil beneath, which filters out additional contaminants. In order to limit the amount of pollutants that are lost from agricultural regions to receiving water bodies, vegetative filter strips (VFS) are a common conservation measure that are installed along the boundaries of agricultural fields. VFS also protects water bodies and lessens soil erosion in agricultural lands. By lowering the energy required to transport the sediment, vegetative filter strips create a space where contaminants can be reduced. Infiltration, adsorption, and plant nutrient absorption also contribute to the decrease of pollutants in the buffer. In this investigation, a significant range in the VFS's capacity to remove nutrients and sediments was observed.

3.6.2 Solution for nitrogen overflow:

An essential nutrient for aquatic habitats is nitrogen.Nitrogen, which may be "fixed" by lightning or supplied to soils in fertilizers, is crucial for plant development.Nitrogen gas is used to aid in food preservation by stopping the oxidative damage that causes food to decay.Nitrogen gas and carbon dioxide are used to create a man-made environment that aids in the preservation of packaged foods.

The environment becomes polluted when huge quantity of nitrogen and phosphorus come to the environment because of our activities. Over the past few decades, nutrient pollution has adversely affected numerous streams, rivers, lakes, bays, and coastal waterways, posing major risks to both human and environmental health. On the other hand, nitrogen pollution is the term used to describe the harm that excess nitrogen and nitrogen compounds like nitrous oxides, nitrogen oxide, and ammonia bring to the environment and effect animals, and human health.

Acid rain is the result of reactions between oxygen molecules and other chemicals in the atmosphere caused by the presence of sulfur dioxide and excessive nitrogen oxide compounds. Infrastructure as well as cattle, plants, aquatic plantations, and animals are all harmed by nitric acid rain.

Despite the fact that agriculture is the primary cause of nutrient pollution, communities and the country as a whole should make it a top priority to reduce its negative effects while maintaining good farming practices. We need the fertilizer production regulations and need to use animal manure fertilizers to reduce the nitrogen. On the other hand, it may be possible to find any unexpected nutrient levels by keeping a proactive routine review on the water quality.Reduced nitrogen pollution in the global environment can be substantially attributed to the use of phosphorus free fertilizers.

After Simulation we got the nitrogen load . Among them the peak value occurs in the month October. So we apply the vfs ratio 20% in October month and then nitrogen value is reduced to 15.17% which satisfies the required margin.

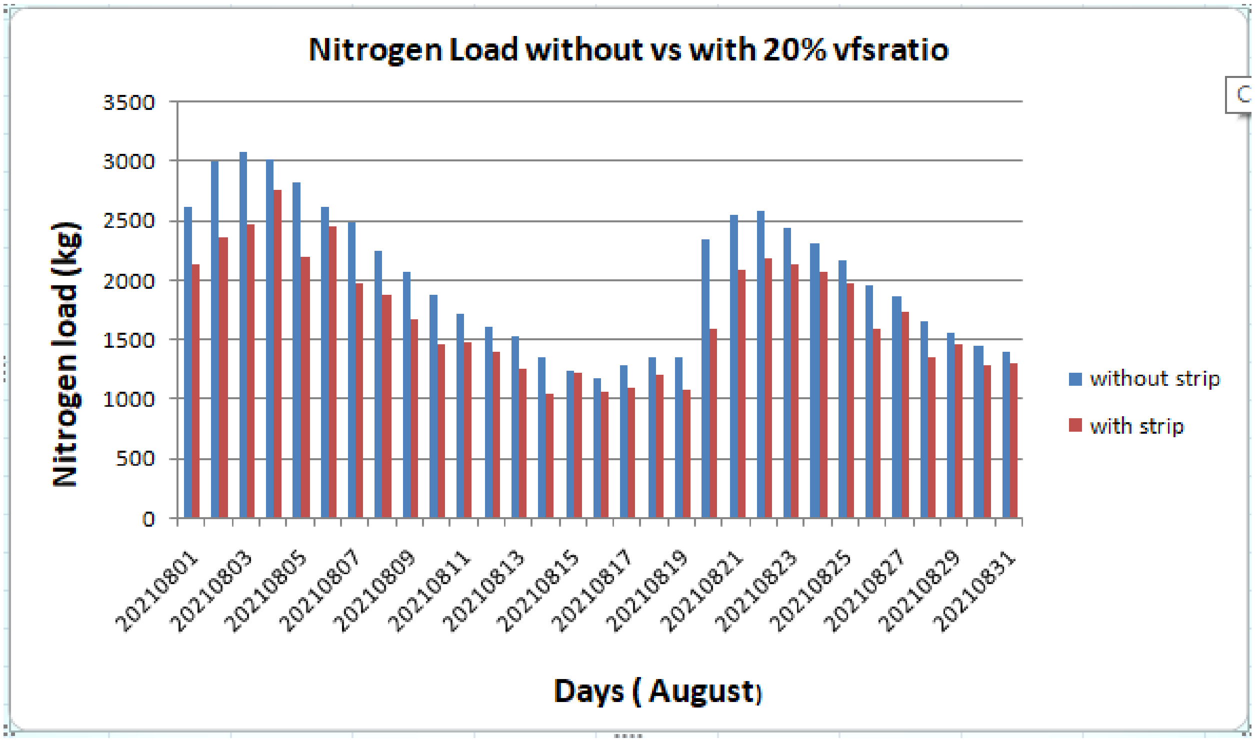


Figure : October month nitrogen load without vs with 20% vfs ratio.

Through our simulation and analysis we have found out that using vegetative stripe can reduce the overflow of nitrogen by almost 15%.

Here is the comparison data chart of 2020 simulated nitrogen load data before applying vegetative filter strip against 2020 simulated nitrogen load data after applying vegetative filter strip:

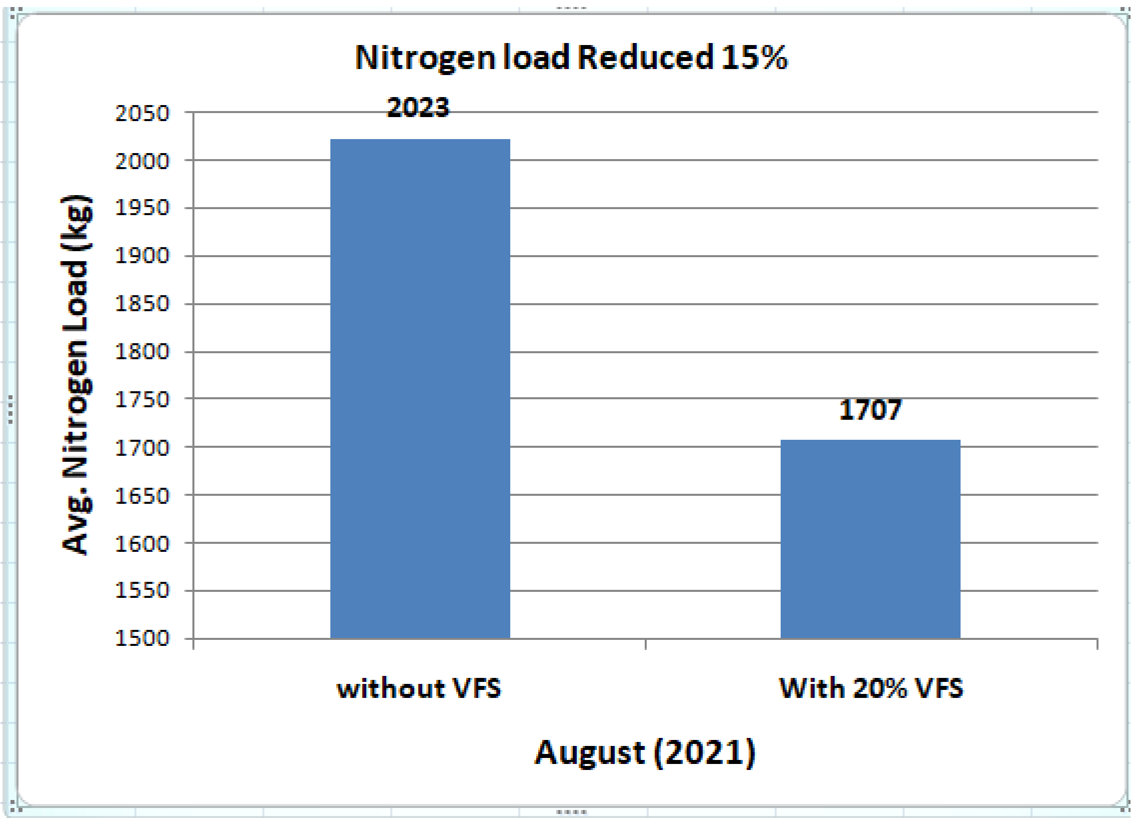


Figure: nitrogen load reducing 15% after using vfs .

Why vegetated Filter Strip is being used:

The term "vegetated filter strip" refers to a surface that is evenly graded with vegetation and collects runoff from nearby impermeable areas. It is also referred to as "filter strip," "grass buffer strip," or "grass filter."

I. Effect the nutrients and other contaminates.
II. Effects on biodiversity.
III. Reduces ditch-bank erosions and control sedimentation
IV. Low maintenance cost for this
V. Imitative natural hydrology
VI. Protection for the ecosystem
VII. Small filter strips may be used in urban area

Figure: Vegetative Filter Strips

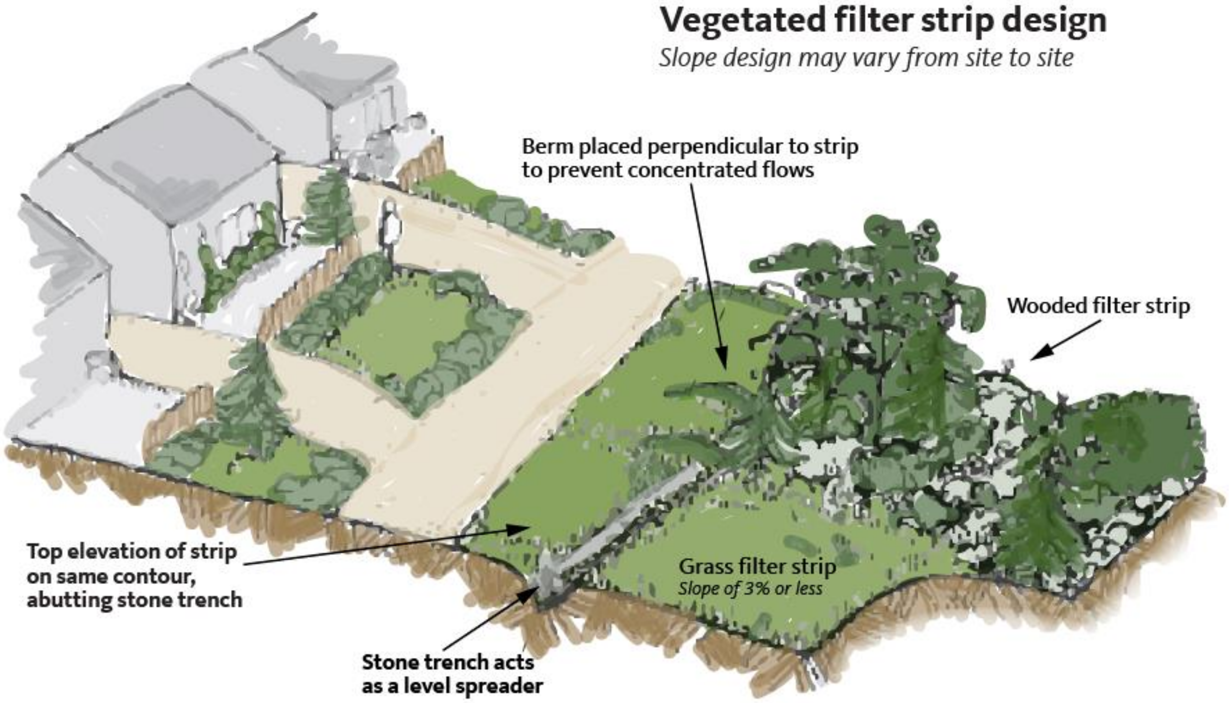


Figure: Vegetative Filter Strips

Review of Milestone Achievements and Revision of Schedule

We arranged meeting with our faculty member and with our thesis mate. As we used ArcGIS and ArcSWAT Software for our hydraulic modeling purpose we cannot use the software without depth knowledge about it and our supervisor helped for this. We bought some data from WDB and analysis the data. For this projects our requirements were for calibration the value need to 0.65 and validation 0.55. And we respectively archived all the requirements. Another requirement was to reduce nitrogen at least 15% and we achieved it also. For nature based solution we used VFSRATIO 20 and we reduced 15% of nitrogen.

4.1 Bill of materials cost of solution

Cost estimation: One of the least expensive storm water runoff prevention techniques is the use of filter strips. Seeding costs can range from \$20 to \$100 per 1,000 ft^2 with superoxide dismutase (SOD) costing \$125 per 1,000 square feet (\$0.40 to \$6.25 per linear foot for a 20- to 50-foot-wide strip) depending on site conditions. The average cost of labor to install vegetative filter strip is around \$2 to \$8 (average \$4) per ft^2. Maintenance costs average \$350 per acre per year or, \$0.009 per ft^2.

Estimated Area to provide vegetative filter strip = 2,828,352 ft^2.

Cost per unit area = \$125 per 1000 square feet = \$0.125 per ft^2

Cost of labor = \$4 per ft^2

Total cost per ft^2 = (\$0.125 + \$4) = \$4.125

Total cost of the vegetative filter strip construction = (2,828,351 x \$4.125)

= \$11666948

Maintenance costs = \$0.009 per square feet

Maintenance cost per year = (2,828,351 × \$0.009)

= \$25456

4.2 Economic analysis

Economic Analysis: Our main objective is toreduce cost using nature based solutions. For our project we have to reduce the nitrogen load at least 15%. To reduce 15% of nitrogen in our area we need vegetative filter strip ratio 20. Vegetative filter strip cost for 20 ratio is \$11666948. If we take the Vegetative filter strip ratio 15 then we will find the Vegetative filter strip construction cost will be \$15555936 and nitrogen load reduce 20%. Again if we take the Vegetative filter strip ratio 25 then we will find the Vegetative filter strip construction cost will be \$9333563 and nitrogen load reduce 12%. As our objective is to reduce 15% of nitrogen so we take VFSRATO 20.

VFSRATIO	Estimated area	Construction cost ($)	Reduction of nitrogen load (%)
15	3771136	15555936	20
20	2828352	11666948	15
25	2262682	9333563	12

5.1 Verification of complex engineering problem

Discuss which of the complex engineering problem solution attributes, as shown in Appendix C, were actually addressed through this project. Provide justification for your assertions.

5.2 Meeting the project objectives

Our project's first Objective was to developing a hydrologic and water quality model to investigate the effect of climate change and land uses on water quantity and water quality (nitrogen load) in a waterbody which we have done and the second objective was to design a nature based solution and reduce nitrogen load which We also achieved and the model shows us that by applying 20% vfs we can reduce 15% nitrogen load.

Conclusion:

To develop essential plans and implement the appropriate measures to lessen the effects of climate change, the forecast of Surface overflow and Nutrient overflow is crucial. Based on numerous data simulations, our model forecasts future surface overflow and nutrient overflow. This will allow us to accurately determine how flow result has changed over time. Additionally, it can alert us to any upcoming flooding or droughts. Our model also offers the chance to assess and select a natural solution to the nutrient overflow issue. Authorities can take the appropriate action against any type of environmental abnormalities based on all the simulation and data analysis.

Task Name	Start Date (MM-DD-YYYY)	End Date (MM-DD-YYYY)	Duration (Days)
Introduction	**02/12/2022**	**02/21/2022**	**7**
Guidelines on software	02/22/2022	04/20/2022	57
Ob. Data Collection	04/21/2022	05/23/2022	32
Necessary SWAT InputFile Collection	05/24/2022	06/01/2022	7
Building swat model	06/02/2022	06/08/2022	7
Running the model	06/09/2022	06/16/2022	7
Calibration	06/17/2022	07/01/2022	14
Validation	07/02/2022	07/09/2022	7
comparing ob. vs sim. future flow data	07/10/2022	07/24/2022	14
Applying VFS in Model	07/25/2022	08/08/2022	14
Comparing Nitrogen load Before and After	08/09/2022	08/16/2022	7
Guidelines on Report	08/17/2022	08/24/2022	7
Completing First Draft of Project Report	08/25/2022	09/01/2022	7
Checking and Revising Project Report	09/02/2022	09/04/2022	2
Completing First Draft of Project Presentation	09/05/2022	09/06/2022	1
Checking and Revising Project Presentation	09/07/2022	09/07/2022	1

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