# CHAPTER 9. THE IMPACT OF SOIL EROSION ON ENVIRONMENT AND CLIMATE CHANGE AND ITS DETERRENCE TECHNIQUES

## 9.1 General

The process of soil degradation is as old as agriculture itself, its effect on human nourishment and Earth becoming more genuine than any time due to its degree and intensity. The main reason for soil degradation is soil erosion. It is a standard procedure in which wind and water moved particles of soil and uprooted to another area. Firstly, when erosion used to occur naturally the soil is driven at about the same rate as it is made (*Lal, 1990*), so no harm is done to the earth. However, now due to anthropogenic activities, urbanization, and human interference, the rate of soil erosion is 13 to 40 times faster than the rate of creation (Zuazo and Pleguezuelo 2009). This accelerated Soil Erosion is one of the most significant worries of Earth's property surface. It affects the environment and is one of the causes of global climate change.

## 9.2 Introduction

Soil disintegration is an overall matter of concern today. We can't list the benefits of legitimate fertile soil in one single chapter; such enormous are its utilities. Let's simply express that soil supports life on earth. Each living being including people, creatures, plants, small scale living being everything lives on the soil. As the soil degradation and contamination was deficient, soil erosion has now extended and just added to our devastation (Gao et al., 2018). In case all the soil is disintegrated away, that day isn't far away when there will be no productive soil left for life (Lal, 2019). This is the high time for us to monitor the effect of soil erosion on the environment and to develop deterrence techniques for soil disintegration.

Soil erosion by water is process containing four phases including first the detachment, second breakdown, third redistribution, fourth sediment deposition. The soil natural carbon, i.e., Soil Organic Carbon (SOC) is affected in all the phases. The erosion is a selective procedure, i.e., it preferentially expels the light particles first and afterward the more massive particles. Being concentrated in the surface soil and of low density (under 1.8 mg per $m^3$) SOC is preferentially expelled by surface overflow (Lal, 2019). Aggregated soil prompts encapsulation of SOC, and thus it shields it from the microbial procedure and mineralization, yet amid soil disintegration, the detachment and breakdowns of aggregate make the soil carbon vulnerable against decay (Wang et al.,2017). The rate of mineralization is quicker initial three phases when contrasted with the last stage of soil erosion that is sediment deposition (Lal, 2019). Further, primarily anaerobic conditions can complement bio methanation prompting emission of Methane gas and to de-nitrification which is a microbial facilitated process where nitrate is reduced and ultimately produces moleculer Nitrogen and release into atmosphere. Hence accelerated soil erosion can lead increment in the release of Greenhouse gases those are Carbon dioxide, Methane, Nitrogen dioxide . The measure of emission of these gases relies on the different land type and soil type.(Lal, 2005).

Impacts of accelerated soil disintegration on food, security, water quality, and siltation and so on have previously been recognized, but its impact on carbon dynamics and discharge of GHGs into the environment have not been given the emphasis they merit. Even though the exchange and redistribution of SOC by breaking down is bright and significant known, its impact on the global carbon budget is neither comprehended nor accounted. Therefore, this section audits the impact of erosion on soil carbon dynamics.

Before attempting to model the remedies of soil erosion or analyzing the impacts of climate change, a researcher needs to study the topographic characteristics of the study area and nearby surrounding. Also, the study of the land uses land cover dynamics needed to be done. The location of all the water bodies, the Reservoir is needed to be known, and the climate of the study area needed to be observed. The preliminary work which is required to be done before analysis and modeling are:

1) Identifying the land use land cover and the slope of the study area.

2) Planning and mapping of naturally occurring geological formation of soil types which may be potentially responsible for soil erosion.

To conserve soil or prevention of soil erosion, many types of research and works are done. Zuazo and Pleguezuelo, 2008 had reviewed about the prevention of soil erosion by plant covers. Balaguruswamy, 2017 has proposed various methods for controlling soil erosion. Jeong et al., 2012 modeled sediment filtration basins for controlling soil erosion in the urban basin.  Various soil conservation practices can be studied in an article by (Dumanski and Peiretti, 2013). Meyer et al., 2017 have proposed five ways of preventing soil erosion for homeowners. Many researchers analyzed the impact of LULC dynamics on soil erosion. (Zhang et al., 2015, Shivhare et al., 2018, Welde and Gebramariam 2017)

The most commonly used soil erosion control measure is the plantation. Plants reduce runoff that is helpful in protecting soil from getting eroded (Rey 2003, Duran et al., 2006). The plant produces the energy of rain with the canopy, and their roots bind the soil (Baets et al., 2007). Also, vegetation stops the flow of soil by acting as a barrier. The distribution of vegetation along the slope is an essential factor for decreasing soil erosion (Francia et al., 2006). Apart from this prevention, prevention techniques of soil erosion are divided into two types:

1) Reducing runoff amount.

2) Reducing runoff velocity.

The amount of runoff can be reduced by increasing infiltration of soil or by preventing runoff directly using diversion channels or interception ditches. The velocity of runoff can be decreased by using Hydraulic structures.

The first primary objective of this chapter is to analyze the impact of soil erosion on climate change. For this, the Indian Standard methods of soil testing are used for carbon content analysis of various soil samples. It was also analyzed that, whether soil erosion is really the source of Greenhouse gases which are solely responsible for global warming and climate change. The second primary objective is to propose the deterrence techniques and to analyze the impact of revegetation and hydraulic structures as a prevention measure on soil erosion.

## 9.3 Greenhouse Gases Emission during Erosion

There has been a fast increment in the environmental concentration of $CO_2$ and other GHGs into the climate. For instance, the amount of $CO_2$ has expanded by 31% from 1750 to 1999 and is increasing at an average rate of 0.4% per year (Lal 2005). There are comparative increments in the concentration of other GHGs, which have raised concerns in regards to the identification of sources and sinks of these gases. Being non-point or diffused sources, it is hard to decisively gauge nearby, local and worldwide emissions of GHGs because of deforestation, biomass consuming, soil development, utilization of composts and excrements and different exercises identified with land use change. Identification of these obscure sources is imperative in creating procedures for mitigating potential climate change or if nothing else decreasing the rate of concentration of GHGs in the climate.

It is in this association that the effect of soil erosion on carbon dynamics should be evaluated dispassionately and quantitatively. Being situated in the region of the soil surface and of low density, SOC is affected by erosional forms. Thus, the impact of soil erosion on carbon dynamics and conceivable outflows of GHGs can't be overemphasized (Lal 2005). The carbon in the soil is encapsulated which prevents the carbon from getting reacted with oxygen and microbes. But soil erosion results in the disturbance of aggregates, and soil organic carbon is exposed to climatic components and bacterial compounds. Substantially vulnerable Particulate Organic Carbon and Dissolved Organic Carbon fractions are at risk of bacterial decomposition and released into the air as Carbon Dioxide together with Methane and Nitrogen Dioxide (Dungait et al., 2012). The destiny of SOC, discharge or gradual addition, at a depositional site, relies upon (i) the type of SOC being transported ( Józsa et al., 2014), (ii) the carbon enrichment magnitude (CER), and (iii) the adjustment components at the depositional site.

A few instances of the gaseous emission from erosion motivated transport of SOC are : In Australia, China, and California the SOC displacement due to erosion is 0.3-1.0 Pg C/yr (Chappel and Baldock 2016), 180 + 80 Tg C/yr (Yue et al., 2016), 1.4-8.0 g C/$m^2$.yr (Yoo et al., 2005) respectively ( Lal 2018).

A study by Worall et al., 2016 reported that accelerated soil erosion is a definite source of Greenhouse gases. He also concluded by his results that if the gross erosion rate would be less than 9100 Mg/$m^2$.yr then the gross soil disintegration in the U.K. would be a net sink of both C and GHGs. The soil carbon at the depositional location can be secured by re-aggregation, profound entombment and the pervasiveness of anaerobic environments. Re-aggregation is undoubtedly influenced by clay & fine sediment content and the properties of clay minerals. The higher the clay & silt content, the more is the physical assurance. Further, re-accumulation is improved by the nearness of 2:1 clay minerals (Lal 2019).

## 9.4 Methodology or Criteria Used for Analysis

### 9.4.1 Analyzing the Impact of Soil Erosion on Climate Change

For analyzing the impact of soil erosion on climate change first the climate of the study area was analyzed. The analysis revealed that since 1969 the average maximum temperature is getting increased from $31.8^0$ C (during 1969 to 1974) to $32.9^o$ C (during 2010 to 2015) (as Shown in Figure 9.1), this increase in temperature shows that this study area is suffering from the problem of global warming. Global warming is a long-term increase in the average temperature of the earth's climate system. In the modern context, the term global warming and climate change are commonly used interchangeably. However, climate change incorporates both global warming and its dangerous effects like changes in precipitation.

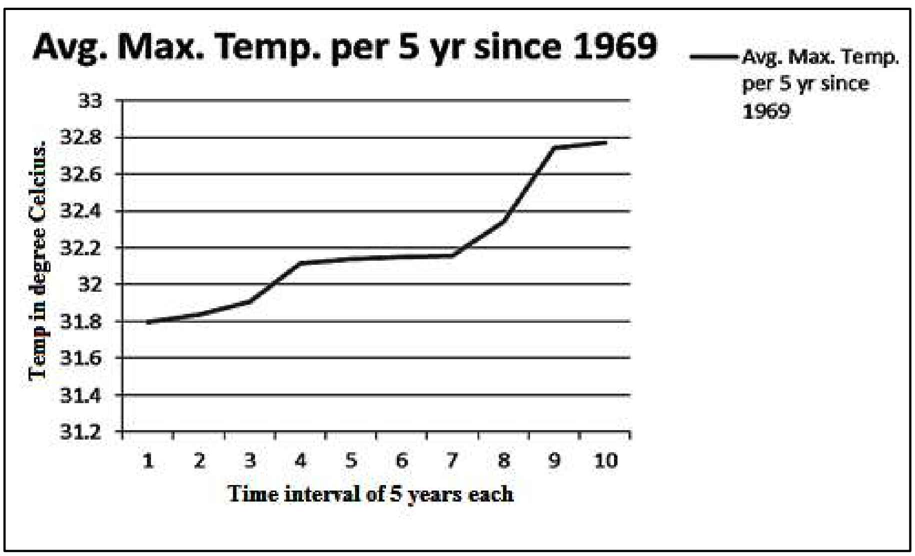


Figure 9.1 Average Maximum temperature per 5yr since 1969

### 9.4.2 Causes of Global Warming

The greenhouse effect is the natural procedure by which radiation from the climate of a planet warms the planet surface to air temperature above what it would be without its atmosphere. When the sun rays approach the earth environment, some of these rays and energy gets absorbed, and rest is reflected back. The energy is absorbed by greenhouse gases which include carbon dioxide, Nitrogen dioxide, Methane and water vapors. Due to this energy absorption the temperature of the atmosphere increases. When the concentration of these greenhouse gases increases in the atmosphere, the temperature rise is high which adversely affect the life on earth, this rise in temperature is known as global warming. So the main reason behind global warming or climate change is the increasing concentration of GHGs in the atmosphere

### 9.4.3 Is Soil Erosion Responsible for Global Warming?

Accelerated soil degradation includes the preferable evacuation of surface carbon because it is concentrated in the region of the soil surface and has a lower density than the other constituents. This evacuated carbon is then exposed to climatic components and bacterial enzymes. This exposure leads to mineralization and microbial reaction resulting in the emission of carbon dioxide. When the soil is redistributed, due to the breakdown of aggregated soil the methanogenesis takes place resulting in the emission of Methane Gas. Also while deep burial and re-aggregation, nitrification and de-nitrification take place resulting in the emission of Nitrogen dioxide. The details of this procedure are shown in Figure 9.2. and explained clearly in section 9.3, that soil erosion is the clear source of greenhouse gases and is responsible for global warming and climate change.

The present chapter is to analyze that one of the leading causes behind global warming in the study area is soil erosion or not? For doing this, the organic carbon content was tested in several soil samples. These soil samples were taken from different sites which were suffered from soil erosion and also taken from the area where soil erosion does not occur. The carbon content of the soil samples of erosion-prone sites was then compared to the samples taken from the sites where soil erosion is negligible.

The carbon content is tested using Indian Standard methods of test for Soils (IS 2720: Part XXII) explained in detail in Appendix 1. The reagents used for this experiment are Potassium Dichromate, Ferrous Sulphate, Sulphuric Acid, Orthophosphoric Acid, and Indicator solution of Sodium Diphenylamine Sulfonate dissolved in 100 ml of distilled water. This method helped me to find out the percentage weight of the organic carbon present in soils. If as a result, the carbon content of the non-eroded sample is more than the eroded sample then it would be clearly concluded that carbon is removed during soil erosion and may have mineralized and microbial reactions would have occurred resulting in the emission of carbon dioxide which led to the climate change and global warming.

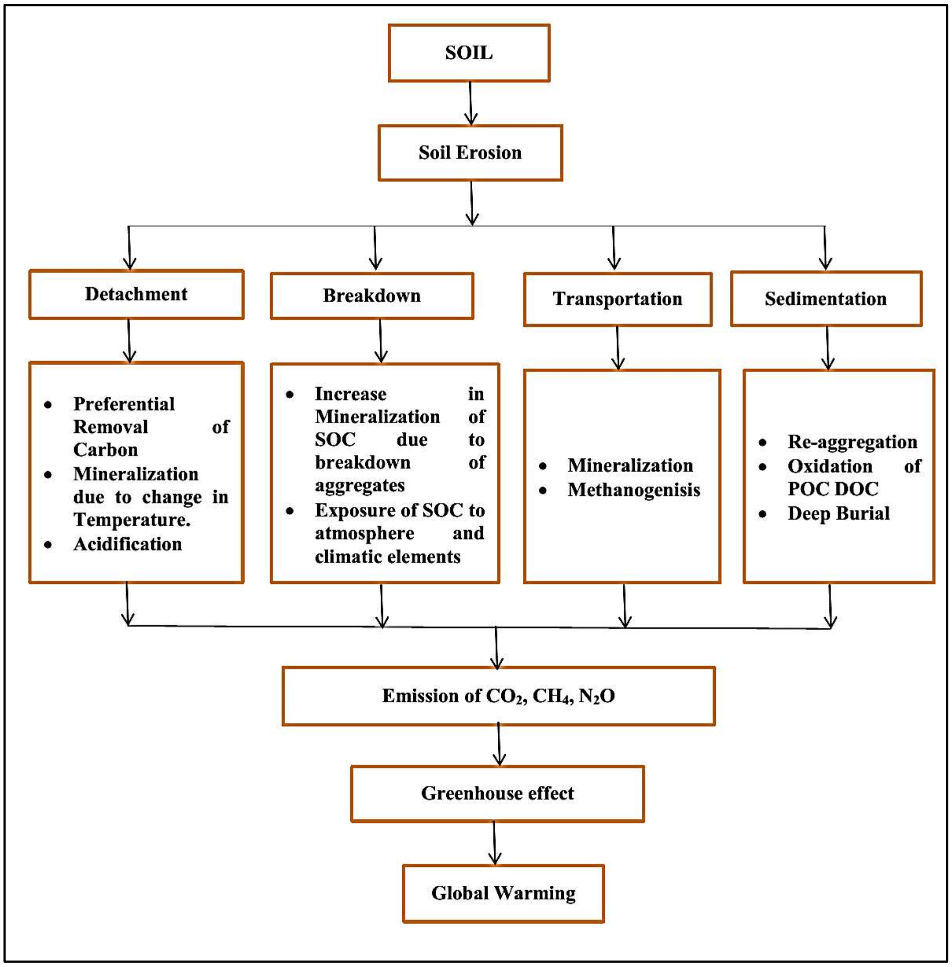


Figure 9.2 Soil erosion a cause of global warming

### 9.4.4 Calculation Used for Determining the Carbon Content of Soil

The total volume (V ml) of potassium dichromate used to oxidize the organic matter in the soil is given by the following formula:

$$V = 10.5\,(1 - r/X) \qquad (9.1)$$

where

$r$ = total volume of ferrous sulfate used in this test, and

$X$ = total volume of ferrous sulfate used in the standardization test

The percentage of organic matter (OM) present in the oven-dried the sample shall be calculated from the following formula:

$$OM, percent\ by\ weight\ = \frac{0.67w2V}{W1\,W3} \qquad (9.2)$$

where

W2= weight on the oven-dry basis of the soil sample passing 10 mm IS Sieve,

V= total volume of potassium dichromate used to oxidize the organic matter,

W1= weight on the oven-dry basis of the total soil sample taken for the test before sieving, and

W3 = weight on the oven-dry basis of the soil specimen used in the test.

NOTE- The method is based on the determination of the organic carbon content of the soil, and it assumes that soil organic matter contains an average of 50 percent of carbon by weight. With the technique employed approximately 77 percent of the carbon in the organic material is oxidized. These factors are included in the formula.

### 9.4.5 Method for Proposing First Deterrence Technique and Analyzing Its Impact on Soil Erosion

Covering the land by plants and vegetation is the best measure for preventing soil erosion. The significance of plant cover is controlling water disintegration (erosion) broadly acknowledged. For the time being vegetation impact erosion for the most part by blocking precipitation and ensuring the soil surface against the effects of raindrops and by hindering overflow. In the long haul, vegetation impacts the motion of water and sediments by expanding the soil total dependability and attachment and also by enhancing infiltration. Hence there is a relationship between vegetation cover and erosion range for an extensive variety of natural condition. The relationship can be defined in by equation 9.3

$$Soil\ loss_r = e^{-\beta V} \qquad (9.3)$$

Where,

$Soil\ loss_r$= relative soil loss,

V = vegetation cover and

β = constant (0.0235 to 0.0816)

This β varies according to the type of vegetation. For runoff, this relation is given by equation 9.4

$$Runoff_r = e^{-\alpha V} \qquad (9.4)$$

Where,

$Runoff_r$= relative runoff,

V = vegetation cover and

α = constant (0.0103 to 0.0843)

Keeping in mind the primary goal and guarantee achievement of any vegetation exertion, it is important to set up a plan which will consider the climatic conditions and topography of a study area. It is essential for the study in the area before revegetation. For analysis the following points should be considered:

1) Climatic conditions of the study area.
2) Which plant will do well in the study area?
3) which plants have the best attributes of erosion control

There are various vegetation techniques which could be applied for better and faster revegetation

**a) Top Soiling**

The arrangement of topsoil over prepared subsoil before the foundation of vegetation. To give an appropriate soil medium for vegetative development while giving some restricted here and now disintegration control ability.

**b) Temporary and Permanent Seeding:**

The planting and establishment of quick growing and/or perennial vegetation to provide temporary and/or permanent stabilization on exposed areas. Brief seeding is intended to balance out the soil, what's more, to secure bothered territories until the point when lasting vegetation or other disintegration control measures can be built up.

**c) Hydroseeding:**

Hydroseeding is a planting procedure that uses a slurry of seed and mulch. Usually utilized as an erosion control procedure. The use of grain, compost and a paper or wood mash with water in the shape of the slurry is showered over the region to be revegetated. To set up vegetation rapidly while giving a level of moment assurance from raindrop effect.

**d) Mulching:**

Mulches are free covers or sheets of material set on the surface of the developed soil. Natural mulches likewise enhance the state of the dirt. As these mulches gradually break down, they give fundamental issue which helps keep the dirt free. This enhances root development, builds the penetration of water, and furthermore enhances the water-holding limit of the soil. Mulching aids soil dampness protection diminishes overflow and disintegration, controls weeds, and advances the foundation of beautiful vegetation.

**e) Turfing:**

A surface layer of earth containing a full development of grass and its tangled roots are turf. Turfing is an artificial substitute for such a dense layer, as on a playing field. The foundation and constant adjustment of bothered zones by laying a persistent front of grass turf. To give quick vegetative cover to settle soil on aggravated zones.

In the present chapter, the SWAT model was used to calculate the sediment yield values of all the 46 sub-watersheds, using LULC of 2015 and climate data from 2005-2015 as input data. The result was then validated and calibrated utilizing Sufi-2 algorithm. Table 9.1 shows the sediment yield values and land use land cover of each watershed. It is clear from the table that the sub-watersheds SW36, SW23, SW29, and SW35 are the sub-watersheds with the highest values of sediment yield and most of the area of these watersheds was covered with Barren land, Rangeland and agricultural land. Agricultural land, barren land, and rangeland are most prone to soil erosion. So, in this study for reducing soil loss, part of the rangeland, Barren land and agricultural land of the sub-watersheds with high sediment yield values were proposed to be converted into forest land. By using dynamic land use the land cover property of ArcSWAT. Again the SWAT model was run after applying the land use changes, and the results were compared with the swat results with today's land use conditions. The results will estimate the improvement in soil erosion after applying proposed forestation in the sites which are prone to soil erosion.

Table 9.1 shows the sediment yield values and land use land cover of each watershed.

| **Sws No.** | **LULC FRSD** | **LULC URBN** | **LULC RNGE** | **LULC/ AGRL** | **LULC BARR** | **Sediment Yield** |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 66.81 | 27.82 | 1.43 | 2.61 | 0.18 |
| 2 | 0.00 | 85.96 | 9.65 | 0.40 | 3.29 | 0.16 |
| 3 | 0.04 | 55.00 | 36.59 | 3.25 | 3.90 | 0.12 |
| 4 | 0.00 | 68.43 | 15.82 | 3.05 | 5.70 | 2.47 |
| 5 | 0.00 | 58.32 | 21.48 | 3.84 | 9.70 | 0.90 |
| 6 | 0.00 | 77.11 | 19.63 | 1.03 | 1.67 | 0.12 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7 | 0.00 | 44.20 | 24.05 | 6.63 | 7.18 | 5.29 |
| 8 | 0.00 | 73.91 | 21.51 | 1.09 | 1.53 | 0.30 |
| 9 | 0.00 | 73.91 | 21.51 | 1.09 | 1.53 | 0.16 |
| 10 | 0.00 | 69.64 | 22.40 | 2.78 | 1.35 | 1.54 |
| 11 | 0.02 | 66.93 | 27.62 | 2.75 | 2.27 | 0.03 |
| 12 | 0.01 | 55.18 | 27.26 | 3.16 | 7.56 | 1.94 |
| 13 | 0.04 | 44.00 | 27.23 | 6.15 | 12.75 | 1.10 |
| 14 | 0.05 | 57.91 | 33.80 | 4.31 | 3.32 | 0.05 |
| 15 | 0.26 | 51.09 | 36.90 | 4.89 | 6.37 | 0.05 |
| 16 | 0.10 | 54.28 | 39.00 | 2.84 | 3.67 | 1.98 |
| 17 | 0.12 | 33.32 | 47.09 | 13.00 | 5.48 | 0.25 |
| 18 | 0.68 | 32.67 | 54.24 | 1.29 | 10.41 | 0.09 |
| 19 | 1.93 | 54.68 | 31.03 | 6.27 | 5.25 | 0.04 |
| 20 | 0.45 | 61.67 | 30.68 | 3.35 | 2.19 | 0.10 |
| 21 | 0.23 | 63.68 | 20.23 | 1.67 | 6.75 | 1.06 |
| 22 | 1.64 | 19.14 | 60.78 | 4.45 | 13.46 | 0.57 |
| 23 | 11.94 | 16.99 | 47.17 | 3.91 | 19.05 | 10.09 |
| 24 | 4.86 | 13.09 | 64.01 | 7.24 | 9.56 | 0.31 |
| 25 | 2.12 | 23.93 | 57.29 | 11.35 | 4.68 | 0.16 |
| 26 | 3.40 | 19.98 | 64.63 | 3.46 | 7.85 | 0.44 |
| 27 | 1.47 | 58.35 | 25.34 | 3.97 | 3.91 | 0.95 |
| 28 | 9.71 | 28.77 | 21.96 | 20.20 | 10.72 | 0.88 |
| 29 | 17.77 | 22.06 | 21.37 | 20.90 | 9.67 | 10.80 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 30 | 7.00 | 43.37 | 24.92 | 7.46 | 7.62 | 1.44 |
| 31 | 26.56 | 19.88 | 33.21 | 4.64 | 14.06 | 4.40 |
| 32 | 10.52 | 15.03 | 56.54 | 8.07 | 8.69 | 7.94 |
| 33 | 24.91 | 14.76 | 34.61 | 6.20 | 17.62 | 7.85 |
| 34 | 3.44 | 26.56 | 28.80 | 27.20 | 8.56 | 4.50 |
| 35 | 25.13 | 16.21 | 41.92 | 10.65 | 4.65 | 9.96 |
| 36 | 7.56 | 10.79 | 55.31 | 12.07 | 12.83 | 33.63 |
| 37 | 21.81 | 15.24 | 29.17 | 16.68 | 13.01 | 1.88 |
| 38 | 6.46 | 28.78 | 32.66 | 16.20 | 9.19 | 3.90 |
| 39 | 22.29 | 10.82 | 37.77 | 8.48 | 19.72 | 4.53 |
| 40 | 16.01 | 19.49 | 36.19 | 7.49 | 16.61 | 3.57 |
| 41 | 22.69 | 18.67 | 35.36 | 6.46 | 14.63 | 5.55 |
| 42 | 51.00 | 4.00 | 27.00 | 11.00 | 5.00 | 8.87 |
| 43 | 50.56 | 4.95 | 26.48 | 8.35 | 6.34 | 7.32 |
| 44 | 33.96 | 5.86 | 34.50 | 12.00 | 12.41 | 4.83 |
| 45 | 50.97 | 1.01 | 25.60 | 11.23 | 9.47 | 5.27 |
| 46 | 47.08 | 2.34 | 26.26 | 10.03 | 11.35 | 1.99 |

### 9.4.6 Methodology for Proposing Hydraulic Structures for Reducing Soil Erosion

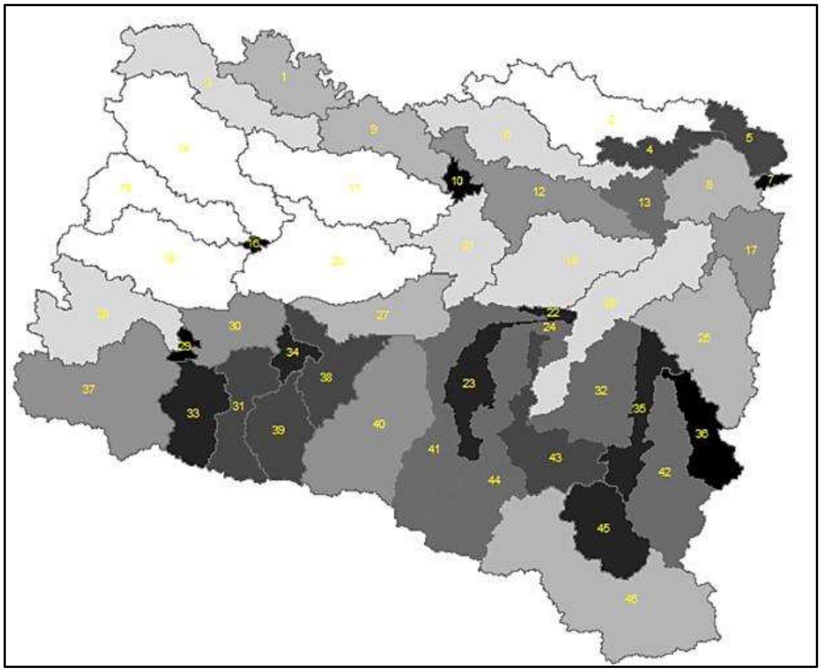

Figure 9.3(a) watershed showing runoff, darker the watershed higher is the value of Runoff.

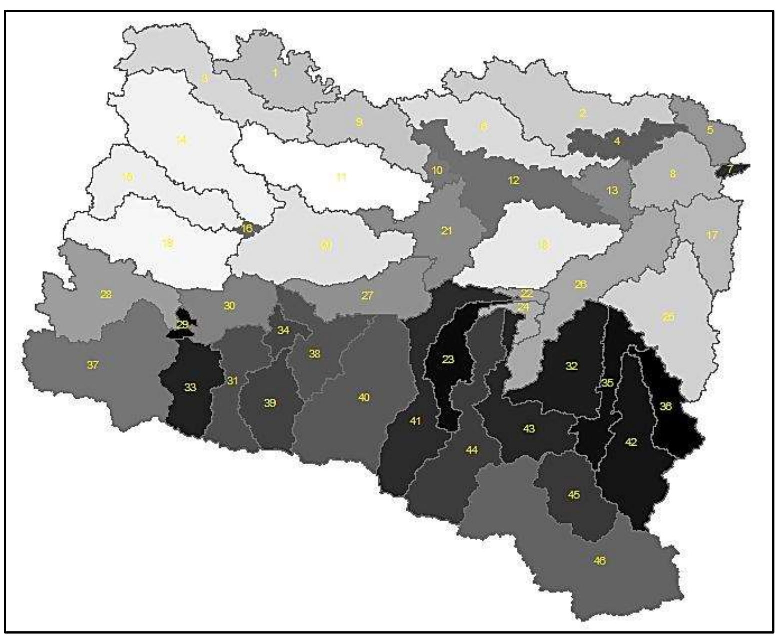

Figure 9.3(b) watershed showing soil erosion, darker the watershed higher is the value of Soil erosion.

In Figure 9.3 (a) and 9.3(b), it is clear that in most of the places where the slope and runoff are more the sediment yield is also high. So, in this section, hydraulic structures (like check dams, farm ponds, Gabion, Anicut, and bunds) were proposed and modeled as the measures to reduce runoff velocity and volume in the sub-watersheds where the leading cause of soil erosion was steep slope and Runoff. Soil and water conservation practices are the primary elements of the watershed management program. Conservation practices can be divided into two main categories: 1) in-situ and 2) ex-situ management. Land and water conservation practices include the construction of contour bunds, graded bunds, field bunds, terraces building, large bed, and furrow practice and other soil-moisture conservation practice these are known as in-situ management and protect land degradation, improve soil health, and increase soil-moisture availability and groundwater recharge. However, construction of a check dam, farm pond, gully control structures, pits excavation across the stream channel is known as ex situ management. Ex-situ watershed management practices reduce peak discharge to reclaim gully formation and harvest the substantial amount of runoff, which increases infiltration rate of soil and hence decrease the soil erosion.

Digital elevation models (DEMs) is useful for predicting areas of enhanced runoff, drainage areas, flow directions, and channelized flow. Flow accumulation is used to generate a drainage network, based on the direction of flow of each cell. By selecting cells with the highest accumulated flow, a network of high flow cells can be created. These high-flow cells should lie on stream channels and at valley bottoms. Flow accumulation has been useful for predicting locations of headwater and perennial streams and threshold values of flow accumulation can predict channelized stream sections. Terrain and GIS-based modeling approaches have also been proposed for assigning the widths of no cropping zones (“buffers”).

Flow accumulation and sink map were generated from DEM imagery using ArcGIS software. Flow accumulation map was used to study the flow accumulation of flow in the study area. Sink map was used to determine the location of a depressing point in the study area, and these depressed points were useful in locating a suitable site for placing farm ponds. In other words, these maps were handy for visualization of surface runoff and placing the suitable structure in the stream.

All maps which are essential for the watershed management were developed for study area through DEM by using ArcGIS. Watershed has been grouped into several sub-watersheds, which has been used as the primary key for modeling of the watershed. For appropriate hydraulic structures, these maps have been used for deciding the locations. Sink layer and flow accumulation layer are an overlay and shown in Figure 9.4. The impact of these structures was estimated using ArcGIS, and then the percentage decrease of runoff and soil erosion was then calculated.

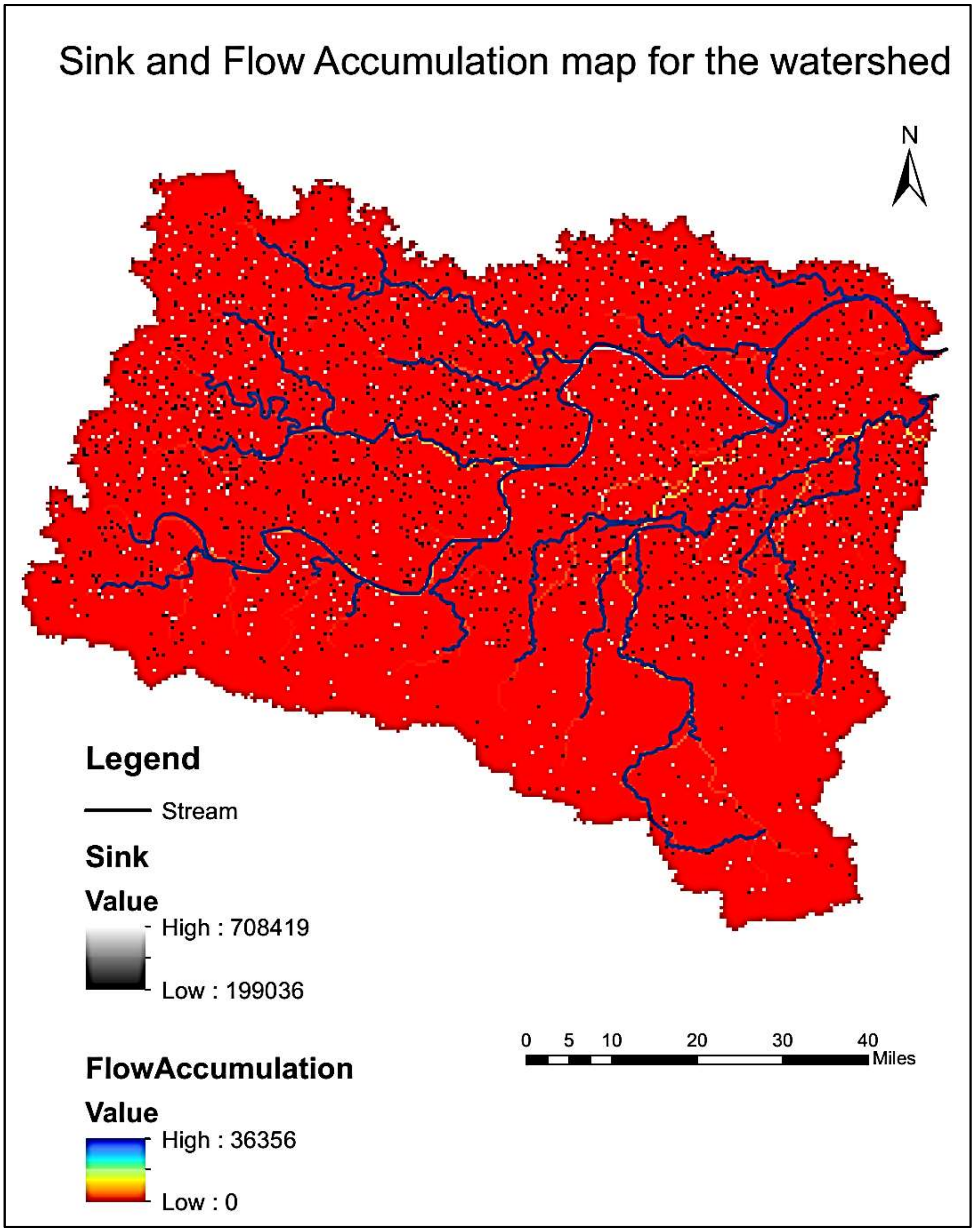


Figure 9.4 Overlaid map of Sink layer and flow accumulation layer

## 9.5 Results

### 9.5.1 Result of Impact of Soil Erosion on Climate Change

After the lab experiments the calculation of carbon content present in the soil samples using "Indian Standards method of test for soils" was done. The result of the calculation is shown in Table 9.2. These results explain that the soil samples of erosion prone sites of study area contain on an average 0.04 gram (per unit area) less carbon then the soil samples of erosion free areas, of the same site. So we can conclude that soil erosion can be one of the reasons behind carbon emission in the form of carbon dioxide from soil. This carbon transported with eroded soil may be deposited in some other places, or also it may have carried into freshwater or oxidized and released into the atmosphere in the form of carbon dioxide.

As the redistributed carbon is generally light and hence quickly mineralized and emitted in the form of carbon dioxide gas. Assuming that 50% of eroded carbon is mineralized. We can calculate that with every gram of carbon loss every year from this study area 3.67 gram of carbon dioxide ( using an element to the molecular mass conversion factor of 44/12,( Chappell et al., 2014)) per year are released into the atmosphere. So as we can see the average carbon loss is 0.04 gram per unit area, it means that about 2350 grams of carbon dioxide are already released from the study area till the present date. This result shows clearly that soil erosion of this area is definitely one of the main reasons for increasing carbon dioxide and other greenhouse gases in the atmosphere and hence increasing the temperature of this Ganga basin. Long-term field experiments are needed to determine the exact amount of carbon dioxide, methane, and Nitrogen dioxide emissions

Table 9.2 Result of Carbon content analysis in Soil

| **Sample number** | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Total weight of the original sample (W1)in gm** | 225.63 | 240.65 | 240 | 241.25 |

| | | | | |
|---|---|---|---|---|
| **The weight of passing soil 10-mm IS Sieve (W2) in gm** | 175.47 | 197.79 | 201.58 | 207.7 |
| **The weight of dry soil specimen used (W3) in gm** | 5 | 5 | 5 | 5 |
| **Volume of potassium dichromate solution used to oxidize organic matter in soil** $V = 10.5(l - r/X)$**, in ml**<br>**Percentage of organic matter in** $OM = \frac{0.67w2V}{WI\,W3}$, | 2.394<br><br>0.249 | 2.69<br><br>0.29 | 3.2<br><br>0.36 | 4.52<br><br>0.52 |

### 9.5.2 Impact of Revegetation on Soil Erosion

For reducing the soil erosion, it was proposed to do the revegetation in the high soil erosion sub-watersheds of the study area. 30 percent of agricultural land, 40 percent of the Barren land and 25 percent of the rangeland were proposed to be converted into forest land by revegetation for the high soil erosion prone sub-watersheds (SW36, SW323, SW29, SW42, SW33, SW32, and SW35). After applying these changes, the overall sediment yield of the watershed was calculated. It was estimated that about 20% reduced overall sediment yield of the watershed. Figure 9.5 shows the graph between Sediment yield before and after applying the revegetation technique.

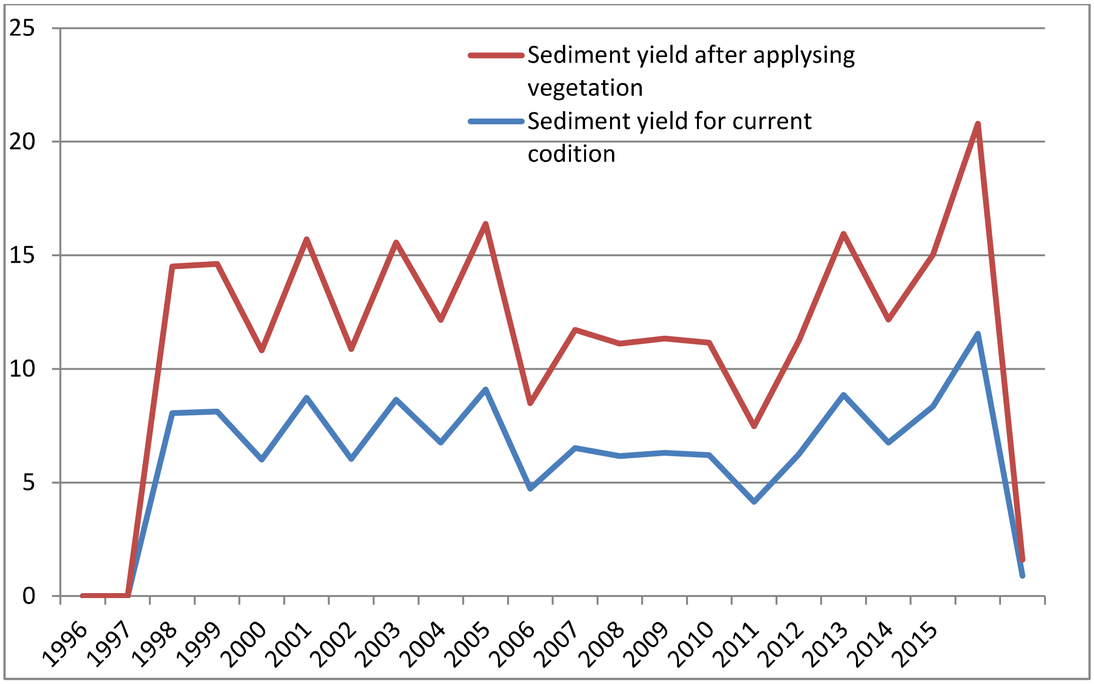


Figure 9.5 shows the graph between Sediment yield before and after applying the revegetation technique.

### 9.5.3 Impact of Proposed Hydraulic Structures on Soil Erosion

For reducing runoff volume and velocity the hydraulic structures like Gabions, check dams, bunds, farm ponds, and surplus weir were modeled in the sub-watersheds with a high volume of Runoff. In these sub-watersheds, the primary cause of soil erosion was the deep slope and high runoff, so the hydraulic structures were modeled to reduce soil erosion. All the gabions were placed in the upper reach of a drainage network for minimizing the transportation of eroded soil for watershed and sub-watershed. These structures are very efficient to trap eroded material from land traveling with runoff by allowing passage to runoff. The transportation of silt started at the origin of the stream; therefore, gabion was placed at that place in the hydraulic structure modeling. Check dams were placed at the junction point of two or more than two streams.

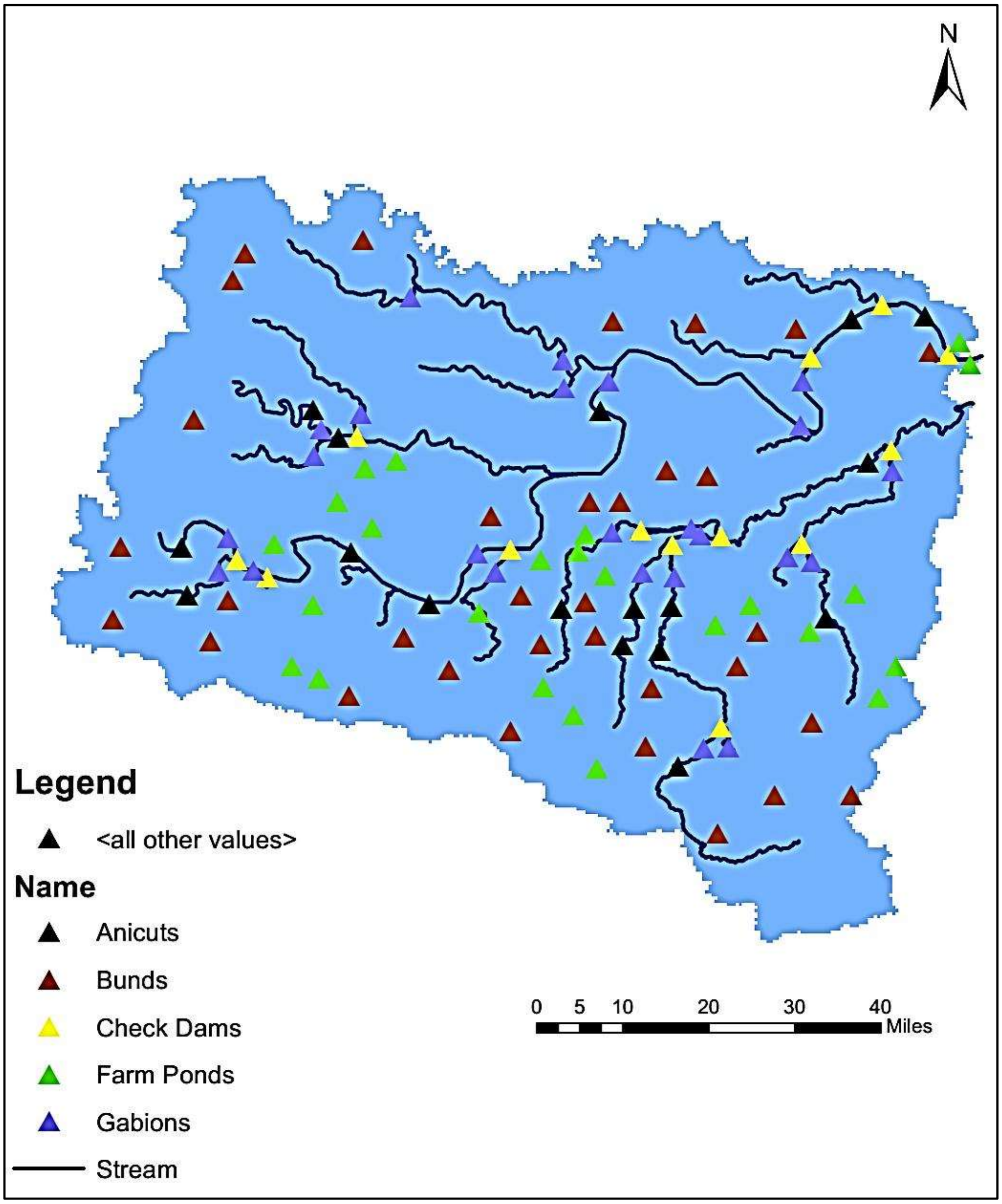


Figure 9.6 proposed hydraulic structures

The locations of the structure were selected after the study of flow accumulation map. Therefore, these low land areas accumulate more water without any further earthwork. The slope of the study area is gentle in nature, so anicut structure has been placed (height less than 1.0 m) throughout the length of the mainstream to make a river perennial, at the interval of 1 km to 1.5 km. In other words, sink map provided a suitable location for farm ponds and flow accumulation map give a suitable location for different hydraulic structures for watershed modeling. Overlying of these two individual maps gives complete modeling for watershed planning. The numbers of the proposed structure for this watershed are listed in Table 9.3. And proposed structures are given in Figure 9.6. Modeling these structures can reduce soil erosion by 25 to 30% for the watershed.

Table 9.3: Detailed disruption of structures for hydraulic structures modeling

| **Type of Structure** | **Farm Pond** | **Submerged Bund** | **Anicut** | **Check Dam** | **Gabion** |
|---|---|---|---|---|---|
| No. of structure | 25 | 33 | 16 | 13 | 24 |

### 9.6 Conclusion

GIS Technologies nowadays occupy a prominent place among the modern computer tools and constitute invaluable support in the decision making of a problem with a spatial decision. In the present study ArcGIS along with SWAT were used for analyzing the impact of soil erosion on climate change and its prevention measures. Considering every one of the four phases of the erosion procedure, it was concluded that soil erosion is an apparent cause of releasing ozone-harming gases or GHGs. The amount and degree of the source rely upon LULC pattern, atmosphere, soil characteristics and the overall measure of various segments of dissolved carbon, and need further research particularly on checking the site-explicit legitimacy of the idea of "dynamic substitution."

Due to the scarcity of fertile soil and to reduce GHGs emission the need for Adopting the soil erosion deterrence techniques is increasingly applicable at this point than at any other time. As the deterrence techniques, the revegetation and some hydraulic structures were proposed in the high soil erosion region of the study area. For analyzing the impact of revegetation a case was created in SWAT by changing some percentage of the current rangeland and agricultural lands of highly soil erosion prone sub-watersheds to vegetation land, then the results were compared to the base case. The comparison concluded that up to 50% of sediment yield could be reduced using revegetation. Hydraulic structures were modeled using flow accumulation and sink map. The use of these structures can reduce the sediment yield and runoff by 20%.

.