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Effects of soil erosion and control: A review

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Abstract
Soil erosion is a major cause of soil deterioration due to physical, chemical, and biological factors which compromises the soil quality and loss of potential damage to the soil matrix i.e., harmful impact on the environment. Physical soil erosion involves a loss of structural integrity, which causes crusting, compaction, and a decrease in water permeability, resulting in wide changes in soil temperature, increased surface overflow, and soil degradation. Chemical soil erosion is the loss of organic matter or nutrients, soil salinity, acidification, soil degradation, and fertility reduction are all examples of soil degradation. Nutrient loss lowers soil's ability to sustain plant growth and agricultural production and increases acidification. Biological soil erosion includes the removal of soil organic matter, reduction in biodiversity, reduction in a soil's capacity to store and absorb carbon, the release of plant nutrients, as well as the emission of greenhouse gases. During the precipitation/ high rainfall intensity/ wind storm the soil is damaged, eroded via Splash erosion, and rill erosion as detachment of soil deposited to dams and reservoirs via transportation of fertile soil. As a result, soil biota is moved towards the graveyard of soil due to the transportation mechanism occurs. Detachment, transportation, deposition mechanism of high rainfall erosivity index. As a soil matrix disturbed the micro-organism which is responsible for the production of organic carbon from organic matter. The expense off- site effects of eroded soil and runoff gravel-bedded rivers which are also sedimentation of lost reservoir/ dam capacity which results in eutrophication of aqueous body and flooding of highways and villages is becoming more recognized. Natural Rainfall patterns have changed as a result of environmental damage by human in satisfy by human activities are likely to grow more prominent in the next decayed. Long-term intensify activity by a human may post a threat to the whole agricultural system throughout the world. All these sides and factors will put extra strain on the soul of the earth (i.e., soil). Forms of precipitation make soil erosion prediction and management more challenging. As a result, increased awareness, technology, and lawful understanding of the soil erosion process will be required to meet the upcoming difficulties of the soil conservation method. The impact of soil erosion origin mechanism as well as control techniques are discussed in this paper.

Keywords: Erosion, soil degradation, run-off, consequences, soil conservation

Introduction
Soil erosion is a process that occurs naturally, by the elements such as wind and water which removes the topsoil. Soil erosion is a continual process that might happen gradually or quickly. It leads to ongoing topsoil loss, ecological deterioration, soil collapse, and other issues. During this process, soil particles are washed away in rivers, valleys, streams, oceans, and faraway locations. A high land slope, the loss of vegetation to make way for farmland, drought, soil tillage, wind, or water can all speed up soil erosion, but water erosion is the most common and significant (Kanungo and Sharma, 2014) [51].

Human agriculture and deforestation have exacerbated the problem. Human impacts have increased at a rate 10-50 times faster than global degradation. Both "off-site" and "on-site" problems result from excessive (or rapid) erosion. Reduced agricultural production & (in natural areas) ecological collapse are both on-site consequences of the loss of nutrient-rich topsoil layer. (Sun, Wenyi, *et al*., 2014) [29].

Desertification is a possible outcome in several instances. Sedimentation of streams and eutrophication of water sources, as well as sediment-related damages to roads and dwellings, are all off-site consequences. Wind and Water erosion are the two main drivers of land degradation; together, they account for around 84 percent of all degraded land on the planet, making excessive erosion one of the world's most serious environmental issues. (Cheraghi M., *et al*, 2016) [8] Soil Erosion is the natural process of wearing away the topsoil, but human activities have accelerated the process. (Nichols, Gary, 2009).

It is often caused by the loss of vegetation or other action that causes the ground to become dry. Soil erosion is caused by mining, construction, grazing, farming, and recreational activities. (Obreschkow, 2011) [7]. Soil erosion causes more than simply land damage. It has caused a huge rise in sediment and pollutants in rivers, blocking waterways and reducing the number of aquatic species. Degraded lands lose the water holding capacity resulting in floods. The health of the soil is critical for farmers and the populations that rely on agriculture for nutrition and livelihood. There are several challenges to resisting soil erosion, but there are solutions to prevent it as well. (Torri, D., 2012) [53].

Causes of Soil Erosion

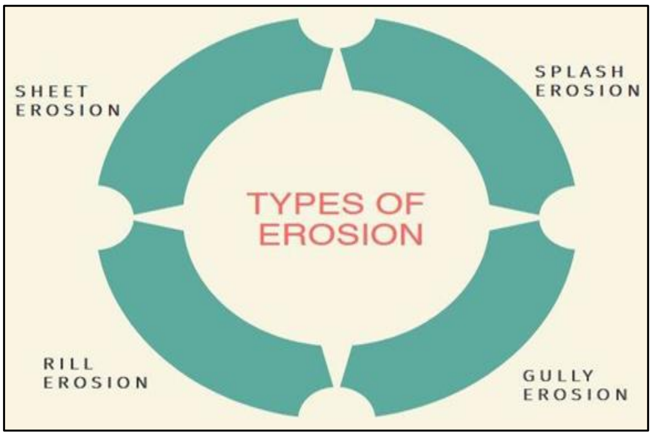
Some of the most important influences on soil erosion include:

A. Rainfall and Flooding

Increased rainfall intensity is the primary cause of soil erosion. This Soil erosion is mostly caused by increased intensive rainfall by sequence. When heavy rainfall occurs first cause is splash erosion and later it will be converted to sheet erosion. It's based on the intensity of rainfall and the speed of raindrops. Rainfall causes 4 forms of soil erosion:

Types of soil erosion

1. Splash erosion
2. Sheet erosion
3. Rill erosion
4. Gully erosion



Types of erosion

Splash erosion: The first stage in the erosion process is splash erosion or raindrop impact. Splash erosion is caused by the impact of rain droplets on the soil surface. Raindrops operate like little bombs when they fall on open or unprotected soil, displacing soil particles and changing soil structure. (Jomaa *et al.*, 2012) [8]. Splash erosion can move soil particles up to 1.5 meters vertically and up to 5 meters horizontally with the support of the wind, based on the soil. (Ryak *et al.*, 2015). Splattered particles can reach 0.6 m above the ground and travel up to 1.5 m horizontally, according to experiments done in the United States. Splash erosion causes the creation of surface crusts, which reduces infiltration and causes runoff to begin (Wirtz *et al.*, 2013)

Sheet erosion: Sheet erosion happens when a thin layer of topsoil is eroded over an entire hillside paddock and it is not always visible/Sheet erosion refers to the separation of soil particles by raindrop impact & their removal downward slope by water moving overland as a sheet rather than in distinct channels or rills. A less or more uniform surface of small particles is eliminated from the total surface of an area, resulting in a loss of rich topsoil in some cases. Sheet erosion is widespread in recently ploughed fields or other areas with poorly sorted soil material and little plant cover. (Mahabaleshwara H and Nagabhushan H M, 2014) [50].

Rill erosion: Soil can be transported indirectly by rainwater, flow of overland water in the form of small channels known as rills; usually rill erosion does not have continuous characteristics, which means that rills formed in one storm can disappear before another storm happens. (It has a distinct V-shape. Mahabaleshwara H and Nagabhushan H M, 2014) [50].

Fig 1: Rill erosion at Research Farm, Lovely Professional University

Gully erosion

Gully erosion occurs when runoff accumulates and flows rapidly enough to detach and transfer soil particles. Gully depth is mainly limited by the level of the bedrock, hence gullies are usually less than 2meters deep. On deep alluvial and colluvial soils, gullies can reach depths of 10-15m. Gully erosion causes the environmental issues, including desertification, flooding, and lake sedimentation (Kirkby, M, Bracken, L., 2009, Torri, D. *et al.*, 2012) [52, 53] as well as agricultural production and decreased soil fertility which has a significant impact on the economy (Zhang, X *et al.*, 2018, Zabahi, M *et al.*, 2018.) [54]

Fig 2: Gully erosion at Research Farm, Lovely Professional University

The soil is dispersed by the rainfall, which is subsequently washed away into surrounding streams and rivers. Soil loss is common in areas where rainfall is very heavy and regular. Floodwater erodes a lot of soil by generating potholes, rock-cut basins, and other features (Julien, Pierre Y. 2010) [4].

B. Agriculture
Soil erosion is primarily caused by farming methods. Agricultural operations cause soil disturbance. The field is ploughed to sow new seeds after the trees have been cleared. Because most crops are planted in the spring, the land is left fallow throughout the winter. During the winter, the majority of the soil is eroded. Tractor tyres also create grooves in the ground, creating a natural waterway. The wind erodes fine soil particles (Cheraghi M., *et al*., 2016) [8] & (Wuepper, David; *et al*., 2020) [43]

Fig 3: Erosion of soil by agricultural operation at Soil Science Research Farm, L.P.U

Factors affecting soil erosion
1. Grazing
Overgrazing by livestock has been identified as one of the most significant causes of soil erosion and nutrient among other factors. (Bezabih *et al*. 2014; Terefe *et al*. 2020) [63, 66]. However, due to differences in land use, topography, environmental, and climatic conditions, runoff, soil, and nutrient losses are very variable (Melak *et al*. 2019) [60] & (Belayneh *et al*. 2019) [65]. The grazing animals eat the grasses and clear the land of plants. Their hooves shake up the earth. Plants are also extracted by their roots. As a result, the soil gets loose and more prone to erosion. (Apollo, M. *et al*., 2018).

Fig 4: Erosion by Grazing at Research Farm, L.P.U

2. Logging and Mining
To complete the logging operation, a vast number of trees are felled. The soil is tightly held by trees. The tree canopy shields the soil from heavy rain. During logging, the soil-protecting leaf litter is also removed. Mining activities also cause ground disturbance and make the soil more susceptible to erosion (Obreschkow, 2011) [7].

3. Construction
As a response of road construction and structures, soil erosion occurs. For building purposes, woods and meadows are destroyed, exposing the soil and rendering it susceptible to erosion.

4. Rivers and Streams
The soil particles are carried away by moving rivers and streams, resulting in V-shaped erosion. (Boardman, John & Poesen, Jean.2010) [33]

5. Heavy Winds
The wind carries the tiny soil particles to remote locations during the dry season or in semi-arid zones. This causes soil degradation and desertification. (Wainwright, *et al*., 2011) [41].

Fig 5: Wind erosion, near Play Grounds, L.P.U

Consequences of Soil Erosion
Soil erosion has a number of severe consequences:

a. Loss of Arable Land
Soil erosion reduces the soil's top fertile layer. This layer is abundant in the critical nutrients that plants and soil requirements. Crop production is hampered by damaged soil, which results in reduced crop productivity. Land degradation has resulted in a decline or loss of land performance throughout the world, whether from an ecological or economic perspective (Akhtar-Schuster M, 2017) [56].

b. Clogging of Waterways
Pesticides, insecticides, fertilizers, and other chemicals are found in agricultural soil. This pollutes the channels that the dirt washes through. Sediments build up in the water, raising the water level and causing floods. (Boardman, *et al*., 2010) [33]

c. Air Pollution
The dust particles combine in the air, causing pollution. Some toxic substances such as pesticides and petroleum can be extremely hazardous when inhaled when the wind comes, and dust plumes from arid and semi-arid regions cause widespread pollution. Air pollution is the leading risk factor as well as the world's most serious environmental threat. (Lelieveld J, *et al*., 2015; Cohen AJ, *et al*., 2015) [57, 58]. Apart from damaging environment health and lowering one's lifespan, air pollution has a negative impact on economic output. (Zivin JG, *et al*., 2012) [64].

d. Desertification
Desertification is caused by soil erosion. It converts fertile areas into deserts. Deforestation and harmful land use lead to more problems. This also results in biodiversity loss, soil degradation, and ecological disturbance. Degradation of land resources due to natural or manmade causes, which has a negative impact on soil fertility, the ecological system, and security of livelihood in dry sub-humid, arid, semi-arid, and areas. Degradation of vegetation, water logging, soil erosion, alkalinization/ salinization, and soil fertility decline are major desertification processes. (Dharumarajan, S., *et al*., 2018) [67].

e. Destruction of Infrastructure

Soil silt deposition in reservoirs and along their banks might limit their efficiency. As a result, it has an impact on infrastructure projects such as embankments, reservoirs, and drainage. It is significant because the expansion of dammed lakes may result in dam collapse, and expose infrastructure down. (Prakash and Nagarajan, 2017) & (Wang *et al*., 2012).

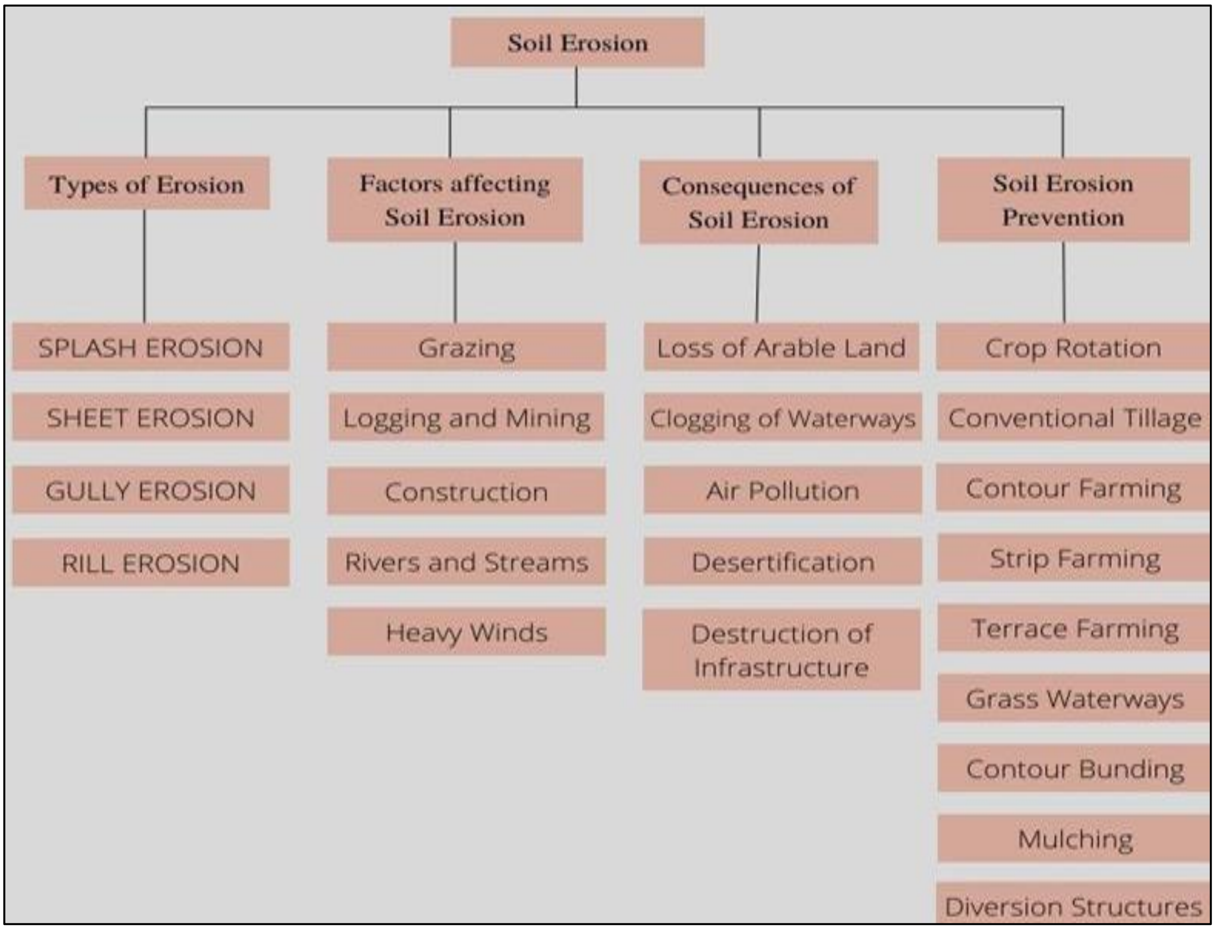
Preventative Measures of Soil Erosion

Soil erosion is a major environmental problem. Steps should be done to resolve this problem. Some methods for reducing soil erosion are as follows:

1. **Crop rotation:** Rotating high-residue crops like Hay, maize, and small grain can help minimize erosion because the residue layer prevents topsoil from being blown away by water and wind. Crop rotation & crop cover increase soil properties such as total organic carbon, microbial biomass carbon, soil aggregate stability, nitrogen content, particle organic matter (OM) and enzymatic activities. (Chu, Zaid, and Eivazi, 2016) [79].
2. **Conventional tillage:** Conventional tillage creates a smooth layer that exposes soil to erosion. Conservation tillage techniques such as strip rotary tillage, no-till planting, chiseling, and disking cover a larger portion of the field surface with crop residue, protecting the soil from erosion forces. Conservation tillage maximizes crop residues on the soil surface to decrease soil erosion because moldboard ploughs and chisels combine the organic matter (OM) on the ground with the sub-soil. Conventionally tilled soils have less residual layer on the surface. (Arora and Saygin, 2011) [80].
3. **Contour farming:** Planting in level row patterns around a hill, rather than up - and - down the slope, has been demonstrated to lessen runoff and the danger of water erosion. Prepare hedgerows after the contours have been drawn. Hedgerows allow uphill rainfall to absorb into the hillside rather than washing away nutrient-rich soil. Ditching is an alternative intervention that improves erosion control, irrigated, and farming practices. (Evans *et al*., 2012) [81].
4. **Strip farming:** Strip farming (planting crops in long strips alternately in a different cropping pattern) has proven useful in situations where a slope is particularly steep or where no other method of erosion prevention is available. (Cheraghi M., *et al*., 2016) [8].
5. **Terrace farming:** Several farmers have effectively combated erosion by cultivating in flat areas established on hillside steps (terrace farming). (Evans *et al*, 2012) [81].
6. **Grass Waterways:** Farmers can reduce most of the soil erosion caused by runoff by growing grass in regions of intense water flow, as the grass stabilizes the soil even while giving an outflow for drainage. (Whisenant, Steve G., 2008) [39] & (Boardman, *et al*., 2010) [33]
7. **Contour bunding:** Contour bunding is an artificial barrier that runs across land slopes, dividing the surface into strips and restricting water flow by reducing run-off amount and velocity. Bunds of this type protect soils from erosions and are suited for slopes of up to 6%. (Subudhi, C. R., 2018) [74]
8. **Mulching:** Mulching is a cost-effective conservation technique, is especially well suited to high-rainfall hill farming, as it reduces soil erosion and enhances soil moisture retention, and suppresses the weeds (Das *et al*. 2016, Choudhary *et al*. 2016) [78]
9. **Diversion Structures:** Often used for gully prevention, diversion structures direct water down the desired channel and away from regions prone to erosion. (Van Beek, Rens, 2008) & (Zhang, X *et al*., 2018) [54]

Other methods to overcome soil erosion

- Plant trees to avoid soil erosion on barren land.
- Cover the plant and grass beneath with mulch and pebbles to avoid soil erosion.
- Mulch mats are used to protect slopes from erosion.
- Use a succession of fiber logs to keep any water or dirt from escaping.
- At the bottom of the slope, a wall can assist keep the soil from draining or eroding.
- Every household should have a proper drainage system so that water flows down into proper water collecting systems (Blanco *et al*., 2010) [40]



Other methods to overcome soil erosion

Erosion and its Chemistry in soil

It is first defined as "the study of chemical features of soils, with a subsequent trend toward application in (1) edaphology, (the study of plant nutrition and growth) and (2) pedology, (the science of soil development or soil genesis") (Tan, 2009) and (Pal, D.K, *et al*., 2012) [86]. In the 1970s, as the environmental movement became more concerned about environmental deterioration, the focus turned to organic and inorganic toxins and pollutants that damage human and environmental health. (Amirinejad, A.A *et al*. 2011) [68].

Soil chemists, ecological chemistry, ecofriendly, a68nd other related topics are discussed. "An integrated combination of inorganic, organic materials, water, and air, known as the four soil ingredients," For all practical purposes, soil chemistry refers to the chemistry of these soil properties, their composition, structure, mutual interactions, and interactions with biospheres, hydrospheres, and atmospheres. Sand, silt, and clay help compensate for the inorganic soil fraction, which is also known as the mineral fraction. Although rock and gravel are geologic materials, pedochemical weathering may turn them into sand, silt, and clay. (Szturc, J., Podhrazska, J., 2013) [70].

Soil Mineralogy

Soil mineralogy is concerned with the chemical properties, structure, physical and chemical properties, crystal features, and electrochemical performance of sand, silt, and clay. There are three stages in the soil system: solid, liquid, and gas. The solid phase is a combination of organic and mineral material that forms the soil's skeletal skeleton. A system of pores is enclosed inside this framework, which the liquid or gaseous phases share. In micromorphological words, the soil fabric is the spatial organization of solid particles and accompanying pores, or voids. Micro morphology is now included in micropedology (Chesworth, 2008; Wilding and Lin, 2006) and (Das, B., *et al*., 2016) [46, 47, 78]

The nature of soil elements, soil organism activity, and other soil-forming mechanisms result in the formation of a sequence of characteristics with distinct soil fabrics. Although the traditional notion compares soil fabric to rock fabric, which is determined by the form and organization of minerals, it is arguably fairer to relate soil fabric to plant and animal tissue fabric. Water and organic material comprising humus and organisms, as well as a variety of organic and inorganic chemicals, make up the soil fabric. Organic compounds play a role in flora and fauna tissue, although they are rarely found in rocks.

Water is moved through the atmosphere as vapour by the wind until it comes back to the earth as precipitation. Part of it soaks into the soil, while the rest percolates underground to reach subterranean pools known as aquifers. Another half of the rainfall is lost as surface run-off, which collects in lakes and rivers before eventually ending up in the seas, where the sun's energy restarts the evaporation process. (Rodrigo J, *et al* 2015) [71]

Different types and amounts of energy can be found in soil water. Water flows because the energy concentration of water varies in different parts of the earth. Variations in the energy status of soil, and water affect the retention of water in soils, its absorption and transportation in plants, and the loss of water to the atmosphere. There are generally three types of energy engaged: potential, mechanical, and electrical (Brady and Weil, 2008) [49].

Soil Microbiology

Soil microbiology includes organic matter, which includes dead organic remains, decomposed organic material, humus, which includes humic substances products (e.g., humic and humic substances acids), and a large living biological population. However, the chemistry of the soil organic components described above is soil biochemistry, which, as previously stated, is a subset of soil chemistry. Soil organic fraction is the natural environmental property that provides a foundation for soil chemistry. (Park, J.H., *et al*., 2015) [73].

The mineral part of the soil is very variable, according to a detailed investigation. Small particles make up the soil. Massive boulders of varied mineralogies have weathered to smaller rock fragments and then soil particles, resulting in these minuscule particles. Soil particles vary in size, shape, and chemical composition. One of the most essential physical features of soil is its pore size. It regulates the flow and storage of water and air. Some are so minuscule that they can only be seen with a microscope. The three types of soil particles that have been recognized are sand, silt, and clay. These three groupings are referred to as soil separation. The particle sizes are split into three groups. Clay is the tiniest particle, whereas sand is the biggest. (Bridgham, S.D., Ye, R., 2013) [34].

Soil Erodibility

Soil erodibility is a measurement of a soil's capacity to withstand erosion based on its physical features. The texture is the most important factor in erodibility, but the shape, organic content, and permeability all have a role. Topsoil with quicker infiltration rates, higher organic matter levels, and enhanced soil structure are more resistant to erosion in general. Silt, extremely fine sand, as well as certain clay-textured soils, are less erodible than sand, loamy sand, and loam-textured soils. The higher the risk of erosion, the larger the intensity and length of a downpour. Raindrop contact on the soil surface can spread aggregate material and break down soil aggregates. Rainfall splash and runoff water quickly remove lighter aggregate materials, including extremely organic matter, silt, sand, and clay. (C. Alewell *et al.,* 2019) [84]

Bigger sand and aggregate particle require more raindrop energy or runoff volumes. The wind carries extremely fine soil particles high into the air and transports them across long distances (suspension). Fine-to-medium-sized soils are raised into the air and then fall back to the surface of the ground, causing crop damage and more soil displacement (saltation). Other indicators of soil erodibility include soil aggregation and the water aggregates percentage and reported the use of the land system has a major impact on soil aggregation, which in turn impacts erodibility. (Xie JY., 2015) [69]

Wind dislodges larger soil particles that are too massive to be lifted from the ground and rolls them along the surface of the ground (surface creep). The abrasion caused by windswept particle breaks it down stable surface aggregates, increasing soil erodibility even further. When there is extra water on a slope that cannot be taken into the soil or is retained on the surface, surface water runoff occurs. Runoff is increased by reduced infiltration caused by soil compacted, crusting, or freezing. Soil erosion is also strongly influenced by land cover and land use. (Kidane, M., *et al*., 2019) [76].

Erodibility by Agriculture operation

Agricultural runoff is at its highest in the spring, whenever the soils are normally moist, the snow is melting, and there is little flora. Tillage activities impact the possibility of soil erosion by water, based on the depth, angle, and timing of ploughing; the kind of ploughing machinery; and the number of passes. In general, the less plant or residual cover at or near the surface is disturbed, the more successful tillage is at reducing water erosion. Water erosion may be reduced by using minimal till or no-till practices. Ploughing and other practices that are carried out vertically and horizontally on-field slopes create channels for run-off water and can hasten soil erosion. Cross-slope farming and contour farming practices reduce surface water runoff concentration and soil mobility. (Chanu, P. H, *et al*., 2019) [85].

Conclusion

Eroding the uppermost soil layer by the natural process is known as soil erosion or soil degradation. It is typically caused by vegetation or any other activity that causes the earth to become dry. Soil erosion is caused by farming, construction, mining, grazing, and other activities. Floods occur when degraded areas lose their ability to hold water. Soil erosion is the biggest problem in different nations. To ensure long-term agricultural productivity, proper management of these important resources is essential. Soil Conservation Practices are strategies that a farmer may use to prevent soil erosion and increase organic matter in his or her soil. Crop rotation, low tillage, mulching, contour farming, strip farming, terrace farming, grass waterways, and contour bunding are some of these approaches.

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