JOURNAL OF RESEARCH TECHNOLOGY AND ENGINEERING, VOL 2, ISSUE 1, JANUARY 2021 ISSN 2714-1837

A review on new technologies in soil erosion management

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Abstract: Soil is one of the essential resources required in many industries, including agriculture. Decaying of soil might weaken the soil properties, composing unsuitable environment for agriculture and other activities. Soil can be eroded with water or the wind, and it has been identified as a natural process. However, an intensified erosion was observed for a few decades, with human activities worldwide. The loss of soil due to erosion might be a minimal displacement or a large scale landslide, depending on the field and level of soil decaying. There are numerous onsite and offsite consequences due to soil erosion, such as loss of yield in agricultural lands, thinning and crusting of topsoil, poor water infiltration and nutrient retention, silting in the surface water sources leading flooding, decreasing dry-water flow, and degrading environmental sustainability etc. Thus, introducing soil erosion control methods are highly important in mitigating and remediating eroded sites. In this review study, the strategies used as conventional soil erosion control, novel applications, and future soil erosion management trends are discussed. Contour planting, mulching with agricultural wastes, and physical structures such as check dams are few of the conventional methods used. There are novel technologies such as using biopolymers, geotextile materials, plastics and rubber cover as mulches, chemical treatments as soil binders, modified weeding technologies in agricultural lands, soil netting, laying of rock blankets, and other improved agronomic practices are discussed in this article. Further, the novel trends in soil erosion prediction and estimation using soil erosion modeling have been examined using examples in this article.

Index Terms: Erosion, New technologies, Soil

1 INTRODUCTION

Sustainable and secure food supply is a challenge in the changing world, with the expedited population growth expected to reach 9 billion in 2050. However, the agriculture sector faces several complications and difficulties in expanding and diversifying production due to climate change, various land degradation processes such as soil erosion, Etc. The soil erosion had influenced the agriculture-based economy, and the product prices have been notably increased during the last few decades by 0.4%-3.5% depending on the food product category [1].

Soil erosion generally means the displacement of the upper layer of soil; it is a form of soil degradation by the action of natural phenomena. Soil erosion may be a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing a severe topsoil loss. The dynamic activity of erosive agents: water, ice (glaciers), snow, air (wind), plants, animals, Etc [2]. A few decades ago, accelerated soil erosion was noticed with human-made reasons such as intensive and extensive agriculture. The soil erosion categorized as natural or the accelerated erosion depending on its severity. In the first category, soil erosion happens with natural factors. Under these factors, erosion can be categorized as water erosion, glacial erosion, snow erosion, wind (aeolian) erosion, zoogenic erosion and anthropogenic erosion are identified. In comparison, the accelerated soil erosion occurs due to human-made reasons such as deforestation, non-suitable farming practices, overgrazing where the soil loss is accelerated [3].

The accelerated soil erosion has been identified as a significant issue in agriculture and ecosystem sustainability, causing topsoil degradation, loss of nutrients, soil fertility, siltation, and eutrophication, reducing downstream water bodies' capacity driving flooding Etc. The loss of soil from farmland may be reflected in reduced crop production potential, lower surface water quality and damaged drainage networks. Soil erosion could also cause sinkholes [2].

2 SOIL EROSION CONTROL TECHNICS AND NOVEL ADAPTATIONS

A large number of erosion control methods are used to control soil erosion caused by a corrosive agent such as water, wind, animals, and humans—a few of the existing erosion control methods and current trends of soil erosion control as follows.

2.1 Mulching

Mulching is a temporary or permanent erosion control mechanism in which the crop residues, garden residues, wood chips, wood fibers, gravels Etc—used to cover the topsoil. Mulching is highly recommended as a sustainable, low-cost application in soil erosion control. Both organic (compost, grass clippings, straw, bark, leaf litter) and inorganic (stone) materials or natural and synthetic materials can be used as mulches [4]. However, the direct applications of wood or straw into the agricultural lands will reduce the N availability. According to a study conducted in a Semi-arid Mediterranean environment, the impact of adding organic mulch was clearly observed. In their study, a drastic reduction of soil loss (80%) was observed with the addition of 17.5 t/ha of olive pruning residues [5]. The effectiveness of applying straw on soil erosion control in asparagus cultivation was absorbed in the UK, and they have observed a drastic reduction of soil loss with the addition of straw. Further, they have compared the effectiveness of adding straw against compost and notably, the impact made with straw was impressive [6].

Plastic and rubber mulchers are common these days in raised bed vegetable production. Other than preventing erosion control, these mulches are used to warm the soil, control weeds, conserve soil moisture, and some landscaping applications such as in playgrounds [4].

Geotextile materials are also used as mulch in some applications, such as facilitating soil water infiltration in some exceptional cases, such as engineered landfills. These materials also facilitate the separation and filtering of materials. Geotextile can be biodegradable, such as Jute, wood fiber, paper, cotton, or synthetic materials such as plastics and mats. The Jute application, coconut coir fiber mulch is considered erosion control blankets or the hydro-mulch, which can be used in permanent vegetative lands. Hydro-mulches are used with binding agents (tackifiers) to hold the mulch together and adhere it to the soil. Seed and fertilizer can also be added to the hydro-mulch for the efficiency of planting and site stabilization [4]. Erosion control mats are also an advanced application in erosion control in steep areas, which can be made with chopped straw, wood fibers, or coconut fibers between Jute or UV-degradable plastic netting layers. There are various applications of these erosion control mats depending on slope, water velocity, longevity, and desired vegetation [4]. Fig. 1 (a) and (b) displays different types of mulches used in soil erosion control; (a) is soil covered with straw and (b) is soil covered with a wood mulch.

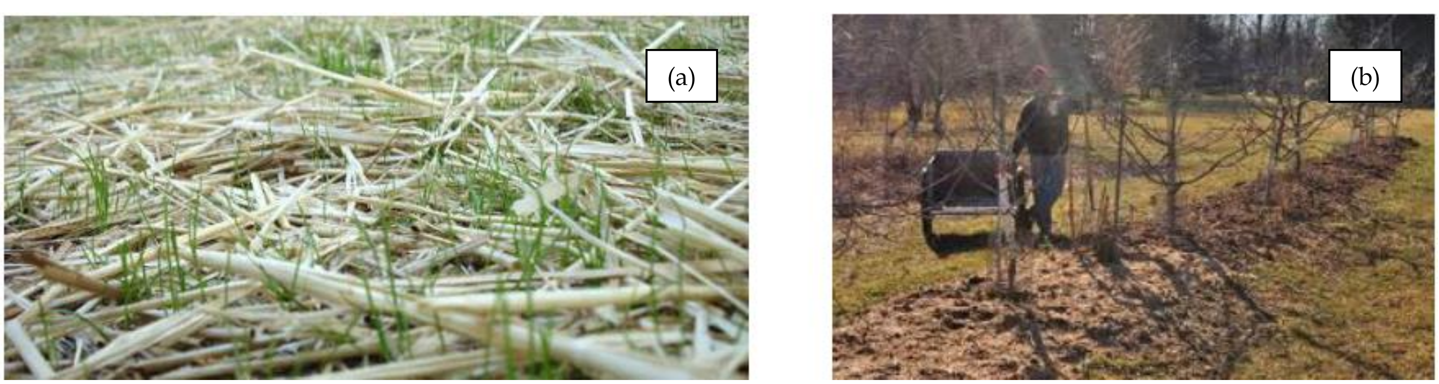

Fig. 1. Different types of mulches used in soil erosion control [4].

2.2 Soil netting

There are some anchoring materials such as jute nets, Mulch tackifiers, and Crimpers. Jute netting a netting made of jute can be applied over the mulch to protect the mulch from wind and water damage. Tackifiers help bind mulch to soil, commonly used with hydro-mulches. Organic tackifiers are made from plant materials such as guar gum, Plantago, coir fiber, or corn starch suit for flat to moderate slopes. Polyacrylamide (PAM) tackifiers last longer than organic tackifiers and are commonly applied to hold soil particles together. Crimps are used to push mulch into the soil to facilitate the proper bonding of soil and mulch. A study conducted in finding the effectiveness of different kinds of soil netting materials in soil erosion control found that reduction of soil erosion with the application. In this study,

jute mat (JM), polyester mat (PM) and polyester net (PN) were installed on slopes, and the soil erosion was estimated using both laboratory and field analysis. According to the laboratory observations, the runoff was reduced by 62.1%, 57.7% and 16.6% and soil loss was reduced by 99.4%, 98.5% and 5.5%, with JM, PM, and PN. Further, the field study conducted in Beijing China shows that incorporating JM, PM and PN increases the soil moisture by 54.5%, 36.3% and 18.7%, respectively and reduction of soil temperature encouraging plant growth in the fields. Thus, they propose using geotextile in sloppy lands to prevent soil erosion by creating favourable conditions in crop growth [7]. Fig. 2 shows a picture of plastic netting that can be used in soil erosion control.

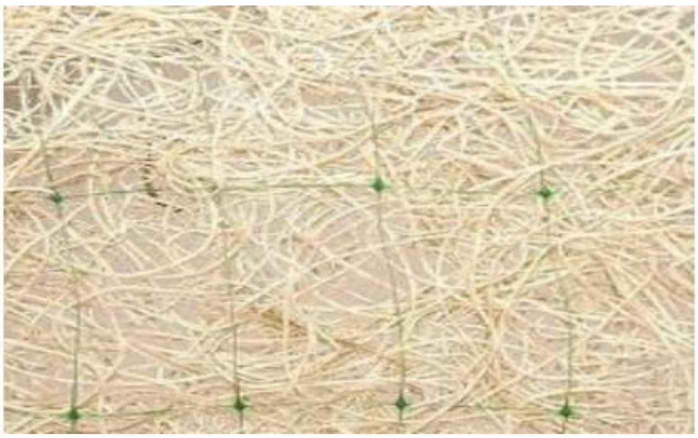

Fig. 2. Plastic netting [4]

2.3 Wattles or fiber rolls

Wattles or fiber rolls are the nettings in tube shape filled with grasses, straw, coir dust, coco fiber Etc. These nettings are usually made with biodegradable materials such as jute, coir, burlap, or synthetic materials, such as polypropylene. These wattles will reduce the flow velocity of runoff water and protect soil against sheet flows and improve sedimentation by acting as a barrier. Appling wattles are done as the final step after completing all the other earthworks to protect the topsoil.

Using coir netting is also an emerging trend in soil conversation by erosion. A study conducted in Idea, using coir nettings, found a drastic reduction of soil loss with the monsoon times. They have observed 99.6% during the pre-monsoon, 95.7% in the monsoon and 78.1% during the post-monsoon reduction in soil loss in the fields covered with coir netting in the non-protected plot. Further, the annual loss from protected plots found to be 94.9% less compared to non-protected plots [8]. Fig. 3 shows the field netting done with coir netting in their study.

Fig. 3. Coir netting used in soil stabilization [8]

2.4 Rock fibers

Rock blankets are placed by keeping small aggregates loosely on the top soils. Rock blankets have commonly applied the places where re-vegetation is difficult and are often used on steep slopes, but not greater than 2:1. This option can be applied simultaneously with other applications such as rock-joint planting. Those will further stabilize the soil. Sometimes geotextile is used depending on the slope before layering the rock blankets to reduce soil erosion. The rock blankets require less management or maintenance unless rocks have dislodged [9].

2.5 Contour planting

Contour planting is another method in soil erosion control. In this method, crops are grown along the contour or across the slope. These contour lines cause water breakage, which reduces the formation of rills and gullies during periods of high water flow. The water break also allows more time for the water to settle into the soil. Erosion can be effectively reduced by planting contours of inhabitable farms on hill slopes and other structural conservation methods. Other than the erosion loss facilitated by contour farming, it has been proved to reduce fertilizer loss, power and time consumption, and wear on machines and increase crop yields Etc. Good results can be obtained when contour farming used in conjunction with such practices as strip cropping, terracing, and water diversion. The soil erosion control mechanism by contour planting is simple but interesting; when the eroded soil particles reach a contour barrier, it slows down, the soil particles settle out, and facilitate the soil water infiltration.

Using Biological hedges is another practice in conventional soil erosion management, but it still applies the novel technologies with this and improves soil protection. Trees in hedges act as a vegetative barrier along the contours, providing sustainable alternatives in erosion management in places where extensive scale management is no longer possible. The hedges may consist of living or dead matter of biological origin, facilitating the runoff soil accumulation in slopes while providing soil organic matter and improving the soil water infiltration by slowing the runoff flowrate. Alley cropping, graded hedgerows, SALT hedges are placed under this category. *Gliricidia, tithania diversifolia,* and *erythrina veriegata* are some of the common plants used in hedges. In a study conducted in Kenya found that the effectiveness of using hedges in erosion control. In there, the soil loss was reduced by 50% at the field covered with natural hedges [10].

Grass hedges are also established across the slope species recommended: *vetivetia zizanioides* (Fig. 4), *cymbopogon nardus, and cymbopogon citratus.* Vetiver, a very fast-growing grass and, until very recently, a relatively unknown plant, process some unique features both grasses and trees by having profusely grown deep penetrating root system that can offer erosion prevention and control the shallow movement of surficial earth mass. Vetiver grass technology (VGT) involves applying this unique grass in erosion and sediment control in agricultural lands, land stabilization in civil construction, mining rehabilitation, and flood mitigation. Here are the benefits of using this technology; The significant advantage of VGT over conventional engineering measure s is its low cost; secondly, as with other engineering technologies, VGT provides a natural and environmentally friendly method of erosion control [11].

Fig. 4. *vetivetia zizanioides* [11]

Traditionally, the cover crops are used in erosion control, and this has been identified as a great tool in sustainable erosion control. The plant roots in the soil hold the soil particles tightly, and covering the topsoil also protects the soil from rainfall splatter. The recommended cover crops are *calopogonium mucuanoides* and *desmodium* species.

2.6 Microbially induced soil stabilization

Microbially induced salt stabilization is one of the well-known phenomena applied in improving porous geomaterials' engineering properties. Calcite precipitation through urea hydrolysis (ureolysis) is commonly used as the chemical agent in this application, which increases the stiffness and shear strength of granular soils. Application of ureolysis technology might reduce the internal soil erosion caused by physical and chemical fluid flow interactions. Bacterial induced ureolysis process is found to be much effective than the conventional methods. A selected species of bacteria is injected into the soil, which expidite the process and enhance the effectiveness [12]. Fig. 5 exemplifies a Scanning Electronic Microscope (SEM) graphs of MICP treated gravel-sand mixture observed in the same study.

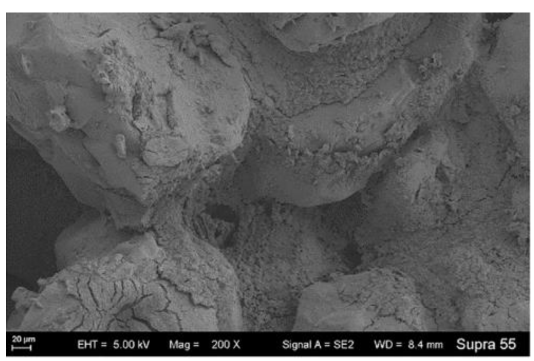

Fig. 5. Scanning Electronic Microscope (SEM) graphs of MICP treated gravel-sand mixture

2.7 Check dams

Check dams are applied for the areas under severe erosion as a physical structure to reduce the down-cutting of water in gullies. Check dams are designed to trap and safely discharge water by lowering the gully gradient by providing periodic steps. Check dams are created as a stepped canal bed profile, which reduces the water velocity running off, ultimately halting the soil erosion. There are different types of check dams, such as Rock pilled check dams, stone check dams, and wooden check dams, depending on the site and site topography.

Live check dams are another design of check damns made of living plants. Here large woody cuttings are planted along the gully. The selection of planting locations usually follows the contours. Thee will act as substantial barriers and trap the materials from moving down. In a study conducted in China found that the impact of implementing check dams in erosion control. The soil sedimentation was 100% in their field study, recommending strengthening the management and construction technology standards of check dams [13]. Fig. 6 elaborates different kind of check dams; (a) Wooden check dam, (b) a rock pilled check dam and (c) a stone check dam.

Fig. 6. Different types of Check dams [14]

2.8 Use of soil amendments

Biochar, a carbon-rich product developed with slow pyrolysis of biomass materials, is commonly used as a soil conditioner. The application of biochar might improve the soil properties, such as soil organic matter content (SOM), water holding capacity, and several other physiochemical properties.

The enrichment of soil with SOM might improve soil aggregation and stability since biochar acts as a recalcitrant C, and the availability of organic functional groups in their surfaces. According to the [[15]], amending highly withered soil with biochar reduced the soil loss drastically; there was a 50% and 64% reduction of soil loss observed at 2.5% to 5% of biochar application, respectively. Further, in their study, they have observed the improvement of soil qualities such as soil pH, cation exchange capacity, water holding capacity, microbial biomass carbon with biochar application.

A study conducted in Kuwait also found the effectiveness in applying soil amendments in reducing wind erosion. According to their findings, a drastic reduction of wind erosion was observed using biochar and animal manure to the topsoils. Thus, this can be introduced as a sustainable approach to soil erosion control in dessert areas [16].

2.9 Stone bunds

The stone band is used on a steep slope, where the soil is not stable enough to keep as risers in terraced lands. The stone bund's foundation is laid down to 22.5 cm, and the bund is raised about 45cm from the upper side. Generally, these bunds are usually constructed for a width of 60 cm [14].

2.10 Silt fences

Silt fences are permeable fences made with synthetic materials to trap the eroded soil before leaving the site. This is a costly method that will require a higher cost in maintenance but still important in some sites where temporary field stabilization actives are going on [14].

2.11 Chemical stabilizers

Some chemicals such as Vinyl, asphalt, rubber, anionic and nonionic polyacrylamide is used in the temporary stabilization of soil. Once these chemicals are sprayed into the ground, it will hold the soil particles and prevent water or wind erosion. This is a typical application, especially during earthworks. The chemicals application is also possible to the places where plants are not growing, temporary stockpiling, rough gradings, Etc. Biopolymers such as chitosan, cellulose, cotton microfibrils, and starch will also facilitate binding soil particles. Using biopolymers is promoted by many countries considering the health and environmental impact of other chemicals [17]–[19].

2.12 Soil erosion prediction technology

Soil erosion prediction method has produced a new generation of soil-erosion prediction technology based on hydrologic and erosion science fundamentals. The prediction of soil erosion is essential in evaluating future risk and applying mitigation mechanisms before the conditions become severe [20]. There are different tools and computer-based models used to predict future soil erosion loss and risk based on the universal soil loss equation. Remote sensing and sediment transportation modeling can be coupled in the further improvements of these models. Erosion risk maps could be generated considering soil erosion in a particular area. Erosion is observed through the mapping system, and the best solutions to reduce soil erosion are carried out. The marked place will support various erosion control technologies ranging from very simple to very complex models. Computer and use of the database will become more widely used and make erosion prediction technology more comfortable. New pathways are opening up as this is a major activity in erosion control [14], [15], [20]–[25].

3 Conclusions

Soil erosion is found as a crucial factor in land resource management. Soil degradation reduces the land value, land productivity and stresses the agriculture-based economy. Management of soil erosion is critical; there are several conventional soil erosion control techniques. However, new improvements are necessary with the accelerated soil erosion caused by human activities. In this review study, a set of novel techniques used in agriculture and geological applications and their effectiveness were identified and complied. Use of new mulching materials, geotextile netting, rock fibres, physical barriers such as check dams, stone bunds, silt fences and chemical stabilizers were identified as novel physiochemical tends in soil erosion control.

Further, some biological measures were identified as new soil erosion control trends, such as new planting materials as hedges, microbiologically induced soil erosion control, and soil amendment. Improving and re-searching these technologies and new findings must be a must when considering soil erosion's annual soil loss.

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