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REVIEW

Nurturing Earth's Foundation: A Comprehensive Review of Soil Conservation Strategies, Challenges and Solutions

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Abstract

Depending on the country, many challenges affect the availability and quality of food, as well as their nutritional status. This is due to intensive agriculture and the exploitation of external inputs, which are degrading the soil, water, and genetic resources, thereby affecting agricultural performance. Soil conservation is an effective and environmentally friendly technique for promoting modern agriculture that helps in the production of food without hurting the environment. Some of the systematic measures used in soil conservation are contour cultivation, terrace cultivation, cover crops, crop rotation, agroforestry, and the like. However, the application of these strategies is not exempt from difficulties, although they are one of the most promising sustainable solutions. These challenges include technological difficulties, the adoption of conservation tillage practices, and long-term research priorities. This is an attempt to provide a brief overview of various strategies in the field of soil conservation, the multifaceted challenges that arise in these processes, and the methods employed to address these difficulties. In conclusion, we feel that the Ministry needs to organize training programs on adequate measures for soil conservation, as policy assistance concerning capacity building is crucial. Given the challenges identified, it may be effective to introduce the elements of soil conservation into the ministries, departments, or institutions concerned and encourage local stakeholders to participate in the process of solution acceptance and implementation.

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Statement of Sustainability: This research was carried out to give insights that highlight the primary need of conserving the soil to maintain the health of the soil that is essential for the reinforcement of agriculture, ecosystems, and environmental sustainability. It illustrates diverse and important soil functions, such as nutrient supply, water-holding capacity, and microbial habitat. The study also explored the impacts of climate change, human land use, and inappropriate land use on soil degradation food security, and the ecosystem. It calls for appropriate soil conservation to offset these negative effects that will be fruitful for upcoming generations.

1. Introduction

Soil is a diverse and multilayered material that supports terrestrial organisms and is a fundamental component of life on Earth. Soil is a prime material for plant growth media made up of organic matter, minerals, water, and air (Shabir et al., 2023). They also help to supply nutrients and an anchor for plants. It holds water, determines the alternation of nutrients, and harbors all forms of microbes (PLANTE, 2007). Physical, chemical, and biological activities are involved in the process of determining soil fertility, structure, and general health (Delgado and Gómez, 2016; Parajuli et al., 2022). Soil is an active component of biogeochemical cycles, and it is the dynamic interface between the lithosphere, atmosphere, hydrosphere, and biosphere (Martin and Johnson, 2012). It impacts various areas such as climate patterns, water resources, ecosystem sustainability, and sustainable agriculture (Powlson et al., 2011). The conservation of the soil is very important, though it is a non-renewable natural resource which has become a key global concern because soils are a limited resource (Aleminew and Alemayehu, 2020). Therefore, its conservation plays a huge role such as supporting farming, sustaining species, and controlling water quality in the world (Raj et al., 2019). Then again, the adverse consequences of climate change, massive human encroachment, and unwise land use have led to serious cases of soil erosion and degradation, which pose a real threat to the future viability of agricultural production as well as the general wellbeing of ecosystems (Hossain et al., 2020; Chaurasia et al., 2024).

Soil conservation is not only a concern at the local level but also has to be prioritized on the global level (Bullock and King, 2011). Loss of productive land, often accelerated by massive deforestation, improper cultivation practices, and unabated urban expansion, clearly and unambiguously endangers global food security in the present context (Katyal et al., 2016). It is also noteworthy that in conditions of food deficiency, people from both urban and rural areas depend to a great extent on gathering local fruits, vegetables, medicinal plants, and other useful resources (Chaurasia et al., 2020). The effects of soil erosion do not reduce only a decrease in agricultural production but also have adverse effects on water bodies by polluting water through sedimentation, thus affecting water quality (Issaka and Ashraf, 2017). Furthermore, the importance of international collaboration in soil conservation intensifies due to the interconnection between soil health, other environmental factors like climate change, and the growing crisis of reduced biodiversity on Earth (Thiele-Bruhn et al., 2012). It is now seen as necessary not only to preserve the capability in soils for supporting the livelihoods of humankind and producing food and feed for the world's growing population but also crucial for maintaining ecosystems, mitigating the effects of climate change, and enhancing the presence of resilience in the landscapes of the earth (El Chami et al., 2020).

Under such circumstances, soil conservation emerges as a phenomenon that necessitates solutions at both local and global levels, including joint efforts, large-scale research and development projects, effective policies, and local approaches (Hurni et al., 2008). For the benefit of future generations and Earth's inhabitants, countries must adopt appropriate measures to protect the soil environment, while simultaneously exploring ways to boost agricultural yields and productivity while maintaining environmental sustainability (Govers et al., 2017). Therefore, the main purpose of this study is to examine, present information, and help future researchers draw attention to the importance of soil conservation for increasing soil fertility. Analysis of the current state of knowledge revealed that people nevertheless pay insufficient attention to approaches for soil conservation measures, even though the clear benefits of these strategies have on soil properties.

2. Methodology for Literature Survey

The article is constructed utilizing secondary data and information obtained from government documents, published research papers from the years 1992 to 2024, reports from diverse organizations, and pertinent websites that were thoroughly examined. The data for this study was gathered utilizing a systematic approach. A complete search for existing literature was conducted using electronic sources such as Google Scholar, PubMed, Scopus (Elsevier), Web of Science, Semantic Scholar, Academia, and other relevant websites. The sources underwent a comprehensive examination, and the conclusions were presented concisely. Furthermore, an essay was prepared after consulting with lecturers from IAAS and AFU.

3. Methods of Soil Conservation

3.1. Contour Plowing

Rather than plow the soil vertically up and down slopes, farmers use a technique called contour plowing, which follows the natural curves of sloping ground (Gebreegziabher et al., 2009). This technique serves to slow down water runoff, preventing soil erosion and the development of gullies by adhering to the contour lines (Valentin et al., 2005). Contour plowing creates horizontal furrows that act as barriers to water flow, enabling it to seep into the soil over time and lowering the possibility of topsoil erosion (Saggau et al., 2023). This method not only prevents erosion but also improves soil fertility and structure by reducing sedimentation (Ghimirey et al., 2024). Improved soil moisture retention is a benefit of contour plowing, especially in regions with erratic topography. Furthermore, this method encourages agriculture to use water more effectively, which can be very important in areas where water scarcity is an issue. Beyond just preventing erosion, it also helps maintain biodiversity, sustainable land management techniques, and eventually the long-term productivity of agricultural fields (Shinde et al., 2019). Adopting soil conservation measures led to some experimental findings. Stevens et al. (2009) reported that contour culture significantly reduced surface runoff compared to up- and down-slope cultivation, although this difference was not statistically significant. In addition, the pattern of sediment and phosphorus losses was similar to that of runoff; contour cultivation produced smaller losses than traditional cultivation techniques. Similarly, Thapa et al. (1999) study revealed that in the mountainous upland soils of the humid tropics, contour grass barrier strips successfully conserve soil by preventing soil movement, lowering translocation flux, and lowering the rates of tillage erosion. These strips serve as organic buffers along the land's contour, reducing soil and water movement to stop soil erosion and topsoil loss. In agricultural environments, their presence minimizes erosion and maintains soil integrity by improving soil stability during tillage operations (Busari et al., 2015).

3.2. Terracing

Among methods of controlling water runoff and ultimate diminution of soil erosion on a slope or steep landform, the method is terracing. This involves developing a chain of stepped levels in the contour lines of the landscape thereby making steep topography to be levels of terraces (Rosenbloom and Anderson, 1994). These terraces act as a buffer and they subdivide the slope into smaller portions, control water flow, and diminish soil erosion (Deng et al., 2021). Because the water is channeled down from one level to another in a controlled manner, less surface runoff is observed and terracing enhances the chances of water absorption from the soil surface. This enhances water infiltration and water holding capacity of the soil and at the same time protects against erosion of the valuable arable layer (Chen et al., 2017). A type of conservation tillage used in agriculture on specific land is terracing which helps in boosting up the agricultural productivity from the rugged land with the conservation of soil structure and landscapes (Bhattacharyya et al., 2016).

Hammad et al. (2004) noted that in a Mediterranean environment, stone wall terracing was seen to decrease the rate of runoff and increase the ability of water to infiltrate into the soil hence helping to conserve soil water. Reducing the likelihood of erosion and enhancing the quantity of precipitation that infiltrates the soil is favorable for wheat plants because they contribute to the more efficient distribution of water in the crops, leading to increased crop productivity (Bhat et al., 2019). Research findings have shown that terrace structures increase the absorption of the terrace soil by 16%, reduce the loss of soil and nutrients, and improve the yield of wheat between 2005 and 2010 by 20% (Rashid et al., 2016). Those practices also minimized the gully formation and runoff that farmers ought to apply terraces to improve the soil moisture and minimize soil erosion.

3.3. Cover Cropping

It is one of the easiest and most fruitful soil conservation methods for the reduction of soil erosion. Intercropping, for example, growing legumes or grasses between cash crops or when the main crop is not grown, cuts the chances of soil being washed away by either water or wind (Blanco-Canqui et al., 2022; Chaurasia et al., 2024). This is because their root structures run deep into the ground creating a firm stand for the soil. The cover crops and above-ground biomass, play the role of providing a barrier to guard the soils from impact by rainfall and prevent surface runoff (Zuazo and Pleguezuelo, 2009). Additionally, the plant residues from the cover crop act as a much that minimizes the formation of soil crusts and enhances water absorption. In the same regard, cover crops enhance the general health of the soil with structure and organic content, increase the resistance of the ground to erosive forces, and retain significant topsoil for sustainable agriculture (Fageria et al., 2005). According to Little et al. (2004), cover crops helped in sustainable potato production by replenishing soil nutrients and acting like green manure. Significantly, white lupin and brassica both can execute the process of biofumigation and equally manage to liberate phosphorus from soil enrich soil health, and also reduce the rate of plant diseases.

3.4. Crop Rotation

Crop rotation is an effective and environmentally friendly method of agriculture since it helps to conduct structural changes to the soil, decrease the likelihood of splash erosion, and decrease nutrient content depletion from the surface soil layers (Bullock, 1992). It is the practice of avoiding growing a particular crop in a certain area for a certain amount of time and changing crops in a particular sequence during a certain number of crops' growing seasons (Chapagain et al., 2020). The increased availability of many forms of plants contributes positively to the quality of the soil as well as reduces its tendency to erode (Lal, 1998). One can understand that different crops require different amounts of nutrients, which in turn can contribute to the improvement of the humus content in the soil, as well as help to eliminate such negative factors as increased density of the soil (Timsina, 2018). Also at certain times, the primary income crops may not be growing and this is when other crops like the cover plants or the deeply rooted plants are planted to keep the soil alive or to check on the rate of percentage soil erosion (Mrunalini et al., 2022). Crop rotation therefore facilitates long-term management of the soils and sustainable practices in handling the lands so that they do not erode easily as depicted in Figure 1.

3.5. Agroforestry

Agroforestry is a sustainable land management system that involves stocking or growing crops alongside trees or bushes (Kang and Akinnifesi, 2000). This serves a key role in protecting the land from gully and stream or river bank erosion and the movement of soil inhabitants (Marahatta et al., 2024). Through their extensive branching networks in the roots, trees contribute to soil stabilization and reduce the prospects for wind and water-borne types of soil erosion (Atangana et al., 2014). Also, tree canopies help shelter the soil surface from rain impact, and organic materials from trees and litter help improve the structure, moisture, and nutrients in the soil (Fahad et al., 2022). Through diversity in Agroforestry systems, vegetation cover that can be double or even triple layer helps in protecting the soil, enhancing the biological diversity and the health of the general ecosystem (Dagar, 2016).

The author Muchane et al. (2020) stated that this rate of soil erosion decreases by 50% when farmers embrace the growth of trees in their farming practices such as growing different types of cereals at a given time. Some of the studies further suggest that the agroforestry system has a positive impact on the structure stability of the soil base, reduces the rate of runoff, and enhances the infiltration capability (Ghimirey et al., 2023). Besides, the soil property outcomes of agroforestry revealed a 2% increase in the pH level and perceived ecosystem services through enhanced security of soil organic carbon by 21%, nitrogen storage by 13%, and a 46% increase in accessible nitrogen and 11% of available phosphorus (Muchane et al., 2020). From the study by Diallo et al. (2019), it is evident that *Faidherbia albida* and *Piliostigma reticulatum* plant-based agroforestry help to enhance the chemical attribute of the soil throughout a hundred soil samplings in a semi-arid area of Niger. The study reveals that under the tree crown specific increases in organic carbon, ammonium nitrogen phosphorus, potassium, calcium, and sodium are observed than the content in the crown neighborhood and control positions (Penne et al., 2010).

3.6. Windbreaks

According to Ucar and Hall (2001), windbreaks, placed deliberately in rows of trees or bushes to lessen the effect of wind on the terrain, are essential for preventing soil erosion. Windbreaks function as barriers to reduce wind speed and produce a sheltered area on the leeward side (Brandle et al., 2004). This shelter lessens the likelihood of lifting and carrying away soil particles propelled by the wind. Because windbreaks prevent wind erosion, they contribute to soil stability, especially in exposed and open agricultural settings (Podhrázská et al., 2021). Additionally, windbreaks improve microclimatic conditions by reducing the drying effect of high winds on the soil (Brandle et al., 2021). Windbreaks provide a protective role that is particularly helpful in arid and semi-arid environments where wind erosion can cause productive topsoil to deteriorate (Guo et al., 2014). All things considered, windbreaks are an important instrument for sustainable land management techniques because they effectively protect the soil from the erosive effects of wind (Bielders et al., 2001). Chang et al. (2021) observed that windbreaks significantly reduce soil erosion by lowering wind speeds. This results in a 20% reduction in soil loss when compared to unprotected farms. At heights of 0.2 meters and 2 meters, respectively, the wind velocities decrease by 27% to 30% (Scheper et al., 2021). Banzhaf et al. (1992) found that reducing the windbreak spacing from 90 to 6 meters dramatically reduced the average wind speed from 2.8 to 2.1 m/s in the years 1985-1987. This resulted in a 15% reduction in potential evaporation and a 50-70% reduction in wind-blown soil particles. Despite these advantages, subsurface water reserves were 14 mm lower at the 6-meter windbreak spacing than at the 20-meter spacing, suggesting that the windbreak vegetation was significantly absorbing water, as Asaro (1996) mentioned.

3.7. Conservation Tillage

Reducing tillage and no-till farming are two types of conservation tillage (Derpsch, 2003). Known as methods for soil conservation and management, these are very essential to reducing soil erosion and fostering sustainability in agriculture (Zuazo and Pleguezuelo, 2009). No-till farming entails minimum disturbance of soil by leaving the crop residues from the previous year's crop, thus acting as an effective measure against soil erosion and the risk that comes with planting crops due to the conservation of soil structure (Somasundaram et al., 2020). Lower tillage leads to less tillage operations, thus there are fewer moments that the soil is disturbed therefore offering better support to the soil and any organic matter on the soil (Mehra et al., 2018). These practices help contribute to forming a protective crust on the top layer of the soil to reduce the flow of water on the surface and the velocity of the droplets of water (Jakab et al., 2017). Conservation tillage enhances the water penetration and water retention capacity, organic matter, nutrient status, and structure of soils which helps to decrease the factors triggering the soil erosion (Peigné et al., 2007). In conclusion, these tactics protect valuable topsoil, which in turn minimizes erosive influences on the land or territory and promotes the feasible and sustainable management of agricultural land (Abdelhak, 2022). As evidenced by Seitz et al. (2019), conservation tillage lowers soil erosion risks greatly; for those in the organic farming faction, reduced sediment delivery is slashed by 61% from 1.87 to 0.73 t/ha. The conventional practice of farming and the no-tillage farming retained the least amount of sediment yield (Tapia-Vargas et al., 2001). The studied average delivery was below the maximum delivery of 3 t/ha to 27 t/ha. First a high level of tilling improved the level of the organic matter from 1.5 t/ha to 46 t/ha (Li et al., 2014). Langdale et al. (1992) did a similar study and discovered that runoff coefficients were down to 6% from the previous 35% on conventional tillage soils; therefore, it proved that conservation tillage helps to prevent soil erosion. Besides, deep-tillage treatments enhance the content of soil organic carbon in the 0-5 cm layer from 0.97% to 2. 37% and also decrease rill and inter-rill erosion rates in soils by a corresponding percentage (Osman, 2018). It also enhances the nitrogen level, compaction, and water-stable aggregation of the soil, and ultimately increases crop production on eroded Ultisols.

3.8. Grassed Waterways

Erosive currents produced by water flow are effectively protected through a conservation strategy known as grassy rivers according to Mekonnen et al. (2015). They are incorporated mainly in agricultural lands and deliberately evolve and repair their banks with grass or any plants with high resistance to erosion (Erktan et al., 2013). Grassy waterways reduce the speed of water by directing water through the vegetation channels where water does not carry silt and through this, does not encourage soil erosion (Zuazo and Pleguezuelo, 2009). Grass does easily get washed by the flowing water because of the large root system of such plants (De Baets et al., 2006). The vegetation also minimizes the ability of the water bodies to shed off sediments because it forms a barrier on the walls of the lake (Morris, 2020). To summarize, grassed streams act as essential features in agriculture as they help in the management of soil and water quality, besides preventing soil erosion (Dosskey et al., 2010). Fiener and Auerswald (2003) stated that grassing of the streams (GWWs) reduced sediment delivery by 97% in a watershed and 77% in another, thus reducing options available for soil erosion. There was a 90% reduction in runoff in one of the watersheds under study and a 10% decrease in runoff within the second watershed without GWWs (Fiener and Auerswald, 2005). It has also been identified that these GWWs' shape affects their efficacy; particularly, the flat ones with wide base indications display greater sedimentation rates (Boano et al., 2020).

3.9. Contour Buffer Strips

Contour buffer strips reduce soil erosion in sloping environments caused by water runoff. Planters normally plant these strips perpendicular to the slope, using vegetation such as cover crops or grasses to slow down water flow (Dabney et al., 2006). Contour buffer strips lessen runoff velocity by obstructing the direct path of running water, therefore reducing soil erosion (Yousuf et al., 2019). These strips' vegetation functions as a physical barrier, holding sediments in place and preventing them from moving below (Poeppl et al., 2020). Furthermore, the plant roots improve soil stability and lessen the chance of erosion. All things considered, contour buffer strips are an important tool for sustainable land management since they prevent soil erosion and improve the general well-being of agricultural ecosystems (Melicher and Špulerová, 2022). Garrity's (1999) study revealed that water flow is slowed by contour buffer strips, which lowers soil erosion and boosts yields by 0.5 t/ha crop. In addition to increasing land values and encouraging investment in intensive farming systems, this technique conserves soil (Kassam et al., 2014). Furthermore, it has stimulated institutional innovation in the Philippines' southern regions by empowering farmer-led Landcare organizations to promote agroforestry among thousands of households (Franzel et al., 2004).

3.10. Straw Mulching

Using straw, which covers the soil surface, is an effective way of preventing it from eroding. This method involves mulching the soil with straw or any remaining crop residues; this acts as a shield against the effect of raindrop splash (Waheed et al., 2023). Straw mulch reduces the impact of rainfall on the soil, thereby reducing the displacement of soil particles and the occurrence of surface runoff (Ngosong et al., 2019). Also, the mulch assists in retaining moisture in the soil, regulating temperatures, and promoting water intake (Demo and Asefa, 2024). Moreover, when straw mulch degrades over time, there is an enhancement of the physicochemical properties and microbial quality of the soil, which would reduce the effects of soil erosion and the overall health of the soil (Prem et al., 2020). By providing a long-term, and economical answer to the issues, this simple method is most beneficial in areas where soil erosion prevails. It shields the soil from the destructive margins of precipitation (Jafari et al., 2022). Bhatt and Khera (2006) found that minimum tillage, when combined with straw mulching, enhances the physical attributes of the soil and slows down soil erosion. Additionally, mulching reduces runoff water by one-third and slows down soil loss, particularly when the mulch covers the entire plot (Iqbal et al., 2020). Likewise, it improves fertility status by raising the maintainable moisture content to 3-7% and lowering the soil temperature by 1.4–2.4 °C (De Jager and Giani, 2021).

3.11. Sediment Basins

Sediment basins are one important component of the strategies for controlling erosion caused by water runoff, which is common in agricultural activities (Rickson, 2014). According to Liu et al. (2015), these basins serve as a temporary sediment accumulation point by storing sediment-rich water before it discharges into water bodies. Finally, as water enters the basin, its velocity decreases, making it incapable of transporting sediment particles, which ultimately settle in the basin (Wang et al., 2017). This reduces the risk of adverse effects on areas used for farming or construction, as the sand doesn't travel downstream and carries away soil particles (Kang et al. 2016). In the context of preventing the loss of bottom sediment from degenerating fields and construction sites or retaining it from polluting water sources, sediment basins can prove to be extremely beneficial (Molle et al., 2010). Sediment basins that are well-designed and implemented play an integral role in preserving soil fertility as well as water quality, and, if possible, removing the effects of soil erosion on water systems at a later date (Mekonnen et al. 2015). According to Mekonnen et al. (2015), GI has proven helpful because it employs sediment basins to act as sediment traps to control sediment-loaded flows, permitting low-velocity runoff and reducing sediment transport, thereby avoiding downstream floods. In this regard, they improve soil fertility by trapping sediment that contains nutrients beneficial to the soil in the catchment, and by fostering vegetative processes that contribute to soil stability by providing organic matter (Nyssen et al., 2009).

4. Challenges in Strategies Implementation

4.1. Technological Challenges

The first of them is that the principles of conservation agriculture are now recognized, but the problem is to implement them in different situations, from a high-tech system of industrialized countries' agriculture to low-tech systems of developing countries' farmers (Jat et al., 2012). These problems are related to the innovation and adoption of implemented technology for sowing with little soil tilt, and the improvement of solutions to crop reaping and handling (Fischer and Connor, 2018).

4.2. Adoption of Soil Conservation Methods

Soil conservation methods enhance the soil's organic matter content and manage soil erosion. This state-of-the-art practice is gradually gaining acceptance in different parts of the world (Dhar et al., 2018). Compared to conventional systems, the methods of soil conservation display more complexity. The primary limitation of preaching these methods has been the absence of adequate information on the site (Christensen et al., 2009). An adequate understanding of system characteristics of flow, interactions between components, and the factors that affect the systems' performance is necessary for effective and optimal management (Melnyk et al., 2003).

4.3. Long-term Research Perspective

It is evident from the long-term perspective adopted in this study that a conservation agriculture system or no tilling with surface residue maintenance is more beneficial only in the long run as indicated by Sahu et al. (2020). As suggested earlier, the first years of applying measures reflected in the Conservation Agriculture Framework might point towards reduced yields (Pittelkow et al., 2015). For enhanced soil-water and nutrient management practices, it is essential to comprehend the nature and dynamics of changes in physical, chemical, and biological regimes (Srivastava et al., 2019). Hence, there is a need to address the need to take a long-term perspective when conducting research in conservation agriculture.

4.4. Measures to Overcome Challenges

Adaptive research is necessary to customize the soil conservation concepts and techniques to suit the specific local conditions (Shiferaw et al., 2009). Local communities and other relevant parties should cooperate to accomplish this task (Reed et al., 2006). Key areas that require attention encompass the choice of crop species, the careful selection and handling of crops and cover crops, the implementation of effective crop rotation strategies, the preservation of soil cover, and the proper operation of conservation agriculture equipment (Scopel et al., 2013). Soil conservation techniques must also be financially advantageous in the short term to increase farmer acceptance (Sattler and Nagel, 2010). Due to the limitations, they face in terms of output and food security, smallholder farmers often prioritize immediate expenses and benefits over those that may arise in the future (Jayne et al., 2010). There is a need for policy assistance to facilitate capacity building through the organization of training programs focused on soil conservation measures (Bloomfield et al., 2018). A lack of skilled personnel at the grassroots level is a significant obstacle to the implementation of these methods (Polat, 2011). Farmers need to get timely help from extension staff who are well-trained and motivated for soil conservation methods to be incorporated into the right ministries, departments, or institutions (Afrad et al., 2019). This is also true for making sure there are enough material, human, and financial resources available (Chaurasia et al., 2023).

5. Conclusion

Thus, the importance of the implementation and the protection of numerous soil conservation programs is clear as it ensures the longevity of agriculture farming practices as well as the consistent health of ecosystems. Nevertheless, due to forces like deforestation, ill-usage of land, and change in climate among other factors that are hardly in doubt known to affect the land comprises of erosion, deterioration, and loss. Yet, there is hope; the arguments to follow will suggest that such an opinion is right. This implies that it is possible to reduce these difficulties through cooperation between different actors in the use of erosion protection measures, introduction of proper utilization of land, ventures in forestry, and raising awareness of people on the protection of the soil. Thus, for the preservation of valuable resources, increased yields, combating adverse effects of climate change, and, in a larger sense, for the survival of the planet, soil conservation and restoration should be encouraged. As such we need to seek the solutions to these problems and put them in place for future generations' benefit.

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References

Abdelhak, M. (2022). Soil improvement in arid and semiarid regions for sustainable development. In Natural resources conservation and advances for sustainability (pp. 73-90). Elsevier. https://doi.org/10.1016/B978-0-12-822976-7.00026-0

Adhikari, K., & Hartemink, A. E. (2016). Linking soils to ecosystem services—A global review. *Geoderma*, 262, 101-111. https://doi.org/10.1016/j.geoderma.2015.08.009

Afrad, S. I., Wadud, F., & Babu, S. C. (2019). Reforms in agricultural extension service system in Bangladesh. In Agricultural extension reforms in South Asi*a* (pp. 13-40). Academic Press. https://doi.org/10.1016/B978-0-12-818752-4.00002-3

Aleminew, A., & Alemayehu, M. (2020). Soil fertility depletion and its management options under crop production perspectives in Ethiopia: A review. *Agricultural Reviews*, 41(2), 91-105.

Asaro, C. (1996). The biology and impact of pine false webworm, *Acantholyda erythrocephala* (L.) (Hymenoptera: Pamphiliidae), in northern New York. State University of New York College of Environmental Science and Forestry.

Atangana, A., Khasa, D., Chang, S., Degrande, A., Atangana, A., Khasa, D., & Degrande, A. (2014). Agroforestry for soil conservation. *Tropical agroforestry*, 203-216. https://doi.org/10.1007/978-94-007-7723-1_9

Banzhaf, J., Leihner, D. E., Buerkert, A., & Serafini, P. G. (1992). Soil tillage and windbreak effects on millet and cowpea: I. Wind speed, evaporation, and wind erosion. *Agronomy Journal*, 84(6), 1056-1060. https://doi.org/10.2134/agronj1992.00021962008400060028x

Bhat, S. A., Dar, M. U. D., & Meena, R. S. (2019). Soil erosion and management strategies. *Sustainable Management of Soil and Environment*, 73-122. https://doi.org/10.1007/978-981-13-8832-3_3

Bhatt, R., & Khera, K. L. (2006). Effect of tillage and mode of straw mulch application on soil erosion in the submontaneous tract of Punjab, India. *Soil and Tillage Research*, 88(1-2), 107-115. https://doi.org/10.1016/j.still.2005.05.004

Bhattacharyya, R., Ghosh, B. N., Dogra, P., Mishra, P. K., Santra, P., Kumar, S., & Parmar, B. (2016). Soil conservation issues in India. *Sustainability*, 8(6), 565. https://doi.org/10.3390/su8060565

Bielders, C. L., Lamers, J. P., & Michels, K. (2001). Wind erosion control technologies in the West African Sahel: the effectiveness of windbreaks, mulching and soil tillage, and the perspective of farmers. *Annals of Arid Zone*, 40(3), 369-394.

Blanco-Canqui, H., Ruis, S. J., Holman, J. D., Creech, C. F., & Obour, A. K. (2022). Can cover crops improve soil ecosystem services in water-limited environments? A review. *Soil Science Society of America Journal*, 86(1), 1-18. https://doi.org/10.1002/saj2.20335

Bloomfield, G., Bucht, K., Martínez-Hernández, J. C., Ramírez-Soto, A. F., Sheseña-Hernández, I., Lucio-Palacio, C. R., & Ruelas Inzunza, E. (2018). Capacity building to advance the United Nations sustainable development goals: An overview of tools and approaches related to sustainable land management. *Journal of Sustainable Forestry*, 37(2), 157-177. https://doi.org/10.1080/10549811.2017.1359097

Boano, F., Caruso, A., Costamagna, E., Ridolfi, L., Fiore, S., Demichelis, F., & Masi, F. (2020). A review of nature-based solutions for greywater treatment: Applications, hydraulic design, and environmental benefits. *Science of the Total Environment*, 711, 134731. https://doi.org/10.1016/j.scitotenv.2019.134731

Brandle, J. R., Hodges, L., & Zhou, X. H. (2004). Windbreaks in North American agricultural systems. In New Vistas in Agroforestry: A Compendium for 1st World Congress of Agroforestry*,* 2004 (pp. 65-78). Springer Netherlands. https://doi.org/10.1007/978-94-017-2424-1_5

Brandle, J. R., Takle, E., & Zhou, X. (2021). Windbreak practices. In North American Agroforestry, pp. 89-126. https://doi.org/10.1002/9780891183785.ch5

Bullock, A., & King, B. (2011). Evaluating China's slope land conversion program as sustainable management in Tianquan and Wuqi Counties. *Journal of Environmental Management*, 92(8), 1916-1922. https://doi.org/10.1016/j.jenvman.2011.03.002

Bullock, D. G. (1992). Crop rotation. *Critical Reviews in Plant Sciences*, 11(4), 309-326. https://doi.org/10.1080/07352689209382349

Busari, M. A., Kukal, S. S., Kaur, A., Bhatt, R., & Dulazi, A. A. (2015). Conservation tillage impacts on soil, crop and the environment. *International Soil and Water Conservation Research*, 3(2), 119-129. https://doi.org/10.1016/j.iswcr.2015.05.002

Chang, X., Sun, L., Yu, X., Liu, Z., Jia, G., Wang, Y., & Zhu, X. (2021). Windbreak efficiency in controlling wind erosion and particulate matter concentrations from farmlands. *Agriculture, Ecosystems & Environment*, 308, 107269. https://doi.org/10.1016/j.agee.2020.107269

Chapagain, T., Lee, E. A., & Raizada, M. N. (2020). The potential of multi-species mixtures to diversify cover crop benefits. *Sustainability*, 12(5), 2058. https://doi.org/10.3390/su12052058

Chaurasia, J., Acharya, N., Parajuli, M., Pokharel S., Rijal, K., Lamichhane, A., Kunwar, S. (2023). Influence of group dynamics on farmers' field schools in Nepal. *Cultural Communication and Socialization Journal*, 62-65. https://doi.org/10.26480/ccsj.02.2023.62.65

Chaurasia, J., Ghimirey, V., & Marahatta, S. (2024). Understanding the Impact of Polycyclic Aromatic Hydrocarbons: Soil, Environment, and Human Health. *Environment & Ecosystem Science,* 8(2), 43-46.

Chaurasia, J., Parajuli, M., & Khadka, G. B. (2020). Changing Approach To Food Self-Sufficiency On The Scenario Of The Pandemic "Covid 19". *Environment and Ecosystem Science*, 4(1), 43-46. http://dx.doi.org/10.26480/ees.01.2020.43.46

Chaurasia, J., Poudel, B., Mandal, T., Acharya, N., & Ghimirey, V. (2024). Effect of micronutrients, rhizobium, salicylic acid, and effective microorganisms in plant growth and yield characteristics of green gram [*Vigna radiata* (L.) Wilczek] in Rupandehi, Nepal. *Heliyon*. http://dx.doi.org/10.1016/j.heliyon.2024.e26821

Chen, D., Wei, W., & Chen, L. (2017). Effects of terracing practices on water erosion control in China: A meta-analysis. *Earth-Science Reviews*, 173, 109-121. https://doi.org/10.1016/j.earscirev.2017.08.007

Christensen, S., Søgaard, H. T., Kudsk, P., Nørremark, M., Lund, I., Nadimi, E. S., & Jørgensen, R. (2009). Site-specific weed control technologies. *Weed Research*, 49(3), 233-241. https://doi.org/10.1111/j.1365-3180.2009.00696.x

Dabney, S. M., Moore, M. T., & Locke, M. A. (2006). Integrated management of in-field, edge-of-field, and after-field buffers 1. *JAWRA Journal of the American Water Resources Association*, 42(1), 15-24. https://doi.org/10.1111/j.1752-1688.2006.tb03819.x

Dagar, J. C. (2016). Agroforestry: Four decades of research development. *Indian Journal of Agroforestry*, 18(2), 1-32.

De Baets, S., Poesen, J., Gyssels, G., & Knapen, A. (2006). Effects of grass roots on the erodibility of topsoils during concentrated flow. *Geomorphology*, 76(1-2), 54-67. https://doi.org/10.1016/j.geomorph.2005.10.002

de Jager, M., & Giani, L. (2021). An investigation of the effects of hydrochar application rate on soil amelioration and plant growth in three diverse soils. *Biochar*, 3(3), 349-365.

Delgado, A., & Gómez, J. A. (2016). The soil. Physical, chemical and biological properties. *Principles of Agronomy for Sustainable Agriculture*, 15-26. https://doi.org/10.1007/978-3-319-46116-8_2

Demo, A. H., & Asefa Bogale, G. (2024). Enhancing crop yield and conserving soil moisture through mulching practices in dryland agriculture. *Frontiers in Agronomy*, 6, 1361697. https://doi.org/10.3389/fagro.2024.1361697

Deng, C., Zhang, G., Liu, Y., Nie, X., Li, Z., Liu, J., & Zhu, D. (2021). Advantages and disadvantages of terracing: A comprehensive review. *International Soil and Water Conservation Research*, 9(3), 344-359. https://doi.org/10.1016/j.iswcr.2021.03.002

Derpsch, R. (2003). Conservation tillage, no-tillage and related technologies. In Conservation agriculture: environment, farmers experiences, innovations, socio-economy, policy (pp. 181-190). Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-017-1143-2_23

Dhar, A. R., Islam, M. M., Jannat, A., & Ahmed, J. U. (2018). Adoption prospects and implication problems of practicing conservation agriculture in Bangladesh: A socioeconomic diagnosis. *Soil and Tillage Research*, 176, 77-84. https://doi.org/10.1016/j.still.2017.11.003

Diallo, M. B., Akponikpè, P. I., Fatondji, D., Abasse, T., & Agbossou, E. K. (2019). Long-term differential effects of tree species on soil nutrients and fertility improvement in agroforestry parklands of the Sahelian Niger. *Forests, Trees and Livelihoods*, 28(4), 240-252. https://doi.org/10.1080/14728028.2019.1643792

Dosskey, M. G., Vidon, P., Gurwick, N. P., Allan, C. J., Duval, T. P., & Lowrance, R. (2010). The role of riparian vegetation in protecting and improving chemical water quality in streams 1. *JAWRA Journal of the American Water Resources Association*, 46(2), 261-277. https://doi.org/10.1111/j.1752-1688.2010.00419.x

El Chami, D., Daccache, A., & El Moujabber, M. (2020). How can sustainable agriculture increase climate resilience? A systematic review. *Sustainability*, 12(8), 3119. https://doi.org/10.3390/su12083119

Erdogan, H. E., Havlicek, E., Dazzi, C., Montanarella, L., Van Liedekerke, M., Vrščaj, B., & Vargas, R. (2021). Soil conservation and sustainable development goals (SDGs) achievement in Europe and Central Asia: Which role for the European soil partnership?. *International Soil and Water Conservation Research*, 9(3), 360-369. https://doi.org/10.1016/j.iswcr.2021.02.003

Erktan, A., Cécillon, L., Roose, E., Frascaria-Lacoste, N., & Rey, F. (2013). Morphological diversity of plant barriers does not increase sediment retention in eroded marly gullies under ecological restoration. *Plant and Soil*, 370, 653-669. https://doi.org/10.1007/s11104-013-1738-5

Fageria, N. K., Baligar, V. C., & Bailey, B. A. (2005). Role of cover crops in improving soil and row crop productivity. *Communications in Soil Science and Plant Analysis*, 36(19-20), 2733-2757. https://doi.org/10.1080/00103620500303939

Fahad, S., Chavan, S. B., Chichaghare, A. R., Uthappa, A. R., Kumar, M., Kakade, V., & Poczai, P. (2022). Agroforestry systems for soil health improvement and maintenance. *Sustainability*, 14(22), 14877. https://doi.org/10.3390/su142214877

Fiener, P., & Auerswald, K. (2003). Effectiveness of grassed waterways in reducing runoff and sediment delivery from agricultural watersheds. *Journal of Environmental Quality*, 32(3), 927-936. https://doi.org/10.2134/jeq2003.9270

Fischer, R. A., & Connor, D. J. (2018). Issues for cropping and agricultural science in the next 20 years. *Field Crops Research*, 222, 121-142. https://doi.org/10.1016/j.fcr.2018.03.008

Franzel, S., Denning, G. L., Lillesø, J. P. B., & Mercado, A. R. (2004). Scaling up the impact of agroforestry: Lessons from three sites in Africa and Asia. *Agroforestry Systems*, 61, 329-344. https://doi.org/10.1023/B:AGFO.0000029008.71743.2d

García-Torres, L., Benites, J., Martínez-Vilela, A., & Holgado-Cabrera, A. (Eds.). (2013). Conservation agriculture: environment, farmers experiences, innovations, socio-economy, policy. Springer Science & Business Media. https://doi.org/10.1007/978-94-017-1143-2_23

Garrity, D. P. (1999). Contour farming based on natural vegetative strips: expanding the scope for increased food crop production on sloping lands in Asia. *Environment, Development and Sustainability*, 1(3), 323-336. https://doi.org/10.1023/A:1010091904395

Gebreegziabher, T., Nyssen, J., Govaerts, B., Getnet, F., Behailu, M., Haile, M., & Deckers, J. (2009). Contour furrows for in situ soil and water conservation, Tigray, Northern Ethiopia. *Soil and Tillage Research*, 103(2), 257-264. https://doi.org/10.1016/j.still.2008.05.021

Ghimirey, V., Chaurasia, J., & Acharya, N. (2023). Major Pest of Mango and Management Practice at Farmer Level in Saptari, Nepal. *Agriculture Extension in Developing Countries,* 1(2), 70-75.

Ghimirey, V., Chaurasia, J., & Marahatta, S. (2024). Plant Nutrition Disorders: Insights from Clinic Analyses and Their Impact on Plant Health. *Agriculture Extension in Developing Countries,* 2(1), 09-17.

Govers, G., Merckx, R., van Wesemael, B., & Van Oost, K. (2017). Soil conservation in the 21st century: why we need smart agricultural intensification. *Soil*, 3(1), 45-59. https://doi.org/10.5194/soil-3-45-2017

Guo, Z., Huang, N., Dong, Z., Van Pelt, R. S., & Zobeck, T. M. (2014). Wind erosion induced soil degradation in Northern China: Status, measures and perspective. *Sustainability*, *6*(12), 8951-8966. https://doi.org/10.3390/su6128951

Hammad, A. A., Haugen, L. E., & Børresen, T. (2004). Effects of stonewalled terracing techniques on soil-water conservation and wheat production under Mediterranean conditions. *Environmental Management*, 34, 701-710. https://doi.org/10.1007/s00267-003-0278-9

Hossain, A., Krupnik, T. J., Timsina, J., Mahboob, M. G., Chaki, A. K., Farooq, M., ... & Hasanuzzaman, M. (2020). Agricultural land degradation: processes and problems undermining future food security. In Environment, climate, plant and vegetation growth (pp. 17-61). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-49732-3_2

Hurni, H., Herweg, K., Portner, B., & Liniger, H. (2008). Soil erosion and conservation in global agriculture. *Land use and soil resources*, 41-71. https://doi.org/10.1007/978-1-4020-6778-5_4

Iqbal, R., Raza, M. A. S., Valipour, M., Saleem, M. F., Zaheer, M. S., Ahmad, S., & Nazar, M. A. (2020). Potential agricultural and environmental benefits of mulches—a review. *Bulletin of the National Research Centre*, 44, 1-16. https://doi.org/10.1186/s42269-020-00290-3

Issaka, S., & Ashraf, M. A. (2017). Impact of soil erosion and degradation on water quality: a review. *Geology, Ecology, and Landscapes*, 1(1), 1-11. https://doi.org/10.1080/24749508.2017.1301053

Jafari, M., Tahmoures, M., Ehteram, M., Ghorbani, M., & Panahi, F. (2022). Agroforestry and its role in soil erosion biological control. In Soil Erosion Control in Drylands (pp. 649-700). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-031-04859-3_7

Jakab, G., Madarász, B., Szabó, J. A., Tóth, A., Zacháry, D., Szalai, Z., & Dyson, J. (2017). Infiltration and soil loss changes during the growing season under ploughing and conservation tillage. *Sustainability*, 9(10), 1726. https://doi.org/10.3390/su9101726

Jat, R. A., Wani, S. P., & Sahrawat, K. L. (2012). Conservation agriculture in the semi-arid tropics: prospects and problems. *Advances in Agronomy*, 117, 191-273. https://doi.org/10.1016/B978-0-12-394278-4.00004-0

Jayne, T. S., Mather, D., & Mghenyi, E. (2010). Principal challenges confronting smallholder agriculture in sub-Saharan Africa. *World Development*, 38(10), 1384-1398. https://doi.org/10.1016/j.worlddev.2010.06.002

Kang, B. T., & Akinnifesi, F. K. (2000, May). Agroforestry as alternative land-use production systems for the tropics. In *Natural Resources Forum* (Vol. 24, No. 2, pp. 137-151). Oxford, UK: Blackwell Publishing Ltd. https://doi.org/10.1111/j.1477-8947.2000.tb00938.x

Kang, J., King, S. E., & McLaughlin, R. A. (2016). Flocculated sediments can reduce the size of sediment basin at construction sites. *Journal of Environmental Management*, 166, 450-456. https://doi.org/10.1016/j.jenvman.2015.10.049

Kassam, A., Derpsch, R., & Friedrich, T. (2014). Global achievements in soil and water conservation: The case of Conservation Agriculture. *International Soil and Water Conservation Research*, 2(1), 5-13. https://doi.org/10.1016/S2095-6339(15)30009-5

Katyal, J. C., Datta, S. P., & Golui, D. (2016). Global review on state of soil health. *Soil Health*, 1.

Lal, R. (1998). Soil erosion impact on agronomic productivity and environment quality. *Critical Reviews in Plant Sciences*, 17(4), 319-464. https://doi.org/10.1080/07352689891304249

Langdale, G. W., West, L. T., Bruce, R. R., Miller, W. P., & Thomas, A. W. (1992). Restoration of eroded soil with conservation tillage. *Soil Technology*, 5(1), 81-90. https://doi.org/10.1016/0933-3630(92)90009-P

Li, N., Yao, S. H., You, M. Y., Zhang, Y. L., Qiao, Y. F., Zou, W. X., & Zhang, B. (2014). Contrasting development of soil microbial community structure under no-tilled perennial and tilled cropping during early pedogenesis of a Mollisol. *Soil Biology and Biochemistry*, 77, 221-232. https://doi.org/10.1016/j.soilbio.2014.07.002

Little, S. A., Hocking, P. J., & Greene, R. S. B. (2004). A preliminary study of the role of cover crops in improving soil fertility and yield for potato production. *Communications in Soil Science and Plant Analysis*, 35(3-4), 471-494. https://doi.org/10.1081/CSS-120029726

Liu, Y., Yang, W., Yu, Z., Lung, I., & Gharabaghi, B. (2015). Estimating sediment yield from upland and channel erosion at a watershed scale using SWAT. *Water Resources Management*, 29, 1399-1412. https://doi.org/10.1007/s11269-014-0729-5

Marahatta, S., Chaurasia, J., Ghimirey, V., & Dahal, S. R. (2024). Beneath the Surface: Earthworms and Their Beneficial Impacts on farming Communities. *Reviews In Food and Agriculture,* 5(1), 06-12.

Martin, Y. E., & Johnson, E. A. (2012). Biogeosciences survey: Studying interactions of the biosphere with the lithosphere, hydrosphere and atmosphere. *Progress in Physical Geography*, 36(6), 833-852. https://doi.org/10.1177/0309133312457107

Mehra, P., Baker, J., Sojka, R. E., Bolan, N., Desbiolles, J., Kirkham, M. B., & Gupta, R. (2018). A review of tillage practices and their potential to impact the soil carbon dynamics. *Advances in Agronomy*, 150, 185-230. https://doi.org/10.1016/bs.agron.2018.03.002

Mekonnen, M., Keesstra, S. D., Stroosnijder, L., Baartman, J. E., & Maroulis, J. (2015). Soil conservation through sediment trapping: a review. *Land degradation & development*, 26(6), 544-556. https://doi.org/10.1002/ldr.2308

Melicher, J., & Špulerová, J. (2022). Application of landscape-ecological approach for greenways planning in rural agricultural landscape. *Environments*, 9(2), 30. https://doi.org/10.3390/environments9020030

Melnyk, S. A., Sroufe, R. P., & Calantone, R. (2003). Assessing the impact of environmental management systems on corporate and environmental performance. *Journal of Operations Management*, 21(3), 329-351. https://doi.org/10.1016/S0272-6963(02)00109-2

Molle, F., Wester, P., & Hirsch, P. (2010). River basin closure: Processes, implications and responses. *Agricultural Water Management*, 97(4), 569-577. https://doi.org/10.1016/j.agwat.2009.01.004

Morris, G. L. (2020). Classification of management alternatives to combat reservoir sedimentation. *Water*, 12(3), 861. https://doi.org/10.3390/w12030861

Mrunalini, K., Behera, B., Jayaraman, S., Abhilash, P. C., Dubey, P. K., Swamy, G. N., & Srinivasa Rao, C. (2022). Nature-based solutions in soil restoration for improving agricultural productivity. *Land Degradation & Development*, 33(8), 1269-1289. https://doi.org/10.1002/ldr.4207

Muchane, M. N., Sileshi, G. W., Gripenberg, S., Jonsson, M., Pumariño, L., & Barrios, E. (2020). Agroforestry boosts soil health in the humid and sub-humid tropics: A meta-analysis. *Agriculture, Ecosystems & Environment*, 295, 106899. https://doi.org/10.1016/j.agee.2020.106899

Ngosong, C., Okolle, J. N., & Tening, A. S. (2019). Mulching: A sustainable option to improve soil health. In Soil fertility management for sustainable development, pp. 231-249. https://doi.org/10.1007/978-981-13-5904-0_11

Nyssen, J., Clymans, W., Poesen, J., Vandecasteele, I., De Baets, S., Haregeweyn, N., & Deckers, J. (2009). How soil conservation affects the catchment sediment budget–a comprehensive study in the north Ethiopian highlands. *Earth Surface Processes and Landforms*, 34(9), 1216-1233. https://doi.org/10.1002/esp.1805

Osman, K. T. (2018). Degraded soils. In Management of soil problems, pp. 409-456.

Parajuli, M., Khadka, G. B., & Chaurasia, J. (2022). A review on comparative effect of chemicals and botanicals in management of brown spot diseases of rice (*Oryza sativa* L.). *Archives of Agriculture and Environmental Science*, 7(1), 127-131. https://doi.org/10.26832/24566632.2022.0701018

Peigné, J., Ball, B. C., Roger-Estrade, J., & David, C. J. S. U. (2007). Is conservation tillage suitable for organic farming? A review. *Soil Use and Management*, 23(2), 129-144. https://doi.org/10.1111/j.1475-2743.2006.00082.x

Penne, C., Ahrends, B., Deurer, M., & Boettcher, J. (2010). The impact of the canopy structure on the spatial variability in forest floor carbon stocks. *Geoderma*, 158(3-4), 282-297. https://doi.org/10.1016/j.geoderma.2010.05.007

Pittelkow, C. M., Liang, X., Linquist, B. A., Van Groenigen, K. J., Lee, J., Lundy, M. E., ... & Van Kessel, C. (2015). Productivity limits and potentials of the principles of conservation agriculture. *Nature*, 517(7534), 365-368. https://doi.org/10.1038/nature13809

PLANTE, A. F. (2007). Soil biogeochemical cycling of inorganic nutrients and metals. In Soil microbiology, ecology and biochemistry (pp. 389-432). Academic Press. https://doi.org/10.1016/B978-0-08-047514-1.50019-6

Podhrázská, J., Kučera, J., Doubrava, D., & Doležal, P. (2021). Functions of windbreaks in the landscape ecological network and methods of their evaluation. *Forests*, 12(1), 67. https://doi.org/10.3390/f12010067

Poeppl, R. E., Fryirs, K. A., Tunnicliffe, J., & Brierley, G. J. (2020). Managing sediment (dis) connectivity in fluvial systems. *Science of the Total Environment*, 736, 139627. https://doi.org/10.1016/j.scitotenv.2020.139627

Polat, F. (2011). Inclusion in education: A step towards social justice. *International Journal of Educational Development*, 31(1), 50-58. https://doi.org/10.1016/j.ijedudev.2010.06.009

Powlson, D. S., Gregory, P. J., Whalley, W. R., Quinton, J. N., Hopkins, D. W., Whitmore, A. P., & Goulding, K. W. (2011). Soil management in relation to sustainable agriculture and ecosystem services. *Food Policy*, 36, S72-S87. https://doi.org/10.1016/j.foodpol.2010.11.025

Prem, M., Ranjan, P., Seth, N., & Patle, G. T. (2020). Mulching techniques to conserve the soil water and advance the crop production—A Review. *Curr. World Environ*, 15, 10-30. http://dx.doi.org/10.12944/CWE.15.Special-Issue1.02

Raj, A., Jhariya, M. K., Yadav, D. K., Banerjee, A., & Meena, R. S. (2019). Soil for sustainable environment and ecosystems management. In Sustainable agriculture, forest and environmental management, pp. 189-221. https://doi.org/10.1007/978-981-13-6830-1_6

Rashid, M., Alvi, S., Kausar, R., & Akram, M. I. (2016). The effectiveness of soil and water conservation terrace structures for improvement of crops and soil productivity in rainfed terraced system. *Pakistan Journal of Agricultural Sciences*, 53(1). https://doi.org/10.21162/PAKJAS/16.1502

Reed, M. S., Fraser, E. D., & Dougill, A. J. (2006). An adaptive learning process for developing and applying sustainability indicators with local communities. *Ecological Economics*, *59*(4), 406-418. https://doi.org/10.1016/j.ecolecon.2005.11.008

Rickson, R. J. (2014). Can control of soil erosion mitigate water pollution by sediments?. *Science of the Total Environment*, *468*, 1187-1197. https://doi.org/10.1016/j.scitotenv.2013.05.057

Rosenbloom, N. A., & Anderson, R. S. (1994). Hillslope and channel evolution in a marine terraced landscape, Santa Cruz, California. *Journal of Geophysical Research: Solid Earth*, 99(B7), 14013-14029. https://doi.org/10.1029/94JB00048

Saggau, P., Kuhwald, M., & Duttmann, R. (2023). Effects of contour farming and tillage practices on soil erosion processes in a hummocky watershed. A model-based case study highlighting the role of tramline tracks. *Catena*, 228, 107126. https://doi.org/10.1016/j.catena.2023.107126

Sahu, G., Mohanty, S., & Das, S. (2020). Conservation agriculture-a way to improve soil health. *Journal of Experimental Biology and Agricultural Sciences*, 8(4), 355-68. http://dx.doi.org/10.18006/2020.8(4).355.368

Sattler, C., & Nagel, U. J. (2010). Factors affecting farmers' acceptance of conservation measures—A case study from north-eastern Germany. *Land Use Policy*, 27(1), 70-77. https://doi.org/10.1016/j.landusepol.2008.02.002

Scheper, S., Weninger, T., Kitzler, B., Lackóová, L., Cornelis, W., Strauss, P., & Michel, K. (2021). Comparison of the spatial wind erosion patterns of erosion risk mapping and quantitative modeling in eastern Austria. *Land*, 10(9), 974. https://doi.org/10.3390/land10090974

Scopel, E., Triomphe, B., Affholder, F., Da Silva, F. A. M., Corbeels, M., Xavier, J. H. V., ... & De Tourdonnet, S. (2013). Conservation agriculture cropping systems in temperate and tropical conditions, performances and impacts. A review. *Agronomy for Sustainable Development*, 33, 113-130. https://doi.org/10.1007/s13593-012-0106-9

Seitz, S., Goebes, P., Puerta, V. L., Pereira, E. I. P., Wittwer, R., Six, J., & Scholten, T. (2019). Conservation tillage and organic farming reduce soil erosion. *Agronomy for Sustainable Development*, 39, 1-10. https://doi.org/10.1007/s13593-018-0545-z

Shabir, S., Ilyas, N., Saeed, M., Bibi, F., Sayyed, R. Z., & Almalki, W. H. (2023). Treatment technologies for olive mill wastewater with impacts on plants. *Environmental Research*, 216, 114399. https://doi.org/10.1016/j.envres.2022.114399

Shiferaw, B. A., Okello, J., & Reddy, R. V. (2009). Adoption and adaptation of natural resource management innovations in smallholder agriculture: reflections on key lessons and best practices. *Environment, Development and Sustainability*, 11, 601-619. https://doi.org/10.1007/s10668-007-9132-1

Shinde, R., Sarkar, P. K., Thombare, N., & Naik, S. K. (2019). Soil conservation: Today's need for sustainable development. *Agriculture & Food: e-Newsletter*, 1(5), 175-183.

Somasundaram, J., Sinha, N. K., Dalal, R. C., Lal, R., Mohanty, M., Naorem, A. K., & Chaudhari, S. K. (2020). No-till farming and conservation agriculture in South Asia–issues, challenges, prospects and benefits. *Critical Reviews in Plant Sciences*, 39(3), 236-279. https://doi.org/10.1080/07352689.2020.1782069

Srivastava, P., Singh, R., Bhadouria, R., Tripathi, S., Singh, H., & Raghubanshi, A. S. (2019). Understanding soil aggregate dynamics and its relation with land use and climate change. In Climate change and agricultural ecosystems (pp. 331-354). Woodhead Publishing. https://doi.org/10.1016/B978-0-12-816483-9.00021-9

Stevens, C. J., Quinton, J. N., Bailey, A. P., Deasy, C., Silgram, M., & Jackson, D. R. (2009). The effects of minimal tillage, contour cultivation and in-field vegetative barriers on soil erosion and phosphorus loss. *Soil and Tillage Research*, 106(1), 145-151. https://doi.org/10.1016/j.still.2009.04.009

Tapia-Vargas, M., Tiscareño-López, M., Stone, J. J., Oropeza-Mota, J. L., & Velázquez-Valle, M. (2001). Tillage system effects on runoff and sediment yield in hillslope agriculture. *Field Crops Research*, 69(2), 173-182. https://doi.org/10.1016/S0378-4290(00)00139-8

Thapa, B. B., Cassel, D. K., & Garrity, D. P. (1999). Ridge tillage and contour natural grass barrier strips reduce tillage erosion. *Soil and Tillage Research*, 51(3-4), 341-356. https://doi.org/10.1016/S0167-1987(99)00047-1

Thiele-Bruhn, S., Bloem, J., de Vries, F. T., Kalbitz, K., & Wagg, C. (2012). Linking soil biodiversity and agricultural soil management. *Current Opinion in Environmental Sustainability*, 4(5), 523-528. https://doi.org/10.1016/j.cosust.2012.06.004

Timsina, J. (2018). Can organic sources of nutrients increase crop yields to meet global food demand?. *Agronomy*, 8(10), 214. https://doi.org/10.3390/agronomy8100214

Ucar, T., & Hall, F. R. (2001). Windbreaks as a pesticide drift mitigation strategy: a review. *Pest Management Science: formerly Pesticide Science*, 57(8), 663-675. https://doi.org/10.1002/ps.341

Valentin, C., Poesen, J., & Li, Y. (2005). Gully erosion: Impacts, factors and control. *Catena*, 63(2-3), 132-153. https://doi.org/10.1016/j.catena.2005.06.001

Waheed, A., Li, C., Muhammad, M., Ahmad, M., Khan, K. A., Ghramh, H. A., & Zhang, D. (2023). Sustainable Potato Growth under Straw Mulching Practices. *Sustainability*, 15(13), 10442. https://doi.org/10.3390/su151310442

Wang, H., Wu, X., Bi, N., Li, S., Yuan, P., Wang, A., & Nittrouer, J. (2017). Impacts of the dam-orientated water-sediment regulation scheme on the lower reaches and delta of the Yellow River (Huanghe): A review. *Global and Planetary Change*, 157, 93-113. https://doi.org/10.1016/j.gloplacha.2017.08.005

Yousuf, A., Lenz, J., & Dar, E. A. (2019). Measures to Control Soil Erosion. In Watershed Hydrology, Management and Modeling (pp. 77-97). CRC Press.

Zuazo, V. H. D., & Pleguezuelo, C. R. R. (2009). Soil-erosion and runoff prevention by plant covers: a review. In Sustainable Agriculture, pp. 785-811. https://doi.org/10.1007/978-90-481-2666-8_48