Integrated Measures for Soil and Water Management

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ABSTRACT

The main obstacles to food security are the immense pressure from the constantly growing population and the diminishing availability of land and water. Intensive agricultural practises hasten the deterioration of soil health. Similarly increased groundwater exploitation also caused a decline in groundwater level. Accelerated soil erosion is a result of anthropogenic activities like slash-and-burn agriculture, overgrazing, deforestation, and intensive and inefficient agricultural practises. This increased rate of soil erosion decreases soil and crop productivity over time by removing organic matter and plant nutrients from the fertile topsoil. A higher canopy cover and mulching of crop residues prevent soil particles from detaching from the soil surface and protect it from intense rainfall, which lowers the rate of surface runoff and lessens the effects of rainfall erosivity and soil erodibility. Moreover, it also conserves soil moisture and retains sediment and organic materials. The threat that agriculture poses to groundwater is also a serious problem, especially because groundwater is a hidden resource and its degradation and restoration frequently occur gradually. However, it is now necessary to offer workable and long-term solutions to keep the groundwater table high. There are many different approaches being used to find a more long-lasting balance. A holistic approach to managing soil and water resources is necessary for both the future viability of agriculture and the preservation of the natural ecosystem. As a result, the adoption of advanced irrigation technologies, no-till farming, conservation tillage, direct seeded rice, precision land levelling, agroforestry, and crop diversification are all essential for soil and water conservation.

Key words: Land degradation, Water-use efficiency, Conservation tillage, Crop diversification, Crops residue.

INTRODUCTION

It has a detrimental influence on the soil and water resources that make up the productive resource base for the agricultural production system. In order to feed the world's expanding population, soil serves as a vital component of all terrestrial ecosystem functions (Paustian *et al*. 2016). The only way to meet the demand for agricultural produce in developing nations like India, where the land-person ratio is rapidly declining, is to increase productivity without harming the environment or sustainability. The primary concern at this time is not just the shrinking amount of cultivable land but also the deteriorating quality of the cropland (Nayyar and Sudhir, 2002). Deforestation, land use changes, soil erosion, unrestricted grazing, waste disposal, and unscientific land management are the main contributors to soil degradation (Zalibekov, 2011). Similarly, over the past four decades, intensive farming has caused the amount of irrigated cropland to double, from 19 to 38%. A limited groundwater resource was used to extract the majority of this water. Crop production is constrained by the availability of water, and both irrigated and rain-fed farming systems need to use scientific water management to advance sustainable agriculture (Kamwar, 2002). The process of cultivating soil, particularly on marginal lands (forests and pastures with steep slopes), typically results in soil compaction, heavy flooding, and soil erosion. Multiple processes, such as compaction, a decrease in soil organic matter, and poor infiltration, contribute to soil degradation. The main goal of soil water management is to ensure proper infiltration and water retention because inadequate infiltration leads to water and soil erosion. A soil's topography, texture, level of organic matter, and crop residues are all factors that affect infiltration. Land management strategies affect the losses and gains of soil organic matter. (Manna *et al*. 2005). Due to the urgent need to make the best use of the available resources, it is essential to use water as sparingly as possible by implementing effective/advanced irrigation techniques. To remain sustainable in a changing climate, irrigation needs to be both expanded and restricted at the same time (AL-agele *et al.* 2021).

Soil relate to Agricultural Sustainability

Plant growth is greatly influenced by the soil. The provision of physical support, heat, water, nutrients, and oxygen is among the benefits to plants. Organic matter and soil minerals provide the essential nutrients that are dissolved in the soil water solution.

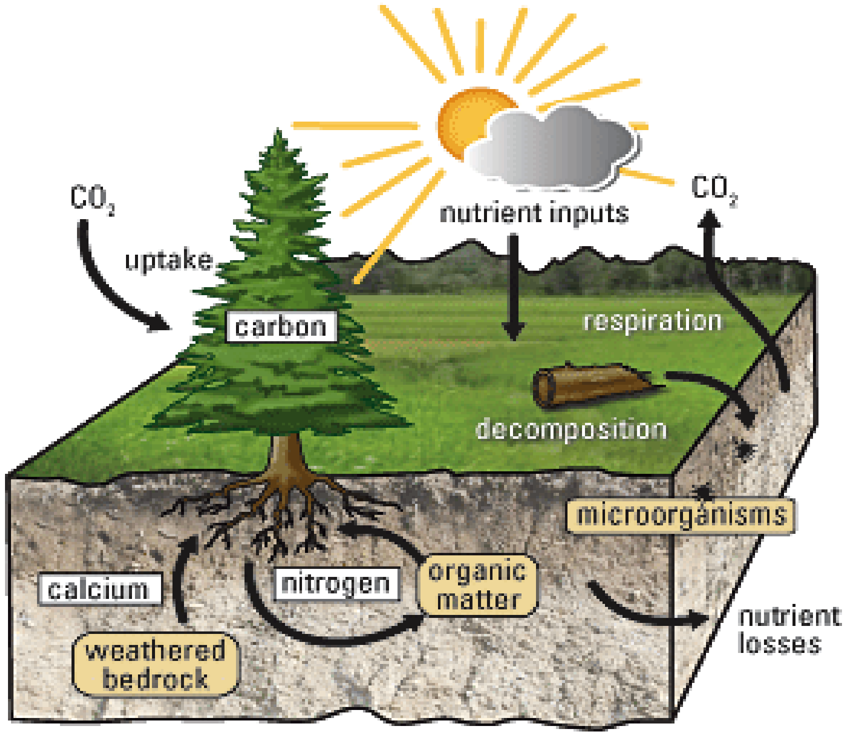

Figure 1. Soil-Plant Nutrient Cycle. Figure illustrates the uptake of nutrients by plants in the forest" soil ecosystem (Source: U.S. Geological Survey).

For their sustainable management, the texture, structure, and water-holding capacity of the soil are extremely important. Generally the ability of the soil to infiltrate water and cycles nutrients to support plant growth can be used to define as soil health. Less soil disturbance, a wider variety of crops, the maintenance of living roots in the soil, and the maintenance of residue all tend to improve the long-term health of native soil. Stable soil aggregates are crucial for the health of the soil because they provide macro and mirco pores, that encourage proper infiltration and aeration required for adequate plant growth.

Soil and Water Management to control soil erosion

The implemented Soil and Water Conservation measures enhance the soil qualities (Teklu, 2005), (Wang *et al*. 2012). The quality of the soil declines as a result of land degradation, which also reduces future potential for the survival of living organisms (Fitzpatrick, 2002). In particular for cultivated land on moderate to steep slopes and areas with scant ground vegetation cover, soil erosion is a serious problem that leads to the degradation of the land. Mechanical, biological, or a combination of methods can be used to lessen runoff and soil erosion (Magunda and Tenwa, 2001). In contrast to mechanical measures, which involve permanent or semi-permanent constructions, biological measures are vegetative measures that involve forestry, agroforestry, horticulture, and agricultural/agronomic techniques (Sarvade *et al.* 2019). To alter the land slope, increase the duration of concentration, enable more runoff water to enter and store in the soil, and decrease sedimentation and runoff velocity, mechanical methods or engineering constructions are used. These methods were combined with biological ones to increase the efficacy and longevity of the control measures. Bunding, contour trenching, terracing, contour wattling, crib structures, geotextiles, loose boulder/stone/masonry check dams, brushwood check dams, diversion drains, and conservation bench terrace are examples of mechanical methods. This in turn shortens the slope, which helps to prevent soil erosion from steep farmland and retain the majority of rainwater (Thomas and Biamah, 1991). Biological measures meanly relate to agronomic/agricultural and agroforestry. Microaggregates and WSA (Warer stable aggregates) having size <0.25mm, highest value in the soils of agroforesrty (Gill *et al*. 2017). In a terrain with a 2% slope, agronomic techniques are applicable. Agronomic practises lessen the effect of raindrops by covering the soil surface, increasing infiltration rate, and improving water absorption capacity of the soil (FAO, 1984). These practices are beneficial as structural ones and also more affordable, sustainable, and successful (Yousuf *et al*. 2019). Important agronomic practises including contour farming, crop selection, crop rotation, cover crops, intercropping, strip cropping, mulching, conservation tillage, organic farming, land design methods, and agroforestry.

Soil organic matter

The improper usage and treatment of soils results in organic matter decrease. Organic matter is crucial for soil biodiversity, structure, aeration, infiltration, water retention, and fertility (Montanarella, 2007). Additionally to acting as a puffer for soil acidity, it provides energy to soil microbes. Organic carbon is the most important component (about 58%) of organic matter and soil quality indicators (Young *et al*. 2015). Activities that result in the conversion of natural ecosystems to agricultural ecosystems cause significant carbon losses (the destruction of forests, the burning of biomass, etc.) (Lal, 1993). The substantial variance in surface soil SOC across different land uses can be attributed to factors such as plant covering, litter fall, root effect, disturbance, and management practises (DeGryze *et al*. 2004, Chen *et al*. 2007). Intensive tillage deteriorates soil structure and enhance soil erosion (Kladivko, 2001). Intense ploughing damages aggregate stability and pore continuity, which causes sediment mobilisation, erosion, and surface hardening (Hamza, 2005). This effect frequently exposes aggregates to physical disruption (Al-Kaisi *et al*. 2014). Soil properties, such as the stabilisation of organic C, soil porosity, water infiltration, aeration, compactibility, water retention, hydraulic conductivity, and resistance to water and overland flow erosion, can be impacted by aggregate stability. For the purpose of sustaining soil productivity, reducing soil erosion and degradation, and thus reducing environmental pollution, it is crucial to maintain high soil aggregate stability. (Six *et al*. 2000). The maize-wheat and agroforestry systems had 65-68 percent higher SOC than the rice-wheat system (Benbi *et al*. 2012). Soil organic matter (SOM), especially the more stable humus, increase the soil's capacity to store water (Bot and Benites, 2005).

Crop Diversification for Improved Soil Health

Crops that return a lot of organic matter to the soil via their roots, root exudates, leaves, and stems, as well as those that may maintain or improve economic yields and minimise nutrient loss through runoff and leaching, are included in crop diversity. Reintroducing crop waste to the soil and increasing soil organic carbon (SOC) through the use of legume crops in crop rotation, whether through traditional cropping techniques or conservation tillage techniques, can improve the sustainability of the entire system (Yang and Kay, 2001). The restoration of residue enhances all beneficial characteristics of soil and reduces soil-nutrient leaching loss (Shafi *et al*. 2007, Bakht *et al.* 2009, Singh *et al*. 2010, Kumar *et al*. 2019). Many earlier findings (Islam and Weil, 2000, Lobe *et al.* 2001, Jaskulska *et al.* 2020) have shown that crop residue incorporation under conservation tillage practise enhances soil attributes like SOC; available N, P, and K; soil aggregates; water-holding capacity (WHC); soil aeration; and soil enzymes. Assessing the soil quality and its trend of change by various crop management practises is crucial for making agricultural practises more sustainable. Different agricultural land-use regimes have a significant impact on the physical, biological, and functional pool of soil organic matter as well as the soil properties (Kaur *et al*. 2018). Availabilty of N, P, K and CEC (Cation Exchange Capacity) possessed high value in surface soils which is associated with clay and organic matter (Kaur *et al*. 2017). With the planting of crops with varied root penetration depths, crop rotation can also aid in reducing bulk density. In comparison to traditional puddled transplanted rice, DSR (direct-seeded rice) has the potential to save water, cut labour costs, and minimise greenhouse gas emissions (Pathak *et al.* 2011). Therefore, increasing the diversity of suitable crop rotation on agricultural fields might eventually result in greater soil health and reduce issues in the long term.

Fig 3. DSR (Direct seeded rice) cultivation by farmers, District Faridkot, Punjab.

Conservation Tillage and Water Holding Capacity

Heavy equipment is used in modern agricultural operations to prepare the seedbed, plant the crop, eradicate weeds, and harvest the crop. Although using heavy machinery might save time and effort, it can also compress the soil and disturb the native soil biota. Modern techniques make some compaction preventable and some reversible, but excessive machine movement during periods of high soil moisture content can cause major compaction problems. Increased soil density caused by soil compaction restricts root penetration depth and restrict healthy plant development. Improved soil organic matter, structure, porosity, and aeration can be achieved by techniques including minimal tillage, mulching, manure utilisation, composting, and legume cultivation. Additionally, it aids in lowering bulk density and soil compaction but also enhances soil moisture availability, decreases evaporation, and water penetration (Mugerwa, 2007). Increasing soil aeration caused by soil tillage causes organic matter to decompose more quickly. This has the unexpected effect of increasing the atmospheric concentrations of carbon and nitrous oxides (greenhouse gases) across vast tracts of farmland, which exacerbates the consequences of global warming.

These challenges are thought to become more significant as a result of climate change, hence the shift in tillage techniques here primarily focused on soil water conservation and protection (Falloon and Betts, 2010). It is possible for carbon to be sunk into the soil during no-till farming. In humid and sub-humid tropics, no tillage has been demonstrated to be more effective. Due to less aggregate disturbance, tilled plots retain more water than untilled plots (Kargas et al 2012). By expanding the storage pores (0.5–50 mm) and the quantity of elongated transmission pores (50–500 mm) in comparison to conventional ploughing, minimal tillage enhanced the soil pore system. In minimum tillage soils, higher micro-porosity is directly correlated with higher soil water content and, as a result, higher plant water availability (Pagliai *et al*. 2004). Surface soil (0-10 cm) with no tillage had higher water holding capacity or moisture content. Water use efficiency has also been reported to be greater in soils under reduced tillage (McVay *et al*. 2006) and No tilaage systems as compared with Conventional tillage (Li *et al.* 2005). Therefore, to improve soil water storage and increase water use efficiency (WUE) follow conservation tillage instead of traditional tillage (Fabrizzi *et al*. 2005, Silburn *et al*. 2007). Su *et al*. (2007) also found that the soil water storage quantity using Zero tillage was 25% higher than Conventional tillage during a six year study, while WUE was significantly higher in Zero tillage than Conventional tillage and Reduced tillage. Thus, conservation tillage has emerged as a practical choice to assure sustainable food production and protect environmental integrity, along with other complementary techniques like soil cover and crop diversification (Corsi *et al*. 2012).

Efficient water management

Effective irrigation water management is the only best way, to getting the most, out of the limited water resources is. This procedure mainly entails the conveyance, regulation, distribution, application, and precise use of irrigation water for crops. In order to raise agricultural yield or values, i.e. the marketable yield of the crop for each unit of water transpired, it is necessary to boost water productivity in both rain-fed and irrigated environments. Reduced drainage, seepage, and percolation, as well as more efficient use of rainfall and available water, are additional requirements. Irrigation efficiency is defined as the ratio of the volume of water that is taken up by the crop to the volume of irrigation water applied. Water use efficiency is mainly related to irrigation methods i.e surface (75% of ag. land), sprinkler (20% of ag. land), and micro-irrigation (5% of ag. land) (Mateos, 2016). These methods have very different application efficacy levels. Micro-irrigation is generally the most efficient (80–91%) and surface irrigation is the least (50–70%). Sprinkler irrigation efficiency is 54–80% (Chimonides, 1995). The seed-lint cotton yield production was 10–19% higher and water use efficiency increased by 35–103% with micro-irrigation relative to furrow irrigation (Ibragimov *et al*. 2007). Grain yields in Zea mays L. with micro, sprinkler, and surface irrigation were 11.8 t/ha, 10.5 t/ha, and 10.1 t/ha. The associated net irrigation water productivity was increased by 1.7 t/ML, 1.4 t/ML, and 1.3 t/ML for micro, sprinkler, and furrow irrigation, respectively (O'Neill *et al*. 2008). Compared to surface irrigation, microirrigation saves 30% of water. (Humphreys *et al*. 2008).

Crop	Saving in water (%)	Increase in Yield (%)
Cauliflower	63	29
Potato	38	38
Tomato	23	42
Bottle gourd	50	36.5

Table 1. Water saving and increase in yield by drip irrigation.

Fig 4. For cultivation of vegetables, drip Irrigation method adopted by Farmer, District Faridkot, Punjab.

Fig 5. For cultivation of vegetables, sprinkler Irrigation method adopted by Farmer, District Faridkot, Punjab.

Precision Land Leveling

The aeration, infiltration, crop stand, and yield are all impacted by uneven soil surface mostly through nutrient-water interactions. Precision land lavelling meets the objectives of achieving a better crop stand, save irrigation water and improves the input use efficiencies. Jat *et al*. (2006) reported that the water productivity of rice with same land configuration and fertility level was improved from 0.55 kg grain/m^3 in traditional leveling to 0.91 kg grain/m^3 water in precision land leveling. Similarly it was improved from 0.86 to 1.31 kg grain/m^3 in wheat. Precision land levelling has demonstrated great promise for enhancing agricultural yields and water productivity, particularly in irrigated agriculture.

Conclusion

The current situation calls for the use of efficient agricultural management techniques to prevent soil and water deterioration. Crop diversification combined with conservation tillage improves the physico-chemical properties of the soil by incorporating crop residue, increasing water infiltration, decreasing runoff, increasing soil water storage capacity, reducing soil bulk density, and helping to reduce greenhouse gas emissions. Adequate soil health helps to remove nutrient constraints on crop production for every drop of water available either through rainfall and irrigation. Eco-friendly water-saving systems, such as sprinkler and drip irrigation, boost water usage efficiency by reducing water losses from seepage, percolation, and evapo-transpiration.

Therefore, adopting more advanced agricultural practises is the only surefire approach to produce crops of excellent quality.

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