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Assessment of Smart Strategies for Mitigating Climate Change Impacts on agricultural Soils

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ABSTRACT
Climate change poses significant threats to global agriculture productivity, impacting soil health and fertility. It accelerates soil organic carbon loss due to soil degradation while soil carbon increase may lead to a great climate change mitigation potential. Therefore, this review aims to assess smart strategies for mitigating these challenges, focusing on innovative approaches that enhance resilience and sustainability in agricultural systems. This review found that climate-smart soil management strategies such as conservation agriculture and agroforestry strategies have been widely adopted to enhance soil organic carbon sequestration and to reduce greenhouse gas emissions while ensuring crop productivity.

Keywords: Climate Change, Agicultural Soils, Mitigation, Smart Strategies, Climate Smart Agriculture

INTRODUCTION
Soils play a vital role in global food production, especially in agrarian societies like Afghanistan. Given the susceptibility of global soil resources to climate change, there is a need to integrate food security strategies with soil protection (Lal, 2014). In arid regions, inappropriate agricultural practices, such as plowing and burning, contribute to soil organic matter depletion and increased Global warming and greenhouse gas emissions (Garcia-Ruiz, 2010). Despite these challenges, agricultural soils and play a crucial role in driving the carbon and nitrogen cycles (Alvaro-Fuentes *et al.*, 2012). To address these issues, there's a growing interest in implementing climate-smart management strategies (FAO, 2016) for sustainable and resilient agriculture.

Smart soil management involves employing diverse strategies to boost agricultural sustainability, increase yields, and minimize environmental impact (Bai *et al*., 2019). Assessing these strategies is crucial for preserving food security, biodiversity, and farmers' livelihoods. Effective strategies enhance resilience and reduce vulnerability in agricultural systems, especially considering the changing climate. Therefore, the objective of this study is to assess various smart soil management strategies and their role in climate change mitigation based on existing literature through a systematic review. The research articles were searched in google scholar using the following keywords: climate and agricultural soils, climate change and soil smart mitigation strategies.

1. Overview of climate change impact on agricultural soils
Soil's significance for meeting global food demand is heightened in the face of climate change, posing a threat to food security like availability, access, utilization and stability, especially in dry regions like Afghanistan. Climate change's impact on soils are anticipated through alteration in soil moisture, increase in soil temperature and CO_2 levels. These changes impact soil processes and properties important for maintaining soil fertility and productivity (Pareek, 2017).

2. Smart strategies and their effectiveness in mitigating climate change
Carbon removals or enhancing soil organic carbon can be done through conservation agriculture and agroforestry strategies to mitigate climate change by agricultural soils (Gracia-Franco et al., 2018).

2.1. Conservation agriculture
Conservation agriculture minimizes soil degradation caused by conventional tillage over the years and promotes minimal soil disturbance, crop diversity and soil cover. Furthermore, it can reduce GHG emissions and increase higher terrestrial carbon removals (Pisante *et al*., 2015). Conservation agriculture smart management strategies

are divided in to two parts 1) conservation tillage and 2) Cover Crops, Organic Amendments, and Crop Rotation strategies.

2.1.1. Conservation tillage

Conservation tillage practices are designed to minimize soil disturbance with documented benefits on soil organic carbon particularly reported for semiarid regions (Almagro *et al*., 2016). This approach involves various tillage methods, which zero tillage (no till) and reduced or minimum tillage are being the most prevalent (Busari *et al*., 2015).

In no-till management, soil disturbance is confined to seed planting and nutrient placement, fostering soil and water conservation effectively (Busari *et al*., 2015). Notably, no-till systems utilize surface residues to maintain soil cover, prevent evaporative soil water losses, and enhance water infiltration leading to soil organic carbon accumulation primarily at the soil surface (Singh, 2014).

On the other hand, minimum or reduced tillage seeks to maintain a tillage regime essential for optimal crop production and weed control while reducing soil disturbance through decreased intensity, depth, or time involved in tillage (FAO, 2012). Generally, reduced tillage requires less energy, reducing erosion and increasing soil water content, soil organic carbon content, and aggregate stability. Minimum tillage fosters soil organic matter and nutrient accumulation throughout the soil profile, improving soil structure (Lopez-Garrido *et al*., 2014). Furthermore, compared to no- till system, reduced tillage may enhance water-use efficiency (Martinez-Mena *et al*., 2013). Despite being a smart management option, conservation tillage may reduce productivity and pose challenges in weed management. Consequently, combining conservation tillage with other strategies such as cover crop, crop rotation, and organic amendments is recommended to enhance soil organic carbon and nitrogen storage and improve soil structure (Garcia-Franco *et al*., 2018).

2.1.2. Cover Crops, Organic Amendments, and Crop Rotation

Cover crops serve additional, intermediary crops aimed at preserving vegetative cover, decreasing erosion and increasing soil organic carbon through heightened belowground biomass and associated root carbon input. Cover crops commonly utilized as mulch or green manure, or they may also be harvested for added economic benefits (Garcia-Franco *et al*., 2018).

The incorporation of organic amendments (fresh, composted, animal, or mixed origin) into the soil is an ancient practice recommended in contemporary conservation management to enhance soil fertility. Organic amendments not only protect soil from erosion but also provide supplementary carbon inputs, enhancing soil organic carbon and improving soil properties like water holding capacity, soil structure, and nutrient cycling (Munoz-Rojas *et al*., 2016). Furthermore, in semiarid soils, organic amendments stimulate microbial activity, fostering the development of secondary carbonates, which may act as a carbon sink in irrigated semiarid agroecosystems (Jacinthe *et al*., 2011).

Crop rotation involving different crops diversifies the agroecosystems, reducing weed density and enhancing overall soil productivity (Liu *et al*., 2006). Varied rooting depth under different crop rotations not only improve water use efficiency but also impact the entire soil profile's organic carbon and nitrogen cycling (Alvaro-Fuentes *et al*., 2012).

2.2. Agroforestry

Agroforestry denotes agricultural systems intertwining arable crops with trees or shrubs, sequestering carbon in both above- and below-ground biomass. Leaf litter from trees contributes to the accumulation of soil organic carbon (Cardinael *et al*., 2015). Humus accumulation is substantial in the topsoil, providing a reservoir for long term soil fertility. In similarity to forests systems, the perennial trees in agroforestry ensure constant soil coverage, increasing intensified humus formation and benefiting soil biota (Garcia-Franco *et al.*, 2018). Another climate change impact is increasing heat stress which is a significant risk to yields. Agroforestry systems play a crucial role in stabilizing yields in semi dry regions. Despite potential reductions in photosynthesis due to shade, these systems can significantly reduce heat and enhance water use efficiency by reducing soil evaporation (Gosme *et al*., 2016). Savanna trees, even with a 65% reduction in solar radiation, have been shown to boost yields through decreased soil temperature. While agroforestry may not always increase yields, it proves to be a multifunctional land use system with various harvestable products, contributing to overall resilience and reduced economic risk during extreme events. The land equivalent ratio (LER) measurement underscores the system's efficiency, particularly in dry and semi dry areas with planted leguminous trees. Beyond direct yield effects, agroforestry's agricultural diversification promotes system resilience and mitigates risks through co-benefits like soil erosion reduction and soil organic carbon storage (Moreno, 2008).

CONCLUSION

In conclusion, soil has a critical role in global food production, particularly in regions like Afghanistan where agriculture is central to the livelihood of the most people. Climate change is known a threat to soil health and productivity. Climate smart management strategies promote carbon inputs, helping to maintain soil structure and physical-chemical protection of soil organic carbon and also mitigating climate change impacts. Climate smart strategies such as conservation tillage, cover crops, organic amendments, crop rotation and agroforestry reported as the perfect smart strategies in many literatures. In the face of climate change impacts, adopting these smart soil management strategies becomes imperative. The comprehensive review underscores the interconnectedness of these strategies and their potential to enhance resilience, reduce vulnerability and contribute to the long term sustainability of agricultural systems. By integrating these approaches, we can strive towards a more secure and resilient food supply even in the midst of changing climate. This study contributes valuable insights for policymakers, researchers and practitioners seeking effective solutions for sustainable agriculture in the context of a dynamic climate.

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