Soil Management Strategies to Promote Higher Crop Productivity within Sustainable Environments

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Abstract: ***According to the increasing population and reduction in the amount of land and some other resources have created tremendous pressure on current agricultural producers for the increasing food demands. Hence, future efforts to feed the growing population should aim for greater agricultural production within sustainable environments. Therefore, some innovative steps are needed, as business-as-usual policies lack the potential to cope with these challenges. The concept of agricultural sustainability and various soil and crop management strategies (SCMS) that have been designed to optimize crop yield under sustainable environmental conditions are discussed, including nutrient management, site specific nutrient management (SSNM), integrated nutrient management (INM), integrated soil fertility management (ISFM), integrated soil-crop system management (ISSM), ridge-furrow mulching systems (RFMS), sustainable water management (SWM), conservation agriculture (CA), sustainable land management (SLM), vertical/sky farming, and integrated crop management, and breeding strategies as well as other approaches combined with technological and behavioral changes. The present review focused on sustainable production system can be developed by combining the multifaceted efforts under SCMS practices with short-and long-term preventive measures. Reducing chemicals plus improvements in the crop input use efficiency could minimize greenhouse gases emissions which protecting the environment.***

Keywords: Agricultural sustainability, soil tillage, land degradation, soil erosion

1.Introduction

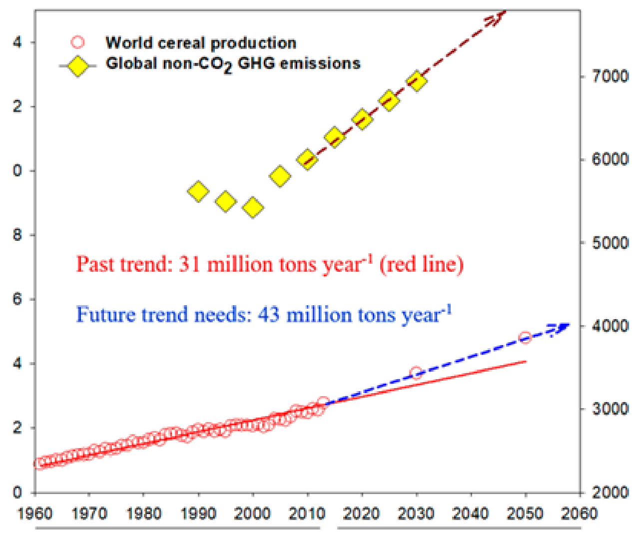
Use and management of soil resources by human being have shaped the development, persistence, decline, and regeneration of human civilizations that are sustained by agriculture. Soil and water are essential natural resources for our domesticated animal-and plant-based food production systems. Agriculture is a relatively recent human innovation that spread rapidly across the globe only 10, 000 to 12, 000 years ago. In such societies during the last ten millennia, humans have developed complex, urban civilizations that have cycled through periods of increasing complexity, awe-inspiring intellectual achievement, persistence for millennia, and, in some instances, perplexing decline.

Due to all these facts agriculture sustains. This is especially true for plant communities, animal populations, soil systems, and water resources. Understanding, evaluating, and balancing detrimental and beneficial agricultural disturbances of soil and water resources are essential tasks in human efforts to sustain and improve human well-being. Such knowledge influences our emerging ethics of sustainability and responsibility to human populations and ecosystems of the future.

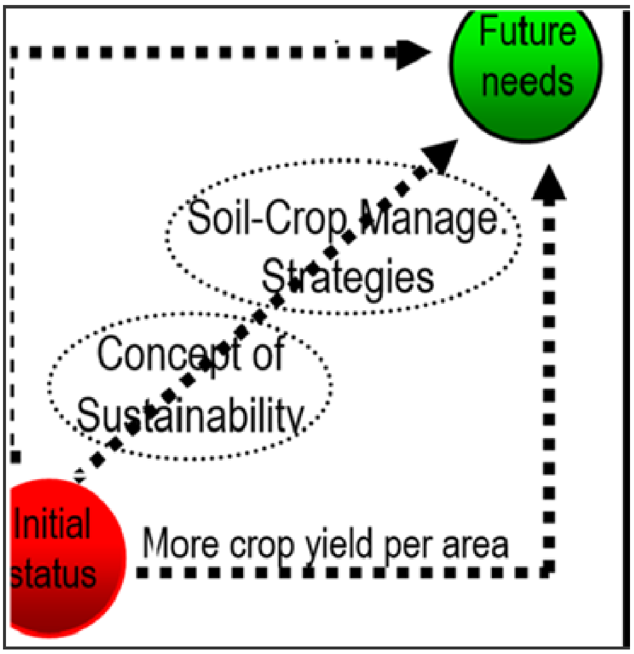
Agriculture is most essential thing for human food and the stability of complex societies, almost all of our evolution has taken place in small, mobile, kin-based social groups, such as bands and tribes. Our social evolution has accelerated since the Agricultural Revolution and taken place synergistically with human biological evolution, as we have become dependent on domesticated plants and animals grown purposefully in highly managed, soil-water systems.

Over the past few decades, modern agricultural science and molecular biology technologies have boosted the production of cereal crops through the development of new germ plasm, but there has been evidence of yield plateaus or decreasing yield gain rates in recent years. For instance, CIMMYT (the International Maize and Wheat Improvement Center) estimated that the potential progress in cereal yield has been decreased to approximately 0.5% per year during recent decades. Thus, increasing the yield potential through both modern breeding technologies and innovative crop/soil management practices have been regarded as important strategies to overcome the barrier of ensuring higher crop productivity with less environmental impact. The present study aims to review the concept of agricultural sustainability, and the various soil management strategies (SCMS) that have been designed to optimize crop yield under sustainable environmental conditions.

Modern agricultural technologies have made it possible for farmers to utilize ample land, modern machinery, and improved inputs to bring under cultivation even bigger farms, thus further increases in productivity can be realized through better varieties, efficient water utilization, and the investment of capital in addition to the availability of fossil fuel energy and other agricultural related chemicals. Improvements in the overall performance of the prevailing crop production units must strive for innovative strategies if the objective of these is to deal with the dual challenge of enhancing yield to fulfill the increasing dietary needs and ensure environmental sustainability.



Past Year



Future Estimate

Figure 1: World cereal production targets and global non-CO2 greenhouse gas emissions (**a**), and concept model (**b**) of higher crop productivity and less environmental impact

2.Soil Management for Sustainable Agriculture

It has long been realized by agricultural scientists that soil management practices are not only pivotal for maximizing the production of agricultural commodities, but are important for controlling the increasing environmental pollution. Thus, attention must be paid to not only protecting soil from erosion (which directly leads to land shortages), but also to adapt practices that avoid soil contamination and degradation.

Soil erosion and land degradation represent critical threats to ecosystem services and agricultural productivity, and such a loss of natural capital assets particularly occurs in semi-arid and tropical regions, where agronomic inputs are low and vegetation cover is poor. The erosion of soil by water and wind are key processes degrading the surface structure of exposed soil by which topsoil is lost, which impairs soil fertility and results in unsustainable agriculture. Recent investigations have indicated that land degradation will continue due to the great increase in global GDP by 2050, soto achieve future food security, sustainable soil management via efficient management of nutrients and suitable conservation practices for soil are some of the key challenges. Multifaceted investigations are direly needed to circumvent permanent deterioration of soil resources by erosion or pollution since soils are not renewable.

As a fundamental component of terrestrial ecosystems, most living organisms are sustained by soil, which is also the key supplier of their nutritional requirements. Managing soil organic carbon (SOC) is of the greatest importance as soil organic matter is directly related to numerous soil properties that are relevant to ecosystem functioning. Even small changes in this large carbon (C) stock can change the atmospheric CO2 concentration, which affects the global carbon cycle and even climate change. For instance, the C store within 0–30 cm of the soil surface is estimated to contain approximately 700 Pg organic C, which is equal to twice the quantity of C in the atmosphere as CO2. This great C stock in soils represents both an opportunity and a threat to the global C cycle and climate change. The challenge is to manage soils to sequester additional C from the atmosphere, which can be achieved by the SCMS practices described below, while sustaining higher crop productivity. An increase in SOC content indicates an accumulation of atmospheric carbon in the soil, which can be achieved by two routes: (i) Increasing the transformation of photosynthates to soil organic matter by enhancing plants' photosynthetic ability, and (ii) slowing the decomposition of the organic matter within the soil. The SOC content of sub-soils is lower and more stable than that of topsoil, which implies that the former has a greater potential for increasing the C store, although the underlying mechanisms are still poorly understood. For instance, the application of biochar to soils has recently begun to attract considerable attention as an innovative soil management practice by scientists and policy makers for its potential role in increasing C sequestration and reducing GHG emissions. Additionally, the development of plants with a well-distributed and deeply penetrating root system should be exploited to achieve this goal. Thus, a full understanding of root architecture is of critical importance in breeding programmes. The application of molecular biology techniques in studying living microorganisms in the soil and their interactions with roots and soil fertility, such as through second-generation sequencing and associated bioinformatics analysis, is providing a deeper understanding of soil biological processes and soil ecology for novel practical applications.

3.Strategies for Optimizing Crop Yield within Sustainable Environments

To ensure greater resilience of ecosystems to the predicted stresses in the future, a transformation from crisis-driven strategies to long-term mitigation measures is required. Over time, various terminologies have been introduced by agricultural scientists to create awareness within their own community as well as among farmers, who can practically adapt them to achieve their goals. The following sections discuss the most common terms with special emphasis on their impact related to agricultural and environmental sustainability.

- **Nutrient Management:**

Managing fertilizer application in the field is one of the greatest challenges since it focuses on maximum efficient utilization of fertilizers to enhance crop yield and ensure environmental safety. Plant nutrient management mainly emphasizes nitrogen and phosphorus as these are the main contaminants that enter and leave fields through fertilizer (both inorganic and organic), or any other major source of plant nutrition entering or leaving the field, including effluent management on dairy farms. Excess nutrients, especially N and P, which are not taken by the plants, may move into the water table or other water reservoirs, thus leading to environmental pollution. Delgado and Lemunyon described that nutrient management is the art and science aimed at linking tillage, irrigation, and conservation of soil and water for the optimization of crop fertilizer use efficiency, productivity, quality, and net profit while minimizing the off-site movement of nutrients with less environmental effects.

- **Site-Specific Nutrient Management (SSNM):**

SSNM can be described as a crop-based approach that provides principles, guidelines, tools, and strategies that allow growers to decide the time and amount of fertilizers to be applied to a crop under actual field conditions at a specific site and season. SSNM as the comprehensive, site-specific nutrient management of a particular cropping season to match the demand and supply of nutrients based on variations in cycling through soil-plant systems. Such types of SSNM try to exploit (1) seasonal and regional variations in environmental yield potential and the demand of a crop for nutrients, (2) variation in the spatial variability of fields in terms of intrinsic nutrient availability, (3) farm-specific within-season dynamics of crop N demand, and (4) site-specific cropping patterns and crop management strategies.

- **Integrated Nutrient Management (INM):**

INM can be defined as using inorganic and organic fertilizers, bio-fertilizers, crop residues, and other living materials in such a balance that enhances fertilizer use efficiency, thus resulting in increased crop yields while indirectly minimizing the environmental risk through balanced fertilizer application. The primary goal is to combine traditional methods with modern techniques of nutrient application that are environment friendly and economically sound cropping systems, which utilize both organic and inorganic fertilizers in a judicious and effective method. All three primary macronutrients, i. e., N, P, and K, and other macro and micronutrient inputs and outputs are managed in INM, with the objective of nutrient cycling with tight synchrony between the demand of the nutrient and its application to soil. Nutrient losses through runoff, leaching, volatilization, and immobilization are reduced in INM, leading to an increase in fertilizer use efficiency.

- **Integrated Soil Fertility Management (ISFM):**

ISFM was described as a fertility management strategy of the soil, which emphasizes the sensible usage of chemical fertilizers, organic manures, crop residues, and resilient germ plasms coupled with an understanding of the skills to employ such practices to local conditions with the objective of increasing the agronomic use efficiency of the applied fertilizers and enhancing crop yield.

- **Integrated Soil–Crop System Management (ISSM):**

This approach identifies three key points: (i) Consideration of all available options to enhance the quality of soil; (ii) exploiting the use of all possible nutrient sources and matching the availability of nutrients with crop needs; and (iii) fitting nutrient and soil management strategies with high-yielding cropping systems. Countries where the N balance has already been achieved can also improve crop productivity and fertilizer use efficiency by utilizing new approaches of ISSM, such as growing better varieties, location-specific agricultural practices, slowly releasing nitrogen amendments, efficient irrigation systems, and proper rotation of crops, etc.

- **Ridge-Furrow Mulching System (RFMS):**

Sustainable agricultural development in arid plus semi-arid regions is primarily restrained by a shortage of water. As an innovative water-saving cultivation technique, the RFMS is also designed to enhance crop productivity under water-scarce rain-fed conditions. This technique involves incorporating plastic film, crop straw, gravel sands, and rocks in the ridges and furrows before or shortly after sowing to cover the topsoil, thus preserving the soil moisture. This practice could be beneficial for channeling water into furrows, reducing soil evaporation, and enhancing the infiltration of soil water deeper into the soil profile, thereby increasing the availability of water to crop plants. For instance, the RFMS practice could increase water use efficiency (WUE) by up to 70% compared with traditional flat or the well-irrigated practice, while it improves N fertilizer productivity and Nuptake efficiency by up to 33% and 45%, respectively, under wheat-maize double-cropping systems in northwest China. In addition, through mulching, the emission of GHGs into the atmosphere can be significantly influenced. It is suggested that plastic mulching under RFMS could serve as a physical barrier to reduce the emission of GHGs and the C footprint of grain crops while increasing grain yield and carbon emission efficiency. However, in some other studies, opposite results were also found

4.Conclusion

It can be concluded that current agricultural practices could previously meet the demands of the population, but future needs are increasing much more rapidly than in the past due to the growing population. Analyses reveal that constantly rising temperatures, higher GHGs emissions, and rapid increases in environmental pollution have made current agro-ecosystems much more susceptible than ever before. Minimizing the application of chemicals, especially as fertilizers and for controlling insects/pests, plus improvements in the input use efficiencies of crops will help minimize GHGs emissions while protecting the environment. Sustainable agriculture holds promise for humankind and the planet Earth, and it can be successful if all developed and developing nations stand together to produce more food with less environmental pressures and thus seek “our common future”

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