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Sustainable Soil and Crop Management Practices to Boost the Crop Productivity and Soil Properties

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Abstract

Reducing poverty and attaining zero hunger and adequate nourishment are critical concerns confronting agronomic planners globally. Enhancing various agronomic methods, which significantly impact crop growth and output, is urgently required to achieve this objective. Soil deterioration has transpired globally due to soil pollution, eroding, salinity, and acidity. The intense farming practices devoid of sustainable practices have resulted in deteriorating soil quality, destruction of land, and significant environmental issues. Future initiatives to feed the expanding population should focus on enhancing agricultural output within sustainable ecosystems. Creative measures are essential in this context since conventional policies are insufficient to address these difficulties. The work proposed Sustainable Soil and Crop Management Practices (SS-CMP) to boost Crop Productivity (CP) and Soil Properties (SP). This includes Nutritional Management (NM), Location-Specific Nutrient Management (LSNM), Comprehensive Nutrition Management (CNM), Comprehensive Fertility Management (CFM) for soil, Comprehensive Soil-Crop Governance (CSCG), Sustainable Water Use (SWU), Agricultural Conservation (AC), Sustainable Soil Management (SSM), vertical cultivation, combined CMP, breeding methods, and additional methodologies amalgamated with scientific and behavioral modifications. Minimizing the use of substances, including herbicides and pesticides, and enhancing the effectiveness of agricultural supply use might reduce greenhouse gas emissions (GGE) and safeguard biodiversity. SS-CMP offers potential benefits for humanity and the World, and its success relies on the collaboration of both rich and developing countries to pursue a shared vision of producing more food with less ecological impact.

Keywords:

Sustainability, crop management, soil properties, fertility management, nutrition management, water use, zero hunger.

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Overview of CMP and Related Works

The primary challenges confronting agricultural policymakers and planners in the forthcoming years stem from the goal of a world devoid of impoverishment and starvation, exacerbated by the increasing living standards in rural areas, where the majority of impoverished individuals reside and are entirely reliant on agriculture for sustenance to meet their food requirements (El Bilali et al., 2020). The solution to alleviate existing suffering resides in formulating a strategy plan that promotes successful agriculture and empowers farmers to attain agricultural advancement, diminish poverty, and maintain substantial returns.

Consequently, the primary issue in the next years pertains to the following inquiry. The goal of agriculture to meet the food requirements of a global population has been projected to surpass 6.4 billion by 2026 (Selim, 2021). Given the escalation of land constraints and water shortages, most agricultural strategies rely on applying chemical fertilizers and cultivating novel CY types. Both components are significantly costly, resulting in elevated pressure and more responsibility for financial investments, ultimately leading to a rise in overall expenses (Okan & Christian, 2024). Concurrently, the cost of fertilizers escalates annually, owing to the increased quantity required in the subsequent two seasons relative to the first season to sustain yield output at an economically viable level. Notwithstanding the augmentation in fertilizer application, a portion of the applied fertilizers and indigenous soil nutrients has already been depleted by current and preceding crops, particularly in farming practices where two to three crops are farmed yearly. Furthermore, the consumption of synthetic fertilizers is not a feasible alternative for many impoverished farmers throughout various global locations, as many lack the financial resources to afford the cost of fertilizers, in addition to their scarcity and unavailability during critical periods (Christina et al., 2024).

Since antiquity, agriculturists have recognized that organic manure may rejuvenate soil vitality; hence, they routinely applied farmyard manure immediately after crop harvests. Thus, the practice of applying organic fertilizers post-harvest has been associated with an improvement of SP and enhancement of its mineral, chemical, and biological characteristics, especially in shallow soils that are characterized by deficient biological matter, minimal native CNM levels, reduced productivity, and the scarcity of essential nutrients (Anisuzzaman et al., 2021; Singh et al., 2024).

Organic farming yields organic food, which many consumers favor despite elevated pricing. In this setting, natural fertilizers, owing to their gradual release, have a more substantial residual influence on following crops compared to inorganic nutrients, which are rapidly diminished by water leaching and runoff into groundwater (Radhakrishnan et al., 2024). Recent calls have urged farmers and agricultural specialists to shift their perspective towards replacing a portion of chemical fertilizers with more economical, sustainable, and efficient, eco-friendly nutrients derived from resources of nature, such as compost, under the prominent concept of CNM.

Within the domain of CNM practices, many subcategories have been delineated, including the application of animal manures, organic and mineral fertilizers, soil supplements, agricultural residues, agricultural waste reusing, agricultural forestry, green fertilizer, and compost (Selim, 2018; Yang et al., 2024). Conversely, researchers have determined that the impact of organic manures is not consistently beneficial, and some organic materials may hinder plant growth, potentially due to elevated levels of phytotoxins and a high carbon-to-nitrogen ratio, especially in immature organic materials (Lutz et al., 2020).

Consequently, the self-recycling of organic waste by farmers may serve as a beneficial and viable alternative for agricultural planners and numerous farmers to surpass conventional organic waste disposal methods despite the minimal risk posed to plants, groundwater, ecological integrity, and human health, thereby optimizing the utilization of existing natural resources (Ducasse et al., 2022; Yatoo et al., 2020).

The primary objective of the CNM goal is to achieve the most efficient and uniform combination that facilitates optimal management and serves as an effective target for fertilizers, ensuring adequate and balanced application of both quantity and quality while being readily assimilated by plants for enhanced yield, without compromising native soil nutrients or contaminating the environment. Achieving this aim is feasible via the judicious use of the CNM method, characterized by a balanced amalgamation of organic, inorganic, and bioorganic bacteria in various procedures (Selim, 2020). Additionally, it may enhance all properties of molecular intake of macronutrients and micronutrient inputs. Furthermore, it may align with CP's needs and mitigate the limitations of nutrient insufficiency without causing any detrimental impacts on the environment or goods. Conversely, mismanagement always results in soil deterioration, nutrient shortage, and rapid soil drainage (Gram et al., 2020).

CNM refers to employing the minimum operational dosage of adequate and balanced amounts of natural and synthetic fertilizers, in conjunction with specific microbes, to enhance nutrient availability and efficacy for sustaining high CP while preserving native SP and preventing environmental pollution. Moreover, several advantages may be derived from the implementation of CNM. CNM may serve as a catalyst, facilitating the transformation of unproductive terrain into productive areas, hence advancing the strategic objective of expanding cultivated land (Chen et al., 2024). Similarly, farmers require knowledge of which plant nutrient combinations optimize nutrient-use effectiveness and how to combine these resources to attain the highest efficiency while ensuring suitable financial returns and a low ecological footprint. A combination of numerous disciplines is essential, including botanical breeding, agricultural science, SP, nutrition for crops, crop protection, and crop engineering (Ayyad & Khalifa, 2021).

Worldwide production of food must be augmented by at least 72% by 2051 to satisfy the escalating need for food driven by the growing population. Agriculture must expand considerably to attain this formidable objective, considering the factors that enhance CP, which are currently diminished or likely to diminish, as they exert an unprecedented strain on the environment. Attaining food security presents a considerable challenge to global agricultural development, alongside the imperative of addressing critical issues to alleviate poverty. Achieving food security and agricultural sustainability is imperative, thus enhancing various agronomic methods that significantly impact CP and yield, such as soil nutrient composition, crop nutrient needs, and soil nutrient equilibrium (Mairura et al., 2022). Many farmers engage in practices that require enhancement, particularly concerning detrimental habits related to the excessive application of fertilizers, stemming from the inherited belief that substantial fertilizer use is essential for sustaining high yields. These reckless practices, endorsed by numerous farmers, lead to the wastage of the majority of supplied fertilizers, contribute to environmental issues, and increase overall expenses. Furthermore, the persistent application of synthetic fertilizers results in significant soil nutrient deficiencies and spoilage of food while adversely affecting the physicochemical properties of the soil by elevating its acidity, thereby hastening the decline of soil health, efficiency, and both stability and long-term viability.

Although the use of artificial fertilizers presents more benefits than limitations, it does not guarantee a spike in CP, as some of the applied fertilizers might stay temporarily in the soil or disappear through vaporization or release into groundwater, leading to significant harmful emissions and associated risks. In light of the factors above, along with elevated expenses and diminishing profitability, shortages, and dumping into the root zone, groundwater pollution emerges as a disease catalyst (Farfoura et al., 2023).

In recent years, agriculturalists and agricultural experts have acknowledged that the continued use of synthetic fertilizers does not necessarily lead to increased yields (Darjee et al., 20223). They have come to appreciate the significance of soil health through using natural fertilizers, which are accessible and cost-effective. These can be utilized independently or with other natural or synthetic resources to improve soil fertility and achieve greater CP without causing adverse environmental effects (Abid et al., 2020).

Regarding the fundamental materials applicable to the CNM system, multiple researchers have identified that an array of substances can serve as components of CNM, including animal manures, organic and mineral-based fertilizers, amending the soil, crop leftovers, and compost (Hashimi & Habibi, 2021; Guo et al., 2020). These substances are typically considered essential components in the eco-friendly framework to guarantee environmentally friendly and secure food cultivation (Peng et al., 2023). Nonetheless, reusing organic material into compost is a complex operational practice that requires additional labor and may result in increased labor and overall costs. However, compared to the numerous long-term benefits, such as enhancing soil quality and guaranteeing food production safety, agriculture may prove an appropriate and acceptable method for many farmers, agricultural specialists, and developers. Consequently, utilizing natural fertilizers facilitates the rebuilding of soil health and sustains productivity over an extended duration; however, at the field magnitude, the exclusive use of natural fertilizers for maintaining CP at an economically viable level is not dependable. Consequently, it should be utilized in conjunction with other fertilizers sourced from inorganic materials to fulfill the nutrient needs of crops.

Sustainable Soil and Crop Management Practices (SS-CMP) to Boost CP and SP

Farming methods are the primary factors affecting food production levels and significantly influence environmental conditions. Regrettably, many of these practices, such as the extensive application of chemical fertilizers and other substances that ensure elevated yields, are neither environmentally friendly nor viable. Consequently, the disparity between the generation and consumption of numerous agricultural goods has expanded at an alarming rate over the past fifteen years, and this excessive utilization of agricultural ingredients presents a significant threat to our surroundings. The present situation necessitates increased CP, which is achieved sustainably to ensure enhanced social, economic, and ecological safety. To attain these objectives, researchers must diligently pursue the discovery of novel approaches for SS-CMP, enhanced CP, and the preservation of existing biodiversity and agroecosystems.

Sustainable development in agriculture seeks to achieve a diverse array of potentially enduring objectives. Sustainability in agriculture is defined as the method of cultivating crops in a manner that optimally benefits humanity and resource efficiency while remaining environmentally friendly. Their appropriateness should extend beyond the welfare of humans to encompass every other organism that exists. Sustainability is grounded in the principles of robustness (the capacity of a system to endure pressures and shocks) and persistency (the capability to remain effective over extended durations). It considers a varied array of socio-economic and environmentally beneficial returns.

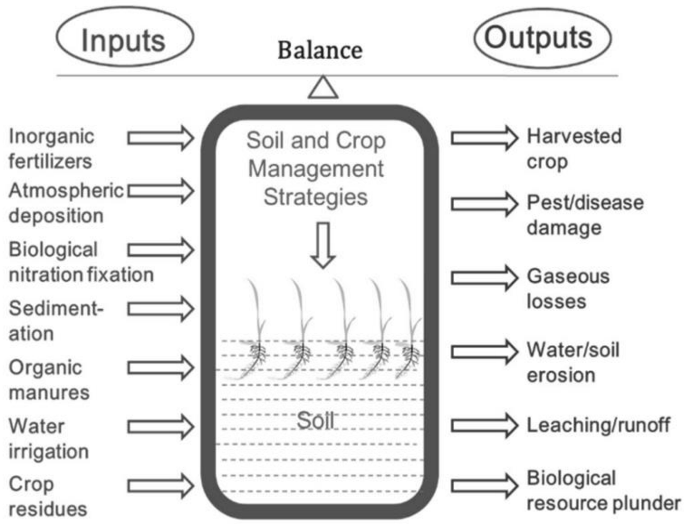

Figure 1. Nutritional balances between inputs and outputs in SS-CMP

A shift from food crisis-driven approaches to ongoing prevention efforts is necessary to enhance the durability of ecosystems against anticipated future shocks. Over the years, researchers in agriculture have developed multiple terms to raise understanding within the neighborhood and among agriculturalists, who can practically implement them to achieve their objectives. The subsequent sections examine the prevalent terminology, focusing on their agricultural and ecological sustainability implications.

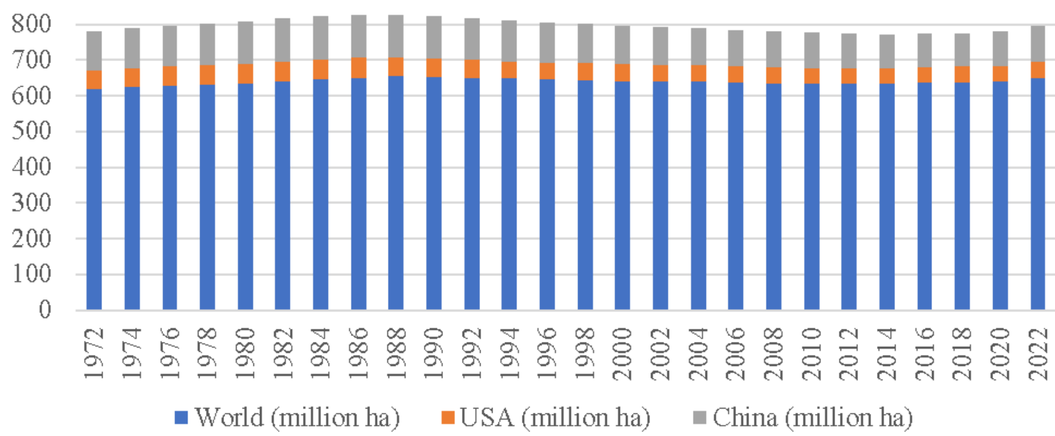

Figure 2. Area of grain cultivation (in a million hectares)

Figure 2, entitled "Area of Grain Cultivation (in million hectares)," illustrates the trends in harvested cereal areas from 1972 to 2022 for the World, the USA, and China. The global harvested area has consistently expanded, increasing from 620 million hectares in 1972 to 650 million hectares by 2022. The harvested area in the USA has experienced minor fluctuations, declining from 50 million hectares in 1972 to 45 million hectares in 2022. The harvested area in China initially rose, reaching approximately 122 million hectares in 1982, then experienced a gradual decline to 93 million hectares in 2018 before a modest recovery to 100 million hectares by 2022. These trends indicate a stable or decreasing area of cereal cultivation in the USA and China, whereas global statistics reveal a slight overall increase in cultivation area over the years. The rise in the cultivation of grains is due to enhanced CY per unit area rather than an expansion of the cultivated area. The future estimates of CP should derive from further improvements in per unit area CY rather than an expansion of crop area.

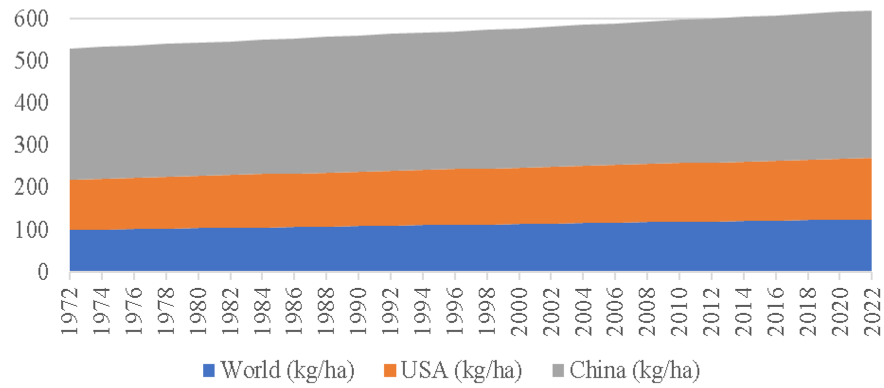

Figure 3. Utilization of chemical fertilizers (in Kg/ha)

Chemical fertilizers primarily consist of phosphorus (P) and nitrogen (N) fertilizers applied to fertile and permanently cultivated land, measured in kilograms per hectare. Figure 3 illustrates a progressive rise in fertilizer application rates globally and in the USA and China from 1972 to 2022. China consistently demonstrates the highest fertilizer application per hectare, commencing at 310 kg/ha in 1972 and escalating to 350 kg/ha by 2022. The United States exhibits fertilizer application rates commencing at 120 kg/ha in 1972 and escalating to 145 kg/ha by 2022. The global average consistently rises, beginning at 100 kg/ha in 1972 and attaining 125 kg/ha by 2022. This upward trend signifies a persistent increase in fertilizer utilization, especially in China, presumably reflecting endeavors to improve CP and agricultural productivity over time.

CMP and Breeding Strategies

Conventional crop farming is regarded as both an art and a science focused on cultivating crops to deliver valuable agricultural products to consumers at a reasonable price while ensuring sufficient profit for the producer. Agriculturists must navigate intricate scenarios and implement measures informed by their comprehension of a multifaceted system encompassing a variety of financial, social, and technical dimensions. Regrettably, stagnating crop yields pose a significant barrier to sustainable agriculture, necessitating substantial efforts to improve the yield potential of primary food crops. Enhanced robustness in management procedures and breeding programs designed to improve yield potentials are two critical areas that can effectively address food scarcity and ecological concerns by 2050. A comprehensive review has recently been conducted on a complementary strategy for enhancing resistance to various hazards in major crops.

The developing utilization of genomics and agricultural biotechnology in contemporary crop plants is essential for improving their performance in diverse stressful conditions, including dryness, soil acidity, saltiness, and temperature stress. Fortunately, novel methodologies in genetics and agricultural physiology have enabled the implementation of more targeted strategies for trait selection. Novel crop varieties can be readily developed to achieve superior yields in adverse conditions. Considering the apprehensions of specific individuals, primarily from developed countries, about the possible adverse effects on public health, genetically modified crops may presently be utilized for non-dietary applications. These measures will alleviate the burden on agricultural land, allowing the majority to be utilized for food crop cultivation. Conversely, this will afford scientists sufficient time to thoroughly assess the risks associated with these genetically modified crops via scientific bio-safety assessment protocols should progress recommence.

SS-CMP

Researchers have developed and implemented various SS-CMP and other reduction methods to promote an understanding of efficient resource input utilization, focusing on sustainable development. All these SS-CMPs seek to enhance CP and mitigate land degradation by regulating various SP, including natural, mineral, chemical, and hydrologic properties, through controlled NM. Figure 1 illustrates that these SS-CMPs uphold a stringent equilibrium between nutrient inputs and outputs through two fundamental principles: (1) aligning the input level with crop need and (2) synchronizing the application period with plant development. These SS-CMP augment CP and conserve SP while safeguarding the environment. These SS-CMPs can utilize animal manures, organic and mineral fertilizers, agricultural waste, crop residues, agriculture and forestry, soil harvesting, cross-cropping, crop switching, fallow periods, watering, and drainage to preserve available plant nutrients and water. SS-CMP includes innovative methods such as applying fertilizer at subsurface depths, utilizing urease inhibitors, or employing coated urea, which may improve nutrient absorption. These modifications may encourage growers to prioritize long-term, environmentally sustainable policies rather than solely focusing on yield-related returns (Jayapriya, 2021).

In the worldwide realm, the efficiencies of nitrogen and phosphorus utilization have become critical objectives. Without synthetic fertilizers, significant yield increases would have been virtually unattainable. Nevertheless, crops remain unutilized, a portion of the applied nitrogen and phosphorus fertilizers. It is released into the environment, substantially decreasing fertilizer efficiency and increasing environmental pollution, particularly in rapidly developing nations. For example, the application of nitrogen and phosphorus fertilizers surged significantly, by 52% annually, from 2000 to 2020 in China, while cereal yields rose merely by 8.5%.

Substantial fertilizer application without a proportional yield increase may result in nutrient imbalances, raising significant environmental pollution issues. An improved balance of nitrogen and phosphorus can be attained without compromising crop yields while markedly diminishing ecological risks by implementing optimal soil and crop management practices, regulating the principal N and P loss channels, and enhancing the efficacy of agricultural extension services. A structural link exists between CP and GGE, whereby modified soil-sustainable CMP can achieve a 38% increase in wheat yield while decreasing greenhouse gas emission density by 19% relative to traditional agricultural systems (Alfatlawi & Alrubaiee, 2020). The application of organic fertilizers, along with appropriate management strategies such as the incorporation of plant leftovers or the implementation of zero-tillage or low-tillage practices, as opposed to chemical fertilizers, can enhance soil quality, augment carbon sequestration and diminish GGE while boosting CP (Mutlu & Tas, 2022).

- ***NM***

Administering fertilizer application in the field presents a significant challenge, as it emphasizes the optimal utilization of fertilizers to improve crop yield while ensuring the environment's health. Plant NM primarily focuses on N and P, as these are the principal pollutants that enter and exit fields via fertilizers (both chemical and organic) or other significant sources of plant nutrition, including wastewater management on milk farms. Surplus nutrients, particularly N and P that plants do not absorb may leach into the water table or other aquatic reservoirs, resulting in environmental pollution. Researchers articulated that NM is both an art and a discipline focused on integrating tillage, watering, and soil and water preservation to enhance crop fertilizer use effectiveness, yield, nutritional value, and net profit while concurrently reducing the off-site migration of nutrients and reducing environmental impacts (Laouamer et al., 2020).

- ***LSNM***

LSNM is a crop-centric methodology that offers principles, recommendations, tools, and strategies enabling cultivators to determine the timing and quantity of fertilizer application for a crop based on real-world circumstances at a particular location and season. LSNM is defined as the thorough, location-specific management of nutrients for a specific farming season, aligning nutrient demand with supply according to fluctuations in cycling within soil-plant systems. These types of LSNM aim to leverage (1) seasonal and neighborhood fluctuations in environmental potential for CP and plant nutrient demand, (2) the geographical variation of fields regarding inherent supply of nutrients, (3) farm-specific within-season changes in crop N need, and (4) location-specific farming practices and management methods.

- ***CNM***

CNM is characterized as the utilization of chemical and organic fertilizers, biological fertilizers, agricultural waste, and other biological materials in a manner that optimizes fertilizer use efficiency, thereby augmenting CP while indirectly mitigating ecological hazards through harmonious fertilizer use. The primary objective is to integrate traditional practices with contemporary nutrient administration methods that are environmentally sustainable and economically viable, employing both organic and chemical fertilizers prudently and efficiently. All three principal macronutrients, namely N, P, and potassium (K), along with other macronutrient and micronutrient inputs and outcomes, are regulated in CNM to achieve a cycle of nutrients that aligns closely with fertilizer need and application to the soil Figure 1. Loss of nutrients via drainage, leakage, oxidation, and adsorption are diminished in CNM, resulting in enhanced fertilizer use effectiveness.

- ***CFM***

CFM is characterized as a soil fertility control approach that prioritizes the judicious application of synthetic fertilizers, natural manure, crop leftovers, and strong germplasms, alongside the requisite skills to adapt these methods to regional circumstances, aiming to optimize the agronomic performance of fertilizers and improve CP. A new study demonstrated that crop waste and manure are essential for improving the fertility of rice farms under CFM. Rice crops exhibit a comparatively superior yield advantage when cultivated with compost or synergistic biological N fixing by legumes, as opposed to synthetic fertilizers.

- ***CSCG***

This methodology, presented delineates three principal points: (i) Evaluation of all available methods to improve soil quality; (ii) utilizing all potential nutrient sources and aligning their accessibility with crop requirements; and (iii) integrating fertilizer and SS-CMP with high-yielding agricultural systems. Countries that have attained N equilibrium can enhance CP and efficiency in using fertilizer by implementing innovative CSCG strategies, including the cultivation of superior varieties, LSNM, slow-release N modifications, effective watering systems, and appropriate crop switching.

- ***SWU***

Water is the paramount resource for the sustainable advancement of agriculture, and enhancing the SWU is the principal challenge facing water use in this sector. Moreover, heightened non-agricultural needs and climate change impose significant pressure on the water available for agriculture. The water supply must align with crop requirements regarding volume and quality at an appropriate cost while avoiding adverse environmental effects. Investment in micro-irrigation systems, such as drip and sprinkler methods, has increased over time due to their enhanced efficiency. In drip irrigation, rainwater is directly delivered to the crop's rooting area, thereby reducing surface evaporation and potentially enhancing CP and SWU by a minimum of 51%. Subsequent research indicates that drip irrigation methods can concurrently mitigate salinization by diminishing precipitation and enhancing the SWU. Researchers must monitor the acidity of land linked to agricultural irrigation, as it is a critical factor restricting CP (Hussain &Taimooz, 2024).

Irrigation timing methods exhibit significant diversity in their application and efficacy. Scheduling is devised by utilizing various options while considering assessing and quantifying soil moisture status and equilibrium, plant stress indicators, climatic factors, and advanced models. In regions experiencing water scarcity due to escalating urban and commercial needs, controlled deficit watering may serve as a feasible strategy to maintain a balance between drought conditions and CP. Controlled Insufficient Irrigation (CII) could substantially enhance the SWU by reducing the requirement for irrigation water, leading to negligible or no decrease in yield. Consequently, the benefits of reallocating the conserved water to irrigate alternative fields significantly outweigh the detrimental effects. Moreover, intermittent wetting, drying, and subsurface drip irrigation techniques are promising methods to enhance SWU. Water preservation and its application in agricultural production can be improved with suitable rewards and governmental service delivery in water-scarce regions.

- ***AC***

AC can be characterized as an agricultural approach that prioritizes continuous soil coverage, minimized damage to the soil, and variability of plant species. It consists of a farming system tailored to the requirements of crops and the surroundings, promoting resource-efficient CP while safeguarding the environment against subsiding soil and destruction of land. The principles of AC primarily encompass three interconnected elements: (1) minimized soil disturbance, (2) preservation of indefinite soil covers, and (3) biological heterogeneity.

Minimal tilling, no-till, and less tillage are agricultural techniques that stem from conservation agriculture, aimed at cultivating crops annually while minimizing soil disturbance through tillage. These techniques typically enhance water accessibility and its absorption into the soil, facilitating carbon capture by reducing Soil Organic Carbon (SOC) breakdown. They can also be advantageous for mitigating soil erosion and improving the soil's biological growth and overall quality, especially in drought-prone or arid areas. Cover-cropping and interchangeable crops are typically employed in zero-tailage agriculture to manage weeds and diseases while enhancing soil nutrient and moisture levels. Alongside various other advantages for agricultural output, zero tillage has been swiftly embraced in numerous global regions.

- ***SSM***

Land is the most significant non-renewable resource, particularly for impoverished populations that rely primarily on it for sustenance. Disrupting this resource can substantially impact agricultural productivity, exacerbate financial difficulties and tensions, and jeopardize existing diversity and ecosystems due to deforestation, resulting in carbon emissions. Through SSM, CP can be augmented by efficiently managing constrained resources, including water, soil, biodiversity, and the surroundings, thereby enhancing the long-term viability of an ecosystem. SSM is characterized as implementing land-use structures that, through suitable management methods, allow land users to optimize economic and social advantages while preserving or improving the environmental support features of land assets. The significance of SSM has become more recognized for its potential to alleviate poverty and combat land degradation globally.

- ***Vertical Cultivation***

Vertical farming is a contemporary cultivation strategy that utilizes advanced technologies such as agricultural technology and hydroponics, wherein crops are grown in misty circumstances or nutrient-rich solutions under-regulated indoor conditions rather than in soil. This method facilitates multiple harvests within a season and mitigates losses due to adverse weather conditions. It significantly expands the area designated for crop production by enabling the cultivation of plants in multiple layers, thereby alleviating the strain on soil resources. This method is considered promising due to its independence from environmental factors, rendering it resistant primarily to fluctuations in conditions outside. Vertical farming enhances opportunities for reusing agricultural debris and diminishes the discharge of agrochemicals to the surroundings, particularly water. Its broader applicability, particularly in urban settings, reduces fuel consumption in the transportation of products from rural to urban regions, thereby contributing to environmental protection.

Conclusion

The proposed initiative, Sustainable Soil and Crop Management Practices (SS-CMP) aims to enhance Crop Productivity (CP) and Soil Properties (SP). This encompasses NM, LSNM, CNM, CFM for soil, Comprehensive Soil-Crop Governance (CSCG), SWU, AC, SSM, vertical cultivation, integrated CMP, breeding techniques, and supplementary methodologies fused with scientific and behavioral adjustments. Reducing the application of substances, such as herbicides and pesticides, while improving the efficiency of agricultural resource utilization could diminish greenhouse gas emissions (GGE) and protect biodiversity. SS-CMP presents prospective advantages for humanity and the planet, contingent upon the cooperation of affluent and developing nations to achieve a collective objective of increasing food production with reduced ecological repercussions.

Author Contributions

All Authors contributed equally.

Conflict of Interest

The authors declared that no conflict of interest.

References

Abid, M., Batool, T., Siddique, G., Ali, S., Binyamin, R., Shahid, M. J., ... & Alyemeni, M. N. (2020). Integrated nutrient management enhances soil quality and crop productivity in maize-based cropping system. *Sustainability*, *12*(23), 10214. https://doi.org/10.3390/su122310214

Alfatlawi, Z. H. C., & Alrubaiee, S. H. A. W. (2020). Effect of spraying wheat of humic acid on the growth and yield of wheat crop (ipa 99 cultivar) in different stages. *Plant Archives*, *20*(2), 1517-1521.

Anisuzzaman, M., Rafii, M. Y., Jaafar, N. M., Ramlee, S. I., Ikbal, M. F., & Haque, M. A. (2021). Effect of Organic and Inorganic Fertilizer on the Growth and Yield Components of Traditional and Improved Rice (Oryza sativa L.) Genotypes in Malaysia. *Agronomy*, *11*(9), 1830. https://doi.org/10.3390/agronomy11091830

Ayyad, S., & Khalifa, M. (2021). Will the Eastern Nile countries be able to sustain their crop production by 2050? An outlook from water and land perspectives. *Science of the Total Environment*, *775*, 145769. https:// water doi.org/10.1016/j.scitotenv.2021.145769

Chen, W., Zhang, J., & Deng, X. (2024). Winter wheat yield improvement by genetic gain across different provinces in China. *Journal of Integrative Agriculture*, *23*(2), 468-483. https://doi.org/10.1016/j.jia.2023.11.015

Christina, B. B., Singh, S., Vineetha, S. B., & Hepsibha, M. (2024). Effect of Organic Manures on Growth and Yield of Cowpea (Vigna unguiculata L.) Varieties. *Journal of Experimental Agriculture International*, *46*(6), 409-416. https://doi.org/10.9734/jeai/2024/v46i62493

Darjee, S., Shrivastava, M., Langyan, S., Singh, G., Pandey, R., Sharma, A., ... & Singh, R. (2023). Integrated nutrient management reduced the nutrient losses and increased crop yield in irrigated wheat. *Archives of Agronomy* and *Soil Science*, *69*(8), 1298-1309. https://doi.org/10.1080/03650340.2022.2084535

Ducasse, V., Capowiez, Y., & Peigné, J. (2022). Vermicomposting of municipal solid waste as a possible lever for the development of sustainable agriculture. A review. *Agronomy for Sustainable Development*, *42*(5), 89. https://doi.org/10.1007/s13593-022-00819-y

El Bilali, H., Bassole, I. H. N., Dambo, L., & Berjan, S. (2020). Climate change and food security. *Agriculture & Forestry/Poljoprivreda i Sumarstvo*, *66*(3). https://doi.org/10.17707/AgricultForest.66.3.16

Farfoura, M. E., Khashan, O. A., Omar, H., Alshamaila, Y., Karim, N. A., Tseng, H. T., & Alshinwan, M. (2023). A Fragile Watermarking Method for Content-Authentication of H. 264-AVC Video. *Journal of Internet Services and Information Security, 13*(2), 211-232. https://doi.org/10.58346/JISIS.2023.I2.014

Gram, G., Roobroeck, D., Pypers, P., Six, J., Merckx, R., & Vanlauwe, B. (2020). Combining organic and mineral fertilizers as a climate-smart integrated soil fertility management practice in sub-Saharan Africa: A meta-analysis. *PloS one*, *15*(9), e0239552. https://doi.org/10.1371/journal.pone.0239552

Guo, Y., Chen, Y., Searchinger, T. D., Zhou, M., Pan, D., Yang, J., ... & Mauzerall, D. L. (2020). Air quality, nitrogen use efficiency and food security in China are improved by cost-effective agricultural nitrogen management. *Nature Food*, *1*(10), 648-658. https://doi.org/10.1038/s43016-020-00162-z

Hashimi, R., & Habibi, H. K. (2021). Effects of organic and inorganic fertilizers applications levels on greenhouse tomato (Solanum lycopersicum) yield and soil quality in Khost Province. *Asian Journal of Soil Science and Plant Nutrition*, *7*(4), 1-10. https://doi.org/10.9734/ajsspn/2021/v7i430117

Hussain, L. I., & Taimooz, S. H. (2024). Measuring the Levels of Heavy Metal Pollution in Al - Diwaniyah River Water Using Oomycetes Fungus. *International Academic Journal of Science and Engineering, 11*(1), 312-316. https://doi.org/10.9756/IAJSE/V11I1/IAJSE1136

Jayapriya, R. (2021). Scientometrics Analysis on Water Treatment During 2011 to 2020. *Indian Journal of Information Sources and Services, 11*(2), 58–63. https://doi.org/10.51983/ijiss-2021.11.2.2889

Laouamer, L., Euchi, J., Zidi, S., & Mihoub, A. (2020). Image-to-Tree to Select Significant Blocks for Image Watermarking. *Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications, 11*(1), 81-115. https://doi.org/10.22667/JOWUA.2020.03.31.081

Lutz, S., Thuerig, B., Oberhaensli, T., Mayerhofer, J., Fuchs, J. G., Widmer, F., ... & Ahrens, C. H. (2020). Harnessing the microbiomes of suppressive composts for plant protection: from metagenomes to beneficial microorganisms and reliable diagnostics. *Frontiers in microbiology*, *11*, 1810. https://doi.org/10.3389/fmicb.2020.01810

Mairura, F. S., Musafiri, C. M., Kiboi, M. N., Macharia, J. M., Ng'etich, O. K., Shisanya, C. A., ... & Ngetich, F. K. (2022). Farm factors influencing soil fertility management patterns in Upper Eastern Kenya. *Environmental Challenges*, *6*, 100409. https://doi.org/10.1016/j.envc.2021.100409

Mutlu, A., & Tas, T. (2022). Foliar application of humic acid at heading improves physiological and agronomic characteristics of durum wheat (Triticum durum L.). *Journal of King Saud University-Science*, *34*(8), 102320. https://doi.org/10.1016/j.jksus.2022.102320

Okan, A., & Christian, C. (2024). Capture of a New-born Shortfin Mako Shark Isurus Oxyrinchus (Lamniformes: Lamnidae), with Updated Records from the Turkish Marine Waters. *Natural and Engineering Sciences, 9*(1), 1-9. https://doi.org/10.28978/nesciences.1472086

Peng, G. A. O., Zhang, T., Lei, X. Y., Cui, X. W., Lu, Y. X., Fan, P. F., ... & Zhang, H. M. (2023). Improvement of soil fertility and rice yield after long-term application of cow manure combined with inorganic fertilizers. *Journal of Integrative Agriculture*, *22*(7), 2221-2232. https://doi.org/10.1016/j.jia.2023.02.037

Radhakrishnan, S., Velanganni, R., & Paranthaman, P. (2024). Groundwater Management: Integrating Geological and Hydrological Data for Effective Decision Making. *Archives for Technical Sciences, 2*(31), 131–139. https://doi.org/10.70102/afts.2024.1631.131

Selim, M. (2018). Potential role of cropping system and integrated nutrient management on nutrients uptake and utilization by maize grown in calcareous soil. *Egyptian Journal of Agronomy*, *40*(3), 297-312. https://doi.org/10.21608/agro.2018.6277.1134

Selim, M. M. (2020). Introduction to the integrated nutrient management strategies and their contribution to yield and soil properties. *International Journal of Agronomy*, *2020*(1), 2821678. https://doi.org/10.1155/2020/2821678

Selim, M. M. (2021). Introduction to the integrated nutrient management strategies, and contribution on yield and soil properties. *Journal of Plant Sciences*, *9*(5), 139-150. https://doi.org/10.11648/j.jps.20210904.13

Singh, N. K., Sachan, K., BP, M., Panotra, N., & Katiyar, D. (2024). Building Soil Health and Fertility through Organic Amendments and Practices: A Review. *Asian Journal of Soil Science and Plant Nutrition*, *10*(1), 175-197. https://doi.org/10.9734/ajsspn/2024/v10i1224

Yang, Y., Zou, J., Huang, W., Olesen, J. E., Li, W., Rees, R. M., ... & Yin, X. (2024). Drivers of soybean-based rotations synergistically increase crop productivity and reduce GHG emissions. *Agriculture, Ecosystems & Environment*, *372*, 109094. https://doi.org/10.1016/j.agee.2024.109094

Yatoo, A. M., Rasool, S., Ali, S., Majid, S., Rehman, M. U., Ali, M. N., ... & Farooq, S. (2020). Vermicomposting: An eco-friendly approach for recycling/management of organic wastes. *Bioremediation and Biotechnology: Sustainable Approaches to Pollution Degradation*, 167-187. https://doi.org/10.1007/978-3-030-35691-0_8