Agronomic Practices for Restoring Soil Health in Cereal-Based Cropping System

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ABSTRACT

Soil health is the capacity of soil to function as a dynamic living system that supports plant growth, maintains environmental quality, and promotes biodiversity. Healthy soil ensures sustainable agricultural productivity by facilitating nutrient cycling, improving water retention, and enhancing microbial activity. Maintaining soil health is essential for sustaining high crop yields, preventing soil erosion, and reducing the risk of land degradation. It also plays a critical role in carbon sequestration, helping mitigate climate change. Additionally, healthy soil supports microbial diversity, which enhances nutrient availability and disease resistance. By preserving soil health, we ensure long-term food security, environmental protection, and ecological balance. Cereal-based cropping systems, particularly rice-wheat systems, play a pivotal role in global food security. However, continuous monocropping, excessive tillage, chemical overuse, and poor residue management have led to severe soil degradation. To sustain high yields while preserving soil fertility, agronomic practices such as crop rotation, organic amendments, conservation tillage, and cover cropping are essential. By adopting these science-backed techniques, farmers can restore soil vitality, enhance sustainability, and ensure food security for future generations.

INTRODUCTION

For centuries, cereal-based cropping systems, particularly rice-wheat rotations, have been the backbone of global food security. However, the relentless pursuit of higher yields has come at a heavy cost—soil degradation. Continuous monocropping, excessive tillage, imbalanced fertilizer use, and poor organic matter management have stripped the soil of its vitality, leading to declining productivity and ecological imbalance. The once vibrant, nutrient-rich soil has become compacted, deficient in essential nutrients, and biologically inactive, threatening the long-term sustainability of these systems.

To reverse this decline, agronomic practices for restoring soil health have emerged as a beacon of hope. Practices such as crop rotation and diversification improve soil structure and microbial diversity, while cover cropping enhances organic matter and prevents erosion. Conservation tillage minimizes soil disturbance, preserving the natural balance of the soil ecosystem. Additionally, integrated nutrient management (INM) optimizes nutrient supply through a balanced approach that combines organic and inorganic inputs. Biofertilizers and microbial inoculants further enrich the soil by promoting nutrient cycling and enhancing root-soil interactions.

By integrating these sustainable practices, farmers can restore soil health, enhance productivity, and ensure environmental sustainability. As we move toward a future where food security and ecological balance are intertwined, adopting these agronomic practices becomes not just a necessity but a commitment to preserving the lifeline of agriculture.

What is soil health?

Soil health is defined as the continued capacity of soil to function as a vital living system that sustains plant and animal productivity, maintains environmental quality, and promotes biodiversity. It reflects the soil's ability to perform essential ecosystem functions such as nutrient cycling, water filtration, carbon sequestration, and supporting plant growth while resisting degradation. Healthy soil maintains a balance of physical, chemical, and biological properties, ensuring long-term agricultural sustainability and ecological stability (Kibblewhite et al., 2008). Maintaining soil health is critical for improving crop productivity, preventing soil erosion, and reducing environmental impacts. Maintaining soil health is now almost important for enhancing crop productivity because of the occurrence of multi-nutritional deficiency in soil (Rattan et al., 2009).

Importance of Soil Health in Cereal-Based Cropping Systems

Soil health plays a vital role in ensuring the sustainability and productivity of cereal-based cropping systems, such as rice-wheat rotations. Healthy soil supports optimal nutrient cycling, enabling efficient uptake of essential nutrients, which enhances crop yield and quality. It also improves soil structure by maintaining adequate aeration, water infiltration, and moisture retention, reducing the risk of waterlogging and drought stress. Organic matter enrichment in healthy soil fosters microbial diversity, which aids in decomposing organic residues, enhancing nutrient availability, and suppressing soil-borne pathogens. Additionally, well-maintained soil reduces soil erosion by stabilizing soil aggregates and minimizing nutrient loss. Improved soil health also mitigates salinity and waterlogging issues, ensuring long-term productivity. Moreover, healthy soil contributes to carbon sequestration, helping combat climate chane by reducing greenhouse gas emissions. In

cereal-based systems, maintaining soil health ensures higher yields, environmental sustainability, and resilience against climate variability, ultimately securing food security for growing populations.

Challenges in Addressing Soil Degradation in Cereal-Based Cropping Systems

Soil degradation in cereal-based cropping systems, particularly rice-wheat rotations, presents numerous challenges that threaten long-term agricultural sustainability. Nutrient depletion and imbalances occur due to continuous monocropping, which exhausts essential nutrients, while imbalanced fertilizer application worsens the situation. Decline in organic matter is another major concern caused by intensive tillage and residue burning, reducing soil organic carbon and impacting soil structure and microbial diversity. Additionally, soil erosion and loss of topsoil result from poor soil management and excessive tillage, removing nutrient-rich topsoil and decreasing fertility. Waterlogging and salinity issues arise from over-irrigation in rice systems, leading to poor drainage and salt accumulation, which reduces soil productivity. Loss of microbial diversity due to excessive use of chemical pesticides and fertilizers weakens soil resilience and disrupts nutrient cycling. Compaction and poor soil structure caused by repeated tillage and heavy machinery limit root penetration and water infiltration. Furthermore, climate change impacts, such as erratic rainfall and rising temperatures, accelerate degradation processes and increase soil vulnerability. Lastly, limited adoption of sustainable practices due to a lack of awareness, resources, and incentives prevents widespread implementation of soil conservation methods. These challenges collectively undermine soil health, posing a serious threat to food security and environmental stability.

Agronomic Practices for Maintaining Soil Health in Cereal-Based Cropping Systems

Maintaining soil health in cereal-based cropping systems requires adopting sustainable agronomic practices that enhance soil fertility and structure. Crop rotation and diversification with legumes, pulses, and oilseeds improve soil fertility, break pest cycles, and promote microbial diversity. Conservation tillage minimizes soil disturbance, preserves organic matter, and maintains soil structure. Incorporating cover crops such as legumes and mustard between cereal crops prevents erosion, adds organic matter, and enhances nitrogen availability. Integrated nutrient management (INM) combines organic manures, compost, and chemical fertilizers to optimize nutrient supply and prevent soil degradation. Residue incorporation and mulching retain soil moisture, improve organic carbon content, and protect the soil surface from erosion. Additionally, biofertilizers and microbial inoculants such as Rhizobium, Azotobacter, and mycorrhizal fungi enhance nutrient cycling and microbial diversity. Efficient water management techniques, including Alternate Wetting and Drying (AWD) and drip irrigation, prevent waterlogging and salinity, ensuring optimal soil conditions. The application of organic amendments like farmyard manure, green manure, and compost further enhances microbial activity and soil organic matter. Regular soil testing and monitoring help maintain nutrient balance and prevent overuse of chemical inputs. Adopting these agronomic practices not only sustains soil health but also ensures higher productivity and environmental sustainability in cereal-based cropping systems.

Future Thrust

The focus should be on conservation agriculture (zero tillage, residue retention), integrated nutrient management (INM) to

balance organic and inorganic inputs, and enhancing microbial diversity through biofertilizers. Precision agriculture technologies like GIS and remote sensing can optimize fertilizer and water use, while water-efficient systems such as drip irrigation and AWD prevent salinity and waterlogging. Promoting soil carbon sequestration through organic amendments, farmer training on sustainable practices, and policy support with incentives will ensure long-term soil health and agricultural sustainability.

CONCLUSION

Maintaining soil health in cereal-based cropping systems is vital for sustainable agriculture and food security. Practices like crop rotation, conservation tillage, residue management, and integrated nutrient management (INM) enhance soil fertility and microbial diversity. Precision agriculture, efficient water management, and organic amendments further ensure long-term productivity. With proper farmer education and policy support, these practices can restore soil health and sustain high yields in cereal-based systems.

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