



Unleashing the Power of Agronomy: Nurturing Sustainable Food System for a Flourishing Future

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The world is facing with the critical challenge of nourishing a growing global population while ensuring the long-term sustainability of our food systems. In this context, agronomy emerges as a powerful discipline that holds the key to nurturing a sustainable food system for a flourishing future. Agronomy encompasses the scientific study of crop production, soil management, and sustainable

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agricultural practices. This article explores the importance of agronomy in addressing the pressing issues of resource optimization, optimizing resource use through precision farming techniques, such as remote sensing, soil and crop sensors, and data analytics.

Keywords: Agronomy; INM; remote sensing; sustainable.

1. INTRODUCTION

1.1 Importance of a Sustainable Food System

- 1.Environmental Conservation:** A sustainable food system ensures the preservation and protection of natural resources, such as water, soil, and biodiversity. It promotes practices that minimize greenhouse gas emissions, reduce pollution, and preserve ecosystems [1,2].
- 2. Food Security:** A sustainable food system is crucial for ensuring food security, which is the availability and access to nutritious food for all individuals. By employing sustainable farming practices, such as crop diversification, efficient irrigation, and responsible use of inputs, we can increase agricultural productivity and resilience to climate change.
- 3. Health and Nutrition:** A sustainable food system prioritizes the production of nutritious and wholesome food. It encourages the cultivation of diverse crops, including fruits, vegetables, and whole grains, while minimizing the use of harmful pesticides and synthetic additives [3,4].
- 4. Economic Development:** It supports small-scale farmers and rural communities by providing them with fair trade opportunities, access to markets, and improved livelihoods.
- 5. Resilience to Climate Change:** By adopting sustainable practices, such as agroforestry, conservation agriculture, and water management techniques, we can enhance the resilience of our food system to climate shocks. Sustainable farming methods help minimize the risks of crop failure, water scarcity, and soil erosion, ensuring long-term agricultural viability.

1.2 Concept of Agronomy and its Role in Nurturing Sustainability

Agronomy is a scientific discipline that encompasses the study of crop production, soil management, and the integration of various

agricultural practices to achieve sustainable and efficient food production. It combines knowledge from fields such as biology, chemistry, ecology, and technology to optimize agricultural systems while minimizing negative environmental impacts [5-8]. The role of agronomy in nurturing sustainability is crucial, as it provides the foundation for creating a resilient and environmentally friendly food system.

Nurturing Sustainability through Agronomy:

- 1.Optimizing Resource Use:** By utilizing precision farming techniques, agronomists help farmers monitor and manage the specific needs of crops, such as water, nutrients, and pesticides. This targeted approach reduces waste, minimizes environmental pollution, and ensures that resources are used effectively, resulting in sustainable agricultural practices.
- 2.Soil Health Management:** Through soil conservation practices like cover cropping, crop rotation, and reduced tillage, agronomists promote soil fertility, water retention, and biodiversity. By preserving the health of the soil, agronomy ensures long-term productivity and reduces the need for synthetic inputs, fostering sustainable farming systems.
- 3.Climate Change Adaptation:** By embracing climate-smart agricultural practices, such as selecting drought-resistant crop varieties, improving water management, and implementing agroforestry techniques, enhance the resilience of agricultural systems.
- 4.Technological Advancements:** Advanced tools such as precision agriculture, remote sensing, and data analytics provide valuable insights into crop health, soil conditions, and pest management.
- 5.Sustainable Intensification:** By adopting innovative farming techniques, such as integrated pest management, efficient irrigation systems, and responsible use of fertilizers, agronomists help farmers produce more food on limited land, reducing the need for further deforestation and safeguarding natural ecosystems Fig. 2.

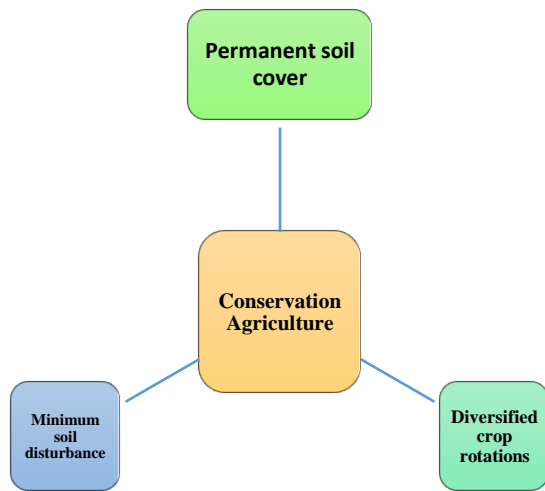


Fig. 1. Principles of conservation agriculture



Fig. 2. Drip irrigation

2. RESOURCE EFFICIENCY IN AGRICULTURE

2.1 Importance of Optimizing Resource Use

Efficient resource management is essential for sustainable and resilient food production systems. Reasons why resource optimization is crucial:

- 1. Environmental Sustainability:** By using resources such as water, land, and nutrients efficiently, we can reduce pollution, conserve natural habitats, and protect biodiversity.
- 2. Mitigating Climate Change:** Precision application of fertilizers and targeted

irrigation practices minimize nitrogen leaching and greenhouse gas emissions, while practices like agroforestry and cover cropping help sequester carbon dioxide from the atmosphere, mitigating climate change impacts.

- 3. Economic Viability:** By optimizing inputs such as fertilizers, seeds, and energy, farmers can reduce production costs while maintaining or increasing yields.
- 4. Water Conservation:** Precision irrigation technologies, such as drip irrigation and soil moisture sensors, enable farmers to deliver water directly to the root zone, minimizing evaporation and reducing water wastage.
- 5. Nutrient Management:** Over-application of fertilizers can lead to nutrient runoff, polluting water bodies and causing ecological imbalances. Agronomic practices that optimize nutrient application, such as site-specific nutrient management and precision fertilization, ensure that crops receive the required nutrients while minimizing environmental pollution.
- 6. Food Security and Resilience:** Limited land availability and increasing environmental pressures necessitate producing more food with fewer resources.

2.2 Explain Precision Farming Techniques and their Benefits

Precision farming techniques, also known as precision agriculture or site-specific crop management, utilize advanced technologies to optimize agricultural practices and improve overall efficiency. These techniques enable farmers to make informed decisions based on real-time data, resulting in several benefits:

- 1. Enhanced Resource Efficiency:** By using technologies like Global Positioning System (GPS) and Geographic Information System (GIS), farmers can accurately map fields, identify variability, and tailor inputs according to specific crop requirements.
- 2. Increased Crop Yields:** By understanding field variability, farmers can identify areas with different soil types, nutrient levels, or water-holding capacity. This knowledge enables them to adjust input applications accordingly, ensuring that crops receive the right amount of nutrients, water, and protection.
- 3. Soil and Environmental Conservation:** Precision farming promotes soil and

environmental conservation by reducing input usage and minimizing runoff.

- 4. Cost Reduction and Economic Viability:** By tailoring input applications, farmers reduce unnecessary expenses on inputs, such as fertilizers and pesticides.
- 5. Data-Driven Decision Making:** Farmers can utilize this data to gain valuable insights into field variability, crop performance, and environmental conditions.

3. SOIL HEALTH AND CONSERVATION

3.1 Significance of Healthy Soil in Sustainable Agriculture

Healthy soil is of paramount significance in sustainable agriculture. It serves as the foundation for productive and resilient farming systems.

- 1. Nutrient Cycling and Fertility:** Healthy soil is rich in organic matter, nutrients, and beneficial microorganisms that play a vital role in nutrient cycling.
- 2. Water Management:** Healthy soil has good water-holding capacity and permeability, allowing it to retain moisture while also draining excess water. Healthy soil acts as a sponge, storing water during periods of rainfall or irrigation and slowly releasing it to plants as needed.
- 3. Soil Structure and Erosion Prevention:** Healthy soil has a well-developed structure with good aggregation. This structure allows for the movement of air, water, and roots within the soil, facilitating nutrient uptake and root development. It also provides a stable environment for soil organisms, promoting biodiversity and beneficial interactions. Sustainable soil management practices, such as reduced tillage and the addition of organic matter, improve soil structure, reducing erosion and enhancing long-term soil health.
- 4. Carbon Sequestration and Climate Change Mitigation:** Healthy soil acts as a carbon sink, sequestering carbon dioxide from the atmosphere and mitigating climate change. Organic matter in the soil plays a crucial role in carbon sequestration. Sustainable agricultural practices that promote the accumulation of organic matter, such as cover cropping, conservation tillage, and crop residue management, enhance carbon storage in the soil. This helps

mitigate greenhouse gas emissions, contributing to climate change adaptation and sustainable land management.

- 5. Biodiversity and Ecological Balance:** Healthy soil supports a diverse range of organisms, including beneficial bacteria, fungi, earthworms, and insects.

3.2 Agronomy's Role in Promoting Soil Fertility and Biodiversity

Agronomy plays a crucial role in promoting soil fertility and biodiversity through various practices and strategies.

- 1. Organic Matter Management:** Organic matter improves soil structure, water-holding capacity, and nutrient availability. It promotes practices such as cover cropping, crop residue incorporation, and the use of organic amendments like compost and manure to increase organic matter content in the soil.
- 2. Nutrient Management:** By conducting soil testing and nutrient analysis, agronomists can determine the nutrient requirements of specific crops and recommend appropriate fertilizer applications. Precision nutrient management helps ensure that plants receive adequate nutrients while minimizing nutrient runoff and leaching, which can harm water bodies and ecosystems.
- 3. Crop Rotation and Diversification:** Growing different crops in sequence helps break disease and pest cycles, reduces soilborne pathogens, and improves soil nutrient profiles.
- 4. Conservation Tillage:** Agronomy encourages the adoption of conservation tillage practices, such as reduced tillage or no-till farming. These practices minimize soil disturbance and help maintain soil structure and organic matter content.
- 5. Integrated Pest Management (IPM):** IPM integrates various pest management practices, including biological control, cultural practices, and judicious pesticide use.
- 6. Soil Conservation and Erosion Control:** By implementing erosion control measures such as contour plowing, terracing, and buffer strips, agronomists minimize soil erosion and the loss of topsoil. These practices preserve soil structure, prevent nutrient runoff, and protect water quality, contributing to the sustainability of agricultural systems.

3.3 Practices Such as Cover Cropping, Crop Rotation, and Reduced Tillage

Cover cropping is an agricultural practice that involves growing specific plant species, known as cover crops or green manure, during periods when the main cash crops are not actively growing. These cover crops are typically selected for their ability to improve soil health, nutrient cycling, erosion control, weed suppression, and overall sustainability of the farming system.

Crop rotation is a widely practiced agronomic technique that involves growing different crops in a planned sequence on the same piece of land over a defined period. Agronomy, as a scientific discipline, plays a crucial role in studying, developing, and implementing effective crop rotation strategies.

Reduced tillage, also known as conservation tillage or no-till farming, is an agricultural practice that involves minimizing or eliminating the mechanical disturbance of the soil. Instead of conventional plowing or intensive tilling, reduced tillage systems leave the soil largely undisturbed or only lightly disturbed [9,10,11].

4. CLIMATE-SMART AGRICULTURE

4.1 Impact of Climate Change on Agriculture

Climate change has a significant impact on agriculture, posing various challenges and risks to food production systems globally.

- 1. Changes in Temperature:** Rising temperatures affect crop growth and development. Extreme heat events can lead to reduced yields, decreased crop quality, and even crop failures. Warmer temperatures also affect the timing of crop planting and harvesting, disrupting traditional agricultural calendars and management practices.
- 2. Altered Precipitation Patterns:** Climate change brings changes in precipitation patterns, including increased frequency and intensity of droughts, as well as more intense rainfall events in some regions. Both droughts and excessive rainfall can adversely affect crop growth, water availability, and soil quality, leading to reduced yields and increased vulnerability to pests and diseases.

3. Water Scarcity and Irrigation Challenges:

Changes in precipitation patterns, combined with increased evaporation rates due to higher temperatures, can result in water scarcity for agricultural purposes. Reduced water availability poses significant challenges for irrigation-dependent agriculture, limiting crop productivity and potentially leading to shifts in cropping patterns and the need for more efficient water management strategies.

4. Shifting Growing Seasons and Climate Zones:

Climate change can cause shifts in growing seasons and climate zones, altering the suitability of specific regions for certain crops.

5. Increased Pests and Diseases:

Climate change influences the distribution and abundance of pests, insects, and diseases that affect crops. Warmer temperatures and altered precipitation patterns can create favorable conditions for the proliferation of pests and the spread of plant diseases.

6. Impacts on Soil Health:

Higher temperatures, changes in precipitation patterns, and increased frequency of extreme weather events can lead to soil erosion, nutrient depletion, and degradation. These factors, combined with the loss of organic matter.

7. Impacts on Livestock and Animal Agriculture:

Heat stress on livestock can reduce productivity, affect reproduction, and increase susceptibility to diseases. Changes in forage availability and quality due to altered rainfall patterns and shifts in vegetation can impact grazing systems. Additionally, changes in the geographic distribution of vector-borne diseases can affect livestock health.

8. Food Security and Socioeconomic Implications:

Reduced crop yields, increased food prices, and decreased availability of nutritious foods can exacerbate food insecurity, particularly in vulnerable regions. B. Explain how agronomy helps farmers adapt to climate challenges.

4.2 Climate-smart Practices and Their Benefits

Climate-smart practices refer to agricultural techniques and approaches that aim to mitigate climate change, build resilience to its impacts, and contribute to sustainable food production systems. These practices offer several benefits

for farmers, ecosystems, and the environment. Climate-smart practices and their benefits:

1. Conservation Agriculture: Conservation agriculture involves minimum soil disturbance, permanent soil cover, and crop rotation. Benefits include:

- Enhanced soil health and fertility through the preservation of soil structure, moisture retention, and reduced erosion.
- Increased carbon sequestration in the soil, mitigating greenhouse gas emissions.
- Improved water use efficiency and reduced irrigation needs.
- Reduced fuel and labor requirements, leading to cost savings for farmers.

2. Agroforestry: Agroforestry integrates trees with crops or livestock systems. Benefits include:

- Carbon sequestration in trees and improved soil organic matter.
- Improved biodiversity and habitat for wildlife.
- Enhanced soil fertility through nutrient cycling and nitrogen fixation.
- Reduced water runoff and erosion, maintaining soil quality.
- Diversified income streams through timber, fruits, and other tree products.

3. Precision Agriculture: Precision agriculture utilizes technology, data, and precise management techniques to optimize inputs and maximize crop production. Benefits include:

- Improved resource efficiency by precisely applying water, fertilizers, and pesticides, reducing wastage.
- Increased yields and optimized crop quality through targeted management practices.
- Reduced environmental impact by minimizing nutrient runoff and pesticide drift.
- Enhanced profitability through cost savings and increased productivity.

4. Diversified Cropping Systems: Diversifying crops and incorporating multiple species within a farming system provides numerous benefits:

- Reduced pest and disease pressures through crop rotation and companion planting.
- Enhanced soil health and fertility by improving nutrient cycling and reducing soilborne pathogens.
- Improved resilience to climate variability by having a range of crops with varying environmental tolerances.
- Increased income stability through diversified markets and reduced dependence on a single crop.

5. Water Management Techniques: Climate-smart water management practices focus on efficient irrigation and water conservation. Benefits include:

- Reduced water consumption through techniques such as drip irrigation, precision sprinklers, and moisture monitoring.
- Enhanced water availability for crops during periods of water scarcity [12,13].
- Improved soil health and reduced salinization by preventing excessive irrigation and waterlogging.
- Minimized runoff and erosion through techniques like contour farming and terracing.

5. TECHNOLOGICAL ADVANCEMENTS IN AGRONOMY

5.1 Role of Technology in Revolutionizing Agronomy

Technological advancements in agronomy have revolutionized the way we approach farming and have had a significant impact on agricultural productivity, sustainability, and efficiency.

1. Precision Agriculture: Precision agriculture utilizes technologies such as Global Positioning Systems (GPS), Geographic Information Systems (GIS), and remote sensing to collect data and make precise decisions regarding crop management.

2. Remote Sensing and Imaging: Remote sensing technologies, such as satellite imagery and drones, provide valuable data on crop health, moisture levels, and vegetation indices.

3. Crop and Soil Sensors: Crop and soil sensors are used to measure various parameters, including soil moisture, temperature, nutrient levels, and crop growth.

4. Genetic Engineering and Genomics:

Genetic engineering and genomics have facilitated the development of crop varieties with improved traits such as resistance to pests, diseases, and environmental stresses. Biotechnology tools enable the transfer of desirable genes into crops, enhancing their productivity and sustainability.



Fig. 3. Spraying nutrients through drones

5. Data Analytics and Decision Support Systems:

This enhances decision-making, improves resource allocation, and increases farm efficiency.

6. Robotics and Automation: Agricultural robots and automation technologies are being developed for various tasks, including planting, harvesting, spraying, and monitoring. These technologies reduce labor requirements, increase efficiency, and enable precise and targeted operations. Robots equipped with sensors and imaging technologies can identify and selectively harvest crops, minimizing waste and improving productivity.

7. Smart Farming and Internet of Things (IoT): Smart farming systems integrate various technologies, such as sensors, actuators, and connectivity, to enable real-time monitoring and control of farm operations. IoT platforms collect and analyze data from farm equipment, sensors, and weather stations, providing farmers with valuable insights for decision-making.

6. SUSTAINABLE INTENSIFICATION

Sustainable intensification refers to the concept of increasing agricultural productivity while minimizing negative environmental impacts and ensuring long-term sustainability. It involves

optimizing resource use, adopting efficient production practices, and enhancing ecosystem services to meet growing food demands without degrading natural resources.

7. CONCLUSION

Agronomy's multifaceted role in promoting sustainable and efficient agricultural practices, adapting to climate change, conserving natural resources, driving innovation, and empowering farmers contributes to a flourishing future. By balancing productivity, environmental stewardship, and socio-economic considerations, agronomy paves the way for a sustainable and prosperous agricultural sector that can meet the food demands of a growing global population while preserving the planet's resources for future generations.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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