Current Trends in Agronomy: Innovations and Future Perspectives

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Abstract *: The main agricultural science, Agronomy, is concerned with the optimization of crop production and management of the soils in a sustainable manner. Agriculture is under tremendous pressure to ensure more food is produced with little resources due to the increasing world population to 9.7 billion by 2050. Modern agronomy has developed out of the traditional methods of crop and soil management to a technology-intensive science that incorporates technology like precision agriculture, GIS, GPS, remote sensing, artificial intelligence, climate-smart practices, biological advances, and online platforms. The innovations also empower farmers to make informed and site-specific decisions which are more productive, use fewer resources and have less strain on the environment. This paper is a review essay of the present trends in agronomy with focus on precision farming, controlled environment agriculture, biological crop protection, and soil health management. Future directions such as digital twins, phytobiome research and combining biotechnology with digital agriculture are touched on as ways of bringing about resilient and productive agricultural systems that will be in a position to secure food security all over the world.*

Keywords: Agronomy, Precision Agriculture, GIS, GPS, Remote Sensing, Artificial Intelligence, Sustainable Agriculture, Biological Inputs, Climate-Smart Practices, Soil Health.

Introduction

The focus of the human society is agriculture as it supplies people with food, fiber, and raw materials that are needed to survive and develop economically (Malhotra, 2017). Agronomy is the study of soil, crops and environmental influences on the production of agriculture. The Green Revolution brought high yield varieties, chemical fertilizers and irrigation methods which reflected on the world food production in an extraordinary manner. Nevertheless, it also resulted in soil erosion, water contamination, and the disappearance of biodiversity (Lal, 2020).

The 21st century involves a two fold challenge of creating more to sustain a rising population and at the same time reduce the use of resources and diminish environmental effects (IPCC, 2023). The agronomy of the present-day era is based on the balance between productivity and sustainability as follows: technological and climate-proof approaches (FAO & ICAR, 2024).

Digital technologies such as GIS and GPS, remote sensing, AI and big data analytics combine with conventional farming expertise (Sharma and Singh, 2024). Spatial analysis of field variability can be performed with GIS and GPS technologies and a precise input is possible. The former offers crop health information in real-time with the help of remote sensing, whereas the latter is able to predict pest outbreaks and optimise their resources (Reddy, 2024; Singh, Sharma, and Gupta, 2024). These tools mark the move in direction of information, precision, ecologically sustainable farming.

Precision Agriculture and Smart Farming

The application of precision agriculture ensures that there is an optimal input of the right quantity at the right time and location to produce maximum output with minimum costs and environmental degradation (Sharma and Singh, 2024). GIS maps the spatial data of soil, topography, and water resources in order to generate management zones (Sharma and Singh, 2024). As an example, the soil fertility maps in Soil Health Card Mission in India enable targeted use of fertilizers, which raises yield by 10 to 15 percent and minimizes the number of nutrient runoff (Prakash, Singh, and Singh, 2023).

GPS gives an accurate position of the machinery so that planting, tillage, and harvesting are done with accuracy (Sharma and Singh, 2024). The GPS-controlled tractors in the USA save 20 percent of fuel and efforts by eliminating overlaps (Sharma and Singh, 2024).

Crop vigor, water stress, and pest infestations are observed in remote sensing, such as satellite-based NDVI (Zhang, Li, and Kumar, 2023). Remote sensing helps Brazil to maximize sugarcane production and cut fertilizer expenses by one-tenth (ISRO, 2023). In Karnataka, India, drone technology can help reduce pesticide use by 30 percent by capturing high-resolution images of a field, allowing spraying precise and thereby preventing the pesticide from falling out (Dhanaragalu, Chenniappan, and Ramalingam, 2022).

Variable Rate Technology (VRT) makes it possible to apply inputs variably to fields. Precision irrigation using IoT in Israel saves 25 percent of water consumed and grows yield by 18 percent (Dhanararaju, Chenniappan, & Ramalingam, 2022).

The use of precision agriculture is on the rise across the globe: about 40 percent of large-scale farms in the USA, 18 percent in Brazil, and 10 percent in India currently utilize precision tools (FAO, 2025).

Artificial Intelligence and Big Data Applications

The models of the AI-based decision support system process gather data provided by sensors, weather stations, and historical data (Singh, Sharma, and Gupta, 2024; Johnson and Miller, 2023). Machine learning forecasts outbreak of pests and diseases, which makes it possible to prevent them. The AI apps available on smartphones can enable farmers to diagnose the diseases using photos (Singh, Sharma, and Gupta, 2024; Johnson and Miller, 2023).

Big data combines field sensors, climate modeling, and market trends, aiding in the forecasting of yields, supply chain management, and policy-making (World Bank, 2024). Microsoft Farm Beats is an IoT-based and AI-driven platform created by Microsoft that works to integrate farm data to achieve precision agriculture, and IBM Watson offers another AI-driven decision support system in the farming sector (Johnson & Miller, 2023).

Robotics mechanizes the automation of weeding and harvesting and sowing, contributing to the efficiency and minimizing the need to rely on manual labor. In Japan, autonomous robots helped decrease the labor expenses by 35% in the cultivation of vegetables (Ghosh and Sarkar, 2024).

Sustainable and Regenerative Agronomic Practices

Sustainable agronomy ensures soil is fertile, water is saved, and the biodiversity is preserved (Lal and Stewart, 2018). Regenerative agriculture heals damaged ecosystems. No-till farming minimizes soil erosion, cover crops improve soil fertility, and agro forestry allows the inclusion of trees to provide shade and capture carbon (Lal, 2020).

Projects in Africa which were led by the FAO boosted crop production by 30 percent using regenerative agriculture and enhanced ecosystem services (FAO, 2025). The System of Rice Intensification (SRI) in India also cut the amount of water by a quarter without lowering yields (Prakash, Singh, and Singh, 2023). Intercropping and crop rotation decrease the occurrence of pests by 15-20 and enhance resilience (Lal, 2020).

Biological Inputs and Eco-Friendly Crop Protection

Biofertilizers such as Rhizobium and phosphate-solubilizing Bacillus enhance the availability of the nutrients (Rao, Singh, and Patel, 2023). Bio pesticide, such as Beauveria bassiana and Neem extracts, are effective in the management of pests without residues (Rao, Singh, and Patel, 2023). Microorganisms and plant extracts produce bioherbicides that deal with weed resistance (Rao, Singh, and Patel, 2023).

Integrated Pest Management (IPM) integrates biological, cultural and mechanical approaches. The markets of the global biopesticides and biofertilizers are expanding at a rate of 12-15 percent every year because of the demand of the organic products and the ban of chemical inputs (FAO, 2025).

Climate-Smart Agronomy

Climate-smart agronomy is adaptive to changes in climate and minimizes greenhouse gasses. Alternate Wetting and Drying (AWD) of rice conserves water, and it cuts the emission of methane by half (FAO & ICAR, 2024). CRISPR-based versions of climate-resilient varieties enhance drought or salinity tolerance in yield (Singh, Sharma, and Gupta, 2024).

Agro forestry and conservation tillage increase the soil carbon sequestration which sequester 1-2 tons of carbon per hectare/year. DSSAT software helps to forecast the time of the crop and the resources (Sinha and Patel, 2024)

Controlled Environment Agriculture (CEA)

CEA is characterized by greenhouses, hydroponics, and vertical farms, and gives an opportunity to control the environment (Reddy, 2024). Hydroponics and aeroponics take the best advantage of space and save on water. Consistent yields with very little use of pesticides are produced by AeroFarms (USA) and Sky Greens (Singapore) (Aerofarms, 2023; Sky Greens, 2024).

The IoT automatically manages climate and irrigation control, which minimizes both labor and energy (Dhanararaju, Chenniappan, and Ramalingam, 2022). The application of CEA is increasing 15 percent/year most specifically in urban agriculture.

Digital Agriculture and Agri-FinTech

Digital agriculture is a combination of financial and technological. Blockchain provides traceability, which is important to exports. ENAM in India enables farmers to get direct links with buyers, which leads to the income increased by 10 to 15 percent (World Bank, 2024).

Agri-fintech is mobile credit, online payments and mobile crop insurance. Association of financial services and real-time data minimizes the risks and enhances financial inclusion (USDA, 2024).

Soil Health and Nanotechnology

Productivity is focused on healthy soil. Microbiomes in soils are involved in the cycling of nutrients (Lal and Stewart, 2018). Nano-urea, or nanotechnology, is efficient in delivering nitrogen, thus minimizing losses and pollution (IFFCO, 2023).

Biochar enhances structure, water retention and captures carbon. Remote sensing also tracks moisture and degradation so that they may be proactively managed (Zhang, Li, and Kumar, 2023).

Future Directions in Agronomy

The future is marked by the advanced integration of technology and the sustainability. Digital twins model farm strategies prior to the implementation. The study of phytobiomes promotes the management of nutrients and pests (CGIAR, 2024).

Innovations will be scaled by global collaborations (ICAR, FAO, CGIAR). Access is equitable when the policies are in line with UN SDGs (United Nations, 2024). The convergence of AI, IoT, and biotechnology will provide the ability to have fully automated farming systems resistant to climatic conditions (Singh, Sharma, and Gupta, 2024).

Conclusion

Agronomy is in its transformative stage where the traditional knowledge is coming into contact with the advanced technologies. Precision, climate-wise, and sustainable agriculture has been made feasible through the incorporation of GIS, GPS, remote sensing, AI and biological inputs. Digital agriculture, regenerative methods, and controlled environment systems can increase the output and save the natural resources. This is likely to be optimized further with the emergence of new technologies, like digital twins and phytobiome, which will guarantee sustainability in food production. To achieve resilient agricultural systems to handle the climatic changes and the increased world population, close cooperation between researchers, policymakers, and farmers will be crucial.

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