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Sustainable Regenerative Agriculture allied with Digital Agri-Technologies

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A significant step toward creating a self-sufficient country would be the development of the agricultural sector. India has a variety of climates and lacks the two main resources needed for agriculture: water and cultivable land. Finding creative solutions to some pressing problems is urgently needed, such as how much we are preparing for a future pandemic and what steps are necessary to restore the nation's agricultural industry in the post-pandemic era. According to this viewpoint, every calamity also presents fresh opportunities to strengthen the country's ecological base.

The post-COVID-19 scenario has also offered a lot of positive impacts on the environment and provided an opportunity to further strengthen our agricultural practices through varied technological processes processing, value addition, and marketing are key components of such interventions. Moreover, for millions of years, wildfires have influenced ecosystems throughout the world, and they continue to do so today (Cetin *et al.*, 2022). People in fire-prone areas have evolved to live and work with fire. The smoke and heat can damage the outermost coverings of crops that are not even apparent to the f ire. Particular kinds of crops can give fuel to the fire. Inhaling smoke and contaminants in the air can negatively impact an agricultural worker's health. Thus, to avoid crop loss due to natural calamities, sustainability is mandatory.

Regenerative agriculture (RA) combines several farming techniques to restore and maximize the potential of degraded landscapes in the framework of agricultural sustainability (Gordon *et al.*, 2023). With an emphasis on soil health, regenerative agriculture is a comprehensive farming strategy that rebuilds and preserves ecosystems in a robust and healthy state. Any way of producing crops and/or livestock that enhances the quality of the product and the availability of the resources that agriculture depends on soil, water, biota, renewable energy, and human effort through natural complexity and contextual capability. Some of the core ideas of regenerative agriculture include preserving soil cover, minimizing soil disturbance, protecting living soil roots all year round, increasing biodiversity, incorporating livestock, and minimizing or eliminating the use of synthetic compounds (like fertilizers and pesticides).

There are several ways that RA might enhance biodiversity and the ecosystem. By significantly increasing the organic carbon and nitrogen-based components that are accessible in the soil, it restores soil fertility. By strengthening soil and plant root structures, RA operations reduce the risk of severe environmental disasters and stop erosion.

Practices of Regenerative Agriculture

Conservation Agriculture: Among the various techniques, conservation agriculture (CA) is one that strengthens and expands agricultural production by boosting its profit and guaranteeing food security, which lowers the need for new inputs and maintains the ecosystem's balance of resources. Minimum tillage in conjunction with other soil conservation techniques is the cornerstone of conservation agriculture. Crop residue, little tillage, or no soil disturbance, and crop rotation are the three components of conservation agriculture methods (Karki and Shrestha 2014). The application of conservation agriculture techniques, such as crop rotation, residue retention, and no-till farming, can reduce the effects of climate change, preserve soil fertility and quality, boost crop production, provide food security, boost economic returns, and preserve the surrounding ecosystem.

Integrated Livestock, Compost or Manure Application: Generally, animals are grazing in field compressing the unwanted plants into the soil by their hooves and composed of source of organic nutrients for the new plants growth that‘s helps to build up organic matter into the soil and provides draft power and manure to agriculture, income, nutritional and other byproducts. The excrement of animals is good source of nutrients for water retention capacity and seed germination (Sahu and Das 2020). About 60% of livestock‘s feeds come from low quality crop residues and 40% from the forest. Compost or manure application helps to improve soil structure, texture, aeration, fertility, nutrients, water infiltration and water-holding capacity. Livestock manure application is the main source of soil nutrients and organic matter through which plant uptake nutrients from the soil. The resentment for crop producers during measurement of organic matter (SOM) levels and soil resilience due to applications of steady combination of forage based rotations and manure. The C:N ratio is the ratio of carbon and nitrogen for improving soil and plant health. Nitrogen is a food source of soil microbes which decomposed and automatically incorporated with soil called organic nitrogen uptake by plant. Ideal C:N ratio is 20:1 for crop production.

Perennial cropping: Because perennial crops can sprout on their own after harvest and don't require annual planting, they decrease the need for human labor, plowing, and ongoing abrasion. A developing movement that seeks to provide a regenerative alternative to conventional farming is the development of perennial crops as substitutes for annual crops. Perennial plants are necessary to preserve the soil's native biota, soil structure, and soil cover. Compared to annuals, these plants have stronger, deeper root systems that improve soil health and stability.

Agroforestry: Trees, herbs and shrubs and also protect the soil run off and erosion through planting trees, herbs and shrubs that enhance the agriculture production and improve the livelihood. Agroforestry is also provided fodder to livestock. It is as regenerative agriculture practices are parallel interrelated with each other which is significantly resulted in food security due to environmental, economic and social benefits. The practice of agroforestry is similar to regenerative agriculture that is composed of five goals as soil fertility and health, water quality, biodiversity, ecosystem health, and carbon sequestration. Agroforestry is plays a major role for improving soil fertility by providing nutrients to the soil, retention of rain water and improving infiltration, reducing soil run off and erosion, producing habitat and food for biodiversity (Elevitch *et al*, 2018).

Digital Technologies in Sustainable Agriculture

Concerns from the public on the use of natural resources must be addressed by agribusinesses. According to this viewpoint, Industry 4.0's digital technologies appear to be collaborators in the modernization of agribusiness. In order to evaluate the unique characteristics of digital transformation in the context of contemporary agriculture, these technologies are directly related to digital transformation. Following the industrial revolution of the nineteenth century, agricultural advancements have continued to increase quickly. The current era, known as "Agri-Food 4.0" or "Agri-tech 4.0," is based on the application of cyber-physical systems (CPSs) in food production systems and precision farming. Examples of contemporary agricultural systems include the usage of smart greenhouses, drones, robotics, sensing devices, wireless sensor networks (WSNs), hydroponics, aeroponics, and vertical farming. Additionally, "Agri-Food 4.0" emphasizes initiatives to lower production costs, use less fuel, water, and fertilizer, and encourage the use of renewable energy. These include machine learning-based solutions that could aid in the acquisition of high-quality crops and cold storage, which can improve inventory management by promptly recognizing trash disposal and supplying customers with only healthful items. According to Du *et al*. (2012), agri-tech 4.0 solutions can lead to significant advancements in the processes utilized by the current supply chains, which can result in competitive advantages for numerous stakeholders.

Soil mapping and fertilizers application : Soil sampling is one way to get field-related data. Nutrient status, cropping history, soil variety, irrigation level, topography, and fertilizers applied to the soil are some significant characteristics that provide information on the soil's suitability for agriculture. The physical, chemical, and biological characteristics of the soil are determined by these factors. Through soil mapping, a certain crop can be planted in a particular field based on the characteristics of the soil. According to the particular soil type, soil mapping offers information on crop types, planting depth, sowing time, and seed appropriateness. The recent study compared and elucidated the effectiveness of Regenerative agriculture practice on soil microbial and nutritive health concerning conventional agriculture and barren soil.

Advanced greenhouses : The intelligent greenhouse has the competence to assess ecological conditions like wind trends, rainfall, wind speed, relative humidity, sunlight intensity, temperature, and CO_2 concentration. Thus, the internal conditions of the greenhouse were monitored to preserve the crop's integrity. The information entered into this smart system can be acquired via wired communication utilizing a machine-machine system and a human–machine system through a graphics control interface.

Low-cost IoT-based systems : Tracing and tracking technology have the potential to significantly improve the food supply chain's performance by minimizing spoiling waste through efficient inventory and product quality monitoring. The Internet of Things is a technology that makes use of internet-connected smart devices. Without human involvement, IoT components and networks exchange data. AI-powered virtual assistants, or chatbots, are being used in the travel, retail, media, and insurance sectors. AI is becoming more and more integrated into modern agricultural techniques, providing farmers with guidance and solutions for specific issues. The wireless sensor network can be applied as an IoT technology that has an impact on the post-harvest supply chain and its transparency. The data is accumulated by the wireless sensor network from multiple types of sensors set up by farmers, growers, or distributors.

Drone or unmanned aerial vehicle (UAV) technology : In agriculture, drones and unmanned aerial vehicles (UAVs) can be utilized for a variety of tasks, including soil and field research, planting, pesticide spraying, crop monitoring, irrigation system management, and plant health evaluation. In more sophisticated iterations, the mechanical structure was altered to improve integrity and address environmental stress-induced deformation. These UAVs are resilient enough to accommodate additional hardware, such as microcontrollers, sensors, cameras, and other small devices. Through embedded devices like gyroscopes, accelerometers, GPS, voltage, and current measurement devices, these devices additionally guarantee user interface monitoring systems. The spray can reach the lower plant parts in the field and underneath the leaves. Thus, such spraying systems are very effective as compared to manual hand-held sprayer operators. Lack of skilled labor capacity is of no issue if such an effective system would be used in a field to safeguard the crop from sowing to harvest.

Agri-robotic systems and IoT-based tractors : Another, smart, sensing, and sustainable solution to agriculture challenges lies in the advent of the Agri-robots that are designed to perform a field evaluation to detect any disorder and monitor plant growth. These robotic systems can walk in space in the fields with their artificial six legs.

Use of nanosensors and remote sensing : Wireless sensors make it simple to retrieve crop status and other parameters. The following are some of the several kinds of sensors used in agriculture. Farmers are now monitoring plant transpiration, irrigation, and humidity in real-time using field-programmable gate array (FPGA)-based sensors (Gasso-Tortajada *et al*., 2010). Depending on specific needs, FPGA-based sensors can offer workable solutions. Acoustic sensors, which can provide inexpensive solutions for a variety of agricultural tasks like soil cultivation, weeding, fruit picking, etc., follow next. The sound absorption spectra show that they are commonly used for monitoring, identifying pests, and assessing seed quality. Light detection and ranging (LiDAR) sensors are widely used sensors for land map ping and segmentation, evaluating soil type, monitoring erosion, farm 3D modeling, and yield forecasting.

Conclusion

As the world's population grows, there is an increasing need to produce enough food to feed everyone while protecting the environment. To support agri-food production systems and strengthen the supply chain, smart, sensing, and sustainable regenerative agriculture technologies must be implemented. Farmers, the environment, and society can all benefit greatly from regenerative agriculture. The digital paradigm based on precision agriculture technologies like intelligent greenhouses, agri-robotics, drones, satellites, smart wireless sensor networks, cloud computing, and blockchain technologies must be given importance to support regen erative agriculture practices for fine-tuning the agriculture sector.

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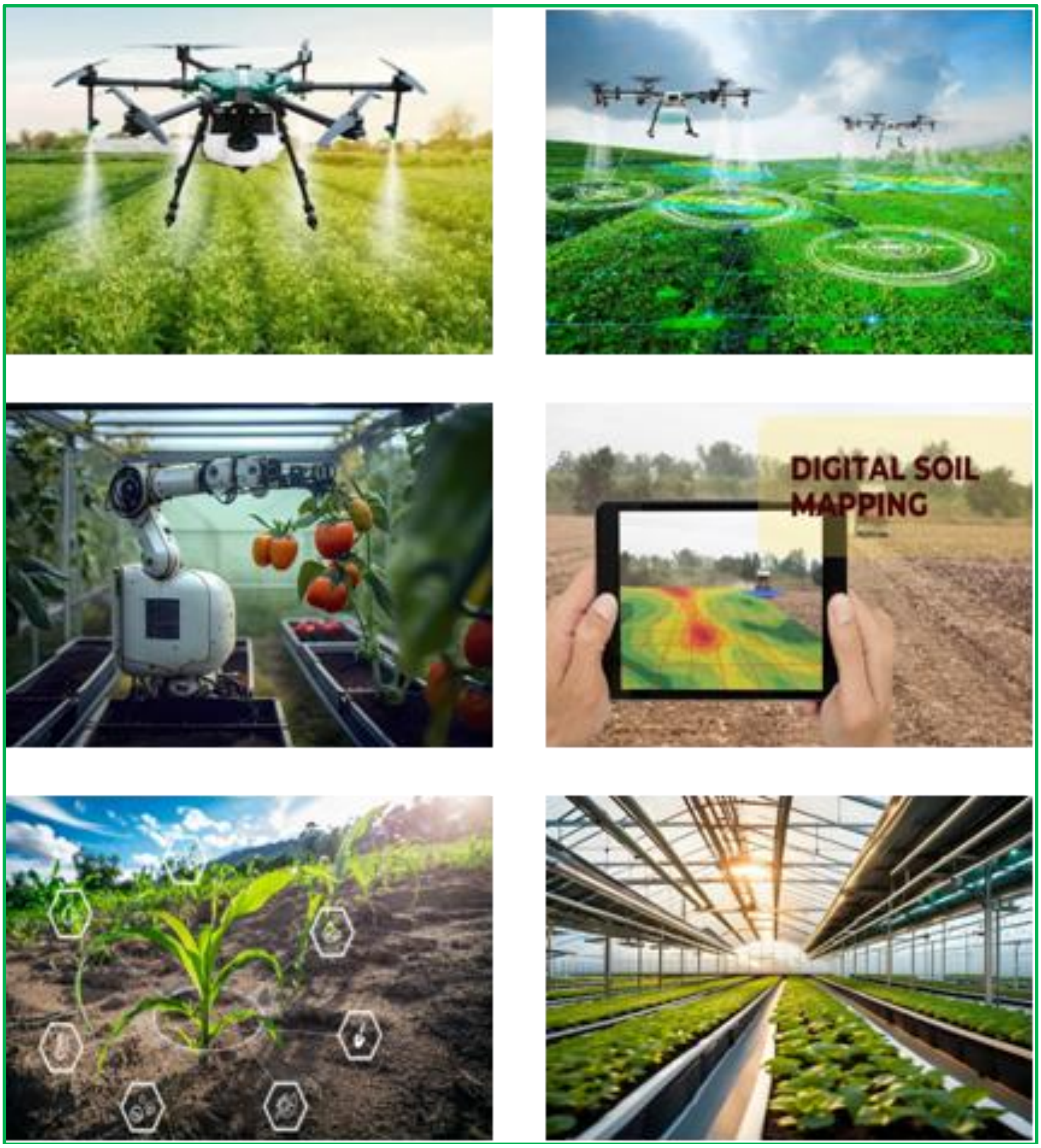
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