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TECHNO-CENTRIC AGROLOGY: RE-SCRIPTING SUSTAINABLE AGRICULTURE

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ABSTRACT

Technological change in smart agriculture is a necessity for enhancing agricultural productivity, especially for sustainable farming systems. Smart agricultural farming is designed on providing the agricultural industry with the infrastructure to leverage advanced technology with the inclusion of big data, the cloud, and the internet of things (IoT) for tracking, monitoring, automating, and analyzing operations.

The driving factors for the adoption of technologies are a combination of demand-related activities together with research efforts. These two most important factors assist in balancing economic efficiency with environmental sustainability. Adopting technologies for sustainable farming systems involves uncertainty and tradeoffs. The tradeoff is experienced when there is a necessity to employ a variety of evolving technologies and farm practices from various stakeholders.

Climate-Smart Agriculture (CSA) first launched in 2009 is an integrated approach to managing landscapes and guiding the management of agriculture in the era of climate change. Resource inputs and interactions from multiple stakeholders are important to address the interlinked challenges of food security and climate change.

The climate-smart agriculture initiative proposed by the Food and Agriculture Organization of the United Nations has attracted international attention. Smart agriculture (SA) has since been recognized as an influential trend contributing to agricultural development. Therefore, encouraging farmers to adopt digital technologies and mobile devices in farming practices has become a policy priority worldwide. However, the literature on the psychological factors driving farmers' intentions to adopt SA technologies remains limited.

The adoption of technologies for smart agriculture is a challenging and dynamic issue for some of the stakeholders namely, farmers, agri-business, and policy-makers. The challenges faced by Indian agriculturists in the year 2022 are in the areas of conserving resources, climate changes, and carbon footprint, decreasing biological diversity, and many more. The utilization of digital innovations in the agricultural sector especially, IoTs in farming, smart agriculture machines and many more emphasis in recent years is coordinating with the adoption of technologies for smart agriculture that is the next breakthrough in the rapid progress of technologies.

Smart agricultural techniques, a big leap from traditional farming are based on certainty and predictability and involve the use of robotics, automation, and cloud software systems that have a real potential to deliver a more productive and sustainable forms of agricultural production. Global Positioning System (GPS) allows farmers to accurately navigate to specific locations in the field, year after year, to collect soil samples or monitor crop conditions.

Smart Agriculture is also implemented using IoT in such a way to keep the cost minimized and provide a simple platform to monitor the parameters for the growth of crops through the internet over IoT. IoT-based smart farming is a network typically designed with sensors that keep a check on light, humidity, temperature, soil moisture to monitor the crop field and automate farming activities. The biggest challenges faced by IoT in the agricultural sector are lack of information, high adoption costs, security concerns, etc. Natural resources, such as land, water, soil, and genetic resources must be better managed so that more productive and resilient agriculture can be achieved. Indian farmers need help to develop climate-smart agricultural practices that can adapt to and mitigate the impacts of climate change, but also have the potential to increase food production.

Smart agriculture is a necessity that can be utilized in one form of smart farming that is much more efficient than traditional methods. With the right data, farmers will be able to take timely decisions, on what crop to sow, when to sow it, and what method to use.

Keywords: Internet of Things, Smart 8farming, Research efforts, Climate Smart Agriculture, Agricultural resources

Agriculture has undergone a sustainable revolution in recent years with the help of digital connectivity in the form of smart farming technology, resulting in sustainable agriculture. The agri-tech revolution, according to Nordmann (2014), can play a significant role and is the way of the future. Nordmann (2014) is of the opinion that this is achievable only if the precautionary principles of various stakeholders support the adoption of necessary steps in every economy for investing in suitable technology and procedures.

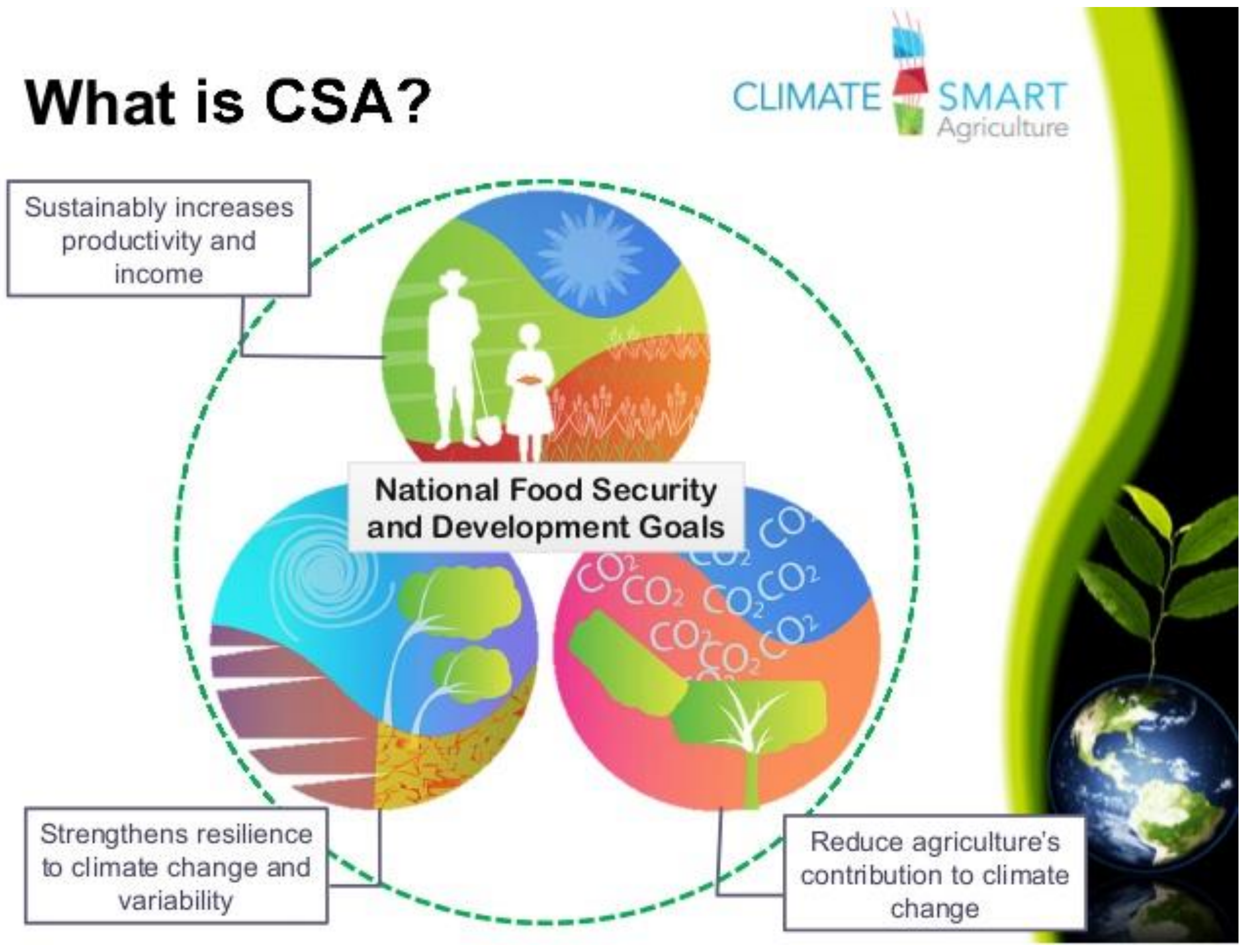
According to the World Economic Forum, the world population will reach 9.8 billion people by 2050. According to research performed by the McKinsey Center for Advanced Connectivity and the McKinsey Global Institute (MGI), this sustainable transformation fuelled by advanced connectivity will bring $2 trillion to $3 trillion in added value to global GDP over the next decade. According to statistics, between 1.9 and 2.2 billion people still rely on traditional agricultural systems for interacting with nature and managing ecosystem services (Fisher et al. 2009).

Climate-Smart Agriculture (CSA) was first introduced in 2009, and the Food and Agriculture Organization's (FAO 2010) approach is an integrated approach that is gaining traction, particularly in developing countries, for transforming and reorienting agro-ecosystems to produce food in the face of climate change. In the investigations of Grainger-Jones (2011), Long et al. (2016), and Mwongera et al. (2016), the outcome of a sustained improvement in productivity and agro-ecosystem resilience is identified (2017).

CSA is an emerging method for increasing food production, biodiversity, environmental quality, agro-ecosystem resilience, livelihoods, and economic growth while addressing climate change consequences, according to Olayide et al. (2016). CSA stands for Community Supported Agriculture, which is an

advanced and innovative method of increasing farm efficiency and effectiveness by utilizing modern information and communication technologies to increase the quantity and quality of products while reducing the amount of human labor required. Irrigation management, crop scouting, harvesting, and seeding all benefit from advanced technology, which involves the use of hardware, services, and software in the farming process. Artificial intelligence, analytics, linked sensors, and other developing technologies have improved the efficiency of water and other inputs, as well as crop cultivation and animal husbandry sustainability and resilience. Farm equipment has grown in size, speed, and productivity as a result of technological advancements, allowing for more effective land cultivation. Seed, irrigation, and fertilizers have all improved significantly, allowing farmers to enhance yields.

FIGURE 1.1 OBJECTIVES OF CLIMATE-SMART AGRICULTURE



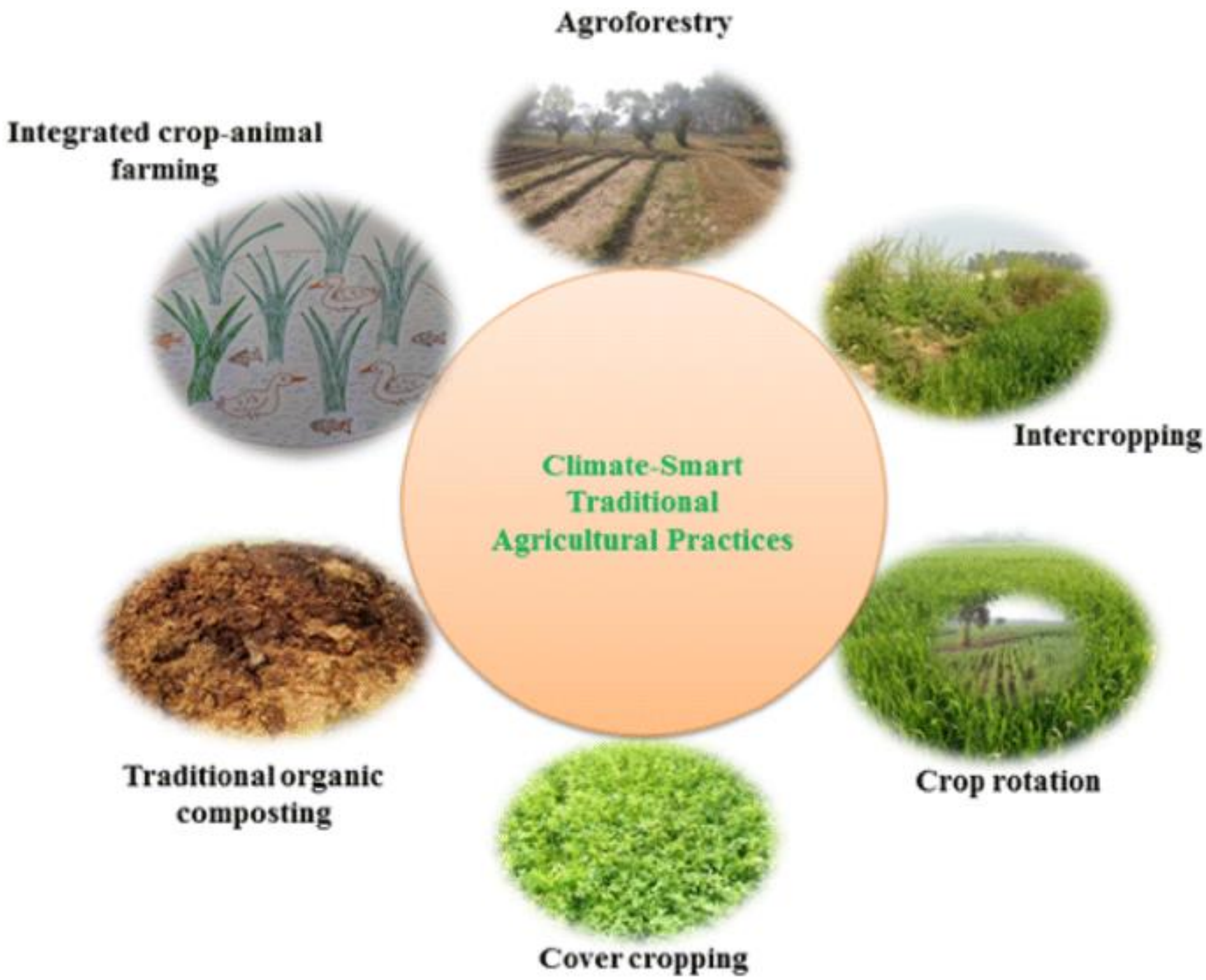
Source: https://csa.guide/sites/default/files/images/WhatisCSAFig1.jpg

The Climate Smart Agriculture strategy is founded on the following concepts and goals, as shown in Figure 1.1:

- **the long-term improvement of agricultural production to enable a rise in income, food security, and development for all people**
- **enhanced shock resistance and adaptive capacity at numerous levels, from agricultural to national**
- **the decrease of greenhouse gas (GHG) emissions and, where practicable, increased carbon sequestration**

Climate change mitigation entails efforts to reduce GHG sources and emissions, as well as human-mediated reductions of anthropogenic forcing of the climate system (Halsnaes et al. 2007). CSA's main goal is to produce sustainable food while lowering GHG emissions and improving the agricultural system's climate resilience (Harvey et al. 2014; Brandt et al. 2015).

FIGURE 1.2 THE CLIMATE-SMART TRADITIONAL AGRICULTURAL PRACTICES



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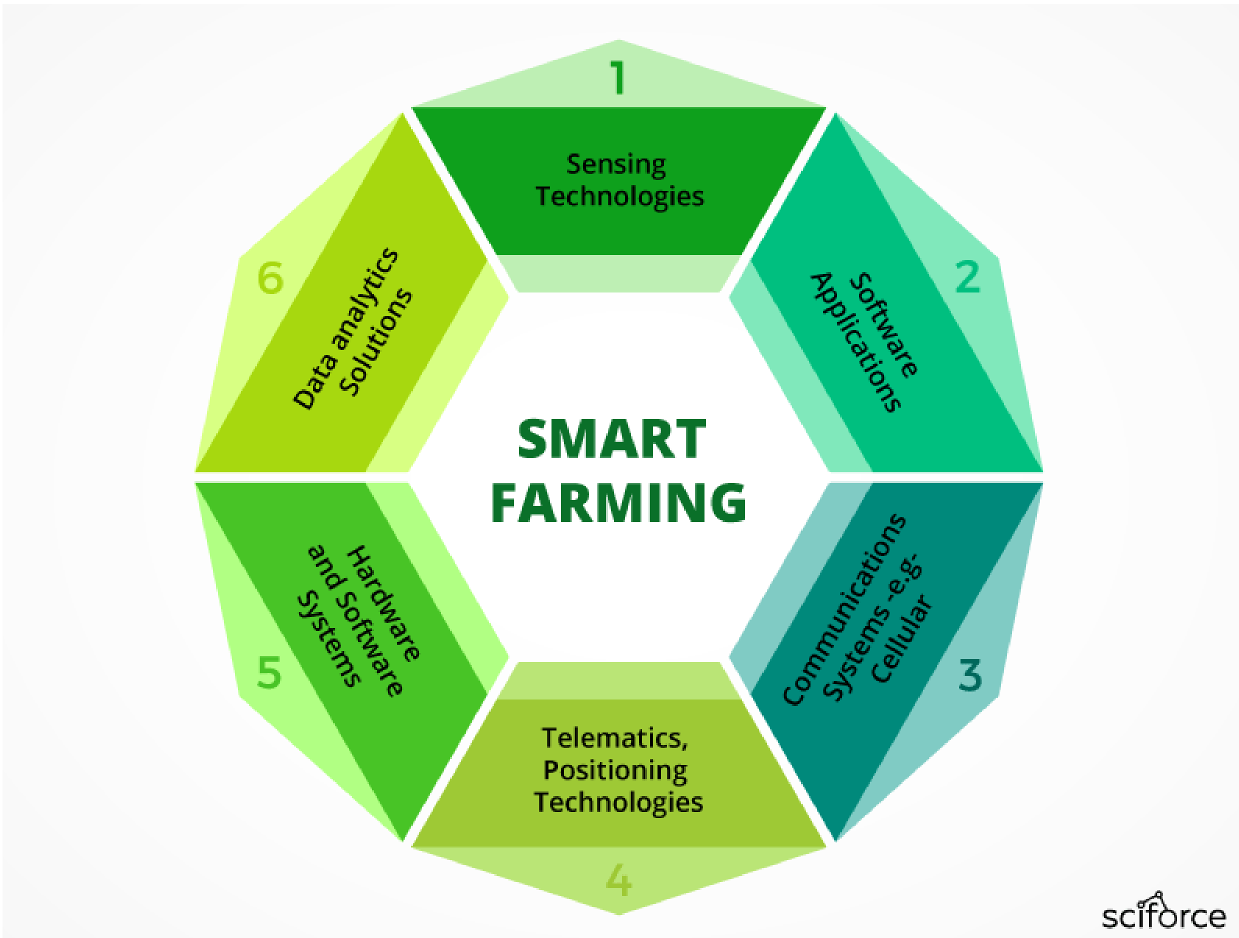
Traditional agricultural practices can be combined with agroforestry, intercropping, crop rotation, cover cropping, traditional organic composting, and integrated crop-animal husbandry by combining Figures 1.1, 1.2, 1.3, and 1.4. According to Wolfert et al. (2017), research based on the notion of technological innovation in the main dimensions could help achieve increased productivity and eco-efficiency through the use of smart technologies like Cloud Computing, Artificial Intelligence, Robotics, and the Internet of Things (IoT). Smart farming approaches, according to Carolan (2016), López, and Corrales (2018), include investment to generate a "technical revolution" to transform food production through the use of signals to increase the precision of fertilizer, pesticide, and herbicide application, as well as investment to determine optimal planting dates for crops around the world.

FIGURE 1.3 OPERATIONAL USE OF SMART FARMING



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According to market research sources such as Research Dive's Informative Business Growth Report, the global smart agriculture market is expected to increase by $54,949.90 million in revenue from 2021 to2028, growing at a notable compound annual growth rate (CAGR) of 10.90 percent. This is due to the increasing strain on the food supply chain as a result of the world's rapidly growing population, which is a major driver of the smart farming business.

The Covid-19 pandemic has had a favorable impact on the smart agriculture sector, which has risen during the crisis. Because agriculture is fully reliant on migrant labor, the movement of laborers back to their hometowns as a result of stringent lockdowns and social isolation has created tremendous chances for smart farming techniques to be adopted.

Agriculture that is climate-smart boosts productivity, improves resilience and reduces climate change. To accelerate the transition to CSA, smallholders must use farming technologies.

For the successful operation of CSA, the following parameters must be considered:

- **The Precision Agriculture Sub-Segment Will Be the Most Profitable: With the use of IoT in agriculture, farmers have been able to increase farm productivity and crop yield, and the precision agriculture sub-segment is predicted to earn $19,743.00 million in revenue by 2028.**

- **Component: Most Productive Solution Sub-Segment Due to the active participation of certain key players in the smart agricultural market in adopting new strategies and innovations to stay ahead in a competitive environment, the solution sub-segment is expected to create revenue of $30,244.50 million by 2028.**

As a result, the concept of a sustainable agricultural system refers to agriculture's ability to contribute to total wellbeing over time by supplying sufficient food and other commodities and services in economically effective and lucrative, socially responsible, and environmentally sound ways.

Building a more complete framework for responsible innovation is a must in the context of sustainable agriculture to satisfy the demand for accelerating the adoption of new technology, and the following measures should be considered:

- **Invest in IoT, artificial intelligence (AI), location GPS, satellite, autonomous tractors or unmanned aerial vehicles, or drones, as shown in Figures 1.5 and 1.6.**

- **Bio-chemicals are being investigated by researchers who are working on biologically produced agrochemicals, bio-materials, and novel kinds of bio-energy.**

- **The Service Supply Chain Must Be Optimized: Customer delivery expectations at varying intervals necessitate cloud-based service component management solutions. Sensors are used to regulate soil, water, light, humidity, and temperature, for example.**

- **Smart greenhouses and confined hydroponic farming are ultra-efficient and can be found in metropolitan areas.**

FIGURE 1.4 OPERATIONAL USE OF SUSTAINABLE FARMING

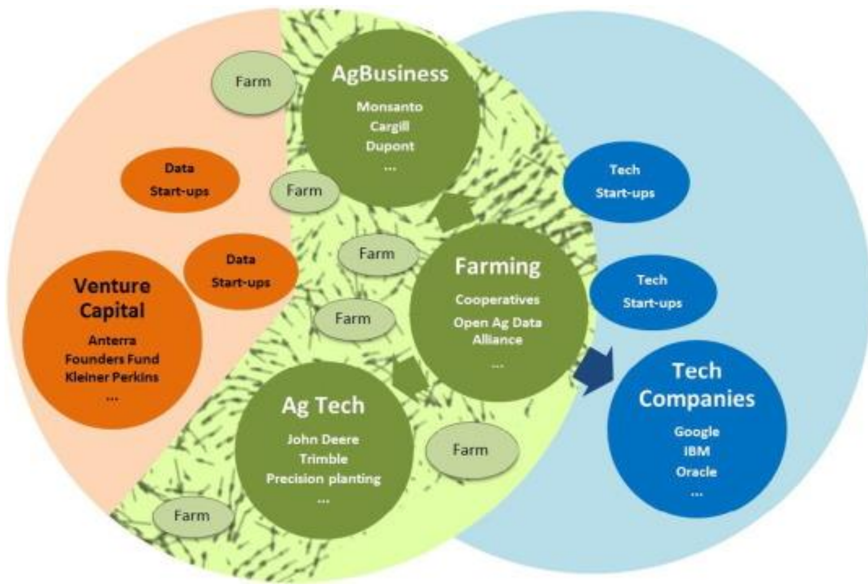

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FIGURE 1.5 THE OPERATIONAL USE OF THE INTERNET OF THINGS

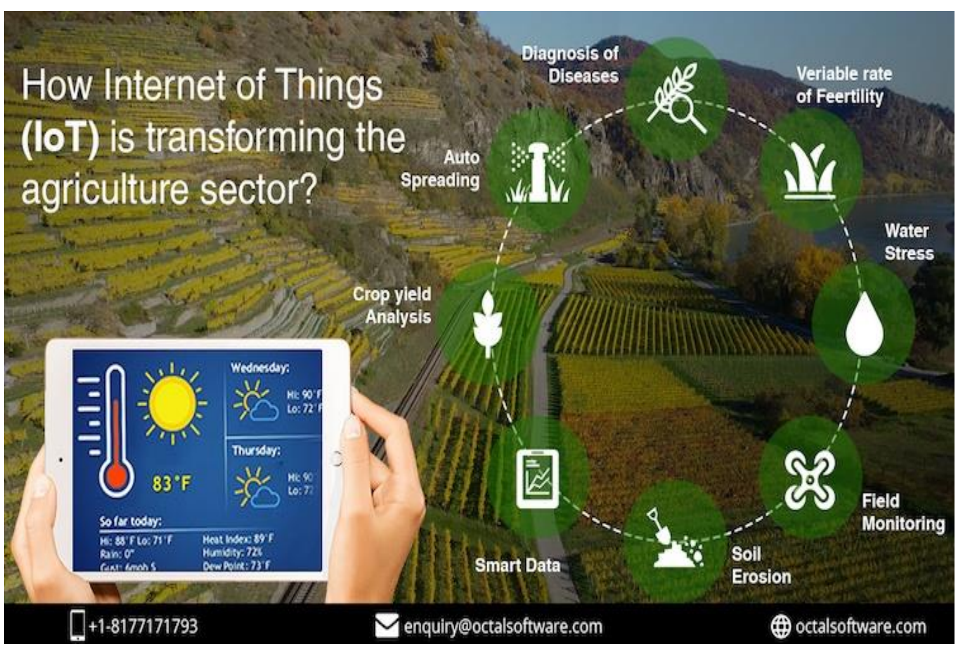

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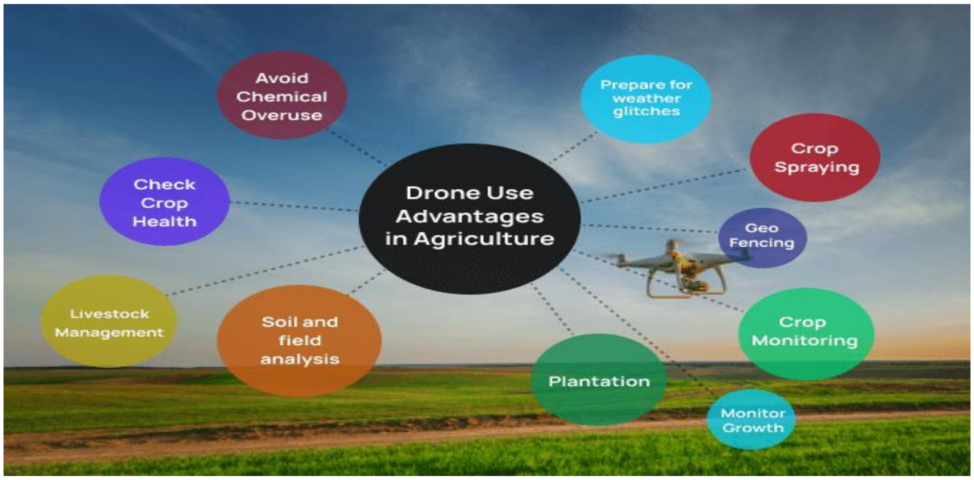
FIGURE 1.6 THE OPERATIONAL USE OF AGRI-DRONES



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According to a market study published by Global Industry Analysts Inc., (GIA), the premier market research company, the global drone market within agriculture would grow at a 35.9 percent compound annual growth rate (CAGR) and reach $5.7 billion by2025, according to a report titled "Agriculture Drones-Global Market Trajectory & Analytics." In the agriculture industry, the deployment of drones can help farmers save time and boost efficiency.

In India, several drone-based agricultural projects are in the works:

- **The Indian government also announced a certification procedure for agricultural drones on January 26, 2022, which can now carry a payload that does not include chemicals or other liquids used in drone spraying. Such liquids can be sprayed as long as the norms and regulations are followed.**

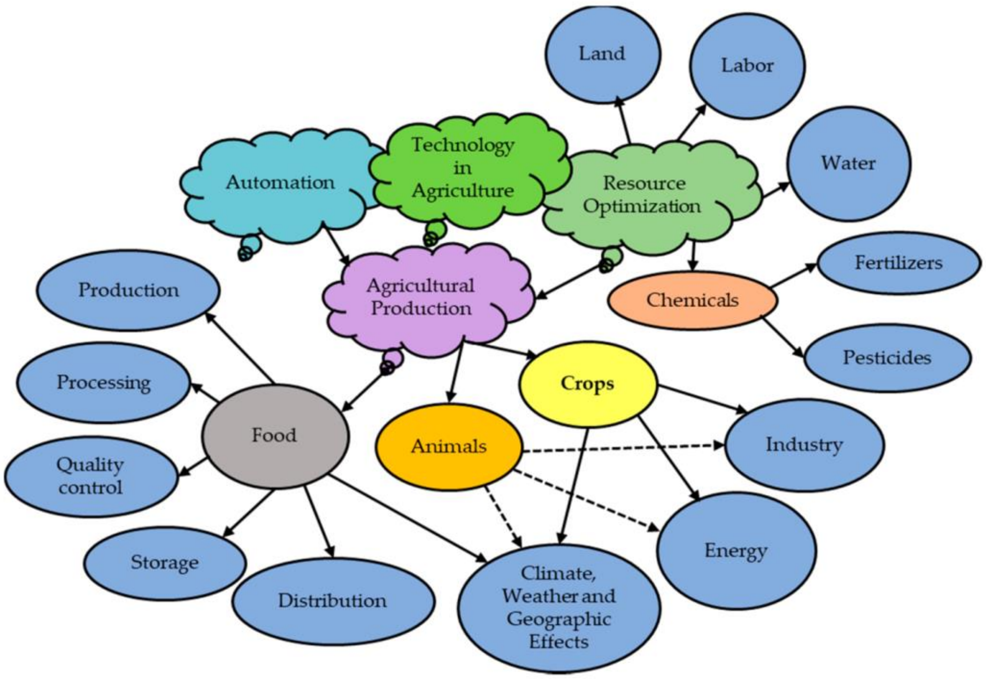
- **The government of India recently offered a 100 percent subsidy or 10 lakhs, whichever is less, up to March 2023 to Farm Machinery Training and Testing Institutes, ICAR Institutes, Krishi Vigyan Kendras, and State Agriculture Universities to promote the use of drones for agricultural purposes and reduce the labor burden on farmers.**

Other issues agriculture faces in five areas, namely efficiency, resilience, digitization, agility, and sustainability have been exacerbated by the COVID-19 situation. Heavy reliance on physical labor has harmed farmers whose workforces are restricted in their mobility during this global pandemic. Significant environmental benefits from reduced travel and consumption during the crisis are also likely to fuel a desire for more local, sustainable sourcing, forcing manufacturers to change long-standing practices. In other words, the crisis has highlighted the need for greater digitization and automation.

Sustainable agriculture, according to Gunton et al. (2016) and Firbank et al. (2018), is a method that increases productivity without harming the environment and encompasses more socially responsible humane aims. There is a trade-off between economic and ecological performance, which can be thought of as a goal, a process, or a set of principles to be followed while tracking the formation and interplay of

sustainable agriculture innovation. Figure 1.7, which depicts the range of agricultural productivity, demonstrates this.

FIGURE 1.7 THE SPECTRUM OF AGRICULTURAL PRODUCTION



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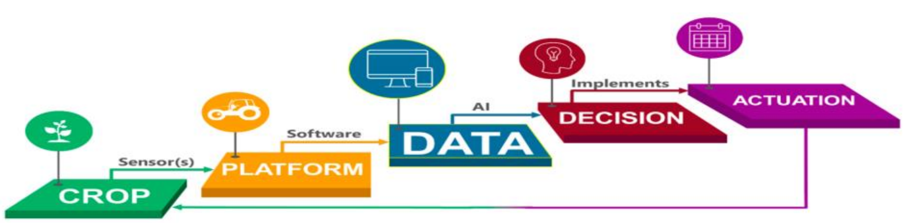
It should be underlined that the unique characteristics of the smart farming revolution present both opportunities and problems for responsible innovation frameworks that must be implemented in an agricultural environment. This is about the expanding identity of responsible inclusion, as seen in Figure 1.8. Responsible innovation, according to Chilvers et al. (2017), Burall (2018), and Jasanoff and Hurlbut (2018), must include innovational designs that rely on research institutions and encourage stakeholder consultation while considering the social and ethical implications of smart agriculture technologies.

FIGURE 1.8: TRANSFORMATION FUELED BY ADVANCED CONNECTIVITY



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- **The smart farming market is classified by agriculture type, software, services, solution, and application, and strategies must be developed to approach the market and establish the primary application areas, such as precision farming, livestock monitoring, and smart greenhouses. It's worth noting that:**

- **The smart farming market is divided into two categories depending on software: web-based and cloud-based.**

- **System integration and consulting, support and maintenance, connection services, managed services, and professional services are the many types of services in the smart farming sector.**

- **The smart farming market is divided into network management, agriculture asset management, supervisory control and data acquisition, logistics and supply chain management, smart water management, and other segments based on the solution.**

- **Yield monitoring, field mapping, crop scouting, weather tracking and forecasting, irrigation management, farm labor management, financial management, feeding management, milk harvesting, breeding management, fish tracking, fleet navigation, and water quality management are some of the applications in the smart farming market.**

As shown in Figures 1.9 and 1.10, the smart farming market is examined using the market size and volume data provided by each country. The smart farming market includes the United States, Canada, and Mexico in North America, Brazil, Argentina, and the Rest of South America in South America, Germany, Italy, the United Kingdom, France, Spain, the Netherlands, Belgium, Switzerland, Turkey, and Russia in Europe.

Stocker et al. (2013) and Schmidhuber and Tubiello (2007) both believe that climate change has affected agriculture directly by altering agro-ecological conditions and indirectly by increasing demand for agricultural production, as seen in Figure 1.11. Because agricultural land is continually decreased owing to urbanization, smart farming is a primary interest of the scientific community to boost yield output at a low cost. The most essential factor in boosting agricultural output and encouraging agricultural development has been technological advancement.

Agriculture is one of the most important components of the global market's agro-food chain. Agriculture faces new problems in meeting expanding demands and meeting international competitive standards in terms of producing high-quality agricultural goods with the help of technologies for sustainable farming systems and policymaker's decisions.

FIGURE 1.9 GLOBAL SMART FARMING

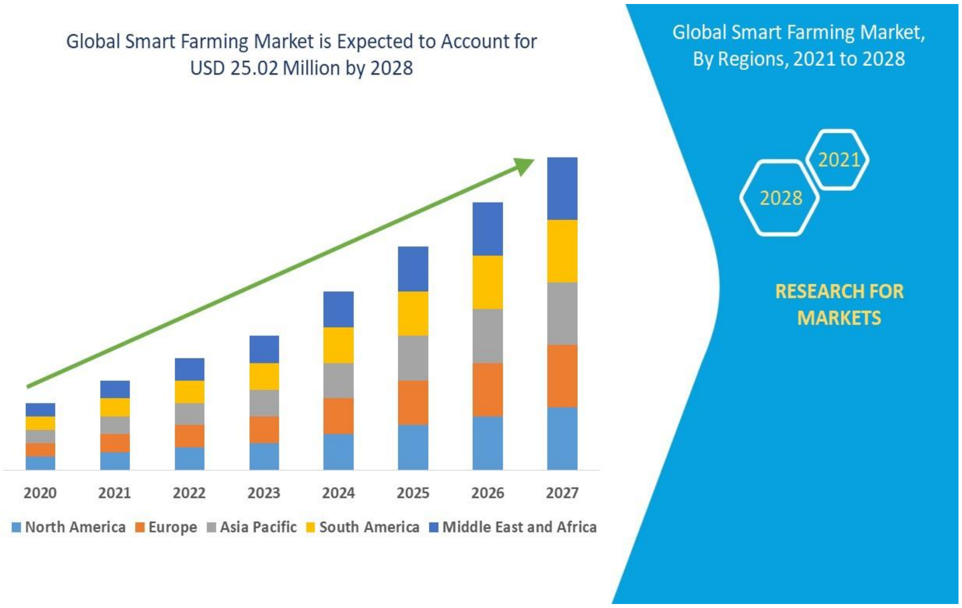

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FIGURE 1.10 GLOBAL DIFFERENCES – CASE OF U.S. AND SOUTH KOREA

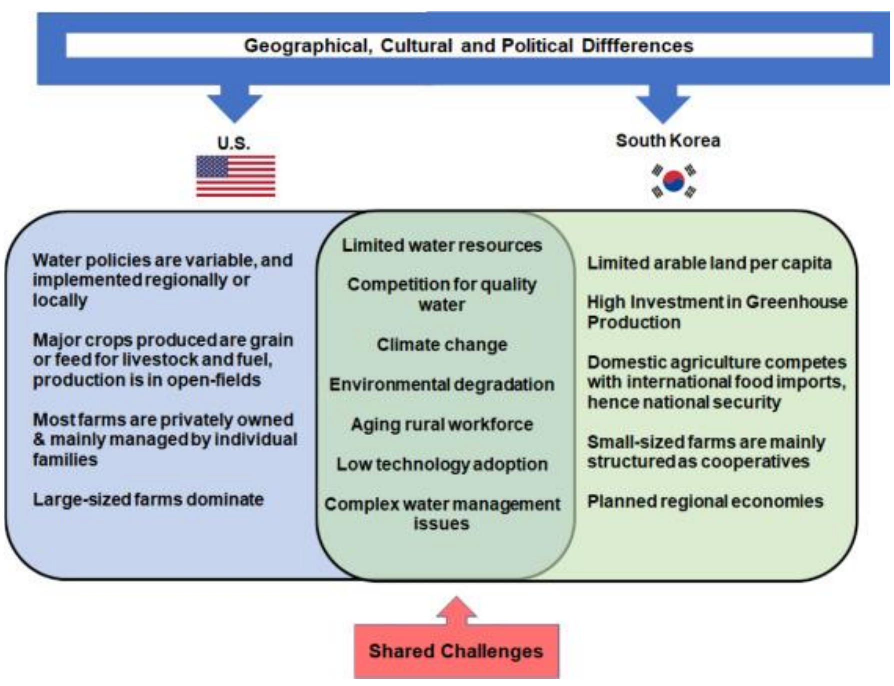

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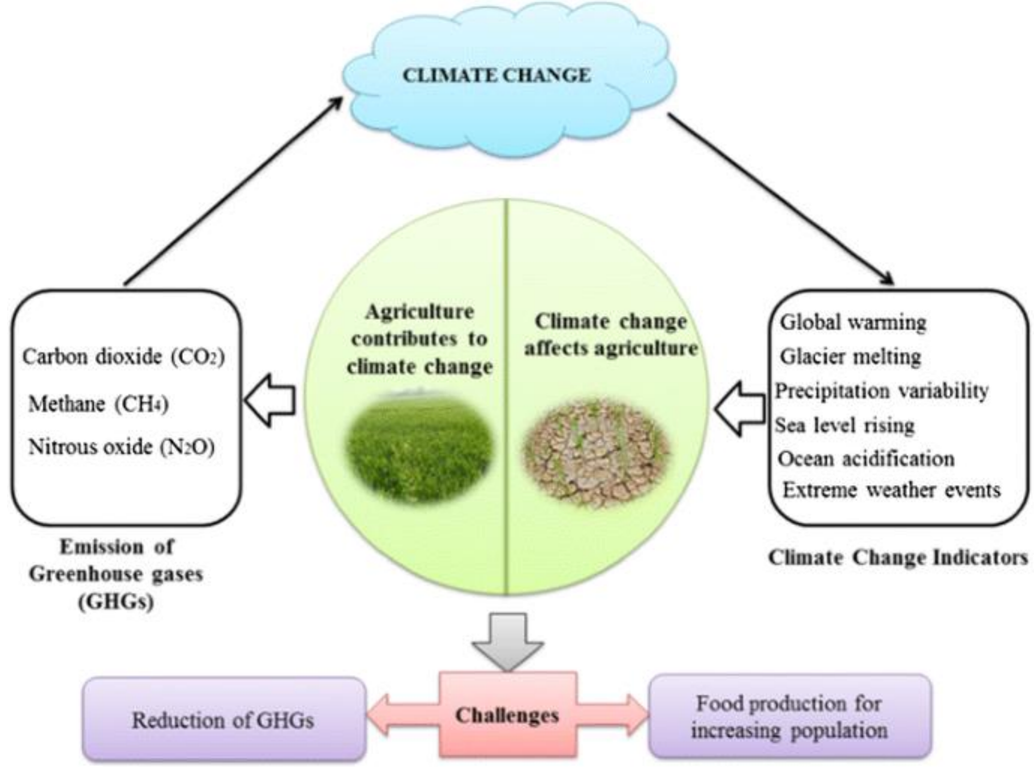
FIGURE 1.11 CHALLENGES ENCOUNTERED IN AGRI-REVOLUTION



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The agricultural sector requires a diverse set of emerging technologies, and the need for agricultural products is driving technology adoption. The degree of competition and the sources of supply are expanding as a result of trade liberalization. Policies, research activities, farmer education, and training all reflect evolving demands, balancing economic efficiency with environmental and social sustainability. Biological pest management, biotechnology, information technology, precision farming, and integrated and organic farming systems are all examples of agricultural methods.

While moving towards more sustainable agriculture, adopting technologies for sustainable farming systems is multidisciplinary and involves uncertainty and tradeoffs. Because of the scarcity of resources, there are opportunity costs in the form of trade-offs that must be made to achieve sustainability goals. In a climate of uncertainty, for example, the decision of technical development and acceptance is made with an element of trial and error in its application. This could have significant implications for the future of research and development efforts, as well as the trend toward better farmer education and training, the shift toward faster and less expensive means of disseminating and sharing information, and the availability of financial resources for the adoption of sustainable farm technologies.
Farmers must be exposed to the appropriate signals to embrace relevant technology, and they will invest in and apply sustainable technologies and farming methods if they expect a return on their investment. This is contingent on having access to the appropriate knowledge, information, and motivation, as well as clear government policies. To put it another way, the entire policy framework, particularly in the context of agriculture policy reform, trade liberalization, and global environmental agreements, requires a more integrated approach in terms of consistency.

Establishing collaborations between academics and farmers for the sake of productivity, profitability, the environment, and society is a more comprehensive framework for responsible innovation in sustainable agriculture:

- **A holistic method to mapping and attending to the larger ecology of advances linked with the fourth agricultural revolution.**

- **To effectively account for various and already existing spaces of engagement in agri-tech, conceptions of "inclusion" in responsible innovation should be broadened.**

- **More real-world testing of frameworks to see if they can make innovation processes more socially responsible.**

Anticipation, inclusivity, reflexivity, and responsiveness are all important aspects of responsible agriculture innovation. For policymakers, technology companies, funders, and researchers to build, test, and revise responsible innovation frameworks to steer the development of smart farming technologies, these dimensions are critical. The work of Eastwood et al. (2017) and Bronson (2018) on responsible innovation can help diverse stakeholders think about how to construct a plan. The announcement by Greece of agriculture digitalization, using big data and the internet of things, can be regarded as a roadmap for responsible agriculture innovation. Agri-tech revolutions have been observed in some nations, including Japan (Japan Times, 2017), other regions of Asia ("Second Green Revolution," The Economist (2014), Ireland (Irish News, 2017), and Australia (Australian News, 2017), (Financial Review, 2016).

Exploring the spatialities of re-scripting and investigating how tools used in smart agricultural techniques are constituted in various ways by different users in various spaces, particularly the introduction of decision support tools that may help to deliver evidence-based guidance to farmers and help to improve productivity and prevent environmental degradation, is required. Farmers' use of decision support tools has been the topic of research for the past two decades, notably in industrialized countries such as Australia, Belgium, Italy, the United States of America, and the United Kingdom, according to Rose et al.(2016) and Rose and Bruce (2017).

To understand processes occurring at the interface between tools and farmers, a case study of decision support tools used on farms in England and Wales highlights the need to examine places on individual farms. To begin with, farmer's and advisers' situated knowledge causes resistance, negotiation, and re-scripting of decision support systems that are thought to convey the view. Second, the introduction of decision support technologies alters farmers' workflows, influencing how and when they engage with various farm locations.

Women farmers in Himachal Pradesh are reaping the benefits of success in sustainable agricultural techniques, according to another case study. While speaking at the National Conclave on Natural Farming in December 2021, Prime Minister Narendra Modi emphasized and asserted that Indian farmers will lead the global mission for 'Lifestyle for Environment' in the twenty-first century, removing agriculture from the chemistry lab and connecting it to the lab of nature. There is evidence that natural or organic farming has been promoted in India to ensure a long-term livelihood.

Women in Himachal are rewriting success stories of low-cost, non-chemical, and climate-resilient natural farming that is supported under the state-run Prakriti Krishi Khushhal Kisan Yojana, thanks to training and capacity-building workshops that began in 2018. According to government data, 90,000 of the 1.68 lakh farmers in Himachal Pradesh who practice natural farming are women, a staggering ratio that reflects a wave of change marked by empowerment–a link to biodiversity and a move toward food security. Approximately 500,000 farmers are practicing natural farming on 2,16,000 hectares of land as of March 2021.

Following Dicks et al. (2014), these decision support tools are most commonly supplied in the form of computer software, mobile applications, or web-based interfaces in a usable form. Farmers, for example, must frequently select how much manure to apply to a specific crop. Various decision support tools, like mobile applications, are used to indicate the number of nutrients contained in manures dispersed at different rates. The farmer can input data such as field size, crop type, spread rate, and manure type into a specifically developed calculator, and the tool will create an evidence-based result that advises how much manure to spread to meet crop nutrient requirements. If yields can be improved without excess nutrients being lost to watercourses, evidence-based decision-making should result in more production, lower costs, and a lesser environmental effect.

Studies conducted by Bellec et al. (2012), Friedland (2001), Husson et al. (2016), Lefèvre et al. (2014), and Pfeffer (1992) have shown the shifts in rural societies caused by the introduction of new technologies, particularly in terms of labor changes, referred to by Cochrane(1958) as the 'Treadmill of Technology,' in which the cycle of improving technology displaces or replaces labor, affects production costs, and changes farm Drones, for example, might lead to increased surveillance of farmworkers and create an increasingly tense situation, while robotics could reduce the need for human labor even further. With these instances in mind, it's evident that technology has the potential to alter the social context in which it operates. As Latour (1992) depicted, technologies can be actors in their own right, sometimes even displacing existing on-farm actors.

Holloway et al. (2014) found evolving zones of ethical relationships between humans, animals, and technology on-farm, where emergent robotic milking technologies are modifying, or re-scripting the creation of new rural subjectivities. The human farmer and human advisory networks will be emphasized, with a special focus on the space of the individual farm. This is significant because many tools are intended to be implemented throughout regions, countries, and even continents, and hence must be relevant to a large user base rather than a single farm.

Re-scripting smart agricultural technologies bring attention to the fact that this can take many forms, including simply using it in a way that the creators did not intend; for example, farmers or advisers disregarding the tool's guidance in favor of their own experiential and situated knowledge. Another angle that has to be explored is the important reason for the resistance, negotiation, and eventual re-scripting of tools by users.

To comprehend the aims for re-scripting sustainable agriculture, the conversation should center on a comparative study based on sustainable agriculture against conventional agriculture. It should be noted that agricultural science has evolved to accommodate the ever-increasing human population. This is since as societies increase, food insecurity becomes more widespread as land for food production becomes scarcer and existing crops become easily depleted. Other causes for a switch to sustainable farming include pollution and environmental degradation.

Traditional farming, according to some analysts, involves analyzing each farm to determine the best crops and water requirements for optimum. Satellite photography detects different zones in farms, allowing for early detection and application only in the affected area, resulting in cost savings and yields, as well as the identification of patterns with simple reporting.

Smart farming, on the other hand, analyses each farm to determine the best crops and water requirements for optimization. There are cost savings with yields and patterns determined with easy reporting thanks to the use of satellite imagery that detects the distinct zones in farms in the impacted region exclusively.

The impact and performance outcome aspects of the techniques used by both modes are to be considered simultaneously with a focus on production, biodiversity, soil composition/erosion, water use, energy use, and greenhouse gas emissions to understand the differences and progress of sustainable and conventional agriculture.

Sustainable or organic farming is an environmentally friendly technique that tries to produce a variety of crops without the use of synthetic chemicals or fertilizers while improving soil composition and increasing biodiversity, preserving the landscape's integrity, and delivering high-quality yields. Conventional farming, on the other hand, necessitates the use of synthetic pesticides and fertilizers to optimize the yield of a specific crop or collection of crops, which are generally genetically engineered, weakening the landscape's ecosystem.

In the instance of conventional farming techniques, Huntley, Collins, and Swisher argue that irrigation, intercropping, and crop rotation have all improved efficiency in agriculture, with the goal of conventional agriculture being to maximize crop production potential. Synthetic chemicals, genetically modified organisms, and other industrial items are used to attain this goal. Unfortunately, preserving a traditional approach jeopardizes biodiversity, soil fertility, and ecosystem health.

Another key factor to remember is that in the conventional system, farmers would dedicate entire fields to a single crop, resulting in uniformity that can decide the success or failure of conventional systems. According to Gabriel, Salt, Kunin, and Benton (2013), a uniform crop is great since it saves time and effort, but it can also limit biodiversity and make crops more susceptible to infections. Farmers can apply pesticides and herbicides to crops more efficiently under a conventional system if they are made up of only one variety of plants, but this has many unforeseen consequences. Figure 1.12 depicts the major issues confronting India's agricultural economy.

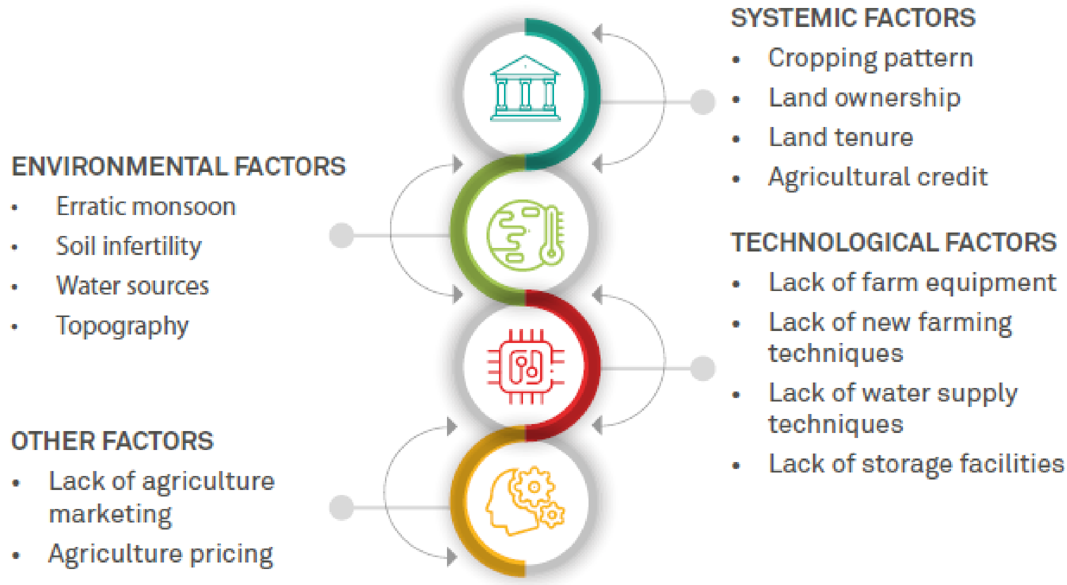
Some systemic or historical constraints, as well as environmental and technological ones, impede the development of India's agricultural output. Environmental influences are primarily determined by topographical features of agrarian land and weather patterns, which have evolved over centuries of agricultural activity extending back to ancient times. The lack of innovation in agricultural techniques as well as the affordability of gear and equipment, have all contributed to technological factors. Let's take a look at each of these aspects individually:

- **Cropping patterns, fragmented land holdings, and insecure land tenure system, and a lack of systematic financing for agricultural credit are all systemic factors that have existed for decades.**
- **The unpredictable monsoon and lack of irrigation infrastructure, soil infertility and insufficient crop rotation, varied topographical features due to soil variants, and climatic circumstances are all environmental concerns.**

- **Lack of farm equipment and innovative farming practices, insufficient water supply, groundwater levels, and insufficient storage facilities are all technological factors that limit production.**

- **The absence of agricultural marketing of Indian agricultural products, the prevalence of illiteracy, and its relationship to agricultural pricing, where the farmer is a price taker rather than a deciding price maker, are all problems that stymie Indian agricultural development.**

FIGURE 1.12 PROBLEMS ENCOUNTERED IN INDIAN FARMING



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Organic agriculture, according to Gomiero, Pimentel, and Paoletti (2011), blends tradition, innovation, and science to enhance the common environment while also promoting equitable relationships and high quality of life for all involved. When organic farming methods are compared to conventional farming methods, it is clear that organic farming methods perform significantly better on various metrics. Sustainable agriculture uses less water and energy, improves soil quality, and avoids the use of synthetic chemicals. Traditional agriculture cannot meet the current population's needs without jeopardizing the environment's purity. Sustainable agriculture can sequester carbon, feed the globe, and enrich the environment all at the same time. Sustainable agriculture is the most practical option to accommodate emerging trends because of its social, economic, and environmental benefits

Sustainable agriculture is a more holistic approach to farming than conventional farming since it relies on ecosystem services and is usually less damaging to the environment. Sustainable agriculture is a natural way to grow food that provides social, economic, and environmental advantages. To produce food, sustainable farming avoids the use of synthetic pesticides, herbicides, and fertilizers. Instead, as proposed by Nicholls and Altieri, farmers will have to sow a range of plants together to increase biodiversity and ward off pests and infections (2012). Whereas traditional systems foster uniformity and rely on synthetic chemicals to guard against disease and pests, sustainable systems use biodiversity as a defense mechanism.

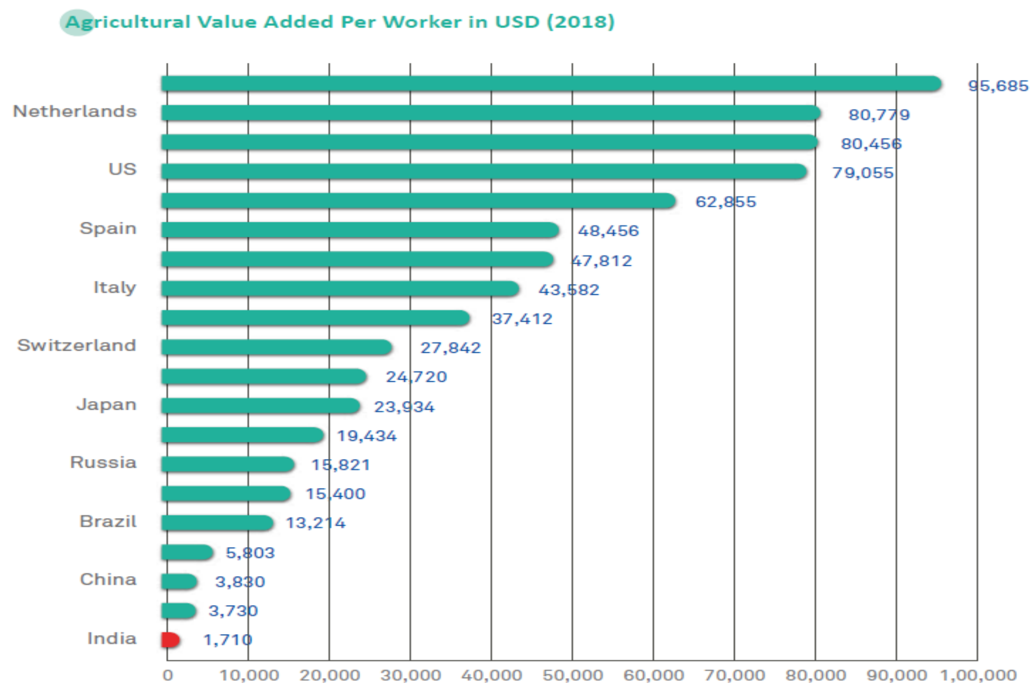
Despite the negative effects of conventional farming methods on farmland, not all conventional farms damage biodiversity. Farmers can utilize low-input alternatives to reduce the number of pesticides and energy they use in a variety of ways. To avoid the use of non-renewable resources, sustainable agriculture uses only natural processes for input and recycles nutrients on-site. Traditional agriculture, on the other hand, necessitates an enormous amount of energy to produce, prepare, and deliver food. Sustainable agriculture has been identified as the best method for managing the world's expanding population, according to studies. Although there are numerous advantages to sustainable agriculture, there are various barriers to its adoption around the world. Because climate conditions differ by location, sustainable agriculture may be the most efficient approach in one part of the world but not in another.

On the surface, the Indian agricultural industry supports 58 percent of the country's population while producing only 15.87 percent of the country's GDP with a Gross Value Addition of 265.51 billion USD (agriculture, forestry & fishing combined). In2018-2019, India produced a record amount of food grains, totaling 283. 37 tonnes. This should be taken into account when calculating the agricultural value-added per worker. Figure 1.13 depicts a comparison of worldwide smart farming metrics.

When the top 20 economies are compared on the criterion displayed in Figure1.13, it becomes clear that India's agricultural production has a lot of room for development provided certain issues are addressed. All of the countries with the lowest agricultural value-added per workers, such as India, Indonesia, and China, are largely developing/underdeveloped economies with high population densities.

Smart farming is inextricably related to the Internet of Things (IoT), cloud computing, and analytics, as its name suggests. IoT is one of the cornerstones of smart farming. Its utility rests in the generation of data about environmental conditions, seed quality, and quantity from multiple sources. Since weather stations are made up of a variety of smart agricultural sensors, climate monitoring is critical. They are strategically distributed across the area to collect data from the environment and deliver it to the cloud. The data collected is utilized to better understand climate conditions, choose appropriate crops, and respond accordingly to improve things. In addition to collecting data, greenhouse automation systems can modify conditions automatically based on preset criteria. In the field, IoT devices capture data relevant to crops, such as temperature, moisture content, and leaf water potential, among other things. They aid in the assessment of overall crop health and the detection of any irregularities to prevent illness.

FIGURE 1.13 GLOBAL INDICATORS OF SMART FARMING



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However, using the cloud in conjunction with IoT devices scattered across the field is fraught with difficulties from three perspectives: data security during data transfer between IoT devices and the cloud, processing speed while doing so, and, most importantly, the cost of cloud computing and bandwidth.

The primary hurdles in Smart Farming adoption, as depicted in Figure 1.14, include the commercial feasibility of tiny landholdings, low farmer income, and the difficulty to acquire IoT and other modern equipment required for smart farming. The adoption of smart agricultural devices is hampered by unskilled personnel who lack proper training and education. In some distant places, the availability of essential utilities such as roads, electricity, and water is also a major concern.

The plan to assure economic feasibility and ease of adoption is a significant topic that has to be worked on. Smart farming will certainly help Indian farmers to produce more and better with less with the correct framework and roadmap in place, as shown in Figure 1.15, allowing them to earn more and improve their standard of living. The solution is to pool small landholdings and other farmer resources into cooperative farm societies that are well-networked to achieve economies of scale. This will make lending easier and more cost-effective for banks while also lowering risks. These cooperatives can save money by purchasing smart devices in bulk. Third-party companies can also provide smart gadgets "as-a-service" to these cooperatives. Furthermore, these vendors must give proper training. For optimum impact, this can also be done in collaboration with government agencies or non-governmental organizations. For simplicity of usage, it would be preferable to have interfaces in vernacular languages.

FIGURE 1.14 KEY CHALLENGES IN SMART AGRICULTURAL FARMING

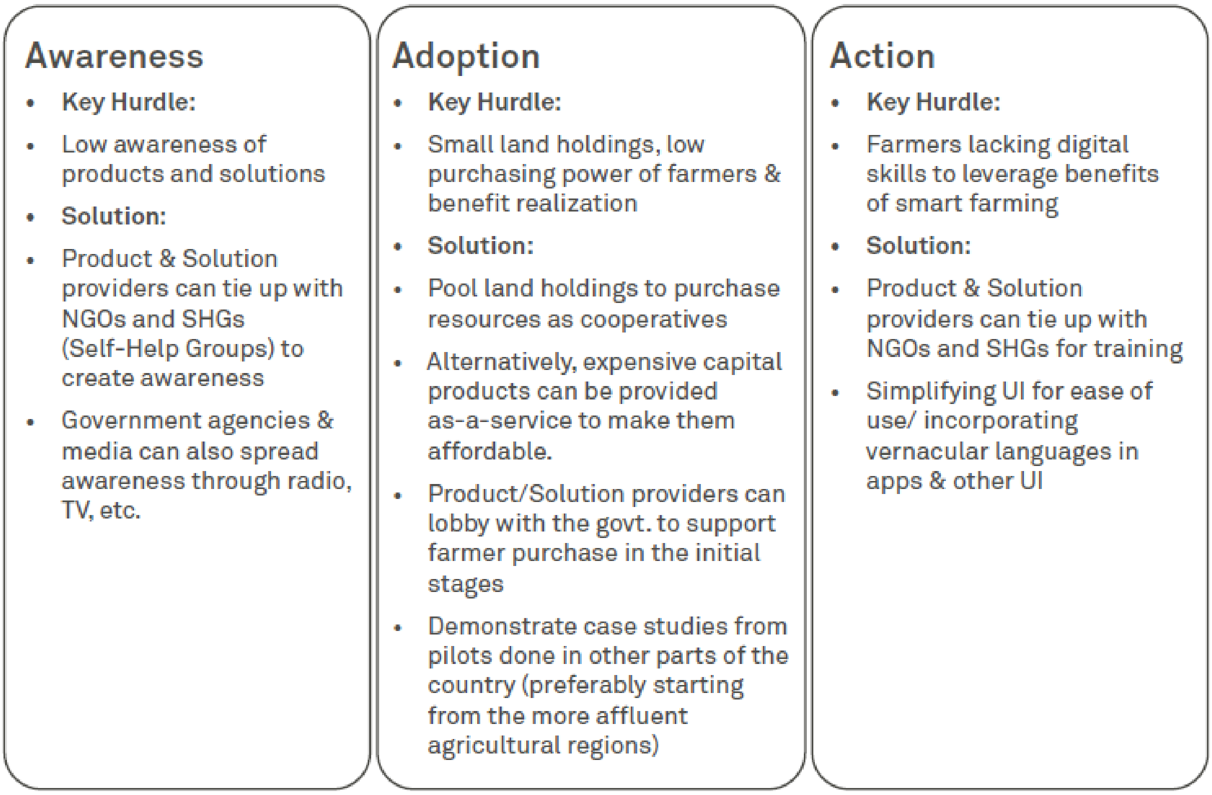

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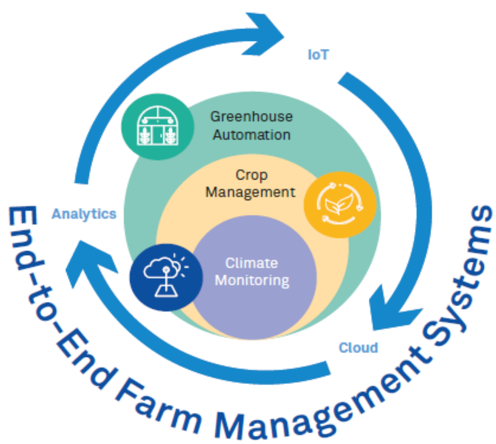
FIGURE 1.15 THE NEED FOR SMART AGRICULTURAL FARMING



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As shown in Figure 1.14, Indian agriculture has numerous obstacles. Smart farming is a possible solution that incorporates contemporary information and communication technology (ICT) into Indian agriculture to create a system that is structured, available at all times, and can be monitored from anywhere in the

world using robotics, drones, and sensor equipment. Hardware (IoT) and software as a service (SaaS) are used in smart or sustainable farming to collect data and provide actionable insights to manage all farm operations, both before and post-harvest. Agriculture as a service (SaaS) is an efficient agricultural strategy that may perfectly eradicate all food safety risks with agritech solutions.

Mr. Sanjay Borkar and Mr. Santosh Shinde, two well-known Pune-based computer experts, launched farmers as Farm Management Software in 2001. Farm Management Software first gained customers in 2004 while working on a project for the Maharashtra Department of Agriculture. Farm Management Software was renamed FarmERP in 2007 after the development of multilingual computer-based training (CBT) kits for farmers, grower associations, non-governmental organizations, government agencies, and agricultural institutes were one of the first companies in the world to bring software to agriculture, serving 1.3 million farmers directly and indirectly over the last decade.

Cropin, an artificial intelligence agritech company established in Bengaluru, India, uses a combination of hardware and software solutions to record, evaluate, and give useful, actionable information to food producers before and after the harvest. The Internet of Things (IoT) provides hardware access to sensors, drones, and robots, while SaaS provides the software required to run the hardware. Cropin is another good example of a company that collects, analyses, and manages farming activities using data analytics and satellite imagery.

In the case of the Digital Green model, a non-profit international development organization has successfully identified that a participatory engagement process combined with simple technology solutions can harness the collective power of technology and grass-root level partnerships where small-scale farming communities produce and share information on best practices for improved productivity and sustainable livelihoods using a cost-effective system. By 2021, Digital Green has successfully empowered over 1.9 million smallholder farmers, with 90 percent of them being women, with better agricultural techniques knowledge.

One of the solutions to the issues presented by Indian agriculture is cloud-based software that collects data on farms and processes it to weather patterns, yields, irrigation, and satellite imaging. Smart farming and sustainable agriculture, from the farmer's perspective, should give added value in the form of better decision-making or more effective exploitation operations and management.

It should be noted that India's budgetary policy and ecosystem are focused and equipped for the agricultural technology transition from conventional to smart farming practices by encouraging innovation and entrepreneurship and utilizing the services of large private enterprises, leading technology companies, investors, and young innovators in India to achieve sustainable higher growth in the agricultural sector.

In recent years, the advent of digital technology has the potential to create the required circumstances in the field of Indian agriculture. The need of the hour is to reinvent technology for sustainable agriculture in the form of agritech solutions that lead to enhanced agricultural productivity, efficiency, and, most importantly, sustainability. Effective data management and well-informed decisions are critical. Increased traceability, which reassures farmers' financial security, can lead to cost-cutting exercises, increased savings, and more efficient farm management in the area of market and price risk management. Sustainable agriculture is a domain that seeks to guarantee that agribusiness develops and concentrates on production and profitability.

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