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Comparative Analysis of Agricultural Business Models, Innovative Tools and Techniques Across Different Countries: A Review

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ABSTRACT

Agriculture is a crucial global sector, though its operational frameworks differ significantly across countries, providing sustenance, employment and raw materials for various industries. This study examines agricultural business models, focusing on technology integration, governmental interventions, market dynamics and cultural influences. Through case studies from the United States, China, India, Brazil and the Netherlands, it highlights the strengths, weaknesses, and unique features of diverse agricultural systems. Key factors such as land availability, labor dynamics, environmental imperatives and trade policies shape these practices and frameworks. Innovation, including precision farming, automation and biotechnology, plays a pivotal role in enhancing productivity and sustainability.Developing countries like India are characterized by smallholder farming, traditional methods and diverse crops. Agriculture serves as a primary livelihood source, but challenges such as fragmented landholdings, poor infrastructure and limited market access hinder modernization. While government initiatives aim to support farmers and promote sustainability, persistent issues like land tenure, water management and rural-urban migration remain barriers to growth. The study underscores the diversity of agricultural business models shaped by historical, institutional and market factors. Technological innovation, sustainable practices and market integration emerge as critical drivers of development. Advancements like precision agriculture—utilizing IoT devices, drones and satellite imagery—optimize resource use, enhance yields and reduce environmental impact. Effective policies, rural infrastructure investments and multi-stakeholder collaborations are essential for resilient agricultural systems that address socio-economic and environmental challenges, ultimately contributing to global food security, economic prosperity and environmental sustainability

Keywords: *Agriculture, Innovation, Business Model, Comparative Analysis, Different countries, Sustainable Development.*

Background

Agriculture serves as the backbone of economies worldwide, playing a pivotal role in food security, economic development and environmental sustainability. However, the structure and dynamics of agricultural systems vary significantly across different countries due to historical legacies, socio-economic conditions, policy frameworks, and technological advancements. Understanding these variations in agricultural business models is essential for comprehending global food systems, addressing challenges and fostering sustainable development.

In this paper, we aim to provide a comprehensive comparative analysis of agricultural business models in select countries, focusing on key players such as the United States, China, India, Brazil and European nations like France and Germany. Each of these countries represents distinct agricultural landscapes, characterized by unique production methods, market structures, policy interventions and socio-economic contexts. The United States stands out as one of the world's largest agricultural producers, known for its highly mechanized and technologically advanced agricultural sector dominated by large agribusiness corporations. Mechanization, technology adoption and policy support are key drivers shaping the U.S. agricultural business model, along with ongoing environmental concerns. In China, a diverse agricultural landscape ranging from smallholder farms to large-scale commercial operations presents a unique set of challenges and opportunities. Government intervention, market liberalization, and environmental sustainability initiatives influence the dynamics of Chinese agriculture, impacting both domestic production and global trade (Juanjuan Cheng *et al.*, 2022).

India, another agricultural powerhouse, showcases the predominance of smallholder farming and the significance of government support in enhancing productivity and ensuring food security. Technological innovation, sustainability practices, and market reforms play crucial roles in shaping the Indian agricultural business model. Brazil emerges as a major player in global agriculture, with large-scale commercial farming dominating its vast agricultural land. Technological innovation, environmental challenges, and market dynamics contribute to the complexity of the Brazilian agricultural business model, influencing both domestic production and international trade. (John Wilkinson, 2016). European nations like France and Germany offer insights into family farming traditions, sustainable practices, and quality food production. Government support, organic markets, and climate change adaptation strategies characterize the agricultural business models in these countries, reflecting a balance between tradition and innovation (Bernd PÖLLING *et al.*, 2017). By conducting a comparative analysis of these agricultural business models, this review paper aims to identify commonalities, differences, challenges, and best practices across diverse agricultural landscapes. Through a nuanced understanding of agricultural systems worldwide, policymakers, researchers, and practitioners can develop informed strategies to promote sustainable development, enhance food security, and address global agricultural challenges.

Overall, this review paper sets the stage for exploring the multifaceted dimensions of agricultural business models, paving the way for in-depth analyses of specific countries and regions in subsequent sections. Traditionally, agriculture has been characterized by labour-intensive practices, limited access to capital and markets and dependency on unpredictable environmental conditions. However, recent advancements in technology are revolutionizing every aspect of agricultural operations, from seed breeding and crop monitoring to harvest logistics and market distribution. Precision agriculture, enabled by the integration of satellite imagery, drones, sensors and data analytics, allows farmers to optimize resource utilization, minimize environmental impact, and enhance productivity.

Furthermore, the concept of regenerative agriculture is gaining traction as a holistic approach to farming that not only sustains but also regenerates the natural resources upon which agriculture depends. By prioritizing soil health, biodiversity conservation and carbon sequestration, regenerative agriculture enhances ecosystem resilience and mitigates climate change while ensuring long-term productivity and profitability for farmers. However, realizing the full potential of innovations in agriculture requires concerted efforts from various stakeholders, including policymakers, researchers, investors and practitioners. Governments play a crucial role in creating an enabling environment through supportive policies, incentives for research and development and investments in rural infrastructure and education. Likewise, research institutions and universities must prioritize interdisciplinary research and knowledge dissemination to bridge the gap between scientific advancements and practical applications on the ground.

Innovations in agriculture business models and technology offer a pathway to sustainable growth and resilience in the face of mounting challenges. By harnessing the power of digitalization, biotechnology and novel business models, the agriculture sector can not only meet the growing demand for food security but also mitigate environmental degradation, promote social equity and foster economic prosperity for generations to come. However, realizing this vision requires collective action and unwavering commitment to building a more sustainable and equitable food system.

This Review paper involves a comprehensive literature review of existing studies, reports, and academic papers on agricultural business models across different countries. Relevant databases such as PubMed, Google Scholar and agricultural research repositories were searched using specific keywords related to agricultural systems, business models and country names. Data extraction and synthesis were conducted to identify key themes, commonalities, differences, challenges and best practices in agricultural business models. The review process involved critical analysis and interpretation of the findings to provide insights into the comparative analysis of agricultural systems.

Literature Review

Business Model in different countries:

A comprehensive study across urban areas in **Spain, Italy and Germany** highlights the adaptable nature of urban farming to diverse urban settings. Commonalities in business models emerge, including low-cost specialization, differentiation, and diversification. Geographical and historical factors shape practices, with Mediterranean regions emphasizing cultural heritage, contrasting with Northern and Central Europe. Urban farming in metropolitan areas focuses on economies of scope, deviating from rural economies of scale. Urban farmers innovate to cater to niche markets, often diversifying their strategies. While some specialize, most adopt diversification, even unconventional entrants like healthcare institutions. Evidence suggests urban agriculture must adopt specialized, differentiated, diversified, or integrated approaches.

Many farms blend multiple models, indicating the potential for sustainability. Further research on merged business models could provide insights for urban farming success (Bernd PÖLLING *et al*., 2017). The study conducted in Qingcheng County of Gansu Province, a significant apple production area in **China,** highlights the pressing need for innovative agricultural practices amidst escalating challenges. Cooperatives have emerged as promising entities, particularly in apple production, showing higher net profits, reduced resource input, lower environmental impact, and lower life cycle costs (LCC) compared to smallholder farmers. Environmental hotspots, notably pesticides and nitrogen-based fertilizers, underscore the importance of adopting low-carbon technologies like organic fertilizers and non-chemical pest control methods. Human labor costs, a major expense, pose challenges due to the labor-intensive nature of apple farming and rural labors migration to non-agricultural sectors. To ensure sustainable apple production, local governments and stakeholders must enhance regulatory mechanisms for cooperatives, facilitating their roles and fostering a healthy apple industry (Juanjuan Cheng *et al.*, 2022).

This study examines the accessibility of agricultural cooperatives for impoverished farmers in **Nepal** and their impact on farm and household income. Findings reveal that Nepal's cooperatives primarily focus on financial services, neglecting essential agricultural production and marketing activities. This limited scope diminishes their effectiveness in addressing farmers' challenges. Increased government involvement in agricultural infrastructure and technology development is urged to enhance cooperative efficacy. Concerningly, some cooperative managers consider shifting focus to savings and credit services due to inadequate government support. The transition to a federal republic has not fully addressed governance challenges. Establishing inter-organizational networks is proposed to improve coordination among government units, civil society, businesses, and cooperatives, aiming to enhance Nepalese livelihoods (Dinesh Dhankal *et al.*, 2021). Study conducted a SWOT analysis of agribusiness entrepreneurship in **Nepal.** The agricultural sector stands as a cornerstone of Nepal's economy, playing a pivotal role in income generation, food security, poverty reduction, and the overall improvement of living standards for its citizens. Comprising approximately 27.1% of the GDP and involving 65.6% of the labours force, agriculture holds a central position in the country's economic framework.

Government data indicates that out of Nepal's total landmass of 147,181 square kilometers, 21% is dedicated to cultivated land, with 6.9% identified as suitable for cultivation (MoALD, 2019). Endowed with a rich agricultural heritage, fertile soil, and diverse, favorable climates, the realm of agribusiness entrepreneurship emerges as a potent catalyst for driving robust economic growth (Daayitwa, 2018 and Sabina Regmia & Kushal Naharkib, 2020). Nepal's agriculture is poised to remain a key economic driver, adapting to technological and economic shifts. This necessitates a sharper market focus, increased competitiveness, and enhanced productivity. Successful agribusiness entrepreneurs must exhibit risk tolerance and a keen appetite for cutting-edge agricultural knowledge. Through innovation, effective management skills, and the application of technology, agribusiness can evolve into a pivotal economic force and a tool for rural development. The country's diverse climate, biodiversity, evolving food preferences, and unique advantages provide a solid foundation for agribusiness amidst stiff competition. However, challenges such as infrastructure gaps, inefficient agricultural systems, limited technology dissemination, and widespread poverty impede its full potential. Traditional farming practices and a shortage of skilled labours contribute to substantial agro-product imports. Exploiting opportunities in agro-processing, tourism, beekeeping, exports, and floriculture could significantly bolster Nepal's agribusiness sector Regmi, S., & Naharki, K. (2020).

The study on Circular Business Models and Circular Agriculture in the Netherlands reveals critical reactions from Dutch farmers regarding the country's Circular Agriculture (CA) ambitions. Many interviewees express concerns that the current ambitions fall short of genuine circularity. They emphasize the importance of closing cycles at the farm level and sourcing inputs locally to truly qualify as circular farming. Some farmers feel that the government's vision lacks decisiveness and urgency, suggesting a need for stricter regulations and clearer directives. Others doubt the efficacy of the proposed business models and express skepticism about the pace of change. Additionally, some farmers question the feasibility of implementing circular agriculture given constraints such as limited fertile land and reliance on imports. Overall, there is a call for more concrete actions and a sense of urgency to truly realize the goals of circular agriculture in the Netherlands Hans Dagevos and Carolien de Lauwer (2021).

Result and Discussion

Business Models Adopted by FDI in Agriculture: The New Business

Vermeulen and Cotula (2010) Studies major Variations in business models that currently exist to describe the existing trends of agricultural investments throughout the world. In their study on agricultural investment, identify at least six such models, which include contract farming, management and lease contract, tenant farming and sharecropping, joint-ventures, farmer-owned business and upstream/downstream or vertical business links.

- The first common type of agriculture investment model is <u>contract farming</u>, which mainly refers to the pre-agreed supply arrangements between local producers (i.e. farmers or growers) and buyers (usually large agribusiness firms). Under such an arrangement, local farmers generally grow and deliver their products for specified quantity and quality at an agreed date in exchange for upfront inputs, such as credits, seeds, fertilizers, pesticides and technical advice, etc., all of which may be charged against the final purchase price, from the agribusiness firms.
- The second model is the <u>management and lease contracts</u>, which generally entail an individual farmer or a farm management company working on agricultural land that

belongs to someone else. Management contracts may take the form of a lease or tenancy, but they also carry with them the connotation of stewardship (i.e. managing the land on behalf of the owner). To ensure incentives for the farm management company, the contract often includes some forms of profit-sharing, rather than a fixed fee, arrangements.

- The third model is tenant farming and sharecropping where an individual farmer or producer works the land owned by a large agribusiness firm or other individual farmer. Under this type of investment arrangement, the land rental fee is normally set at a fixed rate, while the produce generated from such an arrangement is to be split along the pre-agreed percentage between the landowner and the land renter.
- The fourth type of agriculture investment model is joint ventures. Under this type of investment arrangement, two independent market actors, such as an agribusiness firm and a farmers' organization, establish a co-ownership on a business venture. A joint venture arrangement usually involves the sharing of financial risks and benefits between the two parties, and, in most but not all cases, decision-making authority lies following the proportion of equity share between the joint venture partners. In most circumstances, agribusiness firms usually contribute the capital, whereas the smallholder farmers dedicate their lands or other assets to the joint venture. To ensure their ability to participate in such an arrangement, smallholder farmers normally organize themselves through a cooperative or a company.
- The fifth model is a farmer-owned business. Under this model, individual farmers pool together their assets to enter into particular types of businesses. This model normally allows these farmers to collectively determine the processing and marketing processes of their products, gain easier access to finance, and limit the liability that may be faced by each farmer. Such businesses are normally owned by cooperatives, and are commonly developed to facilitate business transactions more efficiently instead of such a business is to be ran by an individual farmer.
- The final model is upstream/downstream or vertical business links, which is mainly an umbrella expression for a set of business opportunities beyond direct agricultural production that exist for both large Agribusiness firms smallholder farmers, and small local enterprises. While upstream examples of such a model include the supply of inputs and business services (e.g. seeds, fertilizers, pesticides, micro-credit, insurance, and advisory), the downstream examples include specialized wholesale and retail.

According to research findings from Lao PDR under two main broad models of investment, namely land concessions and contract farming. According to them, land concessions involve the rights to use land being transferred to the investor for a period of many years. Land concessions are less capital-intensive, less risky, and more flexible than land lease or ownership. Concessions are common in Lao agriculture as all land is technically owned by the state under the constitution, so the sale of land is not possible (Campbell, *et al*., 2012). As per farmer's business model in Indonesia, there are at least four types of contract farming that are commonly used in Indonesia, and these include plasma-nucleus partnership, sub-contracting, harvest and pay, and operational cooperation (KPO – Kerjasama

Operasional). Plasma-nucleus partnership (PIR – Pola Inti Rakyat), or 'core-periphery' partnership, is by far the most popular form of contract farming arrangement in Indonesia. This form of contract farming has been in practice since the late 1970s to improve the welfare of smallholder farmers, or the plasma, through a partnership they establish with an agricultural firm, or the nucleus. This form of contract farming normally involves an agribusiness firm providing the necessary inputs, such as capital, seeds, fertilizers, pesticides, and technical expertise, to the farmers or a collective group of farmers' cooperatives, as well as purchasing agricultural goods produced by the latter. Under this scheme, the smallholder farmer's main responsibility is to produce the required commodities in agreed quantity, quality, and price (Tambunan, T. T., 2014).

According to research on Agricultural business model in **northern Thailand's** Traditional market model vs. village enterprise for export:

- It was observed that farmers under a traditional market model from the two villages did not differ in terms of economic performance. However, farmers engaging in village enterprises for export had a higher income per area compared with those engaged in a traditional market ($2175/ha. higher) owing to significantly higher product prices. Ceteris paribus, farmers with higher education, more experience in mango cultivation and larger cultivation areas tended to have higher incomes. Those with diversification of land use tended to perform better in terms of income e-distribution.
- Farmers' group to sell product collectively vs. contract farming showed that the farmer group attained significantly less income per area, a higher degree of income distribution, a lower cost dependency rate, smaller amounts of loans taken out for cultivation, a lower informal debt ratio and a higher score of life satisfaction compared to seed producers under contractual agreement. Their total income did not differ since most members of the farmers' group had other supplementary crops. Moreover, the GV farmer group used significantly fewer chemicals and more organic fertilizers and substances. Two possible explanations are that: the GV growers are under support by HRDI to apply good and safe agricultural practices.
- Traditional market model vs buyer with social and environmental focus numerous coffee cultivators in Maneepruek opted to sell their coffee cherries to a local SE buyer who prioritized product quality and environmental considerations. This buyer not only offered technical expertise and beneficial soil supplements to farmers but also committed to purchasing the coffee cherries at pre-agreed, higher prices. However, some growers continued to follow traditional practices by selling fresh cherries to local middlemen within conventional market settings. Swift processing is imperative once coffee cherries are harvested to prevent fruit spoilage, underscoring the significance of the location of processors and adherence to conditions set by buyers in ensuring optimal outcomes for farmers Khemarat Talerngsri-Teerasuwannajak and Sittidaj Pongkijvorasin **(**2020).

As per research on agriculture models and best practices from **Brazil** and the Southern Cone highlights innovative approaches in both large-scale business and family farming sectors. Over the past decade and a half, these regions have served as laboratories for evaluating new profiles of agricultural production and marketing, which could be highly relevant for other developing countries, particularly in Africa. In large-scale farming, **Argentina's** new model utilizes the bioinformatics paradigm to replace the traditional "owner-operator" model with a network of suppliers and services, led by a firm rich in proprietary knowledge systems but light on physical assets. The successful diffusion of this model hinges on its adaptability to different institutional arrangements and responses to social and environmental challenges.

On the promotion of family farming**, Brazil** has led in constructing markets for biofuels, aiming for contract integration with family farmers based on cash crops aligned with traditional farming systems and regional specificities. However, challenges exist, with successful integration often limited to better-organized and wealthier family farmers already integrated into the market economy. With global concerns over food security**, Brazil's** experience offers valuable lessons for African nations facing similar challenges. African countries, like Brazil, must navigate diverse farming systems, from traditional communities to small-scale family farms and large commercial operations. This underscores the need for a combination of agricultural zoning, responsible investments, and land tenure guidelines to ensure effective agricultural policies.

Many areas in sub-**Saharan Africa** are looking to Brazil's large-scale grain farming as a model for developing their savannah regions. With over 30 years of experience, EMBRAPA advocates for a shift away from monoculture towards integrated livestock, farming, and ranching systems to ensure long-term sustainability. Brazil also boasts three decades of experience in promoting family farming and traditional farming systems, offering valuable insights for African countries. This highlights the importance of holistic approaches to agricultural development, incorporating inclusive policies and collaboration between stakeholders (John Wilkinson, 2016). Different Types of Business Models of Care Farms in the Netherlands in the Green Care sector, generally three types of business models can be discerned: • Business models for individual farms • Business models for regional foundations of care farms • Business models for regional collaboration between a care institution and several care farms. Care farms Within Green Care, many variations of care farms do exist. From a business economics point of view, we can discern farms in which food production is the economic dominant factor and care activities are secondary, farms that depend on both food production and care, and farms in which the income from care activities is dominant (H.P.A. Eweg and J. Hassink, 2011**)** The financial relation between clients or care institutions and care farmers has different forms (Hassink *et al.,* 2007): a) A direct contract between the client and the farmer, based on the personal budget of the client. b) The farmer can become a sub-contractor of an accredited organization, for example, a care institution. c) The farmer can become a member of an accredited foundation of care farmers such as ‘Landzijde’. d) The farmer becomes an accredited institution himself.

According to (Abdul Rehman *et al.,* 2016) for Modern Agricultural Technology Adoption following intervention are to be undertaken:

- **Autopilot Tractors New GPS tractors and sprayers** can drive accurately and precisely through fields without a driver. On the computer system's board, the user specifies the distance that a particular device would travel along a path. He travels a short distance and sets points A and B to create a line. The GPS has a track to follow and extrapolates that line to parallel lines separated by the width of the tool being used. 2The guidance system is linked to the tractor's steering and automatically keeps the tractor on track so the operator doesn't have to drive. This makes it easier for the operator to focus on other things. Steering is ideal for tillage operations as it eliminates human error in overlap areas and saves fuel and machine time.
- **Crop Sensors** Plant sensors help farmers apply fertilizers very effectively and maximize uptake. Be aware of how your plants are feeling and reduce the chance of leaching or runoff into groundwater. This takes variable rate technology to the next level. Instead of creating a map of prescribed fertilizer for the field before application, crop sensors notify the fertilizer applicator of fertilizer amounts in real-time. Optical sensors can detect the amount of fertilizer a plant needs based on the amount of light reflecting on the sensor.
- **VRT and Swath Control Technology** with VRT and swath control technology, the steering starts to come into play. Swath control is exactly what it sounds like. Farmers control the size of the strip that a particular piece of equipment draws across the field. This savings comes from using fewer inputs such as seeds, fertilizers, and herbicides. Due to the irregular size and shape of the fields, there is inevitably some overlap in each application. The GPS that maps equipment in the field already knows where the equipment has been, and swath control turns off some of the applicators when they enter the overlap area.
- **Monitoring and Controlling** Crop Smartphone-based irrigation systems Mobile technology plays an important role in monitoring and controlling crop irrigation systems. This modern technology allows farmers to control their irrigation systems from their phones or computers instead of driving to each field. Moisture sensors in the soil can transmit information about the moisture level at a specific depth within the soil. This increased flexibility allows for more precise control of water and other inputs such as fertilizer applied through irrigation spigots.
- **Biotechnology** Biotechnology or genetic engineering (GE) is not a new technology, but it is an important technology with untapped potential. A form of genetic engineering that most people have probably heard of is herbicide resistance. Plants can be grown to release toxins that control specific pests. Many use the same toxins found in some organic pesticides. This means farmers don't have to walk across the field to apply pesticides, saving not only pesticides but also labor, fuel and equipment wear and tear.
- **Documentation of Fields via GPS** Due to on-board monitors and GPS the ability to document yields and application rates is becoming easier and more precise every year.

Farmers are getting to the point where they have so much good data on hand that they and figure out what to do with all of it. The favorite form of documentation of every farmer is the yield map and it sums up a year's worth of planning and hard work on a piece of colorful paper. The equipment harvesting rolls through the field and it calculates yield and moisture as it goes tying it in with GPS coordinates. The field is printed when a map of yield.

- **Ultrasounds for livestock** Ultrasound is not only for checking on baby animals in the womb, also can be used to discover what quality of meat might be found in an animal before it goes to market. The testing of DNA helps producers to identify animals with good pedigrees and other desirable qualities. For improving the quality of the herd, this information can be used to help the farmer to improve quality.
- **Usage of Mobile Technology and Cameras** Mobile technology and cameras play a big role for farmers and ranchers who are using all social media sites for all types of reasons. Some are using apps like Foursquare to keep tabs on employees. Putting up cameras around the farm is a trend that's catching on. Livestock managers are wiring up their barns, feedlots, and pastures with cameras that send images back to a central location like an office or home computer. They can keep a closer eye on animals when they are away or home for the night.

The landscape of agricultural practices has been dramatically reshaped by the integration of advanced technologies like the Internet of Things (IoT) and Unmanned Aerial Vehicles (UAVs). These technologies have ushered in a new era of innovation in crop enhancement through the widespread adoption of wireless sensors and IoT devices. Addressing longstanding challenges in crop management such as disease control, efficient irrigation, cultural practices, and drought mitigation, these emerging technologies are revolutionizing agricultural practices. Figure 2 illustrates the primary applications, wireless sensor deployment, and service hierarchy essential for implementing advanced agricultural solutions. The following sections delve into the utilization of advanced technologies to monitor key applications aimed at enhancing crop production (Nawab Khan, 2021).

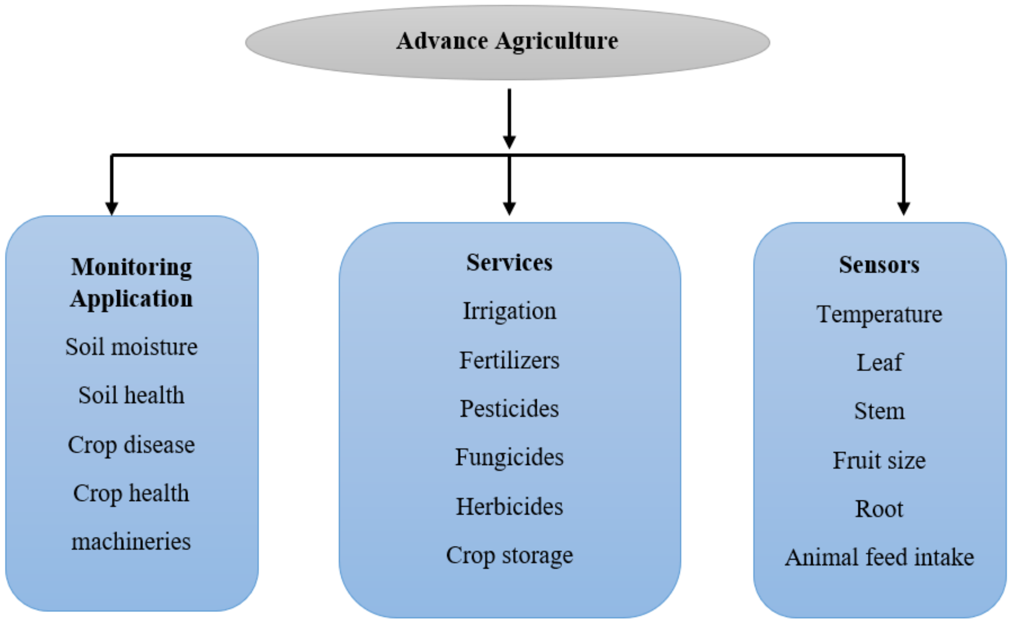


Fig 1 Major applications, services, and sensors for advanced agriculture, modified from Talavera et al.

Soil Monitoring: It is necessary to monitor the soil at the field scale. By obtaining the soil's health information, a grower can make fruitful decisions at different plant developmental stages. The main objective of soil analysis is to measure the content of nutrients present in the soil, which ultimately leads to many treatments to fullfill the level of nutrients. Remarkably, the soil test is suggested annually in the spring season; however, it can be changed according to the local environmental conditions and conducted in the winter or autumn season.

Many researchers have recently developed tools, technologies, and devices to monitor soil health. These new tools are the major resources for farmers and growers, which can be used to monitor soil features such as water holding capacity, moisture, and chemical, and physical properties. These tools also help monitor soil health, such as salinity, pH, soil organic carbon (SOC), electrical conductivity (EC), nitrogen, potassium, and phosphorus, which help estimate required fertilizers. One of the latest tools introduced by Agro Cares is the Scanner and Lab-in-box, which is known as a laboratory, has complete information by services through which it gives soil status information. This is the modified tool used by many farmers without any laboratory for sample analysis. This tool can analyse about 100 soil samples daily.

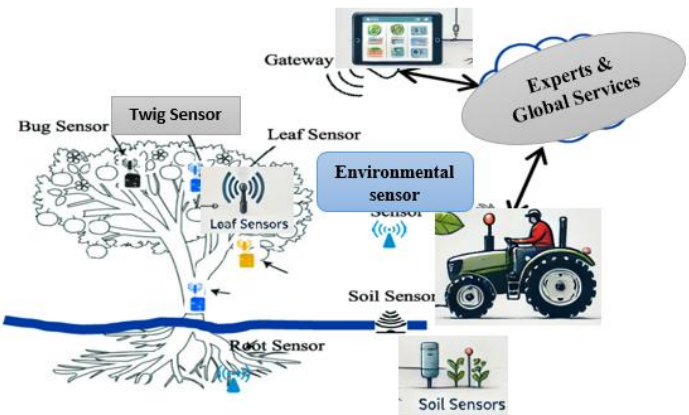
Irrigation Innovative irrigation methods like sprinkler and drip systems are increasingly utilized to mitigate water losses and address water scarcity issues. Traditional methods like furrow and flood irrigation often lead to water wastage and nutrient depletion in soils, negatively impacting crop yields. To combat these challenges, smart irrigation technologies are being adopted, which leverage data on soil types, moisture levels, and weather conditions to estimate crop water needs accurately. Tools such as the Internet of Things (IoT) enable the measurement of air and soil humidity, facilitating enhanced crop management practices and improved agricultural outcomes.

Crop Disease and Its Management Advanced technologies like the IoT are pivotal in reducing hazardous chemical usage in agriculture. They facilitate crop disease monitoring, including pest prediction and weather forecasting, enhancing disease management. While treatment and assessment remain crucial, IoT, wireless sensors and UAVs aid disease identification and pest control. Remote sensing offers cost-effective analysis of crop health, disease, pests, and environmental conditions across large agricultural areas. This tool is low-cost, supports automatic activation, and aids recovery, addressing challenges like poor pollination affecting crop yields.

Fertilizer: Advanced technology enables the precise estimation of nutrient application across space and time, enhancing efficiency while reducing labor. The normalized vegetation index (NDVI) monitors vegetation health, aiding in predicting soil nutrient requirements. This method improves nutrient application efficacy, minimizing environmental impact. Technologies like geographic information systems (GIS), variable rate technology, and global positioning systems (GPS) are employed for nutrient estimation in fields. Fertilizers, vital for crop improvement, are optimally utilized through IoT-driven tools and technology, promoting crop productivity and sustainability.

Crop Harvesting Monitoring and Forecasting: A new technology, such as a developed yield monitor, can be correlated with any machine that is used for harvesting. The yield monitor tool can also be connected to a smartphone application named Farm RTX, which shows accurate harvesting data. It ultimately processes data to the manufacturer's web-based program. This smartphone application can be used to generate high-defined mapping tools and transfer them with other experts and growers to export to other farming tools for monitoring crop yield.

Figure 2. Internet of Things (IOT)-based farm area devices



Advanced Agricultural Approaches: Greenhouse Agriculture Growing plants in controlled conditions is a relatively new technology and a type of advanced agriculture. This technique became popular in the 19th century when several greenhouses were built in Italy, the Netherlands, and France for growing plants, unseasonal vegetables, and fruits. This type of new agriculture technology was enhanced in the 20th century, and countries with climate/weather issues started to apply this technology rapidly. Crops that are grown in a controlled environment require minimum inputs because crops grow under controlled conditions. This controlled environment is developed in the greenhouse. Due to this controlled environment, seasonal and unseasonal crops are grown anywhere and at any time in the world. Several new toolkits such as wireless communication, mobile devices, and other internet devices are used to adopt this technology. Benke and Tomkins, who conducted a comprehensive analysis, reported that advanced toolkits could help to adopt greenhouse technology. Various other toolkits, including prototype-based internet, to monitor weather parameters such as temperature pressure and humidity.

Hydroponics: Hydroponics The most advanced method for seasonal and unseasonal crops is to grow in water under controlled conditions without a soil medium. In this approach, nutrients and fertilizers are applied through the irrigation system. When VF and hydroponics are used in combination, every square meter farm can use almost 95% less water and nutrients without using any chemicals. In a hydroponics system, the accuracy of nutrient measurement is critical. Therefore, a highly reliable wireless control system for tomato hydroponics was proposed. In this method, monitoring the water content and its accuracy is essential. In a prototype based on wireless sensors, it was proposed to provide the cultivation of crops in hydroponics by the turnkey solution, which gives the measurements and estimations regarding the plant growth in the absence of soil media.

Vertical Farming (VF) Arable land decline due to population growth, urbanization, pollution, and soil erosion necessitates innovative agricultural methods like Vertical Farming (VF). VF optimizes resource utilization by cultivating crops in controlled environments, requiring less land compared to traditional farming. Conventional practices contribute to soil degradation, with erosion rates surpassing formation rates. VF mitigates these challenges by conserving soil and reducing freshwater usage, crucial in areas facing water scarcity. Mirai, a Japanese indoor farming tool, minimizes water usage by 40% and energy consumption by 25,000 square meters compared to outdoor farming. Aviation Farm, a VF leader, boosts crop yield by 390 times and slashes water consumption by 95%. Non-dispersive infrared (NDIR) carbon dioxide wireless sensors aid VF control, enhancing crop monitoring efficiency.

Major equipment and technology In traditional agriculture, heavy machinery like harvesters, robots, and tractors dominate farming operations, often supported by communication and remote sensing methods. Advanced farming employs GIS and GPS technologies for precise tasks such as irrigation, sowing, fertilization, and harvesting, enhancing accuracy and efficiency. These techniques are indispensable for site-specific crop management. Modern agriculture relies on two main components: remote sensing programs utilizing UAVs, aircraft, and satellites, and specialized ground and remote sensors. GPS devices pinpoint data collection spots, facilitating location-specific processing. **Smartphone** Due to advancements in research, experts have developed various new tools and approaches strategically to implement smartphone technology in agriculture. Several developing countries, such as Ghana, Kenya, Nigeria, Uganda, Mali, and Zimbabwe, are adopting advanced tools and techniques in agriculture. Moreover, smartphone technology is used in many countries, such as China, Turkey, India, and several African countries, which are listed above. These countries are implementing this advanced technology to increase agriculture production and boost their economies. The use of smartphones in the agricultural sector significantly depends upon numerous aspects. For this purpose, studies were conducted to determine smartphone usage for several agricultural measure.

Soil and Water Analysis New technology such as UAVs can provide accurate data to examine soil and soil water before planting crops, which can help determine which crops are best suited for a particular land. In addition, it can provide information about the type of seed and how it can be grown under particular soils and environments. **Planting** Millions of uncultivated acres globally are inaccessible due to manpower limitations and safety concerns in rough terrain. Drone-based sowing methods are emerging as a solution, reducing expenses by up to 85% and expediting planting with drones capable of planting 100,000 trees in a day. These drones deploy seed pods containing essential nutrients, proving highly effective, with a success rate exceeding 75%. Their adaptability and success make them ideal for plantation in challenging terrain, offering a promising solution for global agricultural and forestry endeavors.

Spraying Pesticides/Herbicides UAVs offer a targeted approach to spraying insecticides, pesticides, and herbicides on crops, unlike conventional methods that cover entire farms unnecessarily. With UAVs, spraying can be focused directly on weeds or specific areas, reducing overall expenses. This targeted approach allows for precise application, minimizing waste and environmental impact. However, UAV spraying faces challenges in handling sudden environmental changes like wind direction, particularly during spraying operations. Despite this, UAVs represent a promising advancement in agricultural spraying practices.

Drones and Other Robots: Farmers and growers harness UAVs for assessing crop growth and monitoring biodiversity and ecological features. Particularly on rugged farmland, UAVs excel in tasks like water spraying and pesticide application. Compared to traditional machinery, drones and robots offer swift and precise spraying capabilities. Recent advancements in swarm technology enable coordinated efforts among multiple drones and robots equipped with various tools, including 3D cameras, enhancing land management capabilities for growers. Moreover, robotics in agriculture have bolstered productivity and increased crop yields by reducing pesticide use, particularly in tasks like weeding and spraying.

Machine Learning and Artificial Intelligence: Machine learning (ML) and artificial intelligence (AI) are employed to analyze data and identify trends. In agriculture, ML/AI is utilized to identify genes that contribute to high-yield crops, providing farmers with seeds suited to their specific location and climate. Additionally, ML/AI algorithms analyze market demand and product availability, enabling growers to make informed decisions about their farming practices. With advancements in ML/AI, growers can accurately classify crop products and discard less desirable ones before planting, thereby optimizing their yields and reducing waste.

Conclussion

The increasing global population is driving up the demand for food, leading to the conversion of forests and arable lands into urban areas. As arable land becomes scarcer, there is a pressing need for highly efficient and advanced technologies to meet the growing food demands of the world population. While some individuals in agriculture may lack innovative spirit and technology, partnerships and collaboration among suppliers, farmers, retailers and buyers exist, albeit with communication gaps. To address these gaps, innovative and advanced technologies are urgently required. This review emphasizes the pivotal role of advanced technologies, particularly the Internet of Things (IoT), in advancing agriculture to meet future demands. Additionally, other advanced technologies such as UAVs, remote and ground sensors, communication technologies, and cloud computing are essential for sustainable agriculture. By adopting these technologies, farmers can enhance their agricultural practices, paving the way for sustainable agriculture. In conclusion, the comparative analysis of agricultural business models and innovative tools across different countries offers valuable insights into the diverse approaches and challenges facing agricultural development worldwide. Through leveraging innovation, collaboration and policy support, the global agricultural sector can overcome constraints and achieve sustainable growth for present and future generations.

References

Benke, K.; Tomkins, B. Future food-production systems: Vertical farming and controlled-environment agriculture. Sustain. Sci. Pract. Policy 2017, 13, 13–26.

Bin Ismail, M.I.H.; Thamrin, N.M. IoT implementation for indoor vertical farming watering system. In Proceedings of the 2017 International Conference on Electrical, Electronics and System Engineering (ICEESE), Kanazawa, Japan, 9–10 November 2017; pp. 89–94.

Benincasa, P.; Antognelli, S.; Brunetti, L.; Fabbri, C.A.; Natale, A.; Sartoretti, V.; Modeo, G.; Guiducci, M.; Tei, F.; Vizzari, M. Reliability of NDVI derived by high resolution satellite and UAV compared to in-field methods for the evaluation of early crop N status and grain yield in Wheat. Exp. Agric. 2018, 54, 604–622.

Chung, S.-O.; Choi, M.-C.; Lee, K.-H.; Kim, Y.-J.; Hong, S.-J.; Li, M. Sensing technologies for grain crop yield monitoring systems: A review. J. Biol. Eng. 2016, 41, 408–417.

D'Oleire-Oltmanns, S.; Marzolff, I.; Peter, K.D.; Ries, J.B. Unmanned aerial vehicle (UAV) for monitoring soil erosion in Morocco. Remote Sens. 2012, 4, 3390–3416.

Dugdale, S.J.; Malcolm, I.A.; Hannah, D.M. Drone-based Structure-from-Motion provides accurate forest canopy data to assess shading effects in river temperature models. Sci. Total Environ. 2019, 678, 326–340.

Elsheshtawy, Y. Cities of sand and fog: Abu Dhabi's global ambitions. Evol. Arab City Tradit. Mod. Urban Dev. 2008, 258–304

Eweg, H. P. A., & Hassink, J. (2011). Business models of Green Care in the Netherlands.

Fortes, E.P. Seed plant drone for reforestation. Grad. Rev. 2017, 2, 13–26.

Ihtisham, M.; Liu, S.; Shahid, M.O.; Khan, N.; Lv, B.; Sarraf, M.; Chen, Q. The Optimized N, P, and K Fertilization for Bermudagrass Integrated Turf Performance during the Establishment and Its Importance for the Sustainable Management of Urban Green Spaces. Sustainability 2020, 12, 10294.

Khan, N.; Medlock, G.; Graves, S.; Anwar, S. GPS guided Autonomous Navigation of a Small Agricultural Robot with Automated Fertilizing System, 0148-7191; SAE Technical Paper; SAE: Warrendale, PA, USA, 2018.

Lee, C. H., Liu, C. F., Lin, Y. T., Yain, Y. S., & Lin, C. H. (2020). New agriculture business model in Taiwan. *International Food and Agribusiness Management Review*, *23*(5), 773-782.

Liang, J.-Y.; Chien, Y.-H. Effects of feeding frequency and photoperiod on water quality and crop production in a tilapia–water spinach raft aquaponics system. *Int. Biodeterior. Biodegrad.* 2013, *85*, 693–700.

Lyra, D.A.; Ismail, S.; Butt, K.U.R.B.; Brown, J. Evaluating the growth performance of eleven'Salicornia bigelovii'populations under full strength seawater irrigation using multivariate analyses. Aust. J. Crop Sci. 2016, 10, 1429.

Manfrini, L.; Pierpaoli, E.; Zibordi, M.; Morandi, B.; Muzzi, E.; Losciale, P.; Grappadelli, L.C. Monitoring strategies for precise production of high quality fruit and yield in Apple in Emilia-Romagna. Chem. Eng. Trans. 2015, 44, 301–306.

Neto, A.J.S.; Zolnier, S.; de Carvalho Lopes, D. Development and evaluation of an automated system for fertigation control in soilless tomato production. Comput. Electr. Agric. 2014, 103, 17–25.

Nishimura, T.; Okuyama, Y.; Matsushita, A.; Ikeda, H.; Satoh, A. A compact hardware design of a sensor module for hydroponics. In Proceedings of the 2017 IEEE 6th Global Conference on Consumer Electronics (GCCE), Nagoya, Japan, 24–27 October 2017; pp. 1–4

Pimentel, D.; Burgess, M. Soil erosion threatens food production. Agriculture 2013, 3, 443–463.

Pölling, B., Prados, M. J., Torquati, B. M., Giacchè, G., Recasens, X., Paffarini, C., ... & Lorleberg, W. (2017). Business models in urban farming: A comparative analysis of case studies from Spain, Italy and Germany. *Moravian geographical reports*, *25*(3), 166-180.

Raut, R.; Varma, H.; Mulla, C.; Pawar, V.R. Soil Monitoring, Fertigation, and Irrigation System Using IoT for Agricultural Application. In Intelligent Communication and Computational Technologies; Springer: Berlin/Heidelberg, Germany, 2018; pp. 67–73.

Reinecke, M.; Prinsloo, T. The influence of drone monitoring on crop health and harvest size. In Proceedings of the 2017 1st International Conference on Next Generation Computing Applications (NextComp), Mauritius, Madagascar, 19–21 July 2017; pp. 5–10.

Regmi, S., & Naharki, K. (2020). A SWOT analysis of agribusiness entrepreneurship in Nepal. *Food & Agribusiness Management*, *1*(2), 60-65.

Sarraf, M.; Kataria, S.; Taimourya, H.; Santos, L.O.; Menegatti, R.D.; Jain, M.; Liu, S. Magnetic field (MF) applications in plants: An overview. Plants 2020, 9, 1139

Siregar, B., Efendi, S., Pranoto, H., Ginting, R., Andayani, U., & Fahmi, F. (2017, September). Remote monitoring system for hydroponic planting media. In *2017 International Conference on ICT For Smart Society (ICISS)* (pp. 1-6). IEEE.

Tambunan, T. T. (2014). Identifying business models adopted by FDI in agriculture in Indonesia. *Journal of Economics and Development Studies*, *2*(1), 99-130. Talerngsri-Teerasuwannajak, K., & Pongkijvorasin, S. (2021). Agricultural business model and upland sustainability: Evidence from northern Thailand. *Current Research in Environmental Sustainability*, *3*, 100085.

Touliatos, D.; Dodd, I.C.; McAinsh, M. Vertical farming increases lettuce yield per unit area compared to conventional horizontal hydroponics. Food Energy Secur. 2016, 5, 184–191.

Tripodi, P.; Massa, D.; Venezia, A.; Cardi, T. Sensing technologies for precision phenotyping in vegetable crops: Current status and future challenges. Agronomy 2018, 8, 57.

Uddin, M.A.; Mansour, A.; Jeune, D.L.; Ayaz, M.; Aggoune, E.-H.M. UAV-assisted dynamic clustering of wireless sensor networks for crop health monitoring. Sensors 2018, 18, 555.

Villarrubia, G.; Paz, J.F.D.; Iglesia, D.H.; Bajo, J. Combining multi-agent systems and wireless sensor networks for monitoring crop irrigation. Sensors 2017, 17, 1775.

Wietzke, A.; Westphal, C.; Gras, P.; Kraft, M.; Pfohl, K.; Karlovsky, P.; Pawelzik, E.; Tscharntke, T.; Smit, I. Insect pollination as a key factor for strawberry physiology and marketable fruit quality. Agric. Ecol. Environ. 2018, 258, 197–204.

Zhou, J.; Reynolds, D.; Websdale, D.; Le Cornu, T.; Gonzalez-Navarro, O.; Lister, C.; Orford, S.; Laycock, S.; Finlayson, G.; Stitt, T. CropQuant: An automated and scalable field phenotyping platform for crop monitoring and trait measurements to facilitate breeding and digital agriculture. BioRxiv 2017, 161547.