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# Modern Technology and Agricultural Development in India

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**ABSTRACT:** Modern Agricultural technology or agrotechnology (abbreviated agtech, agritech, AgriTech, or agrotech) is the use of technology in agriculture, horticulture, and aquaculture with the aim of improving yield, efficiency, and profitability. Agricultural technology can be products, services or applications derived from agriculture that improve various input/output processes.<sup>[1][2]</sup> Advances in agricultural science, agronomy, and agricultural engineering have led to applied developments in agricultural technology.<sup>[3][4]</sup> Agro-textiles is the segmented class of technical textiles that deals focuses on the agriculture sector, with an approach to crop protection and crop development and reducing the risks of farming practices. Primarily agro-textiles offer weather resistance and resistance to microorganisms and protection from unwanted elements and external factors. Agro-textiles helps to improve the overall conditions with which crop can develop and be protected. There are the various textile products, fabrics forms, fibers and techniques used in agro-textiles which are useful for agriculture mainly for crop protection and in crop development for instance shade nets, thermal insulation and sunscreen materials, windshield, antibird nets, which provide minimal shading and proper temperature, air circulation for protecting plants from direct sunlight and birds. Agrotexiles involves mulch mats, hail protection nets, and crop covers, etc. Agro-textiles are useful in Horticulture, aquaculture, landscape gardening and forestry also. More examples of use and application are covering livestock protection, suppressing weed and insect control, etc.<sup>[8]</sup>

**KEYWORDS:** modern technology, agricultural development, India, farming, crop protection, applications

## I. INTRODUCTION

Agribusiness is the industry, enterprises, and the field of study<sup>[1]</sup> of value chains in agriculture<sup>[2]</sup> and in the bio-economy,<sup>[3]</sup> in which case it is also called bio-business<sup>[4][5]</sup> or bio-enterprise. The primary goal of agribusiness is to maximize profit while satisfying the needs of consumers for products related to natural resources such as biotechnology, farms, food, forestry, fisheries, fuel, and fiber.

Studies of business growth and performance in farming have found successful agricultural businesses are cost-efficient internally and operate in favorable economic, political, and physical-organic environments. They are able to expand and make profits, improve the productivity of land, labor, and capital, and keep their costs down to ensure market price competitiveness.<sup>[6]</sup>

Agribusiness is not limited to farming. It encompasses a broader spectrum through the agribusiness system which includes input supplies, value-addition, marketing, entrepreneurship, microfinancing, and agricultural extension.

In some countries like the Philippines, creation and management of agribusiness enterprises require consultation with registered agriculturists above a certain level of operations, capitalization, land area, or number of animals in the farm.

Intensive agriculture, also known as intensive farming (as opposed to extensive farming), conventional, or industrial agriculture, is a type of agriculture, both of crop plants and of animals, with higher levels of input and output per unit of agricultural land area. It is characterized by a low fallow ratio, higher use of inputs such as capital and labour, and higher crop yields per unit land area.<sup>[1]</sup>

Most commercial agriculture is intensive in one or more ways. Forms that rely heavily on industrial methods are often called industrial agriculture, which is characterised by innovations designed to increase yield. Techniques include planting multiple crops per year, reducing the frequency of fallow years, and improving cultivars. It also



involves increased use of fertilizers, plant growth regulators, pesticides, antibiotics for livestock and mechanised agriculture, controlled by increased and more detailed analysis of growing conditions, including weather, soil, water, weeds, and pests. Intensive farms are widespread in developed nations and increasingly prevalent worldwide. Most of the meat, dairy products, eggs, fruits, and vegetables available in supermarkets are produced by such farms.

Some intensive farms can use sustainable methods, although this typically necessitates higher inputs of labor or lower yields.<sup>[2]</sup> Sustainably increasing agricultural productivity, especially on smallholdings, is an important way of decreasing the amount of land needed for farming and slowing environmental degradation through processes like deforestation.<sup>[3]</sup>

Intensive animal farming involves large numbers of animals raised on limited land, for example by rotational grazing,<sup>[4][5]</sup> or sometimes as concentrated animal feeding operations. These methods increase the yields of food and fiber per acre as compared to extensive animal husbandry; concentrated feed is brought to seldom-moved animals, or with rotational grazing the animals are repeatedly moved to fresh forage.<sup>[4][5]</sup>

Organic farming, also known as ecological farming or biological farming,<sup>[1][2][3][4][5]</sup> is an agricultural system that uses fertilizers of organic origin such as compost manure, green manure, and bone meal and places emphasis on techniques such as crop rotation and companion planting. It originated early in the 20th century in reaction to rapidly changing farming practices. Certified organic agriculture accounts for 70 million hectares (170 million acres) globally, with over half of that total in Australia.<sup>[6]</sup> Organic farming continues to be developed by various organizations today. Biological pest control, mixed cropping, and the fostering of insect predators are encouraged. Organic standards are designed to allow the use of naturally-occurring substances while prohibiting or strictly limiting synthetic substances.<sup>[7]</sup> For instance, naturally-occurring pesticides such as pyrethrin are permitted, while synthetic fertilizers and pesticides are generally prohibited. Synthetic substances that are allowed include, for example, copper sulfate, elemental sulfur, and ivermectin. Genetically modified organisms, nanomaterials, human sewage sludge, plant growth regulators, hormones, and antibiotic use in livestock husbandry are prohibited.<sup>[8][9]</sup> Organic farming advocates claim advantages in sustainability,<sup>[10][11]</sup> openness, self-sufficiency, autonomy and independence,<sup>[11]</sup> health, food security, and food safety.

Organic agricultural methods are internationally regulated and legally enforced by many nations, based in large part on the standards set by the International Federation of Organic Agriculture Movements (IFOAM), an international umbrella organization for organic farming organizations established in 1972.<sup>[12]</sup> Organic agriculture can be defined as "an integrated farming system that strives for sustainability, the enhancement of soil fertility and biological diversity while, with rare exceptions, prohibiting synthetic pesticides, antibiotics, synthetic fertilizers, genetically modified organisms, and growth hormones".<sup>[13][14][15][16]</sup>

Since 1990, the market for organic food and other products has grown rapidly, reaching \$63 billion worldwide in 2012.<sup>[17]:25</sup> This demand has driven a similar increase in organically-managed farmland that grew from 2001 to 2011 at a compounding rate of 8.9% per annum.<sup>[18]</sup> As of 2020, approximately 75,000,000 hectares (190,000,000 acres) worldwide were farmed organically, representing approximately 1.6% of total world farmland.<sup>[19]</sup>

Organic farming can be beneficial on biodiversity and environmental protection at local level. However, because organic farming has lower yields compared to conventional farming, additional agricultural land is needed elsewhere in the world, which means that natural land has to be converted into agricultural land. This can cause loss of biodiversity and negative climate effects that outweigh the local environmental gains achieved.<sup>[20]</sup>

Precision agriculture (PA) is a farming management strategy based on observing, measuring and responding to temporal and spatial variability to improve agricultural production sustainability.<sup>[2]</sup> It is used in both crop and livestock production. Precision agriculture often employs technologies to automate agricultural operations, improving their diagnosis, decision-making or performing.<sup>[3][4]</sup> First conceptual work on PA and practical applications go back in the late 1980s.<sup>[5]</sup> The goal of precision agriculture research is to define a decision support system (DSS) for whole farm management with the goal of optimizing returns on inputs while preserving resources.<sup>[6][7]</sup>



Among these many approaches is a phytogeomorphological approach which ties multi-year crop growth stability/characteristics to topological terrain attributes. The interest in the phytogeomorphological approach stems from the fact that the geomorphology component typically dictates the hydrology of the farm field.<sup>[8][9]</sup>

The practice of precision agriculture has been enabled by the advent of GPS and GNSS. The farmer's and/or researcher's ability to locate their precise position in a field allows for the creation of maps of the spatial variability of as many variables as can be measured (e.g. crop yield, terrain features/topography, organic matter content, moisture levels, nitrogen levels, pH, EC, Mg, K, and others).<sup>[10]</sup> Similar data is collected by sensor arrays mounted on GPS-equipped combine harvesters. These arrays consist of real-time sensors that measure everything from chlorophyll levels to plant water status, along with multispectral imagery.<sup>[11]</sup> This data is used in conjunction with satellite imagery by variable rate technology (VRT) including seeders, sprayers, etc. to optimally distribute resources. However, recent technological advances have enabled the use of real-time sensors directly in soil, which can wirelessly transmit data without the need of human presence.<sup>[12][13]</sup>

Precision agriculture has also been enabled by unmanned aerial vehicles that are relatively inexpensive and can be operated by novice pilots. These agricultural drones can be equipped with multispectral or RGB cameras to capture many images of a field that can be stitched together using photogrammetric methods to create orthophotos. These multispectral images contain multiple values per pixel in addition to the traditional red, green blue values such as near infrared and red-edge spectrum values used to process and analyze vegetative indexes such as NDVI maps.<sup>[14]</sup> These drones are capable of capturing imagery and providing additional geographical references such as elevation, which allows software to perform map algebra functions to build precise topography maps. These topographic maps can be used to correlate crop health with topography, the results of which can be used to optimize crop inputs such as water, fertilizer or chemicals such as herbicides and growth regulators through variable rate applications.

Sustainable agriculture is farming in sustainable ways meeting society's present food and textile needs, without compromising the ability for current or future generations to meet their needs.<sup>[1]</sup> It can be based on an understanding of ecosystem services. There are many methods to increase the sustainability of agriculture. When developing agriculture within sustainable food systems, it is important to develop flexible business process and farming practices.<sup>[2]</sup> Agriculture has an enormous environmental footprint, playing a significant role in causing climate change (food systems are responsible for one third of the anthropogenic greenhouse gas emissions),<sup>[3][4]</sup> water scarcity, water pollution, land degradation, deforestation and other processes;<sup>[5]</sup> it is simultaneously causing environmental changes and being impacted by these changes.<sup>[6]</sup> Sustainable agriculture consists of environment friendly methods of farming that allow the production of crops or livestock without damage to human or natural systems. It involves preventing adverse effects to soil, water, biodiversity, surrounding or downstream resources—as well as to those working or living on the farm or in neighboring areas. Elements of sustainable agriculture can include permaculture, agroforestry, mixed farming, multiple cropping, and crop rotation.<sup>[7]</sup>

Developing sustainable food systems contributes to the sustainability of the human population. For example, one of the best ways to mitigate climate change is to create sustainable food systems based on sustainable agriculture. Sustainable agriculture provides a potential solution to enable agricultural systems to feed a growing population within the changing environmental conditions.<sup>[6]</sup> Besides sustainable farming practices, dietary shifts to sustainable diets are an intertwined way to substantially reduce environmental impacts.<sup>[8][9][10][11]</sup> Numerous sustainability standards and certification systems exist, including organic certification, Rainforest Alliance, Fair Trade, UTZ Certified, GlobalGAP, Bird Friendly, and the Common Code for the Coffee Community (4C).<sup>[12]</sup>

## II. DISCUSSION

Digital agriculture, sometimes known as smart farming or e-agriculture,<sup>[1]</sup> is tools that digitally collect, store, analyze, and share electronic data and/or information in agriculture. The Food and Agriculture Organization of the United Nations has described the digitalization process of agriculture as the digital agricultural revolution.<sup>[2]</sup> Other definitions, such as those from the United Nations Project Breakthrough,<sup>[3]</sup> Cornell University,<sup>[4]</sup> and Purdue University,<sup>[5]</sup> also emphasize the role of digital technology in the optimization of food systems. Digital agriculture includes (but is not limited to) precision agriculture. Unlike precision agriculture, digital agriculture impacts the



entire agri-food value chain — before, during, and after on-farm production.<sup>[6]</sup> Therefore, on-farm technologies, like yield mapping, GPS guidance systems, and variable-rate application, fall under the domain of precision agriculture and digital agriculture. On the other hand, digital technologies involved in e-commerce platforms, e-extension services, warehouse receipt systems, blockchain-enabled food traceability systems, tractor rental apps, etc. fall under the umbrella of digital agriculture but not precision agriculture. Emerging digital technologies have the potential to be game-changers for traditional agricultural practices. The Food and Agriculture Organization of the United Nations has referred to this change as a revolution: “a ‘digital agricultural revolution’ will be the newest shift which could help ensure agriculture meets the needs of the global population into the future.”<sup>[2]</sup> Other sources label the change as “Agriculture 4.0,” indicating its role as the fourth major agricultural revolution.<sup>[7]</sup> Precise dates of the Fourth Agricultural Revolution are unclear. The World Economic Forum announced that the “Fourth Industrial Revolution” (which includes agriculture) will unfold throughout the 21st century, so perhaps 2000 or shortly thereafter marks the beginning of Agriculture 4.0.<sup>[8][9]</sup> Agricultural revolutions denote periods of technological transformation and increased farm productivity.<sup>[10]</sup> Agricultural revolutions include the First Agricultural Revolution, the Arab Agricultural Revolution, the British/Second Agricultural Revolution, the Scottish Agricultural Revolution, and the Green Revolution/Third Agricultural Revolution. Despite boosting agricultural productivity, past agricultural revolutions left many problems unsolved. For example, the Green Revolution had unintended consequences, like inequality and environmental damage. First, the Green Revolution exacerbated inter-farm and interregional inequality,<sup>[11]</sup> typically biased toward large farmers with the capital to invest in new technologies.<sup>[12]</sup> Second, critics say its policies promoted heavy input use and dependence on agrochemicals, which led to adverse environmental effects like soil degradation and chemical runoff.<sup>[13][14]</sup> Digital agriculture technologies have the potential to address negative side effects of the Green Revolution. In some ways, the Digital Agriculture Revolution follows patterns of previous agricultural revolutions. Scholars forecast a further shift away from labor, a slight shift away from capital, and intensified use of human capital — continuing the trend the British Agricultural Revolution started.<sup>[15][16]</sup> Also, many predict that social backlash — possibly around the use of artificial intelligence or robots — will arise with the fourth revolution.<sup>[17][18][19][20]</sup> Since controversy accompanies every societal transformation, the digital agricultural revolution isn't new in that respect. In other ways, the Digital Agriculture Revolution is distinct from its predecessors. First, digital technologies will affect all parts of the agricultural value chain, including off-farm segments.<sup>[21][22]</sup> This differs from the first three agricultural revolutions, which primarily impacted production techniques and on-farm technologies. Second, a farmer's role will require more data analytics skills and less physical interaction with livestock/fields.<sup>[23][24][22][25]</sup> Third, although farming has always relied on empirical evidence, the volume of data and the methods of analysis will undergo drastic changes in the digital revolution.<sup>[16][26]</sup> For example, Smart farm systems continuously monitor the behavior of your animals. Giving you insight into their behavior every moment of the day.<sup>[27]</sup> Finally, increased reliance on big data may increase the power differential between farmers and information service providers,<sup>[21][28]</sup> or between farmers and large value chain actors (like supermarkets).<sup>[21]</sup>

Digital agriculture encompasses a wide range of technologies, most of which have multiple applications along the agricultural value chain. These technologies include, but are not limited to:

- Cloud computing/big data analysis tools<sup>[21]</sup>
- Artificial intelligence
- Machine learning
- Distributed ledger technologies, including blockchain and smart contracts
- The Internet of Things, a principle developed by Kevin Ashton<sup>[relevant?]</sup> that explains how simple mechanical objects can be combined into a network to broaden understanding of that object<sup>[29]</sup>
- Digital communications technologies, like mobile phones
- Digital platforms, such as e-commerce platforms, agro-advisory apps, or e-extension websites
- Precision agriculture technologies, including
  - Sensors, including food sensors and soil sensors
  - Guidance and tracking systems (often enabled<sup>[how?]</sup> by GPS, GNSS, RFID, IoT)



- Variable-rate input technologies
- Automatic section control
- Advanced imaging<sup>[30]</sup> technologies, including satellite and drone imagery, to look at temperature gradients, fertility gradients, moisture gradients, and anomalies in a field
- Automated machinery and agricultural robots

The FAO estimates the world will need to produce 56% more food (as compared to 2010, under “business as usual” growth) to feed over 9 billion in 2050.<sup>[31][32]</sup> Furthermore, the world faces intersecting challenges like malnutrition, climate change, food waste, and changing diets.<sup>[33]</sup> To produce a “sustainable food future,” the world must increase food production while cutting greenhouse gas emissions and maintaining (or reducing) the land used in agriculture.<sup>[34]</sup> Digital agriculture could address these challenges by making the agricultural value chain more efficient, equitable, and environmentally sustainable. Digital technology changes economic activity by lowering the costs of replicating, transporting, tracking, verifying, and searching for data.<sup>[35]</sup> Due to these falling costs, digital technology will improve efficiency throughout the agricultural value chain. On-farm, precision agriculture technologies can minimize inputs required for a given yield. For example, variable-rate application (VRA) technologies can apply precise amounts of water, fertilizer, pesticide, herbicide, etc. A number of empirical studies find that VRA improves input use efficiency.<sup>[36][37][38]</sup> Using VRA alongside geo-spatial mapping, farmers can apply inputs to hyper-localized regions of their farm — sometimes down to the individual plant level. Reducing input use lowers costs and lessens negative environmental impacts. Furthermore, empirical evidence indicates precision agriculture technologies can increase yields.<sup>[39]</sup> On U.S. peanut farms, guidance systems are associated with a 9% increase in yield, and soil maps are associated with a 13% increase in yield.<sup>[40][41]</sup> One study in Argentina found that a precision agriculture approach based on crop physiological principles could result in 54% higher farm output.<sup>[42]</sup>

Digital agriculture can improve the allocative efficiency of physical capital within and between farms. Often touted as “Uber for tractors,” equipment-sharing platforms like Hello Tractor,<sup>[43][44]</sup> WeFarmUp,<sup>[45][46]</sup> MachineryLink Solutions,<sup>[47]</sup> TroTro Tractor, and Tringo<sup>[48]</sup> facilitate farmer rental of expensive machinery. By facilitating a market for equipment sharing, digital technology ensures fewer tractors sit idle and allows owners to make extra income. Furthermore, farmers without the resources to make big investments can better access equipment to improve their productivity.

Digital agriculture improves labor productivity through improved farmer knowledge. E-extension (electronic provision of traditional agricultural extension services) allows for farming knowledge and skills to diffuse at low cost. For example, the company Digital Green works with local farmers to create and disseminate videos about agricultural best practices in more than 50 languages.<sup>[49][50]</sup> E-extension services can also improve farm productivity via decision-support services on mobile apps or other digital platforms. Using many sources of information — weather data, GIS spatial mapping, soil sensor data, satellite/drone pictures, etc. — e-extension platforms can provide real-time recommendations to farmers. For example, the machine-learning-enabled mobile app Plantix diagnoses crops’ diseases, pests, and nutrient deficiencies based on a smartphone photo.<sup>[51]</sup> In a randomized control trial, Casaburi et al. (2014) found that sugarcane growers who received agricultural advice via SMS messages increased yields by 11.5% relative to the control group.<sup>[52]</sup>

Finally, digital agriculture improves labor productivity through decreased labor requirements. Automation inherent in precision agriculture — from “milking robots on dairy farms to greenhouses with automated climate control”<sup>[53]</sup> — can make crop and livestock management more efficient by reducing required labor.<sup>[54][55]</sup>

### **III. RESULTS**

Besides streamlining farm production, digital agriculture technologies can make agricultural markets more efficient. Mobile phones, online ICTs, e-commerce platforms, digital payment systems, and other digital agriculture technologies can mitigate market failures and reduce transaction costs throughout the value chain.



- Reducing information asymmetry: Price information affects competitive markets' efficiency because it impacts price dispersion, arbitrage, and farmer and consumer welfare. Since the marginal cost of digitally delivering information approaches zero, digital agriculture has the potential to spread price information. Aker and Fafchamps find that the introduction of mobile phone coverage in Niger reduced spatial price dispersion for agri-food products, especially for remote markets and perishable goods.<sup>[56]</sup> Similarly, price information provided by Internet kiosks ("e-choupals") in India led to an increase in farmers' net profits as traders lost monopsony power.<sup>[57]</sup> Other examples of digital platforms for price information include MFarm<sup>[58]</sup> and Esoko.<sup>[59]</sup>
- Matching buyers and sellers: E-commerce lowers the search costs of matching buyers and sellers, potentially shortening the value chain.<sup>[51]</sup> Rather than go through dozens of intermediaries, farmers can sell directly to consumers.<sup>[60][61]</sup> Market access services can also solve the matching problem without necessarily hosting online transactions. For example, Esoko sends market information (prices for specific commodities, market locations, etc.) to agents and farmers, connecting them to commodity buyers.<sup>[62][59]</sup> All of these matching platforms help smallholders coordinate with buyers and enter both regional and global value chains.<sup>[63]</sup> Finally, it's important to note that digital technologies can also facilitate matching in financial and input markets, not just producer-to-consumer output sales.
- Lowering transaction costs in commercial markets: Digital payments — whether integrated in e-commerce platforms or in mobile money accounts, e-wallets, etc. — reduce transactions costs within agricultural markets. The need for safe, rapid monetary transactions is particularly apparent in rural areas. Plus, digital payments can provide a gateway to bank accounts, insurance, and credit.<sup>[64]</sup> Using distributed ledger technologies or smart contracts is another way to reduce trust-related transaction costs in commercial markets.<sup>[65][63]</sup> Many retail and food companies have partnered with IBM to develop blockchain pilots related to food safety and traceability, and Alibaba is testing blockchain to reduce fraud in agri-food e-commerce between China and Australia/New Zealand.<sup>[63]</sup>
- Lowering transaction costs in government services: Digital payments can also streamline government delivery of agricultural subsidies. In 2011, the Nigerian Federal Ministry of Agriculture and Rural Development started delivering fertilizer subsidy vouchers to e-wallets on mobile phones; by 2013, they had reached 4.3 million smallholders nationwide.<sup>[66]</sup> Compared to the previous program, the e-vouchers cut costs — from 2011 to 2013, the cost per smallholder farmer receiving fertilizer went from US\$225–300 to US\$22. The e-vouchers also reached more smallholders, increasing from between 600,000-800,000 in 2011 to 4.3 million in 2013.<sup>[66]</sup> In the second phase of the program, the Nigerian government developed the Nigerian Agricultural Payment Initiative (NAPI), which distributed PIN-enabled ID cards that hold subsidy information and provide access to loans and grants.<sup>[67]</sup> Other e-wallet/e-voucher systems for agricultural subsidies exist or have been piloted in Colombia,<sup>[68][69]</sup> Rwanda,<sup>[66]</sup> Zambia,<sup>[70]</sup> Mali, Guinea, and Niger.<sup>[71]</sup> Besides reducing subsidy costs, governments can harness digital technology to save time. When Estonia implemented their e-ID and X-Road system, time spent applying for agricultural subsidies decreased from 300 minutes to 45 minutes per person.<sup>[72]</sup>

Rarely does one single digital agriculture technology solve one discrete market failure. Rather, systems of digital agriculture technologies work together to solve multifaceted problems. For example, e-commerce solves two efficiency issues: difficulty matching buyers and sellers, especially in rural areas, and the high transaction costs associated with in-person, cash-based trade.

Though digital technologies can facilitate market access and information flow, there's no guarantee they won't exacerbate existing inequalities. Should constraints prevent a range of farmers from adopting digital agriculture, it's possible that the benefits will only accrue to the powerful.

- Large farms: When a digital agriculture technology requires much upfront investment, only large farms with sufficient assets and credit access will adopt it.<sup>[51]</sup> For example, large farms are most likely to adopt precision agriculture technologies because of high costs.<sup>[82]</sup> Increasingly however, automated mechanization is focusing on more but smaller autonomous machines, instead of fewer but larger machines such as observed with machines that still require human control.<sup>[83]</sup> This trend enables smaller farms to participate in digital



agriculture more evenly with larger farms, as the upfront investment becomes more equal relative to the size of the farm.

- **Digital divide:** The uneven access to information and communication technologies (ICTs) may lead to uneven adoption of — and thereby uneven gains from — digital agriculture. When digital technologies require specific skills, benefits may accrue to digitally literate farmers positioned to take advantage of such opportunities.<sup>[84][85][86]</sup>
- **Gender:** Given gender-based disparities in ICT access<sup>[87][49]</sup> and the gender gap in agribusiness value chains,<sup>[88]</sup> men seem more likely to adopt digital agriculture.<sup>[51]</sup> Therefore, digital technologies could perpetuate gender inequalities in the agricultural sector.<sup>[89]</sup>
- **Unskilled labor:** Advances in on-farm productivity, particularly through digitized automation and precision agriculture, may threaten low-skilled jobs.<sup>[11]</sup> According to the OECD, agriculture will be one of the sectors most affected by automation<sup>[90]</sup> and McKinsey Global Institute projects that automation will displace 15% of agricultural workers in Mexico and 30% in Germany.<sup>[91]</sup>
- **Agribusinesses and service providers:** Increased reliance on big data may increase the power differential between agribusinesses/information service providers and farmers.<sup>[21][28]</sup> If smallholders lack access to and/or control of their data, they may lose bargaining power vis-à-vis large value chain actors (like supermarkets) and data collectors.<sup>[92]</sup>

#### **IV. CONCLUSIONS**

Information and communication technology in agriculture (ICT in agriculture), also known as e-agriculture, focuses on the enhancement of agricultural and rural development through improved information and communication processes. More specifically, e-agriculture involves the conceptualization, design, development, evaluation and application of innovative ways to use information and communication technologies (ICTs) in the rural domain, with a primary focus on agriculture.<sup>[1]</sup> ICT includes devices, networks, mobiles, services and applications; these range from innovative Internet-era technologies and sensors to other pre-existing aids such as fixed telephones, televisions, radios and satellites. Provisions of standards, norms, methodologies, and tools as well as development of individual and institutional capacities, and policy support are all key components of e-agriculture.

Many ICT in agriculture or e-agriculture interventions have been developed and tested around the world to help agriculturists improve their livelihoods through increased agricultural productivity and income, or by reducing risks. Some useful resources for learning about e-agriculture in practice are the World Bank's e-sourcebook ICT in agriculture – connecting smallholder farmers to knowledge, networks and institutions (2011),<sup>[2]</sup> ICT uses for inclusive value chains (2013),<sup>[3]</sup> ICT uses for inclusive value chains (2013)<sup>[4]</sup> and Success stories on information and communication technologies for agriculture and rural development<sup>[5]</sup> have documented many cases of use of ICT in agriculture. Precision agriculture (PA) is a farming management strategy based on observing, measuring and responding to temporal and spatial variability to improve agricultural production sustainability.<sup>[2]</sup> It is used in both crop and livestock production. Precision agriculture often employs technologies to automate agricultural operations, improving their diagnosis, decision-making or performing.<sup>[3][4]</sup> First conceptual work on PA and practical applications go back in the late 1980s.<sup>[5]</sup> The goal of precision agriculture research is to define a decision support system (DSS) for whole farm management with the goal of optimizing returns on inputs while preserving resources.<sup>[6][7]</sup>

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## REFERENCES

1. "Technology and digital in agriculture - OECD". [www.oecd.org](http://www.oecd.org). Retrieved 2019-07-25.
2. ^ Trendov, Nikola M.; Varas, Samuel; Zeng, Meng. "Digital Technologies in Agriculture and Rural Areas" (PDF). Retrieved 17 October 2021.
3. ^ "Digital Agriculture: feeding the future". Project Breakthrough. Retrieved 2019-07-25.
4. ^ "Digital Agriculture | Cornell University Agricultural Experiment Station". [cuaes.cals.cornell.edu](http://cuaes.cals.cornell.edu). Retrieved 2019-07-25.
5. ^ "Home". Purdue University Digital Agriculture. Retrieved 2019-07-25.
6. ^ Shepherd, Turner, Small, and Wheeler (2018). "Priorities for science to overcome hurdles thwarting the full promise of the 'digital agriculture' revolution". *Journal of the Science of Food and Agriculture*. 100 (14): 5083–5092. doi:10.1002/jsfa.9346. PMC 7586842. PMID 30191570.
7. ^ Rose, David Christian; Chilvers, Jason (2018). "Agriculture 4.0: Broadening Responsible Innovation in an Era of Smart Farming". *Frontiers in Sustainable Food Systems*. 2: 87. doi:10.3389/fsufs.2018.00087.
8. ^ Schwab, Karl (2018). *The Fourth Industrial Revolution*. Crown Publishing Group.
9. ^ Schwab 2018. *The Fourth Industrial Revolution*. *Encyclopedia Britannica*. <https://www.britannica.com/topic/The-Fourth-Industrial-Revolution-2119734>.
10. ^ Allen, Robert C. (1999). "Tracking the agricultural revolution in England". *The Economic History Review*. 52 (2): 209–235. doi:10.1111/1468-0289.00123.
11. ^ Freebairn (1995). "Did the Green Revolution Concentrate Incomes? A Quantitative Study of Research Reports". *World Development*. 23 (2): 265–279. doi:10.1016/0305-750X(94)00116-G.
12. ^ Junankar, P. N. (1975). "Green Revolution and Inequality". *Economic and Political Weekly*. 10 (13): A15–A18. ISSN 0012-9976. JSTOR 4536986.
13. ^ Pingali, P. L. (2012). "Green Revolution: Impacts, limits, and the path ahead". *Proceedings of the National Academy of Sciences of the United States of America*. 109 (31): 12302–12308. Bibcode:2012PNAS..10912302P. doi:10.1073/pnas.0912953109. PMC 3411969. PMID 22826253.
14. ^ Food and Agriculture Organization of the United Nations. "Crop breeding: the Green Revolution and the preceding millennia". *FAO Newsroom*.
15. ^ Struik and Kuyper (2017). "Sustainable intensification in agriculture: the richer shade of green. A review". *Agronomy for Sustainable Development*. 37 (5): 37–39. doi:10.1007/s13593-017-0445-7.
16. ^ Bronson (2018). "Smart Farming: Including Rights Holders for Responsible Agricultural Innovation". *Technology Innovation Management Review*. 8 (2). doi:10.1007/s13593-017-0445-7.
17. ^ Rose, David Christian; Chilvers, Jason (2018). "Agriculture 4.0: Broadening Responsible Innovation in an Era of Smart Farming". *Frontiers in Sustainable Food Systems*. 2. doi:10.3389/fsufs.2018.00087.



18. ^ MacNaghten, Phil (2015). "A Responsible Innovation Governance Framework for GM Crops". *Governing Agricultural Sustainability*. pp. 225–239. doi:10.4324/9781315709468-19. ISBN 9781315709468.
19. ^ MacNaghten, Phil; Chilvers, Jason (2014). "The Future of Science Governance: Publics, Policies, Practices". *Environment and Planning C: Government and Policy*. 32 (3): 530–548. doi:10.1068/c1245j. S2CID 144164733.
20. ^ Hartley, Sarah; Gillund, Frøydis; Van Hove, Lilian; Wickson, Fern (2016). "Essential Features of Responsible Governance of Agricultural Biotechnology". *PLOS Biology*. 14 (5): e1002453. doi:10.1371/journal.pbio.1002453. PMC 4856357. PMID 27144921.
21. ^ Wolfert, Sjaak; Ge, Lan; Verdouw, Cor; Bogaardt, Marc-Jeroen (1 May 2017). "Big Data in Smart Farming – A review". *Agricultural Systems*. 153: 69–80. doi:10.1016/j.agsy.2017.01.023. ISSN 0308-521X.
22. ^ Eastwood, C.; Klerkx, L.; Ayre, M.; Dela Rue, B. (26 December 2017). "Managing Socio-Ethical Challenges in the Development of Smart Farming: From a Fragmented to a Comprehensive Approach for Responsible Research and Innovation". *Journal of Agricultural and Environmental Ethics*. 32 (5–6): 741–768. doi:10.1007/s10806-017-9704-5. ISSN 1187-7863.
23. ^ Carolan, Michael (2017). "Publicising Food: Big Data, Precision Agriculture, and Co-Experimental Techniques of Addition: Publicising Food". *Sociologia Ruralis*. 57 (2): 135–154. doi:10.1111/soru.12120.
24. ^ Driessen, Clemens; Heutinck, Leonie F. M. (2015). "Cows desiring to be milked? Milking robots and the co-evolution of ethics and technology on Dutch dairy farms". *Agriculture and Human Values*. 32 (1): 3–20. doi:10.1007/s10460-014-9515-5. ISSN 0889-048X. S2CID 154358749.
25. ^ Holloway, Lewis; Bear, Christopher (2017). "Bovine and human becomings in histories of dairy technologies: robotic milking systems and remaking animal and human subjectivity" (PDF). *BJHS Themes*. 2: 215–234. doi:10.1017/bjt.2017.2. ISSN 2058-850X.
26. ^ Wolf, S.A. and Wood, S.D. (1997). "Precision farming: environmental legitimation, commodification of information, and industrial coordination". *Rural Sociology*. 62 (2): 180–206. doi:10.1111/j.1549-0831.1997.tb00650.x.
27. ^ "Smart farming: a revolutionary system by Fancom for farmers". Fancom BV. Retrieved 19 November 2020.
28. ^ Carbonell (2016). "The ethics of big data in agriculture". *Internet Policy Review*. 5 (1). doi:10.14763/2016.1.405.
29. ^ Gabbai, Arik. "Kevin For example, Ashton Describes "The Internet of Things"". *Smithsonian*. Retrieved 9 December 2018.
30. ^ Zhang, Chunhua; Kovacs, John M. (31 July 2012). "The application of small unmanned aerial systems for precision agriculture: a review". *Precision Agriculture*. 13 (6): 693–712. doi:10.1007/s11119-012-9274-5. S2CID 14557132.
31. ^ FAO 2017. *The Future of Food and Agriculture: Trends and Challenges*. Rome. Accessed 11 July 2019. <http://www.fao.org/3/a-i6583e.pdf>.
32. ^ "Insights: WRI's Blog". World Resources Institute. Retrieved 26 July 2019.
33. ^ Godfray, Beddington, Crute, Haddad, Lawrence, Muir, Pretty, Robinson, Thomas, and Toulmin (2010). "Food Security: The Challenge of Feeding 9 Billion People". *Science*. 327 (5967): 812–818. Bibcode:2010Sci...327..812G. doi:10.1126/science.1185383. PMID 20110467.
34. ^ Searchinger, Timothy D. (19 July 2019). *Creating a Sustainable Food Future*. World Resources Institute. ISBN 9781569739631. Retrieved 26 July 2019.
35. ^ Goldfarb and Tucker (2017). "Digital Economics". National Bureau of Economic Research. Working Paper No. 23684.
36. ^ Stamatiadis (EU Project Manager) 2013. "HydroSense – Innovative precision technologies for optimized irrigation and integrated crop management in a water-limited agrosystem." [http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n\\_proj\\_id=3466&docType=pdf](http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=3466&docType=pdf).
37. ^ Tekin (2010). "Variable rate fertilizer application in Turkish wheat agriculture: Economic assessment". *African Journal of Agricultural Research*. 5 (8): 647–652.



38. ^ Biggar et al. 2013. "Greenhouse Gas Mitigation Options and Costs for Agricultural Land and Animal Production within the United States." ICF International – Report for USDA.
39. ^ Pedersen, Søren Marcus; Lind, Kim Martin, eds. (2017). "Precision Agriculture: Technology and Economic Perspectives". Progress in Precision Agriculture. doi:10.1007/978-3-319-68715-5. ISBN 978-3-319-68713-1. ISSN 2511-2260. S2CID 8032908.
40. ^ Saavoss, Monica (2018). "Productivity and profitability of precision agriculture technologies on peanut farms". USDA Economic Research Service.
41. ^ Ortiz, B. V.; Balkcom, K. B.; Duzy, L.; van Santen, E.; Hartzog, D. L. (1 August 2013). "Evaluation of agronomic and economic benefits of using RTK-GPS-based auto-steer guidance systems for peanut digging operations". Precision Agriculture. 14 (4): 357–375. doi:10.1007/s11119-012-9297-y. ISSN 1573-1618. S2CID 15563611.
42. ^ Monzon, J. P.; Calviño, P. A.; Sadras, V. O.; Zubiaurre, J. B.; Andrade, F. H. (1 September 2018). "Precision agriculture based on crop physiological principles improves whole-farm yield and profit: A case study". European Journal of Agronomy. 99: 62–71. doi:10.1016/j.eja.2018.06.011. ISSN 1161-0301. S2CID 92102740.
43. ^ Diaz, Joy (29 March 2016). "Meet A Tractor That Can Plow Fields And Talk To The Cloud". NPR.org. Retrieved 26 July 2019.
44. ^ "Hello Tractor Site". Hello Tractor. Retrieved 21 October 2020.
45. ^ "Agriculture and food: the rise of digital platforms - Paris Innovation Review". parisinnovationreview.com. Retrieved 26 July 2019.
46. ^ "Location et Prestation de matériels agricoles - WeFarmUp". www.wefarmup.com (in French). Retrieved 26 July 2019.
47. ^ Zuckerman, Jake. "Machinery Link: Where Uber meets agriculture". The Northern Virginia Daily. Retrieved 26 July 2019.
48. ^ Vota, Wayan (31 May 2017). "Uber for Tractors is Really a Thing in Developing Countries". ICTworks. Retrieved 26 July 2019.
49. ^ World Bank (27 June 2017). "ICT in Agriculture (Updated Edition)".
50. ^ "Videos". Digital Green. Retrieved 26 July 2019.
51. ^ World Bank (2019). "The Future of Food: Harnessing Digital Technologies to Improve Food System Outcomes". Washington, DC.
52. ^ Casaburi et al. 2014. "Harnessing ICT to Increase Agricultural Production: Evidence from Kenya."
53. ^ "Digital Agriculture | Cornell University Agricultural Experiment Station". cuaes.cals.cornell.edu. Retrieved 26 July 2019.
54. ^ Morgan-Davies, Claire; Lambe, Nicola; Wishart, Harriet; Waterhouse, Tony; Kenyon, Fiona; McBean, Dave; McCracken, Davy (1 February 2018). "Impacts of using a precision livestock system targeted approach in mountain sheep flocks". Livestock Science. 208: 67–76. doi:10.1016/j.livsci.2017.12.002. ISSN 1871-1413.
55. ^ Seabrook, John (8 April 2019). "The Age of Robot Farmers". The New Yorker. ISSN 0028-792X. Retrieved 26 July 2019.
56. ^ Fafchamps, Marcel; Aker, Jenny C. (1 January 2015). "Mobile Phone Coverage and Producer Markets: Evidence from West Africa" (PDF). The World Bank Economic Review. 29 (2): 262–292. doi:10.1093/wber/lhu006. hdl:10986/25842. ISSN 0258-6770.
57. ^ Goyal, Aparajita (2010). "Information, Direct Access to Farmers, and Rural Market Performance in Central India" (PDF). American Economic Journal: Applied Economics. 2 (3): 22–45. doi:10.1257/app.2.3.22. ISSN 1945-7782. JSTOR 25760218. S2CID 54019597.
58. ^ Andres, Dustin (20 July 2012). "ICT Innovations: with Mfarm, agribusiness meets the app economy in Kenya". USAID Feed the Future: AgriLinks.
59. ^ "Esoko website".
60. ^ Zeng, Yiwu; Jia, Fu; Wan, Li; Guo, Hongdong (24 July 2017). "E-commerce in agri-food sector: a systematic literature review". International Food and Agribusiness Management Review. 20 (4): 439–460. doi:10.22434/IFAMR2016.0156. ISSN 1559-2448.



61. ^ Hobbs et al. 2011. "International e-commerce: a solution to penetrating niche markets for food?" Estey Centre for Law and Economics in International Trade.
62. ^ Brugger 2011. "Mobile applications in agriculture." Syngenta Foundation.
63. ^ Jouanjean, Marie-Agnes (15 February 2019). "Digital Opportunities for Trade in the Agriculture and Food Sectors". OECD Food, Agriculture, and Fisheries Papers, No. 122. OECD Food, Agriculture and Fisheries Papers. doi:10.1787/91c40e07-en.
64. ^ Lonie (2010). "Innovations in Rural and Agricultural Finance: M-PESA: Finding New Ways to Serve the Unbanked in Kenya". IFPRI: 2020 Vision for Food, Agriculture and the Environment.
65. ^ Hakobyan, Artavazd; Buyvolova, Anna; Meng, Yuan Ting; Nielson, David J. (1 January 2018). "Unleashing the Power of Digital on Farms in Russia - and Seeking Opportunities for Small Farms". The World Bank Group: 1–50.
66. ^ Tarazi, Michael; Grossman, Jeremiah (1 June 2014). "Serving smallholder farmers : recent developments in digital finance": 1–16.
67. ^ Martin, Harihareswara, Diebold, Kodali, and Averch (2016). "Guide to the Use of Digital Financial Services in Agriculture" (PDF). USAID.
68. ^ IFAD (2016). "Lessons learned: Digital financial services for smallholder households". International Fund for Agricultural Development.
69. ^ Marulanda and the Bankable Frontier Associates (2015). "Colombia's Coffee Growers' Smart ID card: Successfully Reaching Rural Communities with Digital Payments" (PDF). Better Than Cash Alliance.
70. ^ Sitko, Nicholas J.; Bwalya, Richard; Kamwanga, Jolly; Wamulume, Mukata (2012). "Assessing the Feasibility of Implementing the Farmer Input Support Programme (FISP) Through an Electronic Voucher System in Zambia". Food Security Collaborative Policy Briefs 123210, Michigan State University, Department of Agricultural, Food, and Resource Economics.
71. ^ World Bank Group (2019). "AFCW3 Economic Update, Spring 2019: Digitizing Agriculture - Evidence from E-Voucher Programs in Mali, Chad, Niger, and Guinea".
72. ^ Kärner, Ene (21 September 2017). "The Future of Agriculture is Digital: Showcasing e-Estonia". *Frontiers in Veterinary Science*. 4: 151. doi:10.3389/fvets.2017.00151. ISSN 2297-1769. PMC 5613108. PMID 28983486.
73. ^ Cook and McKay. "Top 10 Things to Know About M-Shwari." Consultative Group to Assist the Poor - Blog. 2 April 2015.
74. ^ "Winning in African agriculture | McKinsey". [www.mckinsey.com](http://www.mckinsey.com). Retrieved 26 July 2019.
75. ^ "FarmDrive". [farmdrive.co.ke](http://farmdrive.co.ke). Retrieved 26 July 2019.
76. ^ Sylvester, Gerard (2018). "E-agriculture in action: drones for agriculture" (PDF). FAO and ITU.
77. ^ World Bank (27 June 2017). *ICT in Agriculture (Updated Edition): Connecting Smallholders to Knowledge, Networks, and Institutions*. The World Bank. doi:10.1596/978-1-4648-1002-2. hdl:10986/27526. ISBN 9781464810022.
78. ^ Poulblanc, Christophe (26 October 2018). "Let's Get Digital: Un-Blocking Finance for Farmers in Senegal". USAID Feed the Future: Agrilinks Blog.
79. ^ Mitchell, Tara (2014). "Is Knowledge Power? Competition and Information in Agricultural Markets". The Institute for International Integration Studies Discussion Paper Series.
80. ^ Nakasone, Eduardo, ed. (2013). *The Role of Price Information in Agricultural Markets: Experimental Evidence from Rural Peru*. IFPRI.
81. ^ Thomas, Susan. "LOOP Mobile App Makes Farm to Market Linkages Easy". Digital Green. Retrieved 26 July 2019.
82. ^ Schimmelpfennig (2016). "Farm Profits and Adoption of Precision Agriculture" (PDF). USDA Economic Research Service. Report no. 217.
83. ^ "Swarm robotics and the future of farming | AHDB". [ahdb.org.uk](http://ahdb.org.uk).
84. ^ Acemoglu, D (1998). "Why Do New Technologies Complement Skills? Directed Technical Change and Wage Inequality". *The Quarterly Journal of Economics*. 113 (4): 1055–1089. doi:10.1162/003355398555838. hdl:1721.1/64397.



85. ^ Goldin and Katz (2008). *The Race Between Education and Technology*. Cambridge, MA: Belknap Press.
86. ^ Cole and Fernando (2012). "Mobile'izing Agricultural Advice: Technology Adoption, Diffusion and Sustainability". Harvard Business School Finance Unit. Research Paper No. 13-047.
87. ^ Demircuc-Kunt, Asli; Klapper, Leora; Singer, Dorothe; Ansar, Saniya; Hess, Jake (19 April 2018). *The Global Findex Database 2017: Measuring Financial Inclusion and the Fintech Revolution*. The World Bank. doi:10.1596/978-1-4648-1259-0. hdl:10986/29510. ISBN 9781464812590.
88. ^ Roscoe, Alexa; Hoffmann, Nathalie Ilona (1 October 2016). "Investing in women along agribusiness value chains": 1–65.
89. ^ Mendonca, Crespo, and Simoes (2015). "Inequality in the Network Society: An Integrated Approach to ICT Access, Basic Skills, and Complex Capabilities". *Telecommunications Policy*. 39 (3–4): 192–207. doi:10.1016/j.telpol.2014.12.010.
90. ^ Quintini, Glenda; Nedelkoska, Ljubica (8 March 2018). "Automation, skills use and training". OECD Directorate for Employment, Labour, and Social Affairs - Employment, Labour, and Social Affairs Committee. OECD Social, Employment and Migration Working Papers. doi:10.1787/2e2f4eea-en.
91. ^ McKinsey & Company (2017). "Jobs lost, jobs gained: workforce transitions in a time of automation". McKinsey Global Institute.
92. ^ Maru, Berne, De Beer, Ballantyne, Pesce, Kalyesubula, Fourie, Addison, Collett, and Chaves 2018. "Digital and Data-Driven Agriculture: Harnessing the Power of Data for Smallholders." Global Forum on Agricultural Research and Innovation (GFAR); Global Open Data for Agriculture and Nutrition (GODAN); Technical Centre for Agricultural and Rural Cooperation (CTA). <https://cgspace.cgiar.org/bitstream/handle/10568/92477/GFAR-GODAN-CTA-white-paper-final.pdf?sequence=3&isAllowed=y>.



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