Digital transformation for sustainable agriculture: a progressive method for smallholder farmers

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Farming and agri-production system is in danger. The agriculture sector is continuously posing threats to life and living. Challenges have become a common phenomenon for sustainable agriculture. According to the SDG 2030 goals, to achieve 'Zero Hunger' status, the system demands a holistic and adaptive food ecosystem. Digitization will revolutionize the current food system, provided the farmers can adopt and apply it in their routine farming operations. In rural areas, digital literacy is crucial for using digital technology. Establishing and strengthening a 'digital agriculture ecosystem' requires suitable environment from grassroots innovations from the farmers' perspective.

Keywords: Climate change, digital transformation, rural population, smallholder farmers, sustainable agriculture.

TECHNOLOGICAL, economical, ecological and community-based sustainability is attracting the attention of all stakeholders. Climate change threatens the existing agriculture models, thus endangering sustainability.

Digitization has the potential to bring remarkable changes in the rural farming sector. To feed the rising population of developing countries like India, farming needs to become digital to make it more efficient, holistic, inclusive and sustainable. To make farming more digitized and sustainable, we must increase production and productivity, with optimum utilization of resources, energy-efficient action and protect our environment and biodiversity. Digital farming must be able to help our resource-poor small and marginal farmers to make profits and, at the same time, conserve natural resources to protect the environment. AgBalance is a life-cycle assessment tool that enables a farmer to assess and review the contribution of the present farming operation and how it impacts the social, economic and environmental dimensions. With well-defined sustainability, it is essential how relevant technology can fit into appropriate agriculture sectors to realize efficiency, accuracy and transformation. The all-encompassing food production system needs to be more resilient.

Digital farming interventions will help assess resource optimizing opportunities and generate information to bring equilibrium by balancing all dimensions (social, technological, financial) of the food production system.

Timely information accessibility is a prerequisite for decision-making in the farming sector. Information and Communication Technologies (ICTs) are known for expediting the timely dissemination of information and advisory services. Mobile phones are the commonest form of ICTs. They have penetrated all the nooks and corners of rural India, thus shrinking the digital gap and increasing application of ICT by several government organizations. Mobile farming applications (apps) are useful to guide farmers to take proper decisions and that too without any financial liability. Though more than 70% of farmers depend on agriculture as their livelihood, the majority do not have easy access to proper information. mKRISHI, a mobile app developed by the Tata Trust, provides information to 2 lakh farmers in Punjab, India regarding best practices for improving their yield and income. Similarly, Pusa Krishi by Indian Agricultural Research Institute, Agriapp, Kheti badi and Kissan Suvidha are a few apps used by farmers for information regarding soil suitability, water status, product availability, value of agri-products, temperature and rainfall, crop protection measures and other information delivery services.

Such ICT platforms can increase farmers' interactive efficiency amongst all stakeholders. The FAO predicts a food production rise by 70% to fulfill the target by 2050. To address this challenge, efficient management to reduce the overuse of inputs and provide timely information to make proper decisions is mandatory. This is where digital agriculture like the Internet of Things (IoT) and sensors can be employed. However, the use of ICT poses challenges for small farmers at all levels. Probable solutions to make digital farming accessible to farmers are as follows:

(i) Innovative technology and a knowledge-oriented solution is required to provide internet access at an affordable cost.
(ii) Small and marginal farmers are generally deprived of finance. As a result, ICT-enabled solution needs to be economical, which requires innovation.

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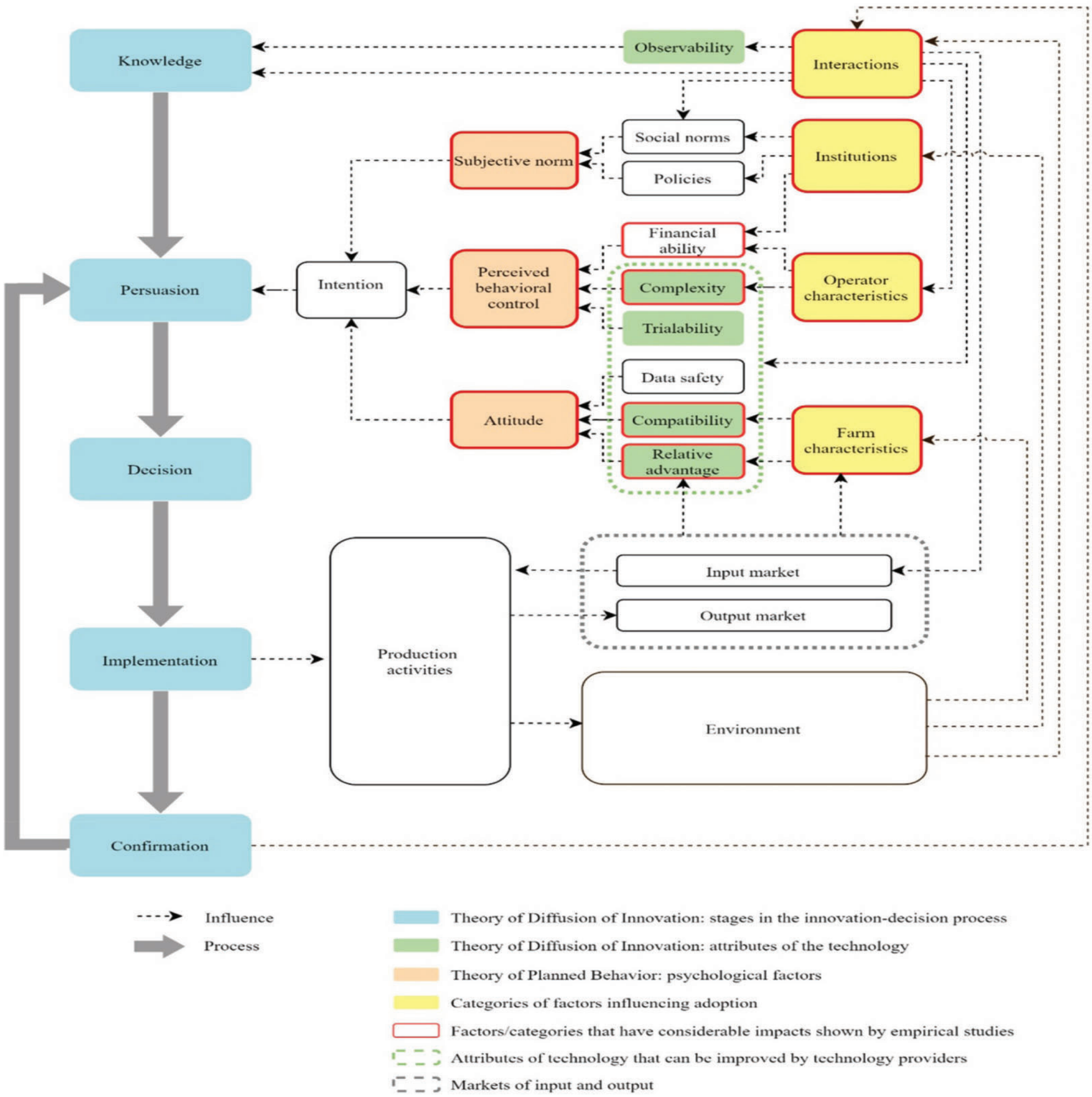

Figure 1. Author's conceptual framework for adoption and diffusion of digital farming technologies.

(iii) Farmers from developing countries have low literacy with poor technical knowhow. Technologies should be friendly to smallholder farmers.

(iv) Unnecessary information is an efficient barrier to smallholder farmers, so they become resilient to shocks and stresses.

Unsustainable practices are leading to severe challenges in agriculture sector. Food production security is being threatened by declining sources of income of farmers. According to the World Bank, 76% of smallholders reported a reduction in their income, while in the Philippines, it was 80%. In the Indian context, 44.2% of agricultural workers and more than 78% of small and marginal farmers are deprived of their own land. In 2020, the Indian GDP, which rose to 5.2% and 4.4% in Q1 and Q2, was reduced by 23.9% and 7.5% respectively. Digital advisory (particularly credit access and on-line money transaction) and agro-based forums linking the market with farmers have made digital agriculture probable solution. In 2020, there was an increase in the use of digital farming services like Ama Krushi (Figure 1).

Digital technology for sustainable agriculture

Digital technology can make agriculture systems more sustainable. Recent innovations like artificial intelligence (AI) and remote sensing (RS), block chain (BC) and IoT are revolutionizing the agri-value chain and improving farming techniques. In contrast to India, countries like The Netherlands and Israel have widely accepted such innovations. Agricultural Digital Infrastructure (ADI) solution developed by CISCO helps enhance knowledge-sharing in farming. The world needs agriculture to meet the growing food demand[1]. Smart farming 4.0 addresses these challenges by utilizing information for meaningful decision-making[2]. There is a wide range of ICT-mediated technologies starting from simple mobile apps to field sensors, drones and robots[2]. A resilient agricultural system in the future will require digital farming technologies[3] which use AI, cloud computing, IoT and BC among others[4]. Labour is expensive and so labour-saving technologies in agriculture have been the prime cause of concern. Anywhere from 26% to 40% of the total production cost is dedicated to labour, often incurred by the producers only. With digital applications, farmers can monitor their agricultural land–soil moisture, humidity and temperature – with the help of sensors and machine-based irrigation practices. A farmer will get an alert on his mobile phone if his farm has sufficient or a moisture deficit. He can monitor water, fertilizer and pesticides requirement using sensors. ISRO's geo-platform, Bhuvan, provides valuable data on plantation, pest surveillance and weather and thus helps save labour. So digital technologies can help reduce labour costs.

The digital India programme initiated by the government of India helps farmers make changes in production and increase income by delivering better prices, a virtual ecosystem, tailored recommendations and direct cash transfers.

The diffusion of innovation and its adoption (DOI) by Rogers[5] and the technology acceptance model (TAM) of Davis[6] both appear to be less pondered for increasing functions and falling prices of mobile handsets[7]. Mobile that delivers advisories about field crops growth, implements, identification of pests and diseases provides real-time data about rainfall and alerts regarding any calamity, local markets offering optimum price for agriproduce, etc.

Digital transformation signifies a few pertinent factors regarding digital efficacy like strategic angles, customer focussed, and ICT-enabled assets, talents, sharpening capacity, innovation and establishment culture. Smart farming technologies result in a dynamic change in world economy and society, and for improvement and change ICT is inevitable.

A resilient food production system requires continuous focus on the social, technological and economic situations. An emerging economy model called circular economy is becoming prominent to bring resilience to the agriculture production system. Digital farming innovations can influence the whole agri value chain in future.

Sustainability achieved through digital farming with some examples from across the world is discussed below.

India's population is growing, but per capita land availability is shrinking. Agriculture productivity needs to be sustainable, so digitalization in farming can help us use our resources efficiently and sustainably, empowering farmers to get the optimum output.

(i) Farm management: All ICT-mediated interventions require specific farm management skills and focus on knowing each piece of land, thus allowing need-based use of seeds and pesticides by farmers in small areas. Judicious use improves productivity by reducing costs.
(ii) Financial services: The Association for People of Haryana (AFPOH) is an ICT-based agriculture initiative in India that facilitates smallholder farmers to access finance for improved agriculture.
(iii) Knowledge and information services: Timely delivery of relevant information is key to sustainability. Kenya Agricultural and Livestock Research Organization (KALRO) a premiere institution has developed more than 14 apps for crop and livestock farmers.
(iv) Market services: E-Krishok and Zero Hunger in Bangladesh and 'Farmers' Advisory Information System in Tanzania provide advisory services on farm inputs.
(v) e-Government services in agriculture: Governments are the key players in the agriculture development sector.
(vi) Digital farmer profiling platforms and services: This platform assists farmers with all types of information.

Internet penetration in rural areas of India has shown an increasing trend. Broadband access has increased by 23.64 million throughout the year 2020, reaching 117 million households in rural areas. India's smart agriculture potential market size has increased to 21%, which indicates that smallholder farmers are keeping benefits.

Digital farming is enabling progressiveness among farmers

Digital technology is transforming global agriculture around the world. An app 'Scouting' developed by Xarvio-Digital Farming Solutions helps farmers identify weeds. They can easily download the app for free and identify, document weed species at the early growth stages by taking photographs from a maximum distance of 50 cm. The algorithm identifies all features of weeds, disease and pest incidence, nutrient deficiencies and leaf damage.

Digital technologies if used in a holistic manner can support farm production in modern day agriculture. Through these technological advancements, farmers can improve their yields while conserving resources, more quickly identify areas of their fields that require attention, collect and categorize data, and so on. Digital agricultural technologies – some of which have been developed by Crop Life International member companies – are already used in many markets. In 2021, we will likely see even more widespread focus on these innovations as companies work to deliver digital solutions to farmers all over the world.

Suggestive measures to encourage Digital farming in rural India are the three A's (availability, affordability and accessibility). Extensive use of the internet, social media, mobile phones and digital skill enhances network coverage in rural areas (one-third of the rural population receives a 3G network) and IT education in rural schools.

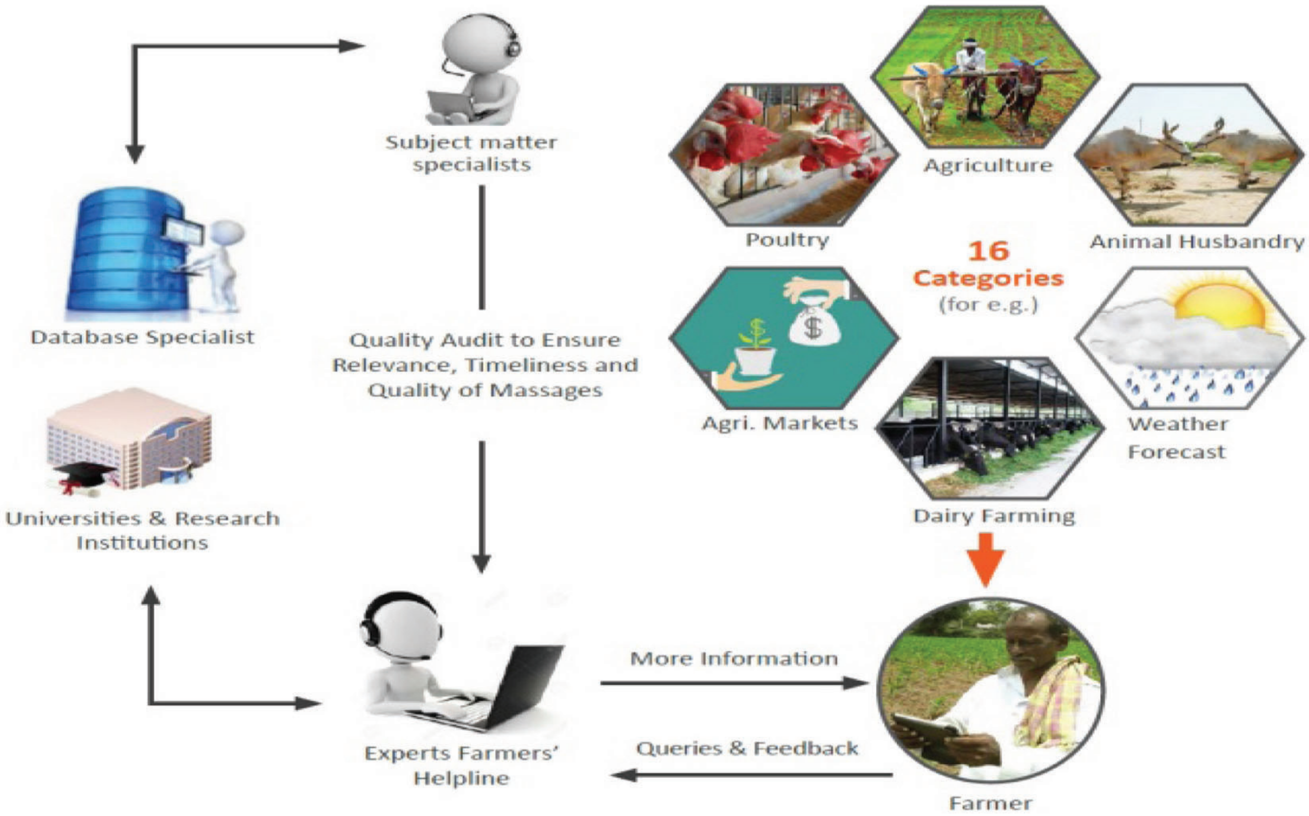

Figure 2. A typical voice-based agro-advisory message flow showing sustainability.

Mobile phones can reduce market disturbances and help farmers plan the production process. Agricultural robots (agrobots) will influence agriculture in the future. Farm agri-robots map, measure and optimize water and irrigation use. MyCrop enables information empowerment and increases production and productivity, and BC to identify poor-quality food (Figure 2).

Future strategies

(1) Enabling the collection of field data regarding, digital technologies. Mobile phones reduce market interference and assist farmers in better planning. Suggestive measures for extensive farming require ICT education among farmers. (2) Developing sustainable business models for the inclusion of small farmers. In the future, digital technology will also help reduce food wastage throughout the value chain.

Digital technologies help advance the United Nation's Sustainable Development Goals (SDGs)

Digital farming helps advance many SDGs, but primarily three of the following: (i) Zero Hunger by building sustainable and productive farming practices and increasing overall production output worldwide; (ii) Climate Action by reducing the negative impact that nitrogen leakage has on the soil and groundwater; and (iii) Life on Land, protecting, restoring and promoting sustainable use of terrestrial ecosystems by reducing human impact on soil degradation stemming from low nutrient use efficiency.

Digital agriculture also helps make farming techniques easier, safer and more affordable. The world's first IoT and AI systems for soil and crop management have been developed. These will positively impact agriculture practices, leading to societal and environmental benefits. Traditional agricultural practices are best combined with technological and digital innovations. This optimizes both productivity and efficiency in terms of cost, labour and resources. Some emerging technological advancements that seem exciting are robotics, machine learning, AI and IoT.

Conclusion

Digital technologies like big data and analytics, IoT, AI and Machine Learning, BC and Cyber-F systems are primarily adopted to improve farm efficiency and competency.

They provide solutions to increase social, ecological and financial sustainability. Farmers are gradually becoming tech-savvy and agri-digitization is progressively growing with a wider perspective. Digitization has yielded fruitful results to the efforts made so far and has set a benchmark for farmers to utilize such innovations and bring impact on their own life and livelihood. Digital farming is synonymous with smart decision-making, higher productivity, better quality produce and a profitable market using advanced technologies towards shaping a brighter future.

1. Finger, R., Swinton, S. M., El Benni, N. and Walter, A., Precision farming at the nexus of agricultural production and the environment. *Annu. Rev. Resour. Econ*., 2019, **11**(1), 313–335; https://doi.org/10.1146/annurev-resource-100518-093929.
2. Bacco, P., Alexander, P., Moran, D., Rounsevell, M. D. A. and Smith, P., OECD, 2019 Modelling the perennial energy crop market: the role of spatial diffusion. *J. R. Soc. Interf.*, 2013, **10**, 20130656; https://doi.org/10.1098/rsif.2013.0656.
3. Walter, A., Finger, R., Huber, R. and Buchmann, N., Opinion: smart farming is key to developing sustainable agriculture. *Proc. Natl. Acad. Sci. USA*, 2017, **114**(24), 6148–6150; https://doi.org/10.1073/pnas.1707462114.
4. Torky, M. and Hassanein, A. E., Integrating blockchain and the internet of things in precision agriculture: analysis, opportunities, and challenges. *Comput. Electron. Agric*., 2020, **178**, 105476; https://doi.org/10.1016/j.compag.2020.105476.
5. Rogers, E. M., *Diffusion of Innovations (5th edition)*, The Free Press, London, UK, 2003.
6. Davis, F. D., Technology acceptance model for empirically testing new end-user information systems: theory and results. Doctoral dissertation, Massachusetts Institute of Technology, USA, 1985.
7. Food and Agriculture Organization (FAO), Information and communication technology (ICT) in agriculture: a report to the G20 Agricultural Deputies, FAO, Rome, Italy, 2017.
8. Alexander, P., Moran, D., Rounsevell, M. D. A. and Smith, P., Modelling the perennial energy crop market: the role of spatial diffusion. *Sustainability*, 2020, **12**, 8596; doi:10.3390/su12208596-www.mdpi.com/journal/sustainability.
9. Aubert, B. A., Schroeder, A. and Grimaudo, J., IT as enabler of sustainable farming: an empirical analysis of farmers' adoption decision of precision agriculture technology. *Decis. Support. Syst*., 2012, **54**(1), 510–520; https://doi.org/10.1016/j.dss.2012.07.002.
10. Dessart, F. J., Barreiro-Hurlé, J. and van Bavel, R., Behavioural factors affecting the adoption of sustainable farming practices: a policy-oriented review. *Eur. Rev. Agric. Econ*., 2019, **46**(3), 417–471; https://doi.org/10.1093/erae/jbz019.
11. Drewry, J. L., Shutske, J. M., Trechter, D., Luck, B. D. and Pitman, L., Assessment of digital technology adoption and access barriers among crop, dairy and livestock producers in Wisconsin. *Comput. Electron. Agric*., 2019, **165**, 104960; https://doi.org/10.1016/j.compag.2019.104960.
12. ILOSTAT, Employment database. International Labour Organization, Geneva, Switzerland, 2019 (retrieved May 2019).
13. Walton, D. M. *et al*., Jeanne Adoption and abandonment of precision soil sampling in cotton production. *J. Agric. Resour. Econ*., 2008, **33**(3), 428–448; 10.22004/ag.econ.46556.
14. Klerkx, L., Jakku, E. and Labarthe, P., A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. *NJAS – Wageningen J. Life Sci*., **90–91**, 100315; https://doi.org/10.1016/j.njas.2019.100315.
15. Kutter, T., Tiemann, S., Siebert, R. and Fountas, S., The role of communication and cooperation in the adoption of precision farming. *Precis. Agric*., 2011, **12**(1), 2–17; https://doi.org/10.1007/s11119-009-9150-0.
16. Lowder, S. K., Skoet, J. and Raney, T., The number, size and distribution of farms, smallholder farms, and family farms worldwide. *World Dev*., 2016, **86**, 16–29.
17. Zheng, S., Wang, Z. and Wachenheim, C. J., Technology adoption among farmers in Jilin Province, China. *China Agric. Econ. Rev*., 2018, **11**(1), 206–216; 10.1108/CAER-11-2017-0216. Towards using ICT to enhance flow of information to aid farmer sustainability in Sri Lanka December 2012, Australasian Conference on Information Systems (ACIS), vol. 23, pp. 1–10.

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