Chapter 29
Smart Agriculture: A Tango Between Modern IoT-Based Technologies and Traditional Agriculture Techniques

Gaurav Dilip Tikas and K. B. Akhilesh

Abstract According to the UN report 2017 on population, the global population is going to rise to approximately 9.8 billion by the year 2050, most of which is going to be concentrated around the larger parts of Asia in developing economies like China, India, Pakistan, etc. These countries would be under tremendous pressure to provide essentials like food, water and clean climate to their citizens under challenging situations such as diminishing supply of cultivable land, non-renewable energy and freshwater. Smart agricultural techniques can provide a possible set of solutions to improve the lives of farmers and consumers by technologically advancing the process of cultivation, protection and storage of agricultural production. It intends to help the agro-based decision-makers in taking informed decisions regarding maximizing crop yields and optimizing resources on a real-time basis. Applications of Internet of Things (IoT-based) technologies can also be extended beyond the farms to areas as fish farming, insect-breeding, livestock or even space farming. Success of such solutions depends upon how well the IoT-based technologies 'tango' with the traditional farming techniques.

29.1 Introduction

Approximately 7.6 billion people are currently inhabiting our planet. This number is estimated to cross 8.6 billion by the year 2030, approximately 10 billion by the year 2050 and 11.2 billion by the year 2100, as indicated by the latest World Population Prospects 2017 report (United Nations, Department of Economic and Social Affairs 2017). China and India continue to be the two most inhabited countries, comprising 19% (1.4 Bn. residents) and 18% (1.3 Bn. residents) of the total global population. In the next five to seven years, the population of India is estimated to surpass that

G. D. Tikas (✉)
Toyohashi University of Technology, Aichi, Japan
e-mail: tikkas.gaurav2@gmail.com

K. B. Akhilesh
Department of Management Studies, Indian Institute of Science, Bangalore, India
e-mail: kba@iisc.ac.in

© Springer Nature Singapore Pte Ltd. 2020

K. B. Akhilesh and D. P. F. Möller (eds.), *Smart Technologies*,
https://doi.org/10.1007/978-981-13-7139-4_29

of China and before 2050, Nigeria will surpass the population of USA. On the other hand, some of the developed nations like Germany (80 million: year 2020) and Japan (125 million: year 2020) are going to be 'shrinking' in population since their estimated population by the year 2050 will be around 75 million and 107 million, respectively (United Nations, Department of Economic and Social Affairs 2017). Between the years 2017 and 2050, approximately half of the global population growth is estimated be concentrated in just nine countries: the Democratic Republic of the Congo, India, the United Republic of Tanzania, the USA, Nigeria, Pakistan, Ethiopia, Uganda and Indonesia. This concentration of global population growth in some of the poorest countries on the planet poses a huge challenge in front of these governments while implementing the 2030 Agenda for Sustainable Development. United Nations has identified 17 of such sustainable development goals addressing health, education, poverty, gender equality, climate change, etc. (United Nations General Assembly 2015). However, the larger question that still remains unanswered is—where will the food for all these people come from? Smart farming (SF) may just be one of the possible technological solutions that can rescue mankind, as elaborated in the subsequent sections.

29.2 Smart Farming

Smart farming can be described as the application of modern technologies like 'Internet of Things' IoT-based devices to conventional farming technologies and equipment to deliver comprehensive solutions for farm management (Ongwae 2017). It involves the use of advanced hardware and software technologies in an integrated framework so that devices can seamlessly communicate with each other using Internet and cloud networks. The idea is to eliminate the human intervention and allow machines to communicate with each other, except in most of the critical decision-making situations (Gondchawar and Kawitkar 2016). Use of data analytics, machine learning and artificial intelligence can help the farmers to identify and predict some of the critical scenarios such as demand forecasting, crop yield and harvesting time (Wolfert et al. 2017). The cloud-based technologies help in easy interoperability, computing and storage of data in a connected environment.

One of the important features of IoT-based technologies is the power that it provides the users to remotely operate hardware devices using software applications. IoT-based companies are leveraging this aspect and creating powerful mobile apps that can enable farmers to remotely manage their farms (Shahzadi et al. 2016). This helps farmers to take real-time decisions regarding how to maximize the crop yield, optimize the resources and monitor the growth of crops without being present on the farm. Real-time information about climate uncertainties like rainfall, humidity and temperature can be made available for the farmers so that farming practices can be planned accordingly (Sen and Madhu 2017). Precise data about activities outside the farm like market conditions, daily prices and sales can be made available to farmers on his/her smartphone. Such end-to-end coverage of activities which can take care of the entire life cycle of the crops from the seed-stage to the point-of-sale stage, can be accomplished through smart farming technologies.

29.3 Smart Farming: Merits

Smart farming can help decision-makers in taking informed decisions regarding maximizing crop yields and optimizing resources on a real-time basis. It helps them in reducing wastage of time, money and effort, which can then be utilized judiciously on other important aspects. The use of low-powered sensors and other smart equipment can help reduce the carbon emissions and counter climate change (Ojha et al. 2015). IoT-based systems along with advanced image processing techniques can allow real-time analysis of plant images to determine their health. Such systems also help in determining the optimum amount of fertilizer required for a particular plant and the decision regarding the quantity of the fertilizer and other chemicals can be taken by the farmers.

Apart from these decisions, smart farming can also help farmers to measure and monitor the fertility levels and other important components of the soil. Such information can also have a huge impact on the water requirements of the crop. Accurate estimation of the water demand for various time-periods can be calculated in order to manage the available stock of water. Precise information about the climate and the inherent uncertainties can help the farmer in timely management of critical resources (Walter et al. 2017). All these features need to be properly aggregated and presented in a user-friendly application which can be run from a computer or a smartphone. Such functional ease-of-use can be a potential game-changer in the agricultural technologies.

29.4 Smart Farming: Disadvantages

It has been found that excessive use of pesticides, chemicals and fertilizers can negatively impact the quality of the agricultural land. In some cases, it has even lead to the spread of harmful diseases in plants, livestock and even humans. Loss of fertility levels in agricultural land can be attributed to excessive use of harmful technologies and improper waste management. Smart farming demands a high level of initial investment in technology and infrastructure, which most of the small farmers may not be able to afford. Farming is still a low profit making profession, so the willingness of farmers to invest in high-tech innovations may be less likely in the near future. Along with this, the low literacy rates of farmers may be a barrier for them to easily adopt new technologically intensive solutions (Pattanayak 2016). Even after adopting the new technology, they might require intensive training and guidance on how to operate and maintain such technologies.

Acceptance of such complex technologies will be dependent on the open-mindedness of the agricultural community. Various doubts and apprehensions regarding safety, privacy and security of critical data regarding their farms and equipment need to be cleared before farmers can adopt these technologies (Walter et al. 2017). Along with these, aspects such as increasing dependency on machines, loss of decision-making control and 'employment' will have to be dealt with in a mutually acceptable manner. The fear of losing jobs due to increasing levels of automation will be the most sensitive dimension in this debate and technology-driven organizations will have to get all the stakeholders on-board, in order to make it a real success.

29.5 Smart Farming: Opportunities

Integrated IoT-based solutions which are a combination of application-specific hardware as well as software are important towards solving farm management problems. Modularity in such integrated solutions increases their applicability to a variety of domains beyond conventional agriculture, namely fisheries, insect-breeding, livestock and tissue culture (Soumyalatha and Hegde 2010). Modularity can also help in marketing and selling these IoT-based solutions to different types of farmers based on their land holdings (big, medium and small). Creating IoT-based technologies to integrate farm hardware (equipment) with software applications and user interface can enable the creation of complete end-to-end solutions to solve a specific problem.

Especially, IoT technology-based start-ups can start creating their products or services in this direction and slowly build their capabilities around these aspects. Once their prototypes are ready, they can then slowly think about scaling up their operations around the world. It is important for them to be 'G-local' in spirit to provide world-class solutions to local problems in their chosen territories. The success of such integrated solutions will largely depend on their ability to assist the farmers in taking critical decisions (Gondchawar and Kawitkar 2016). Especially, during the times of high volatility and uncertainty, if these IoT-based technologies can provide real-time data and information which can help the farmers to maximize their yield, reduce their wastage and optimize their resources, then the chances of commercial success can be improved.

Some of the important IoT-based farm hardware that have already been conceptualized are autonomous farm vehicles, drones and irrigation systems (Yadav 2016). Unmanned tractors capable of driving heavy, medium and light loads have been developed which can be powered by conventional as well as unconventional energy resources. Drones have been developed, which can be fitted with hyper-spectral cameras to take pictures, analyse and provide information whether the vegetables, fruits, etc. are ready for consumption (Walter et al. 2017). High-powered drones can also be used for spraying fertilizers, pesticides and water to those areas where humans cannot reach easily. Large incubation spaces can be created indoors under climate-controlled conditions like artificial light, irrigation and heating mechanism to cultivate certain crops. Vertical farming is one emerging area which can be used for growing green leafy vegetables, creepers and other suitable herbs.

A GUI-based software can be created to control such hardware systems equipped with advanced sensors to monitor temperature, humidity and light. Sensors can also be developed to detect air quality, bacteria and other harmful viruses in the ambience. This is specially required for early-stage detection of contagious diseases in livestock like cows, pigs and chicken. Sensors can also be developed to detect the quality of water in fish-farming tanks or containers to constantly monitor the presence of harmful elements. Special sensors can be employed to detect the precise location of pests in the huge land and targeted pesticides and laser-shoots can be used to weed them out (Ojha et al. 2015). All this data collected by the sensors can be made available to the farmers in a lucid way so that they can take decisions in an informed manner.

Real-time data aggregation, analysis and making it available in a user-friendly manner carry tremendous potential for start-ups operating in this domain. The latent business value in this process can potentially turn around the fortunes of a start-up (Wolfert et al. 2017). On the one hand, it allows the start-up to leverage the key data regarding managing farms and on the other hand, it gives them a chance to empower their end-users with an ability to monitor their farms remotely. Advanced machine-learning algorithms, artificial intelligence and big data analysis can even help a farmer to accurately predict the precise harvesting time and the amount of farm produce, which can then be sold at a better rate in the market (Wolfert et al. 2017). It can also help the farmer, manage the post-harvesting supply chain and logistics in order to minimize the storage losses. Even during the storage, the health of the produce can be constantly monitored. All these hardware, software and data management-related aspects covered in the integrated farm management solutions can turn around the dwindling state of agriculture in India and help it become self-sufficient and self-reliant in food production, storage and security.

29.6 Smart Farming: Challenges in India

In India, more than 80% farmers are small landholders (SLs) having less than two hectares farm size. They contribute more than 50% of total agricultural output (Khatri-Chhetri et al. 2016). Small landholders face a number of challenges such as lack of access to easy credit financing, key agricultural insights and direct access to markets. This eventually results in agriculture as a 'low profit' making exercise and hence, losing its attractiveness as a career option or a business opportunity. This is also one of the key reasons why the area under cultivation in India is consistently diminishing over the last few years. Adding on to it, the vast diversity in the climate, soil and cultural practices in India does not allow easy relocation of farmers from one place to another. This reduces their options to migrate or look for new opportunities even if they wish to stay in the farm-based profession. Most of them are forced to give up farming and switch to other labour-intensive jobs in urban areas, hence creating a scarcity of skilled personnel in farming (Khatri-Chhetri et al. 2016).

It is also very difficult for small and medium farmers to conceptualize, customize and deploy advanced farming techniques along with the 'best practices' in farm management suitable to their requirements. This reduces their propensity to accept and adopt innovative solutions, which in the long-run can provide better returns. The importance of sustainable farming and environmental issues associated with outdated technologies and wastage also need to be understood by the farmer community (Sen and Madhu 2017). Reorienting, restructuring and empowering them towards advanced farming technologies will be one of the biggest challenges ahead.

29.7 Smart Farming: The Way Ahead

Kennedy Space Center (NASA) is collaborating with the Aldrin Space Institute, Florida, to study the growth of certain plants under 'martian' conditions. The agreement was signed in June 2016 and began operations in September 2016 (Heiney 2016). NASA is helping out in kick-starting the project, assessment and selection of the 'Martian simulant'. On the other hand, students and professors in the Florida Institute are providing the seeds, regolith simulant and data collection. Project 'Veggie' will enable experiments related to plant growth on the International Space Station. The soil on the planet Mars is full of crushed volcanic rock called regolith and also contains certain toxic chemicals. The 'Martian' soil was sourced from Hawaii on the basis of spectral data procured from the Mars Orbiters in order to explore the nutrients essential for plant growth, under those conditions (Heiney 2016). The 24-day pilot project started with studying the growth of lettuce plants under three typical conditions: Martian soil, Martian soil with nutrients and normal soil.

It was observed that the growth rates were slightly slower (2–3 days) than that in the controls, and in order to gain a better understanding of the growth patterns in Martian farming. It was also noticed that their roots were not as strong as the controls (Heiney 2016). The main experiment will be extended to other varieties of plants especially healthy and nutritious food items such as radishes, snow peas, tomatoes etc. which regularly feature in the astronaut's diet. Such path-breaking experiments may open up new opportunities in food production, even in the outer space (Heiney 2016).

29.8 Conclusion

Applications of Internet of Things (IoT-based) technologies to conventional farming seem to have the potential to solve one of the major crises mankind may be facing in a few years from now. With exponentially increasing demands and diminishing resources, especially in the developing countries, adopting smart farming technologies may help in informed decision-making and better farm management solutions. Integrated farm management solutions which take care of the hardware as well as the software aspects of farming can help farmers in maximizing their crop yields and optimizing their resources on a real-time basis. Applications of such integrated solutions can also be extended to fish farming, insect-breeding and livestock or even space farming.

It is also important for original equipment manufacturers (OEMs), especially in India, to aim towards completing at global levels in terms of quality of their solutions. They must also think of creating world-class products which are flexible, modular and easy to adapt to the local conditions. Such high-quality 'G-local' solutions which are widely applicable in different domains and easy to deploy around the world can surely bring commercial success to such OEMs. Conceptualization of creative solutions between previously unconnected domains requires a unique skill set along with the ability and willingness of product development teams. It also requires innovative capabilities in the top management teams at such OEMs to approve of such 'innovative and risky' ideas.

Just like in Tango, where two contradictorily different entities shrug off their individuality to intricately connect and synchronously step with each other on the beats of the soulful music, we wish that modern IoT-based technologies creatively blend with traditional farming to come up with beautiful innovations that can change the future of agriculture in the developing as well as the developed world. Analogous to a Tango performance, a leader (usually a man) is expected to be majestic, passionate and decisive in initiating a particular step and a follower (usually a woman) is expected to follow it with grace, affection and elegance, in smart farming domain—IoT-based technologies will have to take the initiative and conventional farming will have to follow, in order to create 'game-changing' agricultural technologies of the future. In order to be accepted by the target audience from around the world, such solutions will have to be 'G-Local' in nature which provides world-class solutions for local problems.

So, if somebody is willing to take the risk of creatively blending 'IoT-based technologies' with 'convention agriculture', the floor is all yours!

However, it'll take *two to Tango*!

References

Gondchawar, N., & Kawitkar, R. S. (2016). IoT based Smart Agriculture. *International Journal of Advanced Research in Computer and Communication Engineering*, *5*(6), 838–842. http://doi.org/10.17148/IJARCCE.2016.56188.

Heiney, A. (2016). Farming in "martian gardens," 2017. Retrieved from https://www.nasa.gov/feature/farming-in-martian-gardens.

Khatri-Chhetri, A., Aryal, J. P., & Sapkota, T. B. (2016). Economic benefits of climate-smart agricultural practices to smallholder farmers in the Indo-Gangetic Plains of India Economic benefits of climate-smart agricultural practices to smallholder farmers in the Indo-Gangetic Plains of India. *Current Science*, *110*(April), 1251–1256. http://doi.org/10.18520/cs/v110/i7/1251-1256.

Ojha, T., Misra, S., & Raghuwanshi, N. S. (2015). Wireless sensor networks for agriculture: The state-of-the-art in practice and future challenges. *Computers and Electronics in Agriculture, 118,* 66–84. https://doi.org/10.1016/j.compag.2015.08.011.

Ongwae, C. (2017). *Smart farming: Standards for sustainable agriculture*.

Pattanayak, S. (2016). State of Indian agriculture 2015–2016. *Ministry of Agriculture & Farmers Welfare*, 280. Retrieved from http://eands.dacnet.nic.in/PDF/State_of_Indian_Agriculture,2015-16.pdf.

Sen, S., & Madhu, B. (2017). Smart agriculture: A bliss to farmers. *International Journal of Engineering Sciences & Research Technology, 6*(4), 197–202.

Shahzadi, R., Tausif, M., Suryani, M. A., & Ferzund, J. (2016). Internet of things based expert system for smart agriculture. *International Journal of Advanced Computer Science and Applications, 7*(9), 341–350.

Soumyalatha, & Hegde, S. G. (2010). Study of IoT : Understanding IoT architecture, applications, issues and challenges. *International Journal of Advanced Networking & Applications (IJANA)*, 477–482. ISSN: 0975-0282.

United Nations, Department of Economic and Social Affairs, P. D. (2017). World population prospects the 2017 revision key findings and advance tables. *World Population Prospects The 2017*, 1–46. http://doi.org/10.1017/CBO9781107415324.004.

United Nations General Assembly. (2015). Transforming our world: The 2030 agenda for sustainable development (1), 1–5. https://sustainabledevelopment.un.org/content/documents/7891Transforming%20Our%20World.Pdf. http://doi.org/10.1007/s13398-014-0173-7.2.

Walter, A., Finger, R., Huber, R., & Buchmann, N. (2017). Opinion: Smart farming is key to developing sustainable agriculture. *Proceedings of the National Academy of Sciences, 114*(24), 6148–6150. https://doi.org/10.1073/pnas.1707462114.

Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M. J. (2017). Big data in smart farming—A review. *Agricultural Systems, 153,* 69–80. https://doi.org/10.1016/j.agsy.2017.01.023.

Yadav, A. (2016). Design and implementation of smart agriculture using embedded system. *International Journal of Engineering And Computer Science*, *5*(12), 19344–19347. http://doi.org/10.18535/ijecs/v5i12.13.