Future of Precision Agriculture in India

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Chapter
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Future of Precision Agriculture in India

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Abstract

The yield and quality of crops depends on various biotic, abiotic and management related parameters. In conventional agriculture the farmers relied on their experiences. Due to human perception often there is uncontrolled use of resources and inputs resulting in not only natural resources wastage and environmental pollution but also financial loss of farmers. Precision agriculture uses technology such GPS, sensors, Internet of Things, robotics, drones, machine learning al decision support systems etc. to optimize the use of natural resources and farm inputs for a specified yield and quality of crops. The future of precision farming is moving towards extensive use of machine learning techniques and image analysis. However, the major constraints are loss of job, data security, lack of motivation, training and so on.

Keywords: Aotic, abiotic, management, environmental pollution, crops, farming

1. Introduction

Agricultural production is the result of the combined effects of natural resources, biotic factors, agro inputs and management. A harmony in interaction of above can only make it a sustainable venture. In the developing countries a considerable portion of population remains engaged in agriculture as in India about 54 percent of people are directly and indirectly involved in agriculture and allied activities. However, agriculture contributes only 15 percent to country's gross domestic product (GDP). Indian agriculture passed a long journey since independence. The country witnessed nightmare of absolute shortage of food grains supplies in the 1960s, however, achieved sufficiency after adoption of Green Revolution. At present, India is one of leaders of crop producer with a production of 285 million tonnes of food grains in 2018-19 and estimated to reach at 292 million tonnes in 2019-20 (Economic

Times, 2020). India's horticulture output is around 311 million tonnes in 2018-19 (GOI, 2019). Besides, India is the second largest producer of fruits and vegetables worldwide. In milk production India ranks first in the world accounting more than 13 per cent. The agricultural growth rate is supported by favourable investments, technological development and policy support.

The green revolution is also associated with negative agro-ecological consequences. During recent period, India is facing a great challenge in terms of achieving much needed agricultural sustainability to feed the populous nation because of threats appeared as yield plateauing, degradation of land and water, scarcity of irrigation water, genetic erosion and vulnerability in farming, climate change and associated problem and inferior yield harvested by the farmers than the potential and poor realization of consumer currency. The solution of these problems is complex. An alternative left for enhancement of agricultural productivity and assuring sustainability from limited natural resource without any negative consequences is by efficient utilization of resources and maximization of input use efficiency. Now it is the right time to exploit the modern tools by accumulating all available technologies into the platform of agriculture for enhancement of return from agriculture as well as to achieve sustainability in crop production. Precision agriculture (PA) can merge all technologies with agriculture for boosting up the productivity with input use efficiency (Hakim *et al.* 2016; Shafi *et al.* 2019).

2. Precision Agriculture and its Scope in India

Green revolution provided self-sufficiency in food grains production. In spite of the significant development in agriculture, the average productivity of many major crops are far less than of potential productivity of Indian high yielding varieties/ hybrids with fullest utilization of resources and inputs. Further, for some of the crops, the average yield output in India is less than other countries with existing technologies. Interestingly, the crop yield of the most agriculturally rich locality of the country is far below than the average yield of many high productive countries of the world (Ray *et al.* 2001). Moreover, the environmental issues associated with agriculture may be considered as a warning against over exploitation of resources. These factors warrant the need for application of latest, improved and inter-disciplinary approach as PA.

PA is a data and technology-driven farming practice to detect, analyze and take appropriate measures to manage the variations in parameters of the field. Its goal is to optimize productivity and profitability, and ensure protection of natural resources and sustainability. In PA, new algorithms are used to improve the decision making process for managing different aspects of crop production. Advancement in space technology and IT revolution created a new replacement arena for farm sectors. Therefore under the changed circumstances it is essential to understand over the new cutting edge technologies evolved in the field of agriculture and customized modification as per the farm sectors. It is true that at present pan India adoption of PA is tough as because entire farm sector is not ready to adopt sophisticated and refined technology, however, there are some comparatively developed pockets as well as activities managed by progressive farmers where PA can be adopted as incubators for improved technologies.

Agriculture in India is performed mainly by small and marginal farmers under the close supervision of farmer's family members and farming is a family responsibility to them. These small and marginal farmers of India mainly adopt management, apply input and take decision related to farming on the basis of their knowledge and experience, financial capacity, extension services provided and availability of resources. Micro-situation specific variability agricultural practices are commonly prevailing in the developing countries in decision making by the farmers and this close relation of the farmers with crop management may be considered as some sort of spatial treatment based on supervision and experience. But this crude form of precision technology is needed fine tuning and modification in the light of modern technologies (Mondal and Basu, 2009). Recent researches in integration farmer knowledge, precision agriculture tools and crop simulation modeling can be very useful for country like India in taking decision and management for poor-performing patches in farming (Oliver *et al.* 2010). In this way India can enter into the field of evergreen revolution.

3. Need for Precision Agriculture

Agriculture of the developing countries as well as the global food system is facing many challenges today and technocrats are suggesting some management options with existing and proven technologies. But under ever-changing environmental conditions it will be difficult to cope up with future challenges which may require involvement of novel technology based approaches. The reduction in productivity per unit area, decreasing and degrading natural resources, emerging threat due to global warming and climate change and stagnation in farm income have posed a major challenge in agricultural prosperity. These ultimately direct for adoption of the newly developed technology options for sustaining farm productivity. Generally, an entire field is managed by adoption of recommended package of practices developed on the basis of some average condition, which may or may not exist in the entire farmland, therefore, precise crop management is needed which can recognize site-specific variables within agricultural lands and adjust management strategies accordingly with a better capability of decision making. The progressive farmers are aware that the variability in yields across the landscape and many times they manipulate management practices as per their previous experience. These variations can be traced scientifically by different tools for better management practices in terms of responsiveness to different yield causing factors. Precision agriculture provides the scope to automate the collection and analysis of data for accuracy to make an appropriate decision.

4. Conventional Agriculture vs. Precision Agriculture

The major steps in an agricultural process involve: (a) selecting a location, (b) soil preparation, (c) seeding and planting, (d) irrigation (e) fertilizer and pesticide applications, (f) weeding and (g) harvesting. In conventional agriculture utilization of resources and inputs in all these stages are not optimum, usually on the higher side, sometimes even on the lower side. This affects adversely the quality of crop, yield, and environment and above all, the financial gain of the farmers. This is where precision farming comes in. It uses technology to determine and deliver the optimum amount targeting a specified yield.

In place of manually selecting a location people are using GPS or GIS data. Soil preparation technique based on past experiences of the farmers has been replaced by use of sensors for measurement of temperature, humidity, volatile matter etc. The quality of levelling of lands by bullocks and tractors has been improved by utilizing Laser-guided precision land leveler. Instead of doing seeding and planting manually, farmers are exploring automated tools such as precision drills, seed drills, broadcast seeders, air seeders and so on. In place of conventional irrigation system farmers are using automated and controlled fertigation system empowered by Internet of Things (IoT) (Maitra *et al.* 2020). Automated weeding machines and drones for weed removal and localized application of herbicides have replaced the conventional manual ways. Mechanical tools and robotic arms have paved their way in place of manual harvesting. Thus, precision farming shows a marked shift from conventional one in terms of use of satellite data, drones, sensors, IoT, robotics and precision tools, the objective being optimization of resources and inputs based on technical data.

5. Components of Variability

The basic steps in precision farming are assessment and management of variability, followed by evaluation. Information or database is the primary thing in assessing variability in agriculture. To manage in-fields variability, spatially or temporally, data related to biotic and abiotic factors are important and databases in this regard need to be developed. Following are the components where variability can be assessed for adoption of PA.

- **Soil:** physical properties (texture, structure, moisture holding capacity, bulk and particle density); chemical properties (pH, electrical conductivity, available plant nutrients);
- **Crop**: planting geometry (row to row and plant to plant spacing, plant stand); nutrient composition of standing plant, plant stress due to biotic and abiotic factors, weed, insect and disease, potential economic and biological yield;
- **Climate**: air temperature, temperature around plant canopy, relative humidity, rainfall, solar radiation, day length, wind velocity.

The available multi-disciplinary and latest technologies help in the understanding of the variations and site specific agronomic recommendations to manage the production system.

Variability assessment is the most important part in precision agriculture as because above factors and the processes control the crop performance and yield behaviour and may change in space and time. Quantification of variability as well as determination of various combinations responsible for the spatial and temporal differences in crop productivity is the important challenges for PA. Different scientific technologies are available for assessing spatial variability and those are applied in PA. Once the variations are properly understood, requirement of agronomic inputs can be matched to known conditions on the basis of crop management decisions. Those are site specific management and use correct applications management equipment. Enabling technologies can make precision agriculture feasible, economically viable and sustainable for enhancement of crop productivity. Precision crop management will certainly enhance input use efficiency and greater productivity which will lead to the ultimate goal for achieving sustainability (Pierce and Nowak, 1999).

6. The Future Shifts

6.1 Machine learning applications

Scientists can use artificial intelligence/machine learning (ML) based simulations to evaluate how a type of crop may perform when faced with different soil types, weather patterns etc. (Mokaya 2019) as well as deliver required amount of nutrient (4R rule) or pesticide at the right place at the right time. This simulation will help agriculture scientists to more accurately predict the performance of the crops. Supervised or unsupervised ML algorithms such as, convolution neural network, Bayesian network, support vector machine etc. have been used by researchers. Farmers can utilize ML tools to take appropriate decisions to maximize the return on crops. These applications are well demonstrated in Fig. 1.

1. **Chat-Bot:** ML technology can be used to create chat-bots (Mostaço *et al.* 2018) to answer to the questions of the farmers, suggesting recommendations on specific agricultural issues.
2. **Unmanned aerial vehicles (UAV):** UAV can take pictures and collect data about a particular location. Its use can reduce operational cost and help monitoring of a large area. UAV may pave new strategies of improving crop yields through spraying, counting of plants, detecting anomalies etc. ML techniques can help in the movement, analysis of data and actions for the UAVs.
3. **Robotic agriculture:** Robotic agriculture may play a major role in next 10-15 years. Driverless tractors will be used for farming autonomously. They will interpret the GPS, radars and sensor data using ML to identify obstacles and decide the application of the farm inputs (Chunhua and John 2012).

4. **Automated irrigation system:** Automated irrigation system coupled with conventional weather prediction tools will help to predict the required water resource. It requires real time ML application to maintain the level of water and nutrient in soil.

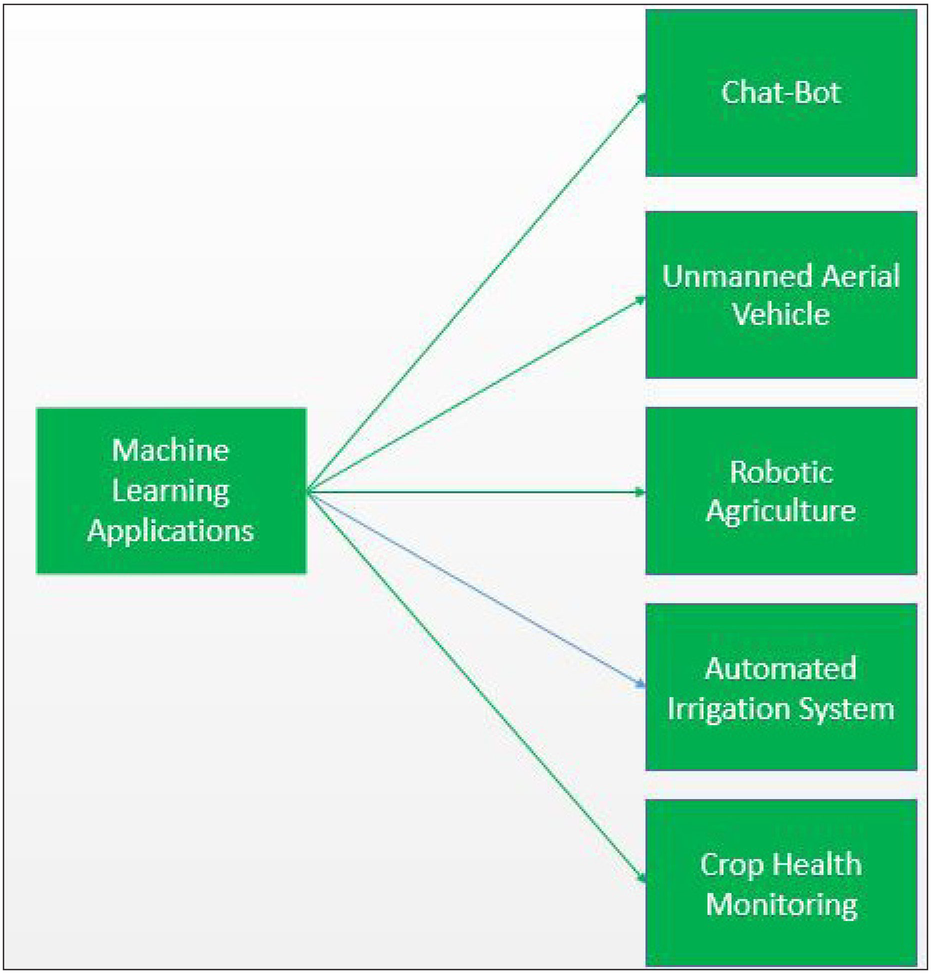

Fig. 1: Machine Learning Applications

5. **Crop health monitoring:** Monitoring of crop health and exploring possibility of pest attack can be monitored by combining ML to hyperspectral and multispectral image analysis. Deep learning ML applications can generate alerts in case of a disease or pest. Detection at an early stage will help minimize the losses (Priyanka *et al.* 2018).

6.2 Big data and IoT

Farmers need to know three things; (1) the parameters which are relatively stable during the growing season (2) the parameters showing change and (3) information to understand why a crop is facing difficulty to grow. These three things can be addressed using big data and Internet of Things (IoT). Analysis of data can help making appropriate decisions leading to improved yield. The decrease in size of smart electronic devices will make the decision making process easier.

6.3 Saving of Manual Labour

Precision farming will reduce human intervention. Thus, even on situations, demanding social distancing precision farming will continue.

6.4 Differential GPS

GPS signals from satellites result in delays to reach the ground while passing through the different layers of earth's atmosphere. This time lag causes some errors into the GPS engine, introducing an error in locating a position. This is commonly known as pseudo-range errors. Differential GPS basically helps in correcting positional errors of GPS signals. It uses a fixed, known position to eliminate the pseudo-range errors. A static base station set up on the ground is used to provide correction messages to the time lags for the signals. In future the trend is moving from GPS to differential GPS to enhance the precision in position.

6.5 Sensor technology

The sensors used to monitor different parameters are usually costly and are of contact type. The contact reduces the life of the sensors through chemical interactions. Thus the future trend is going towards low-cost non-contact type sensors. In this process there is a major shift towards image analysis-based sensors. However, those sensors suffer from the effect of lighting conditions. Algorithms have been developed to minimize the effect of lighting conditions. To meet the need of sensors image segmentation, feature extraction, deep learning approaches, convolution neural network (Abdullahi and Zubair 2017) etc. are gaining importance.

7. Constraints

Precision Agriculture is progressing slowly compared to the expected pace. There is still a need for an advanced decision-support system to make right decisions at the right time. Less focus on temporal variation, lack of whole-farm focus, precise crop quality estimation methods, insufficient product tracking and environmental auditing are hindering the growth of PA in India. Fig. 2 shows possible constraints in precision agriculture (https://teks.co.in/site/blog/precision-agriculture-top-15-challenges-and-issues/) may pose challenges in future:

(a) Interoperability of different standards: With the progress in technology scientists are developing new tools and IoT platforms. The interoperability among them may create a concern in the future. For success in future, it is necessary to integrate standalone devices and gateways to holistic, farmer-friendly platforms.

(b) Training: PA requires implementation of new-age technologies. For small farmers, setting up of IoT and sensor networks will become a challenge. Training of farmers on different PA tools is of significant importance and the success of PA will rely on the training. Lack of knowledge can adversely affect the yield or quality.

(c) Internet Connectivity: In many villages strong, reliable internet connectivity is not available. Unless there is a significant improvement in network performances and bandwidth speeds PA will remain problematic. Cloud-based computing also needs to become stronger. In farmlands with tall, dense trees and/or hilly terrains, reception of GPS signals can become a major issue.

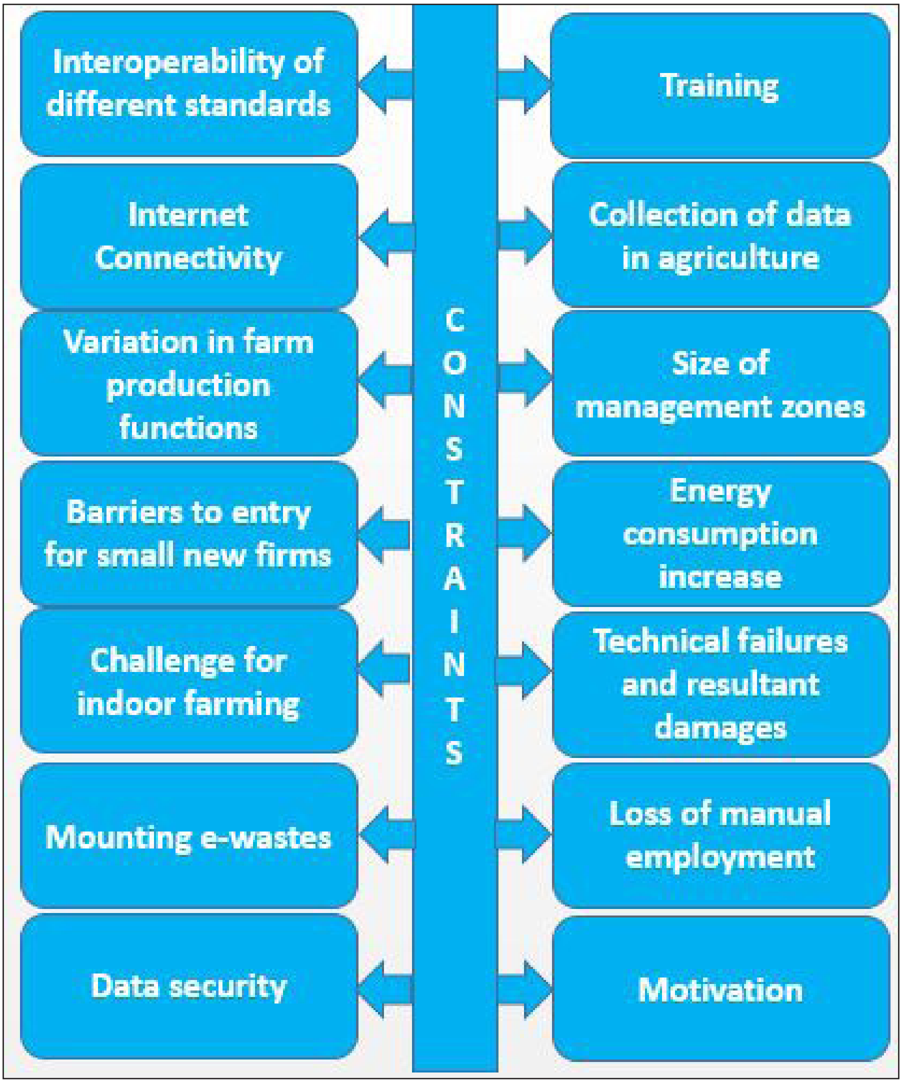

Fig. 2: Constraints of Precision Agriculture

(**d) Collection of data in agriculture:** It modern PA information is gathered from multiple data points. It is very difficult to monitor and manage every single data point on a regular basis, over the entire growing seasons. The problem is even significant in large multi-crop lands.

(e) Variation in farm production functions: In-depth economic analysis needs to define the "correct production function" (output as a function of key inputs, such as nutrients, fertilizers, irrigation, etc.). However, the production function varies with crops, various zones of a farm, and also the crop/plant-growth cycle. Unless the production function is rightly defined, there will always be a chance of application of inputs in incorrect amounts.

(f) Size of management zones: Traditionally, farmers consider their entire fields as a single farming unit. That approach will hinder the implementation of PA and increase the cost of establishing IoT per farmer.

(g) Barriers to entry for small new firms: Due to the significant cost involvement in infrastructure as well as upgradation of technology the big players in agro-IoT will control the PA. It will be difficult for the smaller players to sustain and lack of competitiveness will be there in future. Lack of competitiveness may increase the burden on the farmers.

(h) Energy consumption increase: In precision agriculture use of optimum resources will help move towards a greener planet. On the contrary, use of too many gadgets may increase the energy requirement. Thus, more resources will be required to meet the growing need for energy. There is a need to develop gadgets that will consume less energy for the success of PA in future.

(g) Challenge for indoor farming: Most PA methods suitable for conventional outdoor farming. Due to the paucity of land farmers are getting involved in vertical indoor farming. These indoor farming practices are not encouraged by PA.

(h) Technical failures and resultant damages: Significant dependence of agriculture on technology may result in serious damage in case of a malfunction. A crop may face water stress in case of failure of soil moisture sensor. Thus, there is a need to develop robust sensors and technologies to immediately respond in case of a failure.

(i) Mounting e-wastes: Up-gradation of hardware on a regular basis will lead to piles of obsolete hardware. Those discarded IoT tools and computers and outdated electronic devices may create a major problem in future. There is a need to plan the disposal of the e-wastes.

(j) Loss of manual employment: A large number of agricultural workforces may lose their job in future. Thus other sectors need to be prepared to absorb the people who lost their jobs.

(k) Data security: Proper protection of data against malware and data thefts is required for the success of PA. The PA platform should be ready to prevent attacks by hackers.

(l) Motivation: The positive effect of PA is not felt within a short time. Thus, there is a need to motivate the farmers otherwise the implementation of PA will become only a concept.

8. Conclusion

The future of precision farming is mainly extensive application of machine learning and image analysis techniques. Machine learning techniques will be applied in chat-bots, unmanned air vehicles, robotics, automated irrigation systems and crop health monitoring. IoT and big data, differential GPS, non-contact sensors will influence precision agriculture in future. Compared to conventional agriculture, precision farming will optimize the use of resources and inputs based on analysis of acquired data. Use of optimized resources will be beneficial for the farmers as well as for the environment. However, there will be challenges with respect to loss of job, data security, sensor malfunction, e-waste handling, interoperability of systems, training, motivation etc. Proper planning can make precision farming a success in future.

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