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Precision Agriculture: Is India Lagging Behind?

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ABSTRACT

Variations in the soil and the environment have been known to human race since they started to manage their land. The soil is variable and so as the soils parent material, landscape, micro climate, previous uses. Hence crop development, disease, yield and its quality also varies spatially. Precision agriculture involves addressing soil and field variations with a view to optimizing agricultural practices using tools and technologies such as GNSS and GIS. It originated in the 1980s and optimizes the benefits for sustainable productivity growth, which is so crucial when Indian agriculture is going through structural transformation. Its composition has shifted from traditional food grains to high-valued commercial products. The emerging IT revolution has encouraged farm sector of India to adopt Precision Agriculture technique as applied mostly in the developed countries.

Key words: High-valued commercial products, IT revolution, Precision agriculture, Structural changes.

Variations in the soil and the environment have been known to human race since they started to manage their land. The soil is variable and so as the soils parent material, landscape, micro climate, previous uses and so on. Hence crop development, disease, yield and its quality also varies spatially. Such variations basically Precision Agriculture (PA) tries to understand. According to National Research Council, USA, Precision Agriculture can be defined as "the management strategy that uses information technologies to bring data from multiple sources to bear on decisions associated with crop production". Precision Agriculture emerged in the mid of 1980s. From the mid 1970s to early 80s farmers became more aware of the likely benefits of better record keeping and they started to understand the crop input requirements. Farmers were started to realize the benefits of managing crops within fields by zones. This change was acknowledged in the advanced countries due to better technological enhancements and increasing the size of farm machinery, (Oliver, 2013). It was during 1980s the revolution based on information technology began and as a result in modern times Precision Agriculture came into existence. It is a way that helped increase awareness in the soil conditions along with crop conditions with the help of Global navigation satellite system (GNSS), GISs and micro computers. Initially it was used for fertilizer distribution to varying soil conditions across an agricultural field (Gebbers and Adamchuk, 2010). Apart from Crop management precision agriculture is adopted in viticulture horticulture and even in case of live stock management. PA technique helps in optimizing production and profitability along with low negative impact in the environment and hence it is suitable for sustainable agriculture. Moreover, precision agriculture enhances product quality. Though, quantifying the benefit that PA holds to the farmers is not possible, but in various studies it is found out that this new technique is helpful for the farmers. However, the operation of such technique requires farmers' knowledge regarding ICTs and hence it is necessary to provide them adequate knowledge regarding how to handle such technology in an efficient manner so that they can avail the benefit of such new idea that is ranging in the field of agriculture in almost all the countries. Some examples of counties using precision agriculture are tea industry in Tanzania and Sri Lanka to the production of sugar cane in Brazil; rice in China, India and Japan; and cereals and sugar beets in Argentina, Australia, Europe and the United States. According to the United Nations press release of May 2011, the world's population is growing fast and it is forecasted to reach by 9 billion by 2050 and more than 10 billion by 2100. As population is increasing at a continuous rate, farmers have to produce more yields to meet the growing demand while keeping in view the soil sustainability along with keeping the environment healthy for future generation. According to Oliver (2013), developed countries are withdrawing lands from cultivation to manufacturing industries, buildings, roads and so on, while many low and middle income countries still have the scope to bring new lands into production with technological advancements and new crop varieties. In Asia this is not possible as almost all the cultivable land is in use but this land extension for cultivation is possible in Brazil but at the expenses of native forest which is important for global eco-system.

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Industrial-Agriculture that dominates the developed world is highly mechanized and often monoculture. It is basically based on large fields and firms and uses more amounts of fertilizers, pesticides, water and other chemicals which are not good for a healthy lifestyle. It not only has harmful impact on humans but also on the environment and it is seen that this practice is not sustainable for soil health. To reverse this trend we have to introduce different approaches to sustain food security. In such scenario adoption of Precision Agriculture could ensure food security along with soil sustainability. In traditional farming system fertilizers and pesticides are applied uniformly leading to over application and under application in some areas. It has implications to the farmers in terms of cost of loosing of materials on the one hand and on the other loosing of the potential yields. Moreover, environmental loss is the major cost that is associated with over application of pesticides in the field. If the pesticide moves out of the field due to rain and if it reaches the ground or surface water it can cause much potential harm to the humans and animals and to the sea animals. So with greater knowledge regarding the soil and crop conditions, pesticides and fertilizers can be used in precise manner. And this is the vital role that precision agriculture plays.

Simply, the concept of PA can be defined as follows (Fig 1).

Scenario of Indian agriculture

Even if the share of Indian Agriculture has declined over a period of time but it remains the largest employer and main source of livelihood to the larger number of the rural population (Saha and Verick, 2016). Agricultural performance remains very crucial for rural livelihood, food security and reduction of poverty. Though there has been notable increase in production of food grains in the recent past but the sector has been facing such formidable challenges such as the reduction in the average size of land holding, poor or inefficient water use, diminishing water resources and the unlikely impact of climate change, paucity of farm-labor, inefficient and poor or inefficient marketing infrastructure, rising costs and unpredictability's associated with the volatility in international markets (Barrett, 2021). To make agriculture sustainable and to attain country's food requirement, it is precondition to maintain the health of the soil and water availability at a minimum level that would re-assure farmers to pursue agricultural activities with higher levels of productivity. Indian Agriculture is also witnessing structural changes with changing the composition of agricultural output (production) from traditional food grains to high-valued commercial products. Agriculture is increasingly being driven by expanding demand for livestock products, fish and other high values crops like vegetables and fruits, processed foods and beverages. Export composition changed from traditional to horticulture, meat, mean products and processed products. The food basket in case of India has become increasingly wide-ranging and expenditure on vegetables, milk, fruits, eggs, meat, fish, beverages and processed food is rising rapidly, ultimately leading to changing cropping pattern in the country. Share of livestock and fisheries in Indian agriculture is increasing. Cropped area under fruits and vegetables is increasing indicating horizontal and vertical diversification happening in Agriculture (Deogharia, 2018).

Globally, PA has seen successful implementation in developed nations where advanced infrastructure and technology are widely accessible. For example, the U.S. and Europe have introduced PA methods like GPS and remote sensing to enhance efficiency in large-scale farming (Khanal *et al*., 2020; Yang *et al*., 2015). In countries like Brazil and Argentina, PA has also been used within large-scale commercial crops of sugarcane and soybeans, respectively (Cherubin *et al*., 2022; Monzon *et al*., 2018). However, in developing countries the adoption of precision agriculture is hindered by many challenges. Some of these challenges were discussed by Mondal and Basu (2009) in adopting Precision Agriculture techniques in developing countries especially in India. The emerging IT revolution has encouraged farm sector of India to adopt Precision

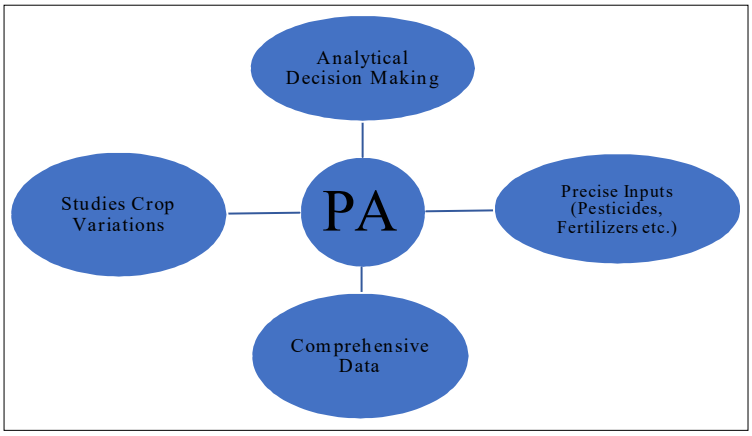


Fig 1: Concept of precision agriculture.

Agriculture technique as applied in most of the developed countries. However, PA techniques of developed countries have to be modified as per the socio-economic condition, digital literacy and other development parameters of country like India. Thus, it is recommended to use balanced soft (visual observation of crop and soil and management decision based on experience and intuition, rather than on statistical and scientific analysis) PA techniques in less developed regions and hard (decision on crop management depends on all modern technologies such as GPS, RS and VRT) PA technologies in developed region of the country like Kerala, Punjab etc. Empirical studies showed that precision agriculture makes farmers gain profit margin and also it is fruitful for soil conservation and sustainable agriculture. This study proposed three common PA technologies for developing countries. They are-small PA techniques for small scale firms, PA technology package based on SPAD, LCC, DSS, GIS, VRT, GPS, *etc.* suitable for consolidated plots, plantation crops and cash crops and Integrated PA techniques based on On-line sensor, image processing, remote sensing (RS), yield monitoring system, VRT, GPS, *etc*. suitable for organized farming sector. In Indian context, Mondal *et al*. (2011) analyzed the importance of adopting Precision Agriculture in competitive global market, due to liberalization of agricultural trade. Though the 'Green revolution' of India, was supply driven, the subsequent or future agriculture will be demand driven. Even though India produces sizeable quantity of yield, the high production cost and very low productivity will throw Indian farmers out of the economic competition in the arena of free market. Again, lack of timely start of research on advanced technology, which can be termed as "knowledge poverty" is one of the main problems of developing countries. Another work by Bhattacharyay *et al*. (2020), discussed about the precision agriculture techniques, its scope and challenges in adopting it in a developing country like India. As per the author, PA adoption is justified on account of uncontrolled use of resources and inputs due to population pressure resulting in not only natural resources wastage and environmental pollution but also financial loss of farmers. However, as the future of precision farming is moving towards extensive use of machine learning techniques and image analysis, it might lead to loss of job, data security issues, lack of motivation, training and so on.

Precision agriculture and food security

As per Thomas Robert Malthus "the power of population is indefinitely greater than the power in earth to produce subsistence (food) for men". Agriculture has not yet followed Malthus' population theory (Malthus, 2023), as overall food production has kept up with world population growth (Erickson and Fausti, 2021). However, the increasing population growth worldwide will place a huge demand on agricultural products as world's population will likely to exceed 9 billion by 2050 as forecasted by United States Census Bureau. The increasing population will lead to decrease in the land available for agricultural production; hence the food production system has to become more efficient which implies more production while using less amount of land. Here arises the main question, whether precision agriculture can be a way for achieving food security? In this regard many studies can be found which states that precision agriculture can be a way to achieve food security. According to (FAO, 2020), food security can be defined as a situation in which all people at all time have physical, social and economic access to adequate, safe and nutritious food that meet up their nutrient needs and food preferences for a healthy and active life. "As per global estimates it indicates that more than 750 million are hungry and that of under nutrition prevalence, which counts for about 12.9% people in developing regions are unable to consume sufficient food for a healthy and active life. Hence, the main challenge of today and tomorrow is of doubling food supply to ensure food security (FAO, 2020). Precision Agriculture (PA) or Precision Farming (PF) includes innovative agricultural management practices that serve these purposes. PA has been greatly promoted for the potential use of high-tech tools to sustainably intensify food production through increasing yields and profits, decreasing the environmental impacts of production and improving food safety and transparency in the food system through the data collected by precision agriculture technologies" (Demirbaş, 2018). As per Phillips (2014), combining PA with existing Nutrient Management strategies, such as 4R Nutrient Management, Integrated Soil Fertility management etc. resulted 67% increase in crop yield globally. "Hybrids were introduced in the early 20th century, pesticides became mainstream agricultural tools in the mid-1900s to protect crops from weeds, insects and disease and in that same era was the green revolution where improved genetics coupled with management practices and commercial fertilizers greatly increased productivity. All of these are considered paradigm shifting factors that have affected food security" (Erickson and Fausti, 2021).

The adoption of Precision Agriculture (PA) has been widely recognized as a key solution to addressing the challenges of modern agriculture, particularly in the context of growing population pressures and limited agricultural land. As the world's population is expected to surpass 9 billion by 2050, agricultural systems must become more efficient, producing higher yields with fewer resources (FAO, 2020) . Precision Agriculture offers a potential path forward by integrating advanced technologies to optimize resource use and reduce environmental impacts.

One of the central benefits of PA is its ability to increase crop yields while minimizing the overuse of inputs like water, fertilizers and pesticides. Studies have shown that PA, when combined with strategies such as Nutrient Management and Integrated Soil Fertility Management, can lead to a 67% increase in crop yield globally (Phillips, 2014). This is especially critical in developing regions where food insecurity is prevalent, with over 750 million people globally

facing hunger and undernutrition (FAO, 2020). By targeting inputs more precisely, PA can help farmers in these regions produce more food while preserving natural resources.

Moreover, PA contributes to environmental sustainability by reducing the negative impacts of traditional farming methods. The indiscriminate use of fertilizers and pesticides has been linked to environmental degradation, including soil erosion, water contamination and loss of biodiversity (Demirbaş, 2018). PA technologies, such as GPS, GIS and remote sensing, allow for more targeted application of these inputs, reducing the risk of over-application and its associated environmental consequences. As a result, PA not only improves productivity but also ensures the long-term health of agricultural ecosystems.

However, despite the potential benefits of PA, its widespread adoption, particularly in developing countries like India, faces several barriers. One of the primary obstacles is digital literacy. Farmers in regions with lower technological adoption may lack the skills necessary to operate and benefit from PA technologies (Mondal and Basu, 2009). In India, for example, PA techniques used in developed countries must be adapted to local socio-economic conditions and technological capacities (Mondal *et al*., 2011). Thus, while PA holds promise for Indian agriculture, its successful implementation will require targeted policy interventions to improve digital literacy and access to necessary technologies.

Furthermore, the high cost of PA technology and infrastructure poses a challenge, especially for smallholder farmers who constitute a significant portion of the agricultural workforce in countries like India. Although PA has been shown to improve profitability in the long run by reducing input costs and increasing yields, the initial investment can be prohibitive. Governments and international organizations must explore financing options and subsidies to make PA more accessible to small-scale farmers.

In the context of food security, PA could play a transformative role in ensuring that agricultural systems are able to meet the food demands of a growing global population while safeguarding environmental resources. As Malthus predicted, the pressure of population growth will continue to strain agricultural production (Malthus, 2023). However, advances in PA technologies provide a counterpoint to Malthusian pessimism by offering solutions to increase efficiency, reduce waste and maintain productivity on a limited amount of land.

CONCLUSION

In conclusion, Precision Agriculture presents a promising avenue for achieving both sustainability and food security in the 21st century. While challenges related to digital literacy, cost and infrastructure remain, these can be addressed through targeted interventions and support for farmers, particularly in developing countries. The continued development and adoption of PA will be critical to meeting global food demands in an environmentally sustainable manner.

Conflict of interest

All authors declare that they have no conflicts of interest.

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