CURRENT APPROACHES FOR SMART AGRICULTURE

Editors

Dr. Satybhan Singh

Dr. Himanshu Trivedi

Dr. Virendra Singh

AkiNik Publications

New Delhi

Published By: *AkiNik Publications*

AkiNik Publications
169, C-11, Sector - 3,
Rohini, Delhi-110085, India
Toll Free (India) – 18001234070

Editors: *Dr. Satybhan Singh, Dr. Himanshu Trivedi and Dr. Virendra Singh*

Edition: *1st*

Publication Year: *2022*

Pages: *528*

ISBN: *978-93-5570-290-6*

Book DOI: *https://doi.org/10.22271/ed.book.1833*

Price: *₹ 1795/-*

Contents

Chapter - 2
Precision Farming

Authors

Satybhan Singh
School of Agricultural Sciences & Engineering, IFTM University, Moradabad, Uttar Pradesh, India

Virendra Singh
School of Agricultural Sciences & Engineering, IFTM University, Moradabad, Uttar Pradesh, India

Himanshu Trivedi
School of Agricultural Sciences & Engineering, IFTM University, Moradabad, Uttar Pradesh, India

RS Chauhan
R.S.M. (P.G.) College, Dhampur, Bijnour, Uttar Pradesh, India

Ramesh Pal
School of Agricultural Sciences & Engineering, IFTM University, Moradabad, Uttar Pradesh, India

Ashesh Narayan
School of Agricultural Sciences & Engineering, IFTM University, Moradabad, Uttar Pradesh, India

Chapter - 2

Precision Farming

Satybhan Singh, Virendra Singh, Himanshu Trivedi, RS Chauhan, Ramesh Pal and Ashesh Narayan

Introduction

The concept of precision farming is based on the Global Positioning System (GPS), which was initially developed by the American defense scientists for the exclusive use of the U.S. Defense Department. The distinctive character of GPS is precision in time and space. Precision agriculture (PA), as the name implies, refers to the application of precise and appropriate quantities of inputs like seed, water, fertilizers and pesticides etc. at the right time to the plants for increasing productivity and to get maximum crop yields. The use of inputs (*.e.* seed, water, fertilizers, manures and pesticides) based on the appropriate quantity, at the correct time and in the appropriate place. The objectives of precision agriculture are to ensure productivity, sustainability and protection of the environment. Precision agriculture is also known as "Satellite Agriculture, As-needed Farming and Site Specific Crop Management (SSCM). Precision agriculture is a data-driven system to farm management that can improves productivity and yields, thereby increasing the overall profitability of farm.

Precision agriculture refers to the judicious use of agricultural inputs with respect to soil, weather and crop need in order to increase productivity, quality and profitability of farming. It is a modern approach of agriculture involving the use of technology in agriculture like remote sensing, Global Positioning System (GPS) and Geographical Information System (GIS) for improving productivity and profitability. Precision agriculture enables farmers to the application of crop inputs more efficiently including irrigation water, tillage, seed, fertilizers and pesticides. More effective utilization of inputs will bring in more crop yield and quality without polluting the environment and will result in sustainable development of agriculture. Hence precision agriculture approach is about doing the good things, in the right place, in the right way and at the accurate time.

Precision Agriculture (PA) is one of the means of producing on-site data to guide decision making, thus to manage the growing of crops for better yield and quality (Leonard, 2016).

Precision agriculture can be defined as "the application of modern information technologies for provide, process and analyze multi-source data of high spatial and temporal resolution for decision making and operations in the management of crops production" (National Research Council, 1997).

Precision agriculture is a management strategy that collects, processes and analyzes temporal, spatial and individual data and combines it with other information to support management options according to estimated variability for increasing resource use efficiency, productivity, quality, profitability and sustainability of agricultural production.

Popular definitions of Precision Agriculture (PA), Satellite Farming or Site Specific Crop Management (SSCM) describe the term as 'a technology-enabled approach to farming management that observes, measures, and analyzes the needs of individual fields and crops'. In simple words farming that collects and uses of plot's data for managing and optimizing the production of crops is known as Predictive farming.

Predictive farming is analogous to taking a pill to target an ailment. The solutions are highly tailored from the type of suitable crop for a soil to the use of pesticides in targeted area only. Adapting to Precision farming reduces the production cost and wastage, as tailored needs of each plot is catered to. Precision farming is practiced by adapting analytical software and use of technical equipment. Rigorous data collection is done on soil testing, measurement of plots, crop and weather pattern analysis through sensor based devices placed in the fields. The data is assess to devise conclusions and based upon those results a very detailed and precise set of practices can be adopted.

Precision agriculture relies upon specialized devices, software and IT services. The approach includes accessing real-time data about the crop conditions, soil and climate, along with other relative information such as hyper-local weather predictions, labor costs and equipment's availability. Predictive analytics software uses the data to provide farmers with guidance about crop rotation, optimum planting and harvesting times and soil management.

Agricultural control centers integrate sensor data and imaging input with other data, providing farmers with the ability to identify fields that require treatment and determine the optimum amount of water, fertilizers and pesticides to apply. This helps the farmer avoid wasting resources and prevent

run-off, ensuring that the soil has just the right amount of additives for optimum health, while also reducing costs and controlling the farm's environmental impact.

In India, Agriculture is mainly known for its countless outcomes from providing food, feed and employment, livelihood to nutritional and ecological securities. There is about total geographical area of 328.7 million ha out of which 182 million ha of the land get affected by land degradation, 141.33 million ha of the land affected due to water erosion as well as wind erosion, water logging and chemical deterioration *i.e.* salinization and leaching losses of nutrients also considered as land deteriorating agent. Likewise, the higher cost of cultivation and lower productivity will throw Indian farmers out of the economic competition. In order to face all these new challenges, study of advanced, eco-friendly technology which can utilize all available resources efficiently for sustainable development of agriculture.

Precision agriculture is such a modern and highly auspicious technology spreading rapidly in the developed countries. A scientific approach to efficiently increment in agricultural production by the use of different innovative technologies in the field with the timely application of required amounts of input to obtained optimum profitability and sustainability without environmental pollution. The precision farming assures the improvement in agricultural productivity with decreasing the cost of cultivation through the systemic utilization of resources. The performance of precision agriculture mostly depends on accurate evaluation of variability, management and evaluation in space time continuum in crop production.

Revolution in technology has changed Indian environment as well as created new hopes for agriculture. Therefore, from a sustainability and economic point of view, it is necessary to grasp these developing new technologies and apply them efficiently along with proper utilization of resources in the agriculture sector.

Equipment and tools required in precision farming

The successful achievement of precision agriculture depends on number factors such as the extent to which the adequacy of input recommendation and the degree of application control. The enabling technologies used in precision agriculture can be grouped in to major categories: Global Positioning System (GPS), Geographic Information System (GIS) and Remote Sensing (RS). Precision agriculture technology makes combination of application of different technologies and all these combinations are mutually inter related and dependable for developments of precision agriculture which are discussed below:

- **Global Positioning System (GPS):** A GPS is not a new invention nor it is limited to agriculture only. Nevertheless, its impact on agriculture is undeniable - from tracking field operations to scanning the location of equipment and livestock. It's safe to say that the invention of the Global Positioning System has laid the foundation of modern-day precision agriculture and still is one of the most widely used field management and precision farming technologies.

It is a set of 24 satellites in the Earth orbit. It sends out radio signals that can be processed by a ground receiver to determine the geographic position on earth. GPS allows precise mapping of the farms and together with relevant software informs to farmer about the status of their crops and which part of the farm requires what input such as water or fertilizer, pesticides etc.

Global Positioning System (GPS) makes use of a series of satellites that recognize the location of farm equipment within a meter of an actual site in the field. GPS receiver provides uninterrupted position information in real time while in motion. The precise location information allows soil and crop management to be mapped at any time. The data can be obtained with GPS receiver either carried to the field or ascended on apparatus allowing users to return to specific locations to treat those areas. GPS receiver with electronic yield monitors usually applied to collect yield data across the land accurately. Farm uses include: mapping yields (GPS + combine yield monitor), variable rate planting (GPS + variable rate planting system), variable rate lime and fertilizer application (GPS + variable rate controller). *e.g.* Locations of soil samples and the laboratory results can be compared to a soil map; irrigation, fertilizers and pesticides can be prescribed to fit soil properties and soil conditions.

- **Geographic Information System (GIS):** GIS is software that imports, exports and processes spatially and temporally geographically distributed data.

GIS systems give farmers a possibility to aggregate data in a visually-rich way. By generating custom color-coded maps, the tool gives a full view on soil condition, crop fertility, insects or disease pressure. The insights, collected by a GIS tool are pressures as they offer data that would not be spotted with the naked eye.

- **Grid Sampling:** It is a method of breaking a field into grids of about 0.5-5 hectares. Soil sampling within the grids is useful for determination the appropriate quantities of fertilizers application.

Geographic information systems (GIS) are computer hardware and software that use location data to generate maps. The main function of an agricultural GIS is to store information *i.e.* yields, yield maps, soil survey maps, remotely sensed data, crop scouting reports and soil fertility status. GIS played an important role in research and natural resources management. GIS has been popularly applied in agriculture, such as groundwater recharge estimation and regional distribution maps for heavy metals scheduling and monitoring of irrigation delivery for rice irrigation systems. For example, better management of the paddy fields for better efficiency and cost effectiveness also made possible with geographical information systems.

- **Automated Planter Controls:** The technology gives site managers remote control over the planting process. Dedicated systems will automatically enable and disable planters if seeds have already been sown in certain fields. The technology increases planting efficiency of machines, reduces the planting time and the wastage of seed and fuel etc.
- **Variable Rate Technology (VRT):** The existing field machinery with added Electronic Control Unit (ECU) and onboard GPS can fulfill the variable rate requirement of input. Spray booms, the Spinning disc applicator with ECU and GPS have been used effectively for patch spraying. During the creation of nutrient requirement map for VRT, profit maximizing fertilizer rate should be considered more rather than yield maximizing fertilizer rate.
- **Yield Maps:** Yield maps are produced by processing data from acclimated combine harvester that is equipped with a GPS, *i.e.* integrated with a yield recording system. Yield mapping involves the recording of the grain in flow through the combine harvester, while recording the factual location in the field at the same time.

Yield mapping is ultimate index of variations of different agronomic parameters in different areas of the farm. Thus interpretation and correlation of map with the spatial and temporal variability of different agronomic parameters helps in improvement of crop management plan for succeeding cropping season.

- **Yield Monitors:** This invention, originates in the mid-nineties, helps farm managers quantify yield variations across the field and determine the catalysts for such (status of soil fertility, weather conditions, differences in crop management practices and so on). Yield monitors are empowered by GPS and sensors to offer deep perceptivity.

Yield monitors can also measures the volume or mass flow rate to generate time periodic record of harvested crop's volume for that period. Yield maps are an essential layer of data in a spatial database for management practices of farm. Interpreting and using the yield maps is a key step in development of precision management skills.

Crop management devices are a pivotal element for efficiently use of precision agriculture technology. These devices are generally placed on the field-they will monitor moisture status of soil, crop health and other relevant biochemical and physical properties of crop and soil. Using crop monitoring devices, a farmer can proactively manage all anomalies in farming system, build prediction-based models and strategies, and prevent potentially harmful diseases.

- **Remote Sensors:** Remote sensors are generally categories of aerial or satellite sensors. They can indicate variations in the colors of the field that corresponds to changes in soil type, crop development, field boundaries, roads, water, etc. aerial and satellite imagery can be processed to provide vegetative indices, which reflect the health of the crop plants.

Remote sensing technology is a very useful tool for collecting information simultaneously or gathering of data from a distance. Data sensors are normally hand-held devices which generally satellite-based are mount on drones. The information useful for soil conditions, crop growth, weed infestation, disease and insect incidence etc. can be recorded with satellite containing electromagnetic remittance and reflectance data of crop. Remotely-sensed data make the possibility for evaluation of crop health and cost-effective site-specific crop management program (SSCMP). The data regarding water stress, crop insect, pest and diseases, nutrient stress, soil compaction and others becomes easily derived in overhead images. Remote sensing can report in-season variability that affects crop yield and is timely enough to make crop management policies that ameliorate productivity and profitability for the current crop. Mapping of weeds against bare soil for row crops at early stages of seedlings has been carried out successfully with the help of remote sensing technology.

- **Proximate Sensors:** These sensors can be used to measure soil parameters as such as N status and soil pH) and crop properties as the sensor attached tractor passes over the crop field.
- **Computer Hardware and Software:** In order to analyze the data collected by other Precision Agriculture technology components and

to make it available in usable formats such as charts, graphs, maps or reports, computer support is essential along with specific software support.

- **Precision Irrigation Systems:** Recent developments are being released for commercial use in sprinkler irrigation by controlling the irrigation machines motion with GPS based regulators. Wireless communication and sensor technologies are being developed to monitor soil and ambient conditions, along with operation parameters of the irrigation machines (*i.e.* flow and pressure) to achieve maximum water use efficiency.

With the growth of precision agriculture using IoT, irrigation monitoring has come a long way. Now, dedicated systems can completely handle irrigation, send real-time alerts to a manager in case of anomalies, distributes the exact quantity of water a given type of crops needs. As a result, a site manager reduces the amount of workforce as well as wastage of water and energy.

- **Precision Farming on Arable Land:** The use of PA techniques on arable land is the most extensively used and most advanced among the agricultural producers. CTF (controlled Traffic Farming) is a whole farm approach that aims at avoiding unnecessary damage in crop production and soil compaction by the use of heavy machinery, reducing costs imposed by standard methods. Controlled traffic methods involve confining all field vehicles to the minimum area of permanent traffic lanes with the aid of decision support systems. Another important application of precision agriculture in arable land is to optimize the use of fertilizers especially, N, P and K.

- **Climate monitoring:** Weather stations equipped with farming stations help farmers track and predict weather conditions in a needed region. After having collected insights from the environment, connected devices send the data to cloud-based storage. From there, farm managers can use the information for climate mapping and crop selection.

- **Cattle monitoring:** Sensors are even more important for animal management than they are for crop maintenance. For one thing, they can serve as location trackers so that a part of the livestock is not lost. Also, farm manager will be getting real-time insights on whether cows, pigs, and other farm animals are not sick or hungry. Connected collar tags are the most widespread form of devices for cattle

monitoring. They cause no stress for the animal, all the while providing farmers with real-time insights.

- **Greenhouse automation:** Delegating greenhouse management to an IoT platform for precision agriculture, many activities and processes in the greenhouses can be fully automated. For example, temperature, humidity and light can be controlled automatically. Even soil or nutrient solution administration within the greenhouse can be managed with the help of artificial intelligence. These are some examples of using IoT for precision farming.

Need for precision farming

In developing countries, 32 percent of food losses occur during food production as analyzed by McKinsey on FAO data.

Conventional farming practices are area centric. There is a general set of crops cultivated throughout an area. All the farmers in that area follow the same methods of soil preparation, crop sowing, crop nurturing, irrigation scheduling and crop harvesting period. What these practices result in is: unpredictability, exploitation of resources and uncontrolled waste production.

Before the use of technology in agriculture, a farmer's probability of yielding good produce was as good as tossing a coin and wishing for heads. Since farmers had no information on their farms, there was no way of learning the causes for crop loss. This practice pushed the farmers towards losses and debt. Advancements in big data analytics, IoT and accessible satellite imagery created optimism for the agriculture sector, thereby combating the issue of unpredictability.

Need for Precision Farming in India:

To meet the huge requirement of food grains about 480 million tonnes by the year 2050, with the increasing challenges of biotic and abiotic stresses experienced by crops, introduction and adoption of new technology in Indian agriculture is inevitable.

Why Precision Farming?

1. To enhance the agricultural productivity with respect to profitability and sustainability.
2. To prevents soil degradation.
3. To reduce the application of chemical fertilizers, herbicides, insecticides and pesticides in crop production.
4. To efficient use of natural resources.

5. To dissemination of modern technology and farm practices to improve quality, quantity and reduced cost of production.
6. To developing favorable attitudes.
7. Precision farming improving the socio-economic status of farmers.

Scope, strategy and adoption of precision farming in India

Precision Agriculture (PA) for small farms can use small farm machinery and robots which will not compact the soil and may also run on renewable fuels like bio oil, compressed biogas and electricity produced on farms by farm wastes. For small farms, precision agriculture may include sub-surface irrigation and drip-irrigation for precise the application of water and fertilizers, weed control, crop harvesting and other cultural practices. Some of these robots are already being used on small farms in the US and Europe and it is expected that they may be deployed in large scale in the future. For small farms, precision agriculture may helps in sub-surface drip irrigation for precise the application of water and fertilizers and robots for weed control, crop harvesting and other practices. Similarly, drones have also been introduced in Japan and the U.S. for mapping the farms, identifying diseases, insects, weeds and so on. Most robotic machines and drones are compact and thus suitable for small farms. India's small farms, therefore, are ideal for the large-scale use of precision agriculture.

The popularity of Precision farming in developed countries results in maximization of agricultural productivity with application of different technologies like satellite using technologies and geographical information systems. The application of precision farming proves economically and environmentally beneficial with optimum utilization of water, fertilizers, herbicides and pesticides other than farm equipment. Therefore, Farmers straight away require timely and reliable sources of information regarding supply of inputs for sustainable agricultural production. The challenges led by the changing environment faced by farmers makes technology not only merely useful, but necessary to keep competitive.

Farmers require substantial knowledge and information about improved farming practices, pricing strategy, market betterment and new policies regarding agriculture technology. When farmer will be able to get information about cost, stock, supply and available market for their produce, farmer would put up their products for sale at the right price and the right time without any degradation of their product quality. Administration and various Agro-based industries can provide a variety of services through mobile technology by which farmers can utilize the information about price, stock and market

practices. It will help them either to reduce the risk of under-selling or over or under-supplying with low price for their produce in a given market. It also gives access to early warning systems to mitigate the risk of losses via control of spread of pathogens due to extreme weather conditions.

Technologies for precision agriculture can significantly reduce the inputs demands and environmental pollution. The application of precision technologies should be commenced in the cultivation of high value commercial crops that may more beneficial to farmers. Any technology not proves economic benefits with their first use, but the long term adoption of a technology surely brings these benefits. The primary objective of precision technology should be to optimize the crop inputs *i.e.* seed, water, fertilizers and other chemicals used in farm production and prevent excess of and beneath application of agricultural inputs for reducing environmental risks rather than to get maximum yield. Furthermore, to get the farmers attention towards this type of agriculture should be the main focus of this strategy. Small farmers should start with a single precision application, whereas the progressive farmers should select more than one precision application on their farms because it will more beneficial to them. Small farmers can use low cost and small machine based variable rate technology. Agencies in the private sector can motivate the progressive farmers to use precision agriculture on their farms by providing them infrastructural support, operational support, coordination and control of farming activities and strategic support. There are several examples of precision nutrient management practices from several countries where farmers and practitioners have overcome the challenges and converted them into opportunities by adopting precision techniques appropriate for their region, operations and resources.

The policy approach to promote precision farming at farm level

1. Identify the niche areas for the promotion of crop specific precision farming technology.
2. Creation of multidisciplinary teams involving agricultural scientists in various fields, engineers, manufacturers and economists to study the overall scope of precision agriculture.
3. Provide complete technical backup support to the farmers to develop pilots or models, which can be replicated on a large scale.
4. Pilot study should be conducted on farmer's fields to show the results of implementation of precision agriculture.
5. Creating awareness among farmers about consequences of applying imbalanced doses of farm inputs like irrigation, fertilizers, insecticides and pesticides.

6. Economical, simple and maintenance free precision machines should be provided to the farmers.
7. Promoting drone application in agriculture.
8. Encouraging local youth through training and incentive to establish service centers for repair and maintenance of machines along with spare parts.

Advantages of precision farming

- **More metrics for agriculture monitoring:** A farmer will be able to continuously monitor a wide range of metrics-including rainfall levels, the number and nature of nutrients that crops need to grow to a peak level, soil samples, fertilizer inputs, and so on. A deeper insight into the state of crops helps farmers make informed decisions across all fields.
- **Suitable planning:** Information technology has provided farming software which can keep better track of agriculture and predict yields. Farmers can efficiently improve their agriculture production with superior utilization of modern farming technology and methodology.
- **Improved decision-making efficiency:** When farmers adopt the use of precision agriculture sensors to monitor the soil moisture, crop health and nutrition levels, they get long-term access to valuable real-time data. This way, a site manager will be able to distinguish patterns and predict changes, potential risks, and yields, both through harvest and the growing season.

Information technology is very useful for farmers, researchers and other people to make decisions regarding their agricultural activities and marketing. The varieties of different sensors with generated data enables better understanding of an interaction of dynamic crop, soil and weather conditions while machinery data leading to more accurate and fast decision making.

- **Access to farm records:** Using technology for farm management increases data accessibility. With precision agriculture, the team members are no longer bound to the office space. Thanks to cloud-based technologies, all the necessary data is free for access any time from any device.
- **Better crop protection:** The excessive use of chemicals is one of the causes of high crop and soil pressure. To protect the site from crop-damaging insects, farmers tend to go overboard with their nitrogen usage. Apart from reducing the environmental sustainability of the

site, using chemicals is expensive. One of the biggest benefits of adopting precision agriculture using Internet of Things is to optimize pest control and use chemicals only when needed and protect crops more efficiently.

- **Irrigation management:** Agriculture accounts for **over 70% of water usage** across the world, according to OECD. As the world is experiencing drinking water shortages, careful distribution at farming sites is imperative. By adopting centralized command-and-control tools, farming teams can tell precisely when to irrigate a given field. As a result, crops are preserved in a better state and the management framework is socially responsible.
- **Agriculture advancement:** With the development of new technologies like improved varieties and hybrids, fertilizers, irrigation technologies like drip or sprinkler system, weeding technologies insecticides, pesticides with their optimum dose and their application on optimum time in the agriculture field helps in sustainable production.
- **Prediction of weather:** Weather prediction becomes also possible with this improved technology. This weather data aware the farmers regarding weather conditions like rainfall, drought, hailstorms etc. and help them to plan accordingly.
- **Marketing:** What and where a suitable market for selling their agriculture produce at a valuable rate is key issues for the farmer community, which can also get achievable with technologies.

Some other advantages of precision agriculture are given below

- It will enhance agricultural productivity and prevent soil degradation in cultivable land resulting in sustained agricultural development.
- It will reduce excessive chemical usage in crop production.
- Water resources will be utilized efficiently under the precision farming.
- GPS allows agricultural fields to be surveyed with ease. Moreover, the yield and soil characteristics can also be mapped.
- Dissemination of information about agricultural practices to improve quality, quantity and reduced cost of production in agricultural crops.
- It will minimize the risk to the environment particularly with respect to the nitrate leaching and groundwater contamination by means of the optimization of agro-chemical products.

- Non-uniform fields can be sub-divided into smaller plots based on their unique requirements.
- It provides opportunities for better resource management and hence reduces wastage of resources.

Drawbacks of precision farming

- High capital costs may discourage farmers to not adopt the modern technology of farming.
- Lack of technical expertise knowledge to purchase, operate and maintain of sophisticated or sensor based equipment.
- Not applicable or difficult and costly for small land holdings.
- Heterogeneity of cropping systems and market imperfections.
- Precision agriculture techniques are still under development and require expert advice before actual implementation.
- It may take several years before the actual collection of sufficient data to fully implement the system.
- It is an extremely difficult task particularly the collection and analysis of data.
- Lack of sensor based machines.
- No alternate use of such implements.
- The farmers are not economically sound to invest in owing agricultural machinery.

References

1. Leonard, E.C. (2016). In Encyclopedia of Food Grains (Second Edition).
2. McBratney, A.; Whelan, B. and Ancev, T. (2005). Future Directions of Precision Agriculture. *Precision Agriculture*, 6: 7-23.
3. Meena, H.; Kumar, D. and Prasad, K. (2021). Precision Agriculture: Present Status & Scope: A Review. Just Agriculture-*Multidisciplinary e-newsletter*, 1(5): 213-219.
4. Mondal, P. and Basu, M. (2009). Adoption of precision agriculture technologies in India and in some developing countries: Scope, present status and strategies. *Elseveir Scirnce direct. Progress in Natural Science*, 19: 659- 666.
5. National Research Council (1997). *Precision Agriculture in the 21st Century: Geospatial and Information Technologies in Crop*

Management. Washington, DC: The National Academies Press. https://doi.org/10.17226/5491.

6. Rehman, A.; Jingdong, L.; Khatoon, R. and Hussain, I. (2016). Modern Agricultural Technology Adoption its Importance, Role and Usage for the Improvement of Agriculture. *American Eurasian Journal of Agriculture and Environmental Sciences*, 16 (2): 284-288.
7. Shanwad, U.K.; Patil, V.C. and Gowda, H. (2004). Honne. Precision Farming: Dreams and Realities for Indian Agriculture. Map India. 2004.
8. Shibusawa, S. (2002). Precision farming approaches to small farm agriculture. *Agro-Chemicals Report*. 2002, 2(4): 13-20.
9. https://www.springer.com/journal/11119
10. https://www.cropin.com/precision-farming
11. https://www.downtoearth.org.in/blog/agriculture/why-farmers-today-need-to-take-up-precision-farming-64659
12. https://en.wikipedia.org/wiki/Precision_agriculture
13. https://www.techtarget.com/whatis/definition/precision-agriculture-precision-farming
14. https://www.iasexpress.net/precision-farming-in-india-features-merits-demerits-and-challenges/
15. https://www.techtarget.com/whatis/definition/precision-agriculture-precision-farming
16. https://www.downtoearth.org.in/blog/agriculture/why-farmers-today-need-to-take-up-precision-farming-64659
17. https://www.digiteum.com/precision-agriculture-technology/#
18. https://madhavuniversity.edu.in/precision-agriculture.html