Precision Agriculture – A Modern Approach To Smart Farming

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***Abstract*— In this paper we delve into the concept of Precision Agriculture. This paper describes the need for precision agriculture, associated technologies, the approach towards achieving it, the obstacles faced in the process and possible solutions that can contribute towards gaining actual momentum in the field of precision agriculture. This paper takes into consideration several research papers generated in last decade and summarizes a detailed understanding of the concept and future direction requiring further research. It provides a starting point for anyone interested in understanding or researching precision agriculture.**

Keywords--Precision Agriculture, Technologies involved, Approach, Obstacles, Need, Solutions, Precision Livestock Farming

I. INTRODUCTION

When we think of agriculture we think of cultivation, plant life, soil fertility, types of crops, terrestrial environment, etc. But in today's world we associate with agriculture terms like climate change, irrigation facilities, technological advancements, synthetic seeds, advanced machinery etc. In short we are interested in how science of today can help us in the field of agriculture. And so comes into the picture Precision Agriculture (PA).

The general definition is information and technology based farm management system to identify, analyze and manage spatial and temporal variability within fields for optimum productivity and profitability, sustainability and protection of the land resource by minimizing the production costs. Simply put, precision farming is an approach where inputs are utilized in precise amounts to get increased average yields compared to traditional cultivation techniques. Hence it is a comprehensive system designed to optimize production with minimal adverse impact on our terrestrial system. [1]

The three major components of precision agriculture are information, technology and management. Precision farming is information-intense. Precision Agriculture is a management strategy that uses information technologies to collect valuable data from multiple sources which factors into the decision-making process. It relies on technologies like GPS (Global Positioning Systems), GIS (Geographic Information Systems), yield monitors, remote mapping sensors and guidance systems for application with variable rate which enables in-depth monitoring of field variations.

II. NEED

The UN world population report estimates that the world's population will reach 9.7 billion people, which is 34 percent higher than what it is today. Much of this growth is expected from developing countries like China, India, Brazil, etc which possess the largest area in the world with regards to arable land for agriculture. To keep up with population explosion and constant rise in income, global food production must witness an increase by 70 percent in order to be able to feed the entire world population. [6]

The answer to this daunting challenge lies in the gathering of real time data, analysis of the agricultural process and the unwavering pursuit towards improvement. Thus researching how existing "precision agriculture" techniques and methodologies, while searching for new ones, can maximize food production, minimize environmental impact and reduce cost is crucial, now more than ever.

We have the opportunity to make a difference using science and technological innovation to address critical issues that will have profound effect on the lives of billions of people," said Ulisses Mello an IBM researcher and Distinguished Engineer. [3].

III. TECHNOLOGIES INVOLVED

A. Global Positioning System (GPS)

GPS is a network of orbiting satellites, sending precise positional details from space back to earth. It's obtaining a birds-eye point of view, but from space. The signals are obtained by GPS receivers, to calculate the exact position and time. It has an accuracy of between 100 and 0.01 m. It enables farmers to identify field information, such as soil type, pest occurrence, weed invasion, water holes, etc based on a precise location. This becomes particularly handy when farmers need to make decisions regarding seed plantation, herbicides, pesticides, fertilizers and irrigational needs. [2]

B. Geographic information system (GIS)

It is a system designed to capture, store, manipulate, manage, analyze and present spatial or geographic data. GIS comprises of hardware, software and procedures for supporting the compilation, storage, retrieval and analysis of geographical attributes and location data to produce maps. GIS binds information in one place so that it can be extrapolated when needed. Computerized GIS maps contain layers of information like yield, soil survey, crop type, nutrient levels and prone pests. A farming GIS database can provide information on field topography, soil types, surface drainage, subsurface drainage, rainfall, irrigation, rates of chemical application and crop yield. Once analyzed, this information is used to understand the relationships between the various elements affecting a crop on a specific site [7]

C. Grid soil sampling and variable-rate fertilizer (VRT) application

Grid sampling is an unbiased, simple and relatively quick method for site specific soil management. Variable-rate technologies (VRT) may be applied to numerous farming operations. They set the rate of delivery of farm inputs based on the soil type. GIS extrapolated information can control processes, such as crop determination, level of seeding, application of fertilizer, pesticide and herbicide at a variable rate in the right place at the right time. It is widely used in developed countries. Grid soil sampling, using the same principles, increases the intensity of sampling. Samples collected in a systematic grid can be mapped to specific locations thus giving us an application map. Grid soil samples are analyzed and interpreted to determine crop nutrient needs. Then using this information a fertilizer application map is plotted. Both maps are fed into a computer which generates a detailed and systematic schedule for plantation and fertilizer needs. [12]

D. Sensors

Sensor technology is an integral part of precision agriculture technology and their application has been widely reported to provide essential information on soil properties, plant fertility and water status.

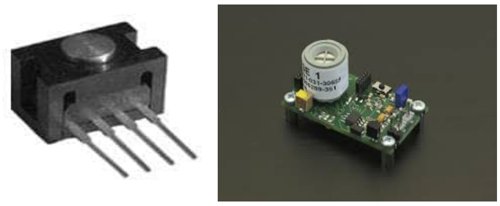
Location Sensors are the sensors that are used to determine latitude, longitude, and altitude within feet.

Optical Sensors use light to measure soil properties.

Figures 1 & 2 : Optical sensors used for scanning crops

Electrochemical Sensors provide key information like pH and soil nutrient levels.

Mechanical Sensors measure soil compaction. They use a probe that penetrates the soil and records resistive forces through use of load cells or strain gauges. [13]



Figures 3 & 4 : Mechanical sensors for soil analysis

Dielectric Soil Moisture Sensors measure the dielectric constant in the soil to assess moisture levels.

Airflow Sensors measure soil-air permeability.

E. Rate controllers

Rate controllers control the delivery rate of chemical inputs such as fertilizers and pesticides, either liquid or granular. It monitors the speed of the tractor/sprayer traveling across the field, as well as the flow rate and pressure of the material, making adjustments in real-time to apply a targeted rate. Rate controllers are frequently used as stand-alone systems.

F. Precision livestock farming (PLF)

Precision livestock farming (PLF) is defined as the application of precision agriculture to the management of livestock production. Processes of precision livestock farming approach focus on animal growth, egg and milk production, detection and monitoring of diseases and aspects related to animal behavior. Systems include monitoring of milk to check fat and microbial levels, helping to identify potential infections, as well as new automated feeding and weighing systems. It also focuses on automated cleaners, feed pushers and other aids. Acoustic sensors detect an increase in coughing of pigs indicating respiratory infection. Other sensors are now used to provide alerts and notifications concerning birthing and fertility.

Figure 5 : Non-invasive technique for monitoring livestock [14]

G. Mobile apps

With the growing use electronic devices like smart phones, tablets, etc and availability of internet connectivity, it is very easy to share or get any information from anywhere. Android apps provide quick and efficient functionality to be grown with technology. In the field like PA farmers can get more benefits from the apps developed for the agriculture monitoring and information exchange. Apps used for agriculture monitoring give information like weather information, market rate and availability etc. Similarly apps can also provide predictive weather analysis, variety of seedlings available, fertilizers, pesticides and herbicides available, etc. [8]

IV. Approach

Precision agriculture can be classified into two broad categories, namely 'soft' and 'hard' PA. 'Soft' PA primarily depends on visual observation of crop and soil and management decision based on experience and intuition. Whereas 'hard' PA utilizes all modern technologies like GPS, RS, VRT etc. relying on statistical analysis of scientific data.

In order to achieve optimal cultivation, farmers need to understand how to cultivate crops in a particular area, taking into consideration a seed's resistance to weather and local infections and the environmental impact of planting that seed. For instance, when planting in a field near a river, it's best to use a seed that requires less fertilizer to help reduce pollution, all the while choosing a crop that requires extensive irrigation.

After the plantation, the decisions made concerning fertilizing and maintaining the crops are time-sensitive and heavily influenced by the weather. If farmers anticipate heavy rains the next day, they may decide not to use the fertilizer, since it would get washed away. Knowing whether it's going to rain or not also factors into the decision making process. With the help of predictive weather analytics this can be achieved. 70 percent of fresh water worldwide is used for agricultural purposes so, is efficient utilization will have a huge impact on the world's fresh water supply.

Weather not only affects crop growth, but also logistics pertaining to harvesting and transportation. Harvesting sugar cane, for instance, requires the soil to be dry enough to support the weight of the harvesting equipment. Else, it could destroy the crop. By analyzing what the weather will be over several days, better decisions can be made in advance about workers deployment. After harvest the logistics of transporting food to the distribution centers becomes the primary concern.

Because inefficient delivery or selecting the wrong market can also adversely affect the farmers' success. A lot of food is damaged, wasted or spoils during distribution, so it's important to transport the food at the right temperature and not hold it for a long time. Even by knowing where it will rain and which routes may be affected, farmers can make better decisions on transportation routes. [9]

V. Obstacles

Lack of whole-farm focus, almost 90% or more of the precision agriculture studies reported that Precision Agriculture techniques have been implemented mostly on a single field or on experimental basis or only on commercial farms. This is because precision agriculture is yet to become an integral part of the normal farming process. Therefore farmers hesitate to choose modern agricultural techniques, which are not known to them.

Lack of Information is also one the primary reasons for limited implementation of PA. Farmers need sufficient information and timely guidance to achieve effective implementation of PA. This is difficult to achieve with the absence of a recognized authority or organization facilitating the awareness of PA techniques and providing the necessary equipment. Farmers need to be familiarized with the use of these equipments and should be kept regularly updated.

Connectivity in rural areas and other remote locations across the world (particularly in the developing countries) strong, reliable internet connectivity is still not available. This, in turn, thwarts the attempts to apply smart agriculture techniques at such locations. Unless the network performances and bandwidth speeds are improved significantly, implementation of precision farming will remain incomplete. Since many agro-sensors/gateways are dependent on cloud services for data transmission/storage, cloud-based computing also needs to become stronger, which also requires strong interconnectivity. In farmlands that have tall, dense trees and/or hilly terrains, reception of GPS signals becomes a big issue.

Lack of Financial resources is one of the major causes for stagnancy in the implementation of PA..Small-scale farmers are restricted by the limited size of their fields and the lack of financial resource to invest in purchase of PA equipments. Due to these reasons they are forced to continue using their traditional techniques for farming. Even with availability of financial aids the size of the field makes PA an impractical choice. [5]

VI. Possible Solutions and Current Applications

It is impractical for small-scale farmers to participate in the implementation of PA for the reasons stated above. However, there is a possible solution. Large Multinational Corporations can enter into agreement with small-scale farmers to provide financial aids and technical equipments required for conducting PA. In return the farmers can share an agreed upon percentage of their profits. This elevates the burden of the farmers, of being aware of the technical know-how and receiving guidance towards effective implementation. For instance, companies like TechMahindra are conducting WhiteBudget research on the subject. [10]

However, this still may be limited in its reach and not provide to all farmers in need of assistance. On the other hand, the government can provide both financial and non-financial assistance. They can actively participate in providing technical assistance. For instance, there are drones that are flying over the fields in the Marathwada region, assessing crop losses due to deficit rainfall and other weather conditions, as the Maharashtra government turns to technology to ensure timely intervention and compensations for farmers in an area known for farmer suicides. The state has also started cloud seeding on a pilot basis in the Marathwada region to create artificial rains. [11]

Some of the current applications include:

Figure 6 : Application of PA by Plantations International in Banglore [15]

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Figure 7 : Application of PA by University of Agricultural Sciences, Raichur [16]

VII. Future Prospects

Future prospects for PA include improvement in the availability and performance of existing technologies. These include improvements in internet connectivity, sensor technology, better and more accurate mobile applications, machinery equipments, etc.

However, the most promising prospect in the future of PA is the application of drones towards the implementation of PA. Drones eliminate the need for GPS and strong internet connectivity it requires. With the drone technology we can speedup crop scouting, identifying pest or nutrient issues in crops and addressing them right away, checking for weather damage, finding pivot breakdowns on irrigation systems, checking drainage system performance, the list goes on.

Figures 8 & 9 : Future advancements in drone applications towards PA [11]

VIII. Conclusion

Technologies like the GPS, GIS, mobile app and sensors can be used for several innovative methods involved in Precision Agriculture. However, Precision Agriculture is still only in the early stages of implementation in most developing countries. The strategic support from the public and private sectors is also in the conception stage. Lack of information, connectivity problems faced in remote areas and lack of financial support are hurdles in the path of Precision Agriculture. Successful adoption of PA comprises of three phases including exploration, analysis and execution. While exploration and analysis are way ahead execution is steadily catching-up. Precision agriculture addresses both economic and environmental issues that surround agriculture production today. Coordination between famers and both the MNC's and the government is gaining momentum. However, concerns about cost-effectiveness and the most effective ways to use the technological tools we now possess, still remains a work-in-progress. In the light of tomorrow's expected need and today's urgent requirement, PA needs to become the only choice and not a choice in the field of agriculture. [4]

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