Precision Agriculture for Small Farm Holders

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Abstract. Precision Agriculture is a data-based decision making farming process taking in-field variability into consideration. It uses multiple advance tools and technologies like GPS, GIS, VRT and provides substantial value in terms of minimizing input and maximizing profit to farmers in regions like Canada, North America who have larger land holding capacity. Precision agriculture technologies require significant investment in terms of capital which is most of the time not feasible for farmers with small farm holding capacity especially in regions like India which is very cost sensitive market.

In this paper, we will glance at various enablers for Precision Farming like environmental / weather impact, and world population etc. followed by various technologies used in Precision Agriculture along with current trends. We will also cover evolution of agriculture industry over period in India along with current Precision Farming trends for small farm holders. We will review aspects like complexity, affordability, technology integration, ease of use etc. and how these may affect the Precision Farming adaption.

We will also see some specific case studies and product where early precision farming solution are being used and its scale. We will conclude paper with our recommendation on overcoming these challenges.

Keywords. *Affordability, Indian Farming, Precision Farming, Technology Integration*

Introduction

Ancient farming practices started with horses and plows. Later power of horses is replaced with horsepower machines. Also horsepower is not only limited to in- farm machines but also distributed over various computing devices like Cloud. Various cutting edge technologies used in Precision Farming are playing significant role in helping farming operations to reach to next high every year. If we look past 20 years of data. According to USDA [10] crop yield for corn in 1987 was around 110 bu/acrs whereas recent 2017 data shows 170 bu/acr. Similarly, for rice 5500 lb/acr in 1987 vs 7504 lb/acrs in 2017.
This unparalleled growth in farming is mostly witnessed in countries like United States, Germany in others where farm holding size is comparatively larger. But for regions like India, adoption of precision farming trends is slower. Apart from small farm holding capacity, there are other multiple reasons for this like ease of operation, availability of resources, cost associated with technology usage, risk appetite etc. In this paper, we will cover various aspects of precision farming in relation with farming cycle and how those are being adopted for Indian farming.

What is Precision Farming

The simple definition of precision farming is to use accurate farming resources at right time and in required quantity to get more and more yield from same size farm and to maintain natural fertility of soil. In order to do this, we have to use latest **Technology** for which we need lot of **Data** and **Computation Power**. Precision farming is based upon several separate technologies which together helps farmer to take site specific decisions so that variability can be handled at sub field level to best utilize resources and to minimize environment impact. As shown in Figure 1, farmer can decide possible application rate for fertilizers and nutrients based upon historical yield data. He can also control his operations for special areas like water reservoirs using GPS operated vehicles.

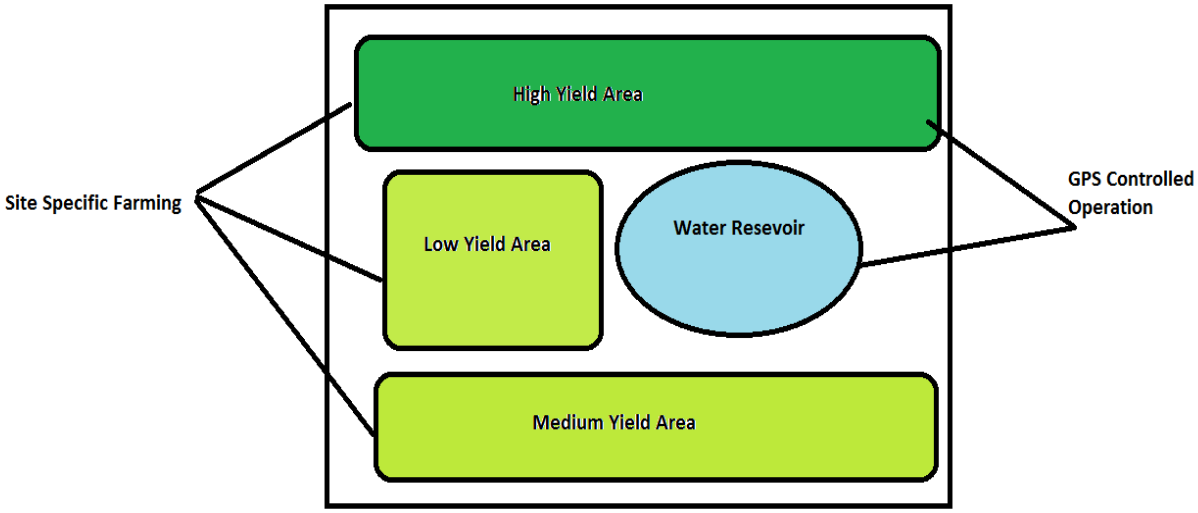

Figure 1: Precision Farming Concept

Advantages of Precision Farming

- Primary advantage of precision farming technologies is to achieve more yield with less input cost.
- With precision farming, different critical attributes of farm or soil can be recorded using different sensing techniques and GPS technology which later can be converted into site specific prescriptions.
- This helps farmers in taking right decision for the farm at right time and also save on input cost.
- Reduced environmental impact with minimal usage of chemicals and fertilizers.

Precision Farming Process

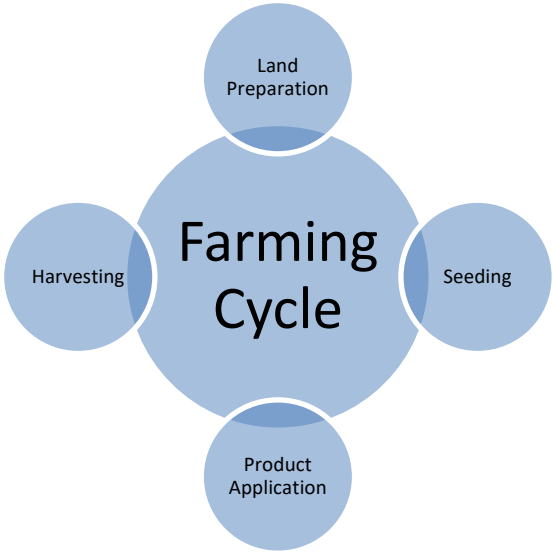

Figure 2: Farming Cycle

Figure 2 represents typical farming cycle. Precision farming techniques are applied at each stage of this cycle.

Land Preparation

Land preparation is first step in overall farming cycle. It also helps in destroying weeds mechanically and loosening soil using tillage operations. With precision farming, a new concept of variable depth tillage has evolved in which depth of tillage is controller according to local soil conditions in order to preserve natural soil structure. [2] This can be performed in both offline and online mode.

In offline mode, different soil characteristics like soil moisture, air contents etc. are measured using remote sensing, manual scouting method or sending soil samples to laboratory. Those inputs are fed to computer based software to map these characteristics against GPS location. These maps are later fed to another algorithms to generate prescription data for site specific tillage depth which are further used on tillage machine which is pulled behind by tractor with GPS installed.

In online mode, same soil characteristics are calculated at run time using sensors installed on tillage or tractor and those are fed to run time algorithms to calculate site specific tillage depth. Maps generated in land preparation can be further used to maintain historical data of soil health and also to take different decisions related to crops. With this, firm seed bed can be created for upcoming seeding operation.

Seeding

Overall farm yield depends upon two factors which shall be handled accurately while seeding operation. Seeds shall be sown at **accurate depth**. If those are too deep, then it will not receive fertilizers from outside world and if those are just on surface, those will impacted with surrounding environment. Also seeds shall be put at **accurate distance** from each other. If those are planted very close to each other, they won't get enough natural resources like sunlight, water and if they are planted far from each other, lot of land would be wasted. Both of these scenarios affects plant growth.

Historically seeding and planting is done manually by hand which involved lot of errors since accuracy is mostly depending on skill of workers and also synchronization between them. With precision farming, seeding operation is done using seeding equipment which can plant seeds at accurate depth and distance. Those equipment would also be fed with soil health data captured during land preparation with which depth and distance between seeds can be adjusted at run time to increase yield and also reduce input cost.

Product Application

Product application is most important phase in farming since this needs to be done more than once depending upon growth of plants and lot of input cost in terms of fertilizers, nutrients is also associated with this. Traditional farmers perform uniform broadcast or band spraying of herbicides or nutrient applicants to get rid of weeds. This has severe impact on environment since chemical are also sprayed in non-weed area.

So with precision farming, site specific product application is performed using Variable Rate Technology (VRT) and GPS. Data gathered during land preparation along with historical yield data is useful for identifying quantity and frequency of chemicals and pesticides required for specific part of farm. That data is fed to computer software to create prescription. VRT helps farmers to use nutrients and chemicals in an efficient way with correct proportion as per crop needs at a given crop site. VRT has potential to improve specific crop quality for example to increase certain protein content in wheat for bakery flour. VRT can be achieved either map based or sensor based. Maps based VRT adjust application rate based upon prescription map. Map based VRT also require precise positioning system. Sensor based VRT does not require map or positioning system. Sensors (either mounted on vehicle or in field) measures soil and crop properties at run time and required application rate is calculated as per sensed data.

Harvesting

For the farmer, harvesting is a critical point in time. Timing of harvesting plays significant role in overall productivity of farm output. Still for most of the specialty crops, harvesting is done manually where efficiency of harvesting mostly depends on again skills of workers. If they harvest under prepared crop it will lose market value and if well prepared crop is not harvested on time, it will be wasted in farm.

In recent area, few farmers are using combine harvesters which automates harvesting operation for some crops. They are becoming more and more useful as harvesting window is getting smaller. Also harvesting contribute to one of the major precision agriculture input called yield map. Those maps goes as input to VRT for precision application and nutrients requirements for site specific crop is calculated. Calculated yield can be incorrect due to loss in harvesting process. Precision harvesting will help in reducing those losses by advanced yield sensors or automating combine settings based upon real time sensors from field

Farming System in India

As per report from World Bank, agriculture and other industries made up more than 17% of India's GDP. Agriculture is also employer for more than 50% population in India. In spite of that, contribution in both GDP and employment from agriculture is decreasing year over year. Also as more populations is moving towards urban towns, getting farm labor is becoming difficult which is impacting overall yield.

Average farm holding capacity in India is less than 4 hectares and which is reducing year over year due to reasons like urbanization, construction of roads, fly overs, dams etc.

Due to all these reasons farmers have slowly started adapting some precision farming technologies in India. Following are some examples for the same.

Water irrigation

Indian farming cycle is still heavily dependent on monsoon rain for farm irrigation. Frequent droughts in recent years have affected crops, irrigation system, soil characteristic etc. In some part of India, lack of monsoon results in poor farm yield due to limited irrigation. India receives 75% of overall rainfall during monsoon from June – September timeframe. This rain needs to be restored to be used for rest of the year. Also unpredicted behavior of monsoon impacts overall farming process.

Due to this, ground water is being used heavily for irrigation in most of the states in India. This has started creating scarcity for ground water as that is not being utilized efficiently. Most of the farmers deliver ground water to farm by flooding them through open channels. With these methods, ground water level is going further deep. As per 2017 report from Indian Ministry of water resources, average ground water level has reached to 7-10 mbgl (meters below ground level) [3]

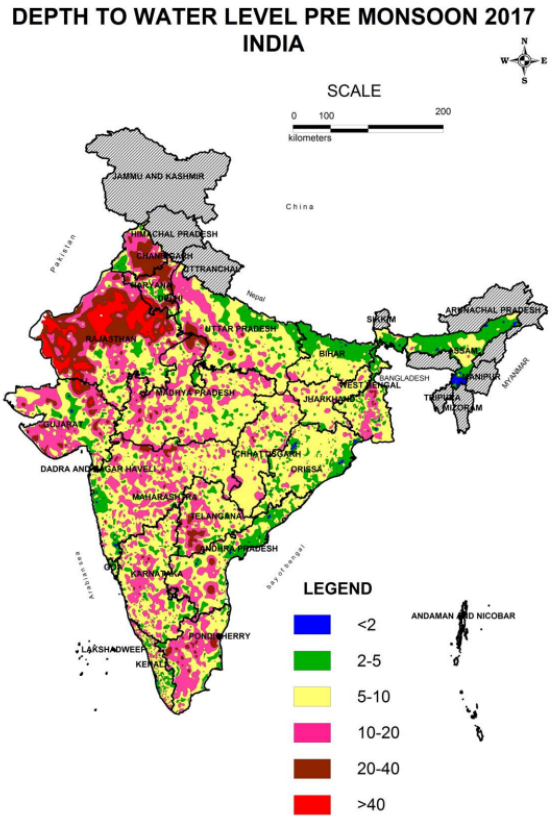

Figure 3: Ground Water Level in India (Source [3])

Due to all these reasons, focus towards micro irrigation has increased in India during last decade. Pradhan Mantri Krishi Sinchan Yojana [5] which was initiated in 2015 to cover more and more acres under various drip irrigation and sprinkler irrigation system with which crops are provided with adequate and required quantity of water. This has resulted in both increase in crop yield and saving of water.

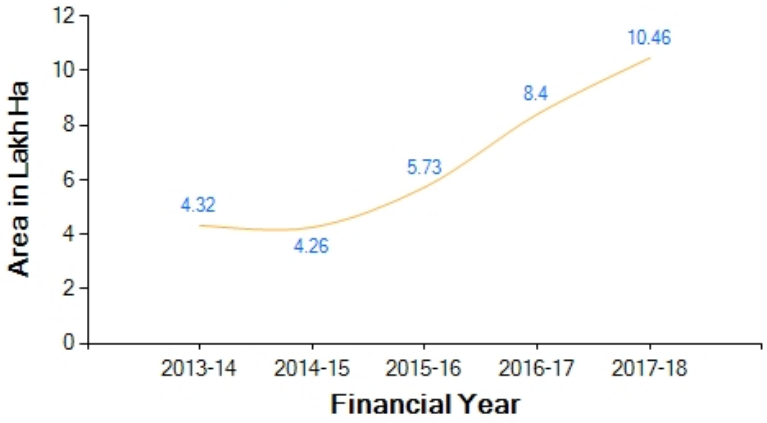

Figure 4: Area added under micro irrigation (Source [5])

Few states in India are taking further steps with lift irrigation in which water is stored at some common chamber at high point and then supplied to various farms with proper and suitable distribution system.

Krishi Tarang

With small farm holding and distributed ownership of farm, types of crops could vary a lot even in same region. Due to that needs of each farmer is different in terms of support required. Also farmers are not familiar with latest technologies like world web to resolve their own queries. Since lot of farmers are at least connected with voice based cellular phones, few state governments have launched services like Krishi Tarang where farmers can get answers to their specific query or specific need with voice call.

With this service, they are also getting more information like precise weather prediction which is helping them to take farm specific decisions specially harvesting as rain during harvest season can impact farm income. This system is also providing customized input recommendation to farmer by studying different characteristics of soil to decide type and quantity of fertilizer and pesticides.

Soil Health Management

Soil Health Management is one of the important factor while taking any farming decision. Government of India has initiated soil health management program under National Mission for Sustainable Agriculture (NMSA) [1]. As a part of this program, multiple soil testing labs are being built where farmer can perform soil testing for different parameters. Farmers are also provided with Soil Health Cards which provides information to farmers on soil nutrient status of their soil and recommendation on appropriate dosage of nutrients to be applied for improving soil health and its fertility. This soil health cards can later mapped to their GPS location and overall soil health maps for particular region can be created.

With this initiative, government is promoting judicious use of chemical / bio fertilizers to maintain soil health and its productivity.

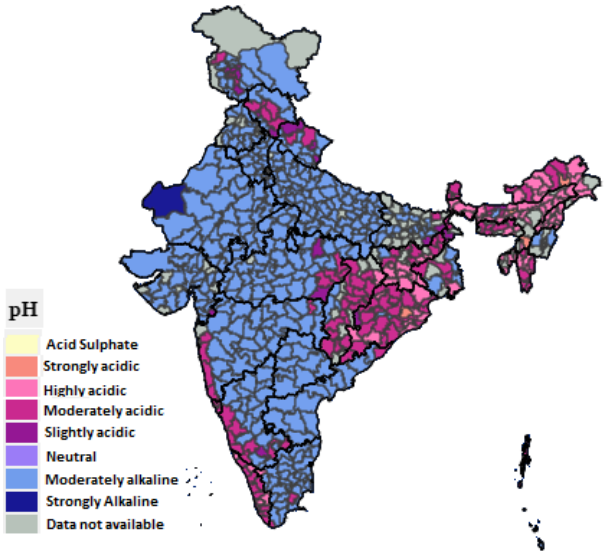

Figure 5: Soil PH Level Chart (Source [7])

Integrated Pest Management

Pest attacks can destroy crops in no time and with suitable weather conditions in India, those are pretty much common. Lack of information related to pest appearance and communication mechanism to alert others resulted in huge yield losses in past. On the other hand heavy usage of pesticides have adverse impact on quality of food and human life.

To resolve this issue, Government of India has established multiple Central Integrated Pest Management Centers (CIPMC) to conduct pest / disease monitoring system. These centers are also conducting trainings for farmers through Farmers Field Schools where farmers gets information about scouting process, mechanical process of pest control and how to use pesticides judiciously. [1] [6]

Farm Mechanization

Farm mechanization is essential input in order to get more farm output with less input. And as more and more people are moving away from farming business, importance of mechanization is increased. Over 80% of farms in India are owned by small individuals or group who can't afford purchasing costly equipment.

To promote mechanization for small farmers, concept of Custom Hiring Centers (CHC) is being developed. Through CHC, hi-tech farming equipment like planters, weed killers, are made available for small farmers. These centers are also creating awareness among farmers related to mechanization through various demonstrations. [1]

Recommended model for Precision Farming

Looking at current trends in precision faming in India, we recommend following model for precision farming adaption with addition of few new stake holders.

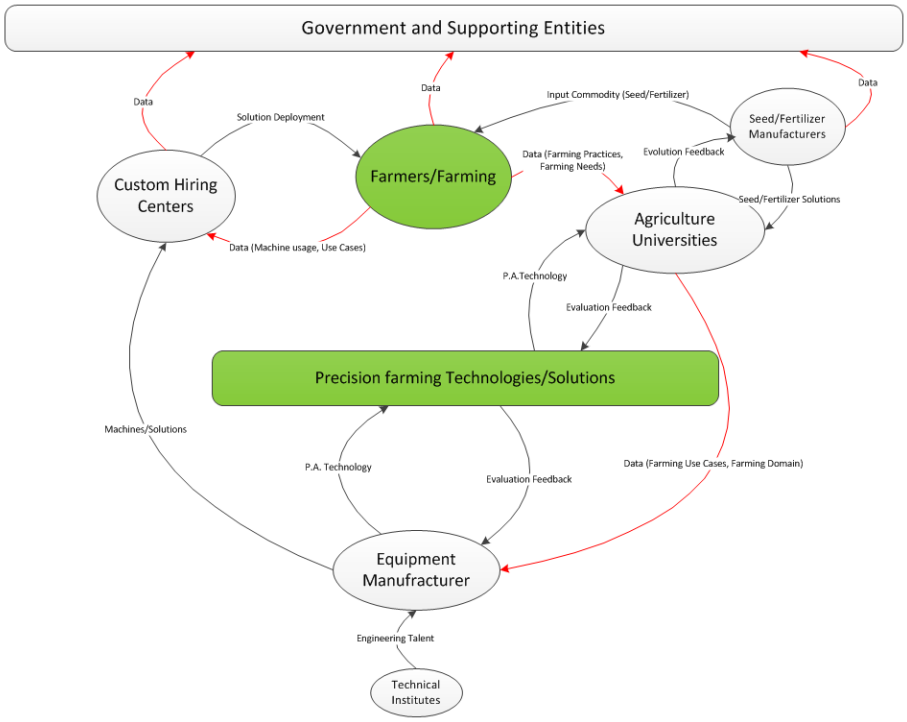

Figure 6: Precision Farming Model

Above model represent how precision farming technology can be matured and tuned to provide better solutions to Indian farmers. Along with agricultural equipment manufacturers (Ag OEMs) we believe agriculture universities and customer hiring center will play critical role in evaluation, adaption and deployment of precision agriculture.

Ag universities can play a role where they can evaluate and working closely with seed/fertilizer/pesticide manufacturer to develop better input commodities and provide or recommend standardize the application rates for it whereas they also collaborate Ag OEMs to build solution to put them in ground. One such example would be to develop special fertilizer to fulfill nutrient need of specific soil or special tool for performing seeding application in particular manner Majority student population in Ag universities is from farming background or active farmers and many of them have criteria to be a farmer to get into university. So, this would give an advantage where students are exposed to PA technologies and commodity during development and make it easier when actual solution comes to market.

On the other hand, Ag OEMs can utilize the custom hiring centers to deploy, the solutions developed to fulfil farmer needs with cost effective way. Many custom hiring centers are subsidies by government to improve farming.

Apart from providing subsides or enabling farmer to make use PA technologies we believe solutions there is shall be clear data protection and privacy policy in place for sustenance and adaption of precision agriculture since precision farming heavily dependent of data and decisions made on that data.

Conclusion and Summary

It is evident from the various research and reports that global food demand would increase at least by 50% by 2050 which needs to be fulfilled with existing or rather reducing size of farmland. Also, we have to be very lean while utilizing the natural resources while doing so. Workd populaton index shows that as India is moving towards the largest population country, precision farming will be the right direction to support local as well global food needs. Majority of Indian farm in most states are extremely dependent on government and subsides. To make precision farming successful agricultural universities and farming equipment manufactures would have to play a key role by evaluating the technology and providing cost effective solutions and we see the need to pilot the adapotion model proposed in the paper. This model can also be simulated and validated to see the feasibility.

We also see a large need of scientific approach and help needed to optimizing farming process, precisely measuring parameters yield, fertilizer/Seed/Pesticide utilization, electronically recording this data for analysis and recommending products to improve the farming in large in Asian countries like India.

To get to successful implementation of precision farming in India we think three major challenges

- Education and awareness about precision farming and the technology
- Cost effective solutions and a better farming model ecosystem considering average farm land size
- Clear definition and policy for data security and privacy

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