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State of the Art and Gap Analysis of Precision Agriculture:
A Case Study of Indian Farmers

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ABSTRACT

Precision Agriculture (PA) is now becoming the base for rapid development of a nation. So many technologies are used in precision agriculture such as Global Positioning System (GPS), Artificial Intelligence (AI), Sensor Network and Geographical Information System (GIS). This manuscript per the authors will review all the factors that influence the precision agriculture. This article describes the major endeavors in the past of precision agriculture. The noble intention behind this literature review and analogy is to figure out the gap between theoretical research and actual needs of farmers. In order to find out the actual requirements manuscripts per the authors have conducted a questionnaire in Rajasthan State of India. This gap analysis would be helpful for researchers to design an effective and efficient decision support system for irrigation and fertilization can be designed for Indian farmers.

KEYWORDS

AI, GIS, GPS, Image Processing, Indian Agriculture System, Indian Farmers, IOT, Precision Agriculture, Rajasthan Farmers, Smart Agriculture, Smart Farming, Survey Study of Farmers

1. INTRODUCTION

India is the land of agriculture, where most of the income depends upon agriculture. According to the survey of India Brand Equity Foundation, 58% of total population has agriculture as primary source of livelihood and INR 17.67 Trillion is estimated as contribution in Total GDP of Indian economy. Integration of computer science and information technology can play a magnificent role in improving the quality of agriculture process. This integration is known as Precision Agriculture (McBratney, Ancev, & Bouma, 2005). Large number of technologies such as Image Processing, Artificial Intelligence, Geographical Information System, Sensor Network and Global Positioning System are included in Precision Agriculture. The first objective of the paper is to review of research work done in the field of precision agriculture, second objective is to compare the research work done in overseas with India, third objective is to analysis the gap between research work published and real implementation of PA by Indian farmers. Followed by Introduction this paper is comprises with component of agriculture, review of past endeavors, broach from literature survey, analysis of gap using questionnaire, conclusion and future work.

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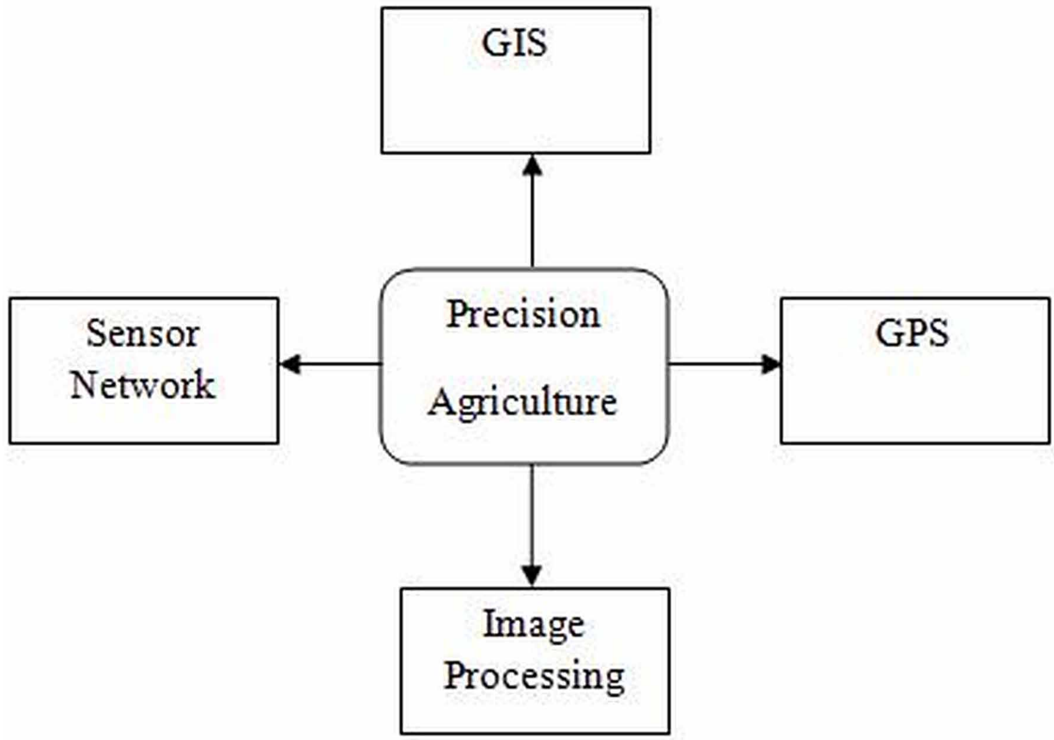
Figure 1. Components of precision agriculture

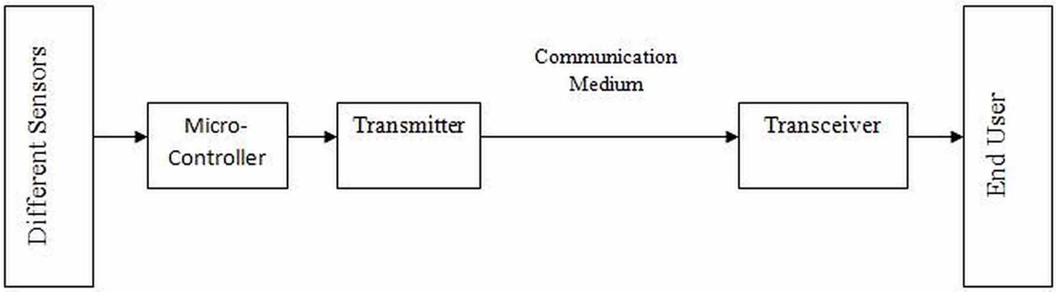


2. COMPONENTS OF PRECISION AGRICULTURE

The Home Grown Cereals Authority (HGCA) define precision farming as being 'management of farm practices that uses computers, satellite positioning systems and remote sensing devices to provide information on which enhanced decisions can be made.' United States Department of Agriculture also defines as agriculture 'as needed' farming and define it as 'a management system that is information and technology based, is site specific and uses one or more of the following sources of data: soils, crops, nutrients, pests, moisture or yield, for optimum profitability, sustainability and protection of the environment'. Components of Agriculture are GIS, Satellite Navigation System, Wireless Sensor and Image Processing.

- Geographical Information System (Rigaux, Scholl, & Voisard, 2002) is a set of computer programs that is used to retrieve, store, manage and analyze spatial and geographical data. Geographical Information System is useful in many fields like Crime Mapping, Hydrology, Water Management, and of course in precision agriculture. There are many open-sources, free and licensed software available for creating maps like ArcGIS, GRASS and OpenStreet, etc. Field mapping, detection of soil erosion and estimation of Evapotranspiration are the fields of precision agriculture where Geographical Information System is used.
- Satellite Navigation Systems provide spatial positioning of a geo-location using satellite. GPS (Global Positing System) is the implementation of navigation system. GPS ("Global Position System, 2018) is the network of satellites that makes available a geographical location to a GPS server with the help of navigation devices. Place location, vehicle tracking, and aviation are the

Figure 2. Scenario of WSN in agriculture



major applications of GPS. In precision agriculture, GPS plays a vital role in tractor guiding, yield mapping and crop monitoring.

- Wireless Sensor Network (Akyildiz, Su, Sankarasubramaniam, & Cayirci, 2002) is an emerging field of research. Wireless Sensor Network is a network of physically scattered sensing nodes which are self-organized but decentralized in nature. Wireless Sensor Networks are used in security, health-care monitoring, fire detection and many other areas. In agriculture, Wireless Sensor Networks used in field monitoring and automated irrigation systems. WSN in Agriculture is shown in below Figure Number 2:

- Image Processing (Baxes & Gregory, 2002) is mainly concerned with the procedure of capturing, enhancing, extracting, compressing and analyzing the digital image. Imaging processing is very useful in designing, medical imaging and pattern recognition. Yet, image processing is used in Geographical Information System, but it has separate applications like identification of Nitrogen, Potassium and Phosphorus (NPK) component of a crop using color of leaf.

3. REVIEW OF PAST ENDEAVORS

The main objective of this paper is to review the efforts made by researchers in this field. Authors are mentioning from the year 2000.

In the year 2000, (Bell, 2000) from Stanford University proposed CPD-GPS based automatic tractor guidance system. CPD-GPS technology was used because it collects the data with carrier phase receiver. These signals are of higher frequency that results of sub-meter accuracy. The future work was of this research is to use real time kinematic GPS. Another authors (Stoll & Kutzbach, 2000) proposed an idea of RTK-GPS (Real Time Kinematic-GPS) based forage harvester. An automatic Steering system was embedded with the harvester, they also developed path planner for the swath harvesting operation. In this technology, they used RTK-GPS because this sensor is independent of field operations and weather. For developing the path planner, a chain of straight-line elements was used. Future work of this research is to develop path planner for more shapes like curves.

In 2001, (Pradhan, 2001) used Geographical Information System and Remote Sensing technology to estimate crop area. The main goal of this work was to develop an information system which would support the decision for selection area of major crops in Hamadan in Iran. This work was carried out with the help of area frame sampling and satellite images which were classified in Geographical Information System software. Another authors (Ray & Dadhwal, 2001) [8] carried out another great use of Geographical Information System and Remote Sensing. They estimated seasonal crop evapotranspiration by estimating Crop Coefficient and Reference Crop Evapotranspiration. As technical point, they used RS data of wide field sensor and on-board IRS-IC satellite. The study was done in Kheda District of Gujrat, India on Tobacco crop. Developing an irrigation scheduler was the described future work.

In the year 2002, not only Geographical Information System but fuzzy sets were also used for data analysis. The work was done by (Feoli, Vuerich, & Zerihun, 2002) the goals of their work was to evaluate the relationship between environmental and socio-economic variables in rural areas and to compute effect of human pressure on natural resources and vice versa. The study was done in the Tigray region of Ethopia. Geographical Information System was used in integration of data generated through fieldwork and from different maps. A large number of maps were used like Geomorphological, Altitude Map, Land-Use Map and NDVI etc.

Artificial Intelligence was used to assists Image Processing. This work was done by (Aitkenhead, Dalgetty, Mullins, McDonald, & Strachan, 2003) the objective of this paper was to develop a procedure to distinguish difference between crops and weed. This procedure was developed in three stages i.e. image capturing, image processing and Image interpretation. The experiment was done with carrot and two weed species Ryegrass and Fat Hen. Pentium III PC was used for processing 24 bit-1279 * 959 images. A six-step algorithm was adopted to identify different plants by providing images of vegetation. Now, the discrimination was done with two methods- Plant Morphology and Neural Network Method. They concluded that Plant Morphology method produced prominent results when plants were isolated from one another, which was practically not feasible. Neural network method was more flexible and required less human intervention. In another research, great work was done by (Seelan, Laguette, Casady, & Seielstad, 2003) they developed UMAC Model for unique learning community approach with the help of Remote Sensing technology. It was divided into four groups, resulting in development of technology, which generated right geospatial product, and to make available in near real time, transfer of vital knowledge using organized training programs.

Soil is the major factor for yield of any crop. Many things affect the health of soil. For time saving and to get accurate results several On-the-Go sensors are available which are described by (Adamchuk, Hummel, Morgan, & Upadhyayain, 2004). They describe four types of sensors i.e. Electrical and Electromagnetic Sensor, Optical and Radiometric sensor, Mechanical and Acoustic sensor and last electrochemical sensors. (Perini & Susi, 2004) designed a decision Support System for integrated production in Agriculture. This Decision Support System was based on *Tropos* which has 5 stages of development. The first stage is Early Requirement Analysis which focuses on the understanding of problem. The second stage is Late Requirement Analysis which on the system to be introduced. The third stage is Architectural Design which is made up of various subsystems known as Actors, which has unique tasks to perform. The third stage is Detail Design which is designed for making a Skelton at the micro level. The last stage is implementation Activity which performs the actual coding part of Decision Support System.

In 2005, (Panigrahy, Manjunath, & Ray, 2005) used Remote Sensing and Geographical Information System to derive indices for assessment of sustainability and efficiency of the system. Previously these indices were collected through survey methods, but they used Geographical Information System, which resulted in time saving. Radarast Synthetic Aperture Radar & India Remote Sensing Satellite was used to derive crop rotation, crop calendar and crop pattern. The study was done in West Bengal-India on Rice, Mustard, Potato and Jute etc.

Information and Communication Technology is very helpful in Agriculture, (Laliwala, Sorathia, & Chaudhary, 2006) designed event-driven based service-oriented Agriculture Information System in 2006. It was multi-layer tier architecture useful for delivering information to end-user for our farmer. Event-Based Service Oriented Information System is shown in Figure Number 3.

As described in figure 2, this architecture has 5 layers which are described as

1. Source of Information: This is information provider layer such as weather data provider, agriculture department and market etc.

Figure 3. Event-based service oriented information system

End-User	Rules Engine	Middle Server	Notification Generator	Source of Information

2. Notification Generator: This is Event & Notification Engine layer, which is responsible for handling events like any change in market price of a crop or any weather forecast.
3. Middle Server: This is Ontology Server Layer, designed especially for agriculture vocabularies and provides information about various services implemented in this Agriculture Information System.
4. Rules Engine: It is the heart of the system. It has a set of rules and constraints which are remarkable for end-user like farmer. When the notification generator notifies an event it suggests some guidelines to the user.
5. End-User: This is WS- Mobile Client Layer where the information is provided to the end-user through web service. This system is capable of delivering information to mobiles, PDAs and laptops.

The future work of this project was to use grid services in this system.

Water scarcity is the main problem that authors have been facing since long and a large amount of water is required for irrigation. (Ines, Honda, Gupta, Droogers, & Clemente, 2006) presented an approach that explores water management options required for irrigation. This work was carried out with the help of Remote Sensing simulation modeling and with the help of GA (Genetic Algorithms). They used data assimilation approach with the help of remote sensing and use SWAP model (Soil-Water-Atmosphere-Plant) for water management.

In 2007, COMMONSense Net Wireless Sensor Network based system was designed by (Panchard, Prabhakar, Hubaux, & Jamadagni, 2007) A Decision Support System helped farmers in highly variable conditions. It was a three-tier architecture model. The first layer was Wireless Sensor Networks, which was used to collect data from the field. Second, Crop Models (Simulators) were used to derive the logic, which was helpful for farmer based on inputs from the first layer. Third, Web based GUI was developed that pass the information to the farmer.

In 2008, ZigBee based Wireless Sensor Network was used to monitor the field. (Lin & Liu, 2008) proposed the architecture, which contained various Sensors, ZigBee Transmitter, and ZigBee Receiver & SOC Platform. Agriculture sensors such as temperature, soil moisture were attached with a circuit which provided input to ZigBee Transmitter via micro controller. At the other end, ZigBee Receiver would receive the data and transfer to a Micro-controller. In this system, System on Chip micro-processor is used that would resend the data to end-user via RJ-45 connector and end user could see the information on a webpage. (Yang & Li, 2007) developed a mobile application for information system for new varieties of Maze in China. This application internally had three modules. First, Information Support Module which was responsible for implementing information about varieties of Maze such as adding, deleting, modifying, cultivation habits and many more. It comprised of digital maps that implemented query based on region. Second was the Problem Diagnosis Module which was specially designed for disease diagnosis, lack of nutrition and cultivation management, it also offers cure and prevention measures. The third module was Business Management Module, which comprises of daily business management and investigation system. The fourth module was Upload and Download module, which was responsible for downloading information about various regions and centers.

Moving to year 2009, On-farm wireless sensors were used for agriculture system by (Pierce & Elliott, 2008). This system was used for real time monitoring and to control various operations of farm. There were two main objectives of this work, first was to develop a better Wireless Sensor Network that could replace Public Agriculture Weather System and second one was to design economic and real-time mobile system that could monitor frost protection equipment named as AgWeatherNet and AgFrostNet. The regional sensor network comprised of AWN200 data logger 900 MHz FHSS (Frequency-hopping spread spectrum) radio frequency. (Kim & Evans, 2009) in irrigation system again used wireless Sensor Network. They developed a Decision Support System comprising of in-filed Wireless Sensor Network implemented in sprinkle system using Bluetooth communication named as WISC. They also developed an algorithm for nozzle sequencing that reduced hydraulic pressure. Indeed, the main application of Wireless Sensor Network is to real time monitoring which authors have seen in the above literature. A lot of work has been done using this same technique, hence authors will not discuss these researches in this paper anymore.

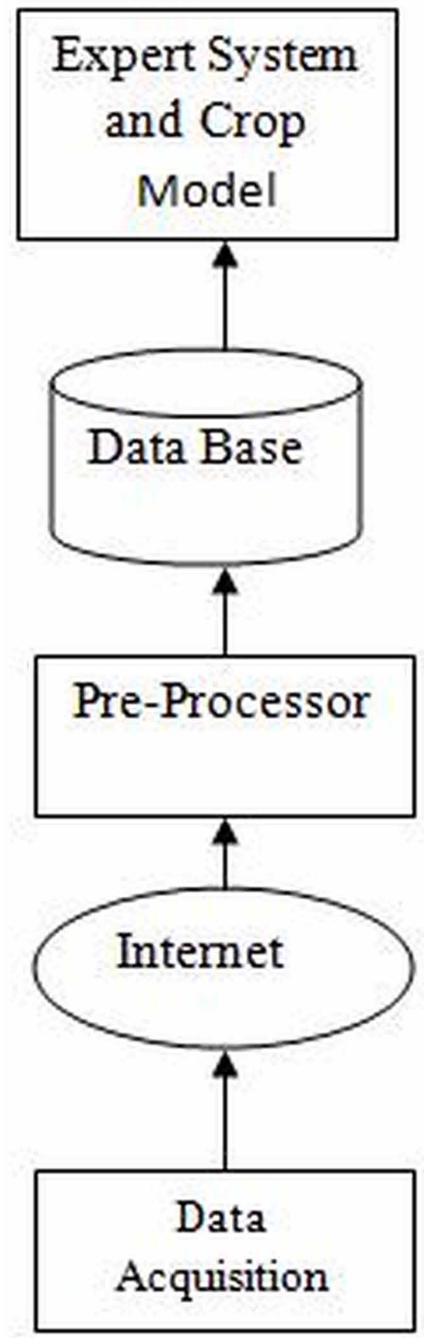
Till now authors discussed about field monitoring, irrigation decision support systems and information systems, but in this 2010 Expert System were developed by (Kalita, Sarma, & Choudhury, 2010) which was capable of diagnosing disease in crop of rice. This system was designed with the help of ESTA (Expert System for Text Animation). This expert system consisted of three modules. Module one was responsible for identifying the problem which was structured in nature and module identify as pattern. The second module was Knowledge Acquisition, which was the actually heart of the system. It comprised of information regarding of symptoms of disease and remedy for subsequent disease. Image database was also attached with this system for maintaining the efficiency of the system. Third module was Knowledge Representation, which was responsible representing the information in structured form. Further, in this year (Li, Qian, Yang, Sun, & Ji, 2010) designed a PDA (Personal Digital Assistant) for keeping the production record. This PDA was not only capable of keeping the production record but also capable of acting as a Decision Support System for traceability in cucumber using Geographical Information System. It was a *Windows* Operating System based PDA which was made of four layers. Layer 1 was operation System which provided facilities for memory storage and high-resolution display. Second Layer, the Software Support Layer was responsible for providing map management and data synchronization. The next layer was Model Layer, which facilitated the user as fertilizer decision support and early warning model, this layer was designed in C#. The last layer was Function Layer that provided facility keeping and decision-making facilities.

As authors move forward in chronological order, technology also changes. In 2011 (Yan-e, 2011) proposed Agriculture Management Information System, which was based on Internet of Things (IoT). IoT was the emerging topic of research at the time. This paper does not focus on a specific objective but elaborates overall parameters of precision agriculture. This design is multi-layered in nature. Layer 1 is Information Acquisition layer that is responsible for collecting information from various technical sources like GPS, Remote Sensing and various sensors. Layer 2 can be called as the Pre-Processor layer is responsible for converting raw information coming from layer 1 in use full information using GIS & Image analysis tools, information centers and data analysis tools. In the next layer, this information is saved into the corresponding databases. The upper most layer is Application Layer which is responsible for design of crop models, Decision Support System and Expert System. Precision agriculture with Internet of Things is shown in Figure Number 4.

In the following work, soft computing is used in agriculture. (Papageorgiou, Markinos, & Gemtos, 2011) designed a Decision Support System for predicting yield of cotton based on FCM (Fuzzy Cognitive Maps). FCM is a special part of AI, which is a graphical representation of knowledge about a system. FCM is a combination of cognitive mapping and fuzzy logic. In this FCM, different soil factors are considered for designing the proposed Decision Support System. The main soil factors are Nitrogen, Potassium, Phosphorous, soil texture, etc. These factors have 2, 3, 4, 5 and 7 fuzzy values.

In 2012, (Intaravanne, Sumriddetchkajorn, & Nukeaw, 2012) used camera of mobile phone as sensor for estimation of ripeness in banana. This was two-dimensional and spectral analysis-based

Figure 4. Precision agriculture with Internet of Things



model. The main concept behind this work was analyzing two spectral images using ultraviolet and white light illumination. The camera of mobile phone was embedded with a white light source and an ultra violet light source. This work was pixel-based work in which WLR (White Light Ratio) and

UVR (Ultra-violet) ratios are calculated using red and green values of that pixel. For identifying ripeness, threshold values are used using this formula:

$$RL\left(x,y\right)=\begin{cases}Immature, & WLR\left(x,y\right)\leq h\\ Ripe, & WLR\left(x,y\right)>h \quad and\ UVR\left(x,y\right)<k\\ Overripe, & WLR\left(x,y\right)>h \quad and\ UVR\left(x,y\right)\geq k\end{cases}$$

Where:
WLR is White light Ratio,
UVR is Ultra Violet Light Ratio
h and k are threshold values depend upon ripe stages on same day and the day before of white light and ultra violet spectrum.

A web-based Decision Support System named as CropScape was developed by (Han, Yang, Di, & Mueller, 2012) which helped farmers in disseminating and exploring cropland data products of US Conterminous. CropsScape offered online responsive maps, statistics of crop acreage, web based geo-processing such as on demand crop statistics and automatic data delivery. This system was divided in three layers i.e. Application Layer, Service Layer and Data Layer. The Application Layer deal with various geospatial based applications that incorporated with online service with local data. The Service Layer was responsible for make available geospatial data and its processing service with the help of Web Map Services, Web Feature Service and Web Coverage Services. The Data Layer was responsible for offering geospatial data, which was stored in database and in file. The data received by data layer was again sent back to the application layer for end-user.

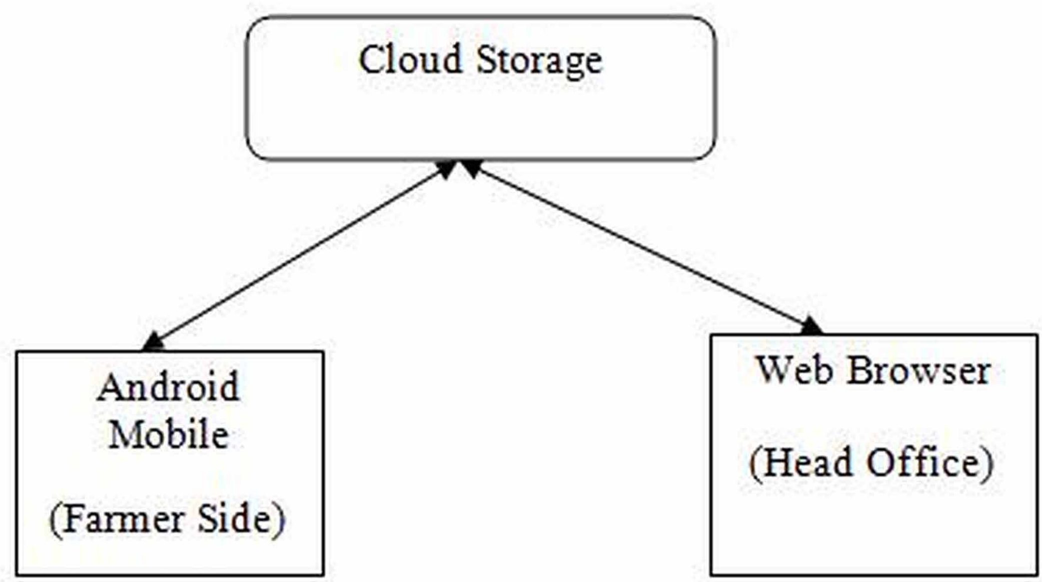
In 2013, (Kongsombut & Chaisricharoen, 2013) developed a smart phone based real time advisory system for orchids. It was model-driven cloud computing based model. It was android based application registered the user and notify the user using the push notification. The information about nursery orchid is also collected from smart phones. There were three types of databases were used in this system. First database was Member Database that registered a nursery orchid as member's profile and notified the member. The second database was Weather Database in which weather information was collected by Metrology Department like air temperature, air moisture and air humidity is stored in this database. The third database was Orchid Care Information which collected information from observation and experience of nurseryman and authentic and measurable research data.

Smart phone was again used by (Confalonieri, et al., 2013) for estimating the Leaf Area Index. Previous methods of estimating the Leaf Area Index were often time consuming and destructive. Indirect methods were also used to estimate the Leaf Area Index based on light transmissions, but they were expensive and had low portability use. A new sensor-based application was designed which implemented two methods APP-L and APP-G based on estimation of gap.

Another methodology for disease identification in the leaves using mobile phone mobile was done by (Prasad, Peddoju, & Ghosh, 2014). The basic features of this system were to identify the diseased patch and transfer the image to the server. Image segmentation was done by k- means clustering approach. The image captured from cell phone was converted into CIE (Comission Internationalede l'Eclairage). 5*5 average filter mask was applied to remove noise from the image. The clustering algorithm was applied to identify the AOI (Area of Image). First cluster was background, second cluster was green portion and the third was non-green portion that diseased area. The AOI that was diseased area was cropped out and sent to the server located at plant pathology laboratory via wireless communication technique. For reducing power consumption in the only segmentation and cropping was done on mobile and remaining operations were performed at the server end.

Moving to the next paper, (Murakami, 2014) developed iFarm a web and cloud-based farm management system. With this technology, a farmer could refer his work plan, feed field data into

Figure 5. Overview of iFrame system



the cloud storage and send this data to the head office. Person at head office could see this data using web browser. He was able estimate the cost and plan better for future. iFrame system is shown in Figure Number 5.

At the head office, the server has some components such as field manager, out-side field manager, task manager and cost manager. For developing this system MySQL, Apache and Ruby on Rails technologies were used. The future work of this was to use Big Data for cultivation management.

(Lin, Wen, Wu, Lin, & Wang, 2014) developed a smart irrigation system. This smart irrigation system was an independent AI and IoT based independent system that could automatically irrigate the farms. There were three phases in the system. The first phase was Input Phase where input could be given through mobile phone and different sensors. The second phase was Processing phase which contained server, database and sprinkle-based irrigation controller. The third phase is output phase that results can be sent to a mobile or can be implemented to a valve. All the information could be kept on cloud storage. The beauty of this system was that farmer could control the irrigation (set off and on) using mobile phones while away from the farm.

In the year 2015, (Giusti & Marsili-Libelli, 2015) designed a fuzzy based Decision Support System for irrigation and water conservation. In this work was an enhanced version of IRRINET model. Fuzzy toolbox of MATLAB was used to develop this model. The main objective of this enhanced model was to aware about whether irrigation is needed and its amount by different set of rules. This model was based on fuzzy inference system which combined fuzzy based soil moisture model. This soil moisture model was designed with total water required to the crop, growing degree-days and crop evapotranspiration. Testing was done on corn, potato and kiwi. In the same year, (Bartlett, Andales, Arabi, & Bauder, 2015) developed an application for irrigation scheduler. It was evapotranspiration and cloud-based application named as WISE (Water Irrigation Scheduling Efficient Application). The main use of this application was to view weather management, soil moisture deficit and was capable of calculating amount of irrigation. Continue with the same year, another smart phone-based application was developed by (Migliaccio, Morgan, et al., 2015) using FAO crop water need (Food and Agriculture Organization, United States). This application was mainly designed for Avocado, Cotton etc. This application had a unique feature that it added on input from clientele groups. However, it is still in the testing phase. Fiber optic NPK Sensor was developed by (Ramane, Patil, & Shaligram, 2015), fiber optic based colour sensor has been developed to determine N, P, and K values in the soil sample. Here colorimetric measurement of aqueous solution of soil has been carried out. The colour sensor is based on the principle of absorption of colour by solution. It helps in determining the N, P, K amounts as high, medium, low, or none. The sensor probe along with proper signal conditioning circuits is built to detect the deficient component of the soil.

Continued in the same year, (Gaikwad & Galande, 2015) presented integration of NPK sensor with wireless sensor network. This experiment is very useful for agriculture scientist and farmers. Various environmental issues like temperature, nitrogen, potassium and air humidity etc. that affect the yield of crop can be monitored by this system. All sensor nodes are wirelessly connected (using WSN802G module) with center server where the data is collected, stored, interpreted and displayed to the desired output system.

Last but not least in the year 2016, Arduino based irrigation system was developed by (Arvindan & Keerthika, 2016). The soil moisture sensor was attached irrigation controller. Irrigation controller was again connected with micro-controller (Arduino–Uno), which was also connected with Bluetooth chip (HC-05 module). This module was responsible for sending and receiving data to/from android phones. The user of android mobile phones was able to control the irrigation system by switching ON/OFF feature on his mobile phone application without being present at the irrigation system.

4. BROACH FROM LITERATURE SURVEY

In the above section, authors have surveyed research papers related with precision agriculture. Authors have studied how these technologies make easy and efficient the process of Agriculture. In this section, authors are summarizing the work done in the field of precision agriculture in the tabular format (Table 1).

India is the country of villages, where agriculture is the prime source of livelihood. Here authors are depicting the ratio of the work in precision agriculture in India and overseas. Work done in precision agriculture in Overseas and India is shown in Figure Number 6.

5. ANALYSIS OF GAP

In the above section, it has seen the development of technology of Precision Agriculture in the past decade. The question that arises here is that does this evolution of technology really affect the farmers? Do these technologies work at the ground level and useful for farmers? To know the answer, one should be aware about the actual need of farmers then it can be answered that this literature is actually beneficial or not. In order to aware the requirements of farmers, conducted questionnaire-based survey of the farmers.

5.1. Area of Study & Target Population

India is a large county with 3.287 million km^2 area. In order to conduct the survey, authors have chosen the Rajasthan state of India (27.0238° N, 74.2179°*E).* Rajasthan is the largest state of India with the area of 342, 239 Square Meter and contribute 10% to the total geographical area of the country. It is located in northwestern part of India. This state has a mix culture, climate condition and agriculture practices of North and West part of India. The major crops of Rajasthan are mustard, barley, wheat, rice, millets etc. These crops are also yielded in various parts of the country. Around 23.3% of the population is cultivator, which is also our target population.

Table 1. Summary of work done in precision agriculture

S.N.	Name of Author(s)	Year	Work done	Technology used	Future Scope
1	Thomos Bell	2000	Automatic Tractor Guidance	GPS	
2	Albert Stoll & Heinz Dieter Kutzbach	2000	Guidance of Forage Harvester	RTK-GPS	
3	Sunil Pradhan	2001	Crop Area Estimation	Remote Sensing and GIS	
4	S.S. Ray and V.K. Dadhwal	2001	Estimation of crop evapotranspiration of irrigation command area	Remote Sensing and GIS	Developing of irrigation scheduler
5	Enrico Feolia, Laura Gallizia Vuerich, & Woldu Zerihun	2002	Evaluation of environmental degradation	Remote Sensing and GIS	
6	M.J. Aitkenhead, I.A. Dalgetty, C.E. Mullins, A.J.S. McDonald & N.J.C. Strachan	2003	Weed and crop discrimination	Image analysis and Artificial intelligence	
7	Santhosh K. Seelan, Soizik Laguette, Grant M Casady, & George A Seielstad	2003	Agriculture Information System	GIS and Remote Sensing	
8	V.I. Adamchuk, J.WHummel, M.T Morgan and S.K Upadhyaya	2004	Review of Sensors for precision agriculture	On the Go Sensor	
9	Anna Perini and Angelo Susi	2004	Decision support system for integrated production in agriculture	GIS and Software Engineering	Development of Software Agent for with reference to a critical pest of apple
10	S. Panigrahy, K R Manjunath, and S. S. Ray	2005	Deriving cropping system performance indices	GIS and Remote Sensing	
11	Zakir Laliwala, Amee Desai, & Sanjay Chaudhary	2006	Agricultural Recommendation System	Software Engineering (JAVA)	Automation in the process discovery, Integration of Grid Services and Web Services to harness the power of grid
12	Amor V.M. Ines, Kiyoshi Honda, Ashim Das Gupta, Peter Droogers, & Roberto S. Clemente	2006	Explore water management options in irrigated agriculture	Remote Sensing and Genetics Algorithm	
13	Jacques Panchard, Prabhakar T. V., Jean-Pierre Hubaux, & H. S. Jamadagni	2007	Resource-Poor Agriculture in the Semiarid Areas of Developing Countries	Wireless Sensor Network	Enhancement of the system is to modify the crop models that currently assess soil moisture indirectly from rainfall and soil characteristics
14	Jzau-Sheng Lin and Chun-Zu Liu	2008	Field Monitoring System	Wireless Sensor Network, ZigBee Technology	

continued on following page

Table 1. Continued

S.N.	Name of Author(s)	Year	Work done	Technology used	Future Scope
15	Yang, Feng and Shaoming Li	2008	Information support System For new Maize variety	Expert System and Smart-Phone	
16	F.J. Pierce and T.V. Elliott	2008	Field Monitoring	Wireless Sensor Network and JAVA	
17	Y. Kim and R.G. Evans	2009	Sprinkler Irrigation Controller	Sensor Network with Bluetooth, GPS and Microsoft Visual C++.Net	
18	Hemanta Kalita, Shikhar Kr. Sarma, & Ridip Dev Choudhury	2010	Diagnosis of Diseases in Rice Plant	Expert System shell ESTA	
19	Jzau-Sheng Lin and Chun-Zu Liu	2010	DSS for traceability in cucumber production	Design of PDA, with .Net Platform	
20	Duan Yan-e	2011	Intelligent Agriculture Management Information System	Internet of Things	
21	E.I. Papageorgiou, A.T. Markinos, & T.A. Gemtos	2011	Predicting yield in cotton crop production	Fuzzy cognitive map, FCM tool	
22	Yuttana Intaravanne, Sarun Sumriddetchkajorn, & Jiti Nukeaw	2012	Banana ripeness estimation	Cell phone with Spectral Analysis	
23	Weiguo Han, Zhengwei Yang, Liping Di, & Richard Mueller	2012	Exploring and disseminating conterminous geospatial cropland data products	Web Based (Java, JavaScript, XML) and GIS	
24	Korakoch Kongsombut and Roungsan Chaisricharoen	2013	Advisory Service for Orchid Care	Android and WSN	
25	R. Confalonieri et al.	2013	Estimating Leaf Area Index	Smart Phone with Camera Sensor	Involve different technical aspects for the use of information acquired at different angles and options for explicitly accounting for the clumping effect
26	Shitala Prasad, Sateesh K. Peddoju, & D. Ghosh	2004	Plant Leaf Disease Identification	Smart Phone with Camera Sensor	
27	Yukikazu Murakami	2014	Cultivation and Cost Management for Agriculture	Web Based, Smart Phone and Cloud Computing	Implementation of Big Data
28	Yu Heng Lin, Chase (Youdao) Wen, Yolanda Wu, Abel Lin, & Yuchen Wang	2014	Smart Irrigation System	IoT, Senor and Smart Phone	

continued on following page

Table 1. Continued

S.N.	Name of Author(s)	Year	Work done	Technology used	Future Scope
29	E.Giust and S.Marsili-Libelli	2015	Irrigation and Water Conservation in Agriculture	SCADA and Artificial Intelligence (Fuzzy Based)	Porting of the FDSS onto the field, where it will be connected with a dedicated sensor/actuator network, required for the complete automation of the irrigation process
30	A.C. Bartlett, A.A. Andales, M. Arabi, & T.A. Bauder	2015	Irrigation Scheduling	Cloud Computing, IOT and Android Development	
31	K. W. Migliaccio et al.	2015	Irrigation Scheduling	iPhone Application and Android Application	
32	Deepa V. Ramane, Supriya S. Patil, & A. D. Shaligram	2015	Detection of NPK nutrients of soil	Fiber Optic Sensors	
33	Gaikwad S.V and Galande S. G.	2015	Measurement of NPK	WSN and Digital Sensor	
34	A.N. Arvindan and D Keerthika	2016	Automated Irrigation System	Arduino based Micro Controller	

5.2. Sampling Technique

Since there is a large amount of target population, and even large amount of sample size, so in order to conduct the survey in successful manner the Two-stage Sampling Technique ("Two Stage Sampling", 2018) is used. This sampling technique is similar to cluster sampling but every time new samples are taken from each cluster.

5.2.1. Selection of City

Government of Rajasthan has divided all districts in six zones. Each zone is represented by one cluster so one city is selected from each cluster using the Lottery method, as depicted in Table 2.

5.2.2. Sample Size

Since samples are in homogenous in nature, because crop pattern, types of soil, ground water level, availability of water, condition of farmers of each selected city are similar, so took twenty-five farmers from each of the selected cities. Hence total sample size is 150.

5.3. Design of Questionnaire

Our objective is to find the gap between the advanced research development in Precision Agriculture and real problems faced by our farmers. For this, we have designed the questionnaire. This questionnaire has thirty-five questions in which nineteen questions are multiple choices with single answer, nine questions have multiple choices with multiple answers and remaining seven questions are open ended. Since farmers are not fluent and comfortable in English language questionnaire is translated to Hindi Language and changed some basic measuring units such as size of land in Hector have asked in *Bigha.*

Figure 6. Work done in overseas

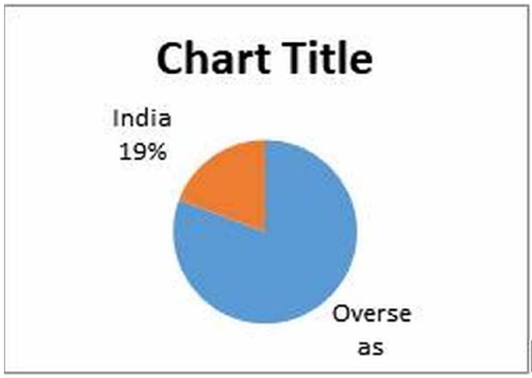


Table 2. Division represents cluster, and selected city

S.N.	Division	Districts	Selected City
1	Jaipur	Jaipur, Alwar, Jhunjhunu, Sikar, Dausa	Jaipur
2	Jodhpur	Jodhpur, Barmer, Jaisalmer, Jalore, Pali, Sirohi	Barmer
3	Ajmer	Ajmer, Bhilwara, Nagaur, Tonk	Ajmer
4	Udaipur	Udaipur, Banswara, Chittorgarh, Pratapghar, Dungarpur, Rajasmand	Udaipur
5	Bikaner	Bikaner, Churu, Sri Ganganagar, Hanumangarh	Churu
6	Bharatpur	Bharatpur, Dholpur, Karauli, Sawai Madhopur.	Bharatpur

5.4. Results from the Questionnaire

In this section, analyzing the responses given by the farmers. This questionnaire was filled by 1568 farmer.

5.4.1. Education

The most important parameter is education. An educated farmer can manage agriculture very effectively. It was found that 39% farmers completed their bachelor's degrees and only 3% of farmers were illiterate. Therefore, it can be concluded that farmers are well educated. The most important result was that 83% of the farmers were fluent in Hindi language only. Education level of farmers is shown in Figure Number 7.

5.4.2. Dependency on Agriculture

The next important issue is that of dependency of the farmer on agriculture. This indicates the role of agriculture in earning livelihood of farmers. Here noticed an unexpectedly low figures indicating only 36% farmers are fully dependent on agriculture and 64% have other sources of income.

5.4.3. Requirement of Irrigation

Rajasthan is an arid region. The average rainfall lies between 200-400 mm. This rainfall is not sufficient for crops that yield in Rajasthan such as wheat, rice etc. Hence most of farmers depend on irrigation from canals, rivers, open wells, Tube well etc. 80% of farmers cultivate their land from rainfall (Basin) and from irrigation. Method of cultivation is shown in Figure Number 8.

Figure 7. Education level of farmer

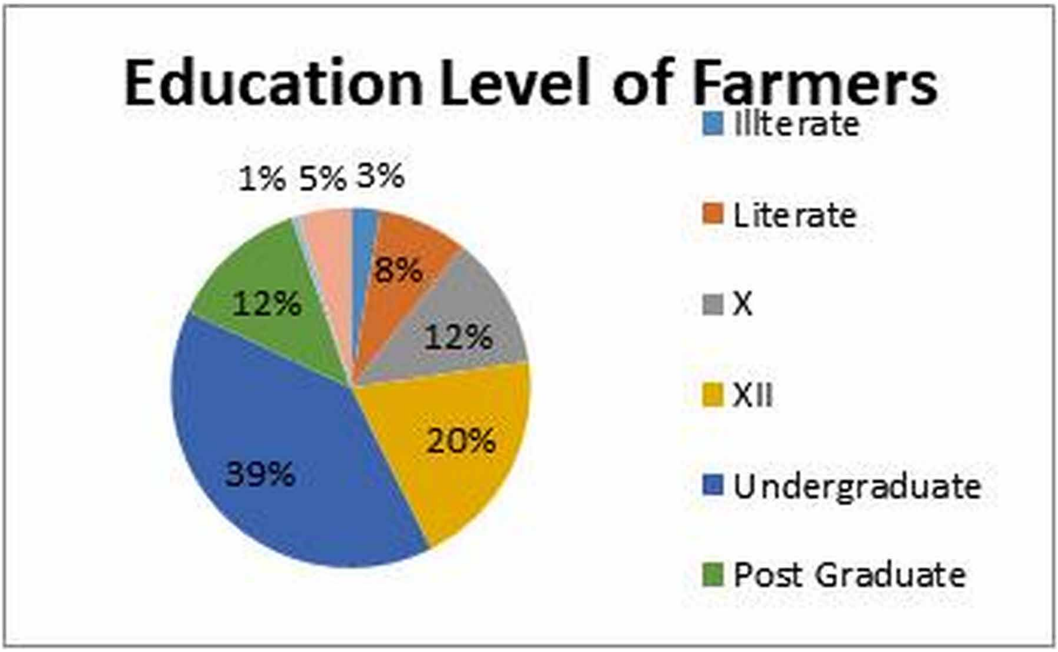
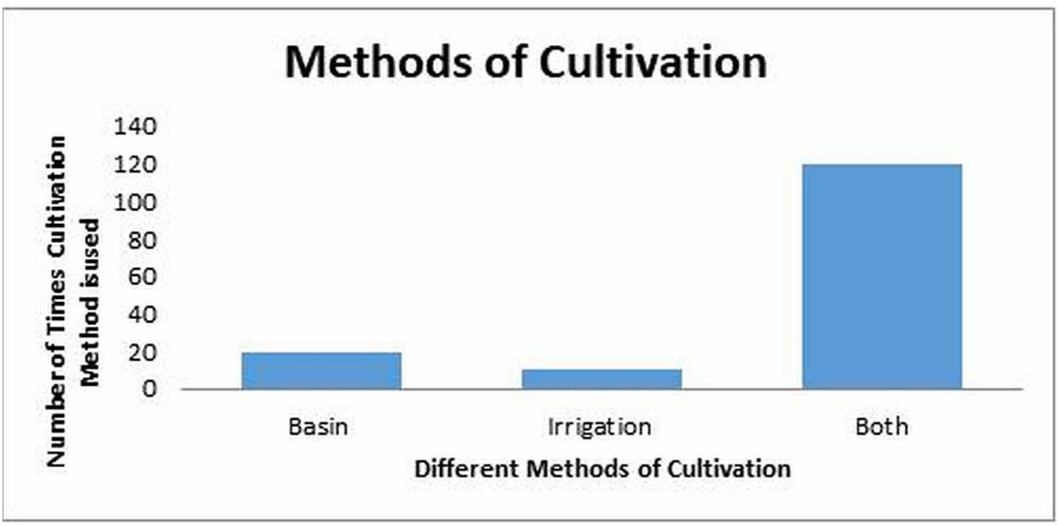


Figure 8. Methods of cultivation



5.4.4. Consideration of Indictors for Irrigation

In order to irrigate the crops, several considerations such as texture of soil, type of crop, color of leaves, stage of crops, soil moisture, environmental temperature, etc. are to be considered. Surprisingly, most of the farmers consider only the type of crop for irrigation and irrigate based on the pre-established requirements of crop, ignoring other factors such as air humidity, stage of crop and soil moisture etc. Indicators for irrigation are shown in Figure 9.

5.4.5. Irrigation as per Requirement

Every crop has a different requirement of water to be supplied. Over and under irrigation are both harmful for crops, which ultimately attack on financial condition of farmers. As per our analysis, only 27.3% farmers plan their irrigation, while the remaining farmers i.e. 72.7% do not plan for irrigation and supply as per the legacy system. As a result, 49% of farmers under irrigate the crop, 39% of farmers over irrigate the crops and disappointingly, only 12% irrigate as per actual requirements. Most of the farmers around (66.7%) use Flood method to irrigate the crops. Some of them have Sprinkle and Drip system to irrigate. It is important to highlight that the Sprinkle and Drip System are not smart sensor-based irrigation systems. Irrigation as per requirement is shown in Figure Number 10.

5.4.6. Consideration of Indicators for Applying Fertilization

After irrigation, providing fertilization to the crop is also very important. Like irrigation, under and excess fertilization badly affects the yield of crop, and it also affects the health of soil. There are mainly three types of fertilizers used in Rajasthan: Compost, Chemical and Bio-Fertilizers. Farmers in Rajasthan apply directly Urea, DAP and Murat Pottash as fertilizer, without understanding about NPK. There are many factors that need to be considered for fertilization such as by testing of soil, noticing color of leaves, as per legacy system and as per stage of crops. Around 54% of farmers apply fertilizer based on stage of crop and only 27% of farmers apply fertilizer by testing of soil, which is the most accurate method of applying the fertilizer.

5.4.7. Obtaining Technical Assistance

Government of Rajasthan is deeply concern about agriculture development. Department of Agriculture and *Krishi Vigyan Kendras* are always help the farmer to solve the problem of farmers and to give suggestions for good farming. *Kisan Sahayta* toll free number and free literature in form of magazines, brochures and handbooks are also available from the government, but surprisingly 50% of farmers do not avail any such assistance. Some farmers, near about 28% visit Department of Agriculture but only 13% of them visit *Krishi Vigyan Kendras*. None of the farmers surveyed any *Kisan Sahyta Number* and used any literature. Obtaining Technical Assistance through various means is shown in Figure Number 11.

Figure 9. Consideration of indicators for irrigation

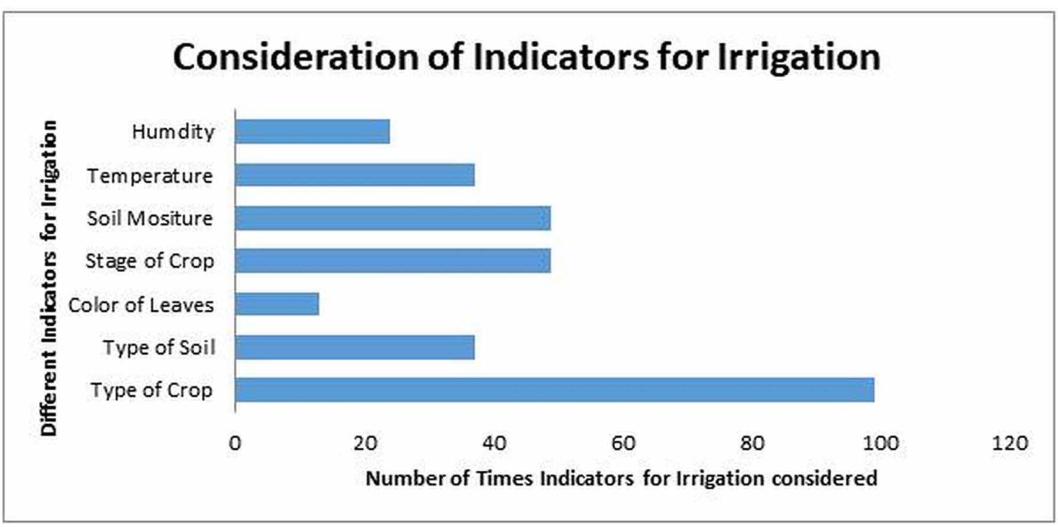


Figure 10. Irrigation as per requirement

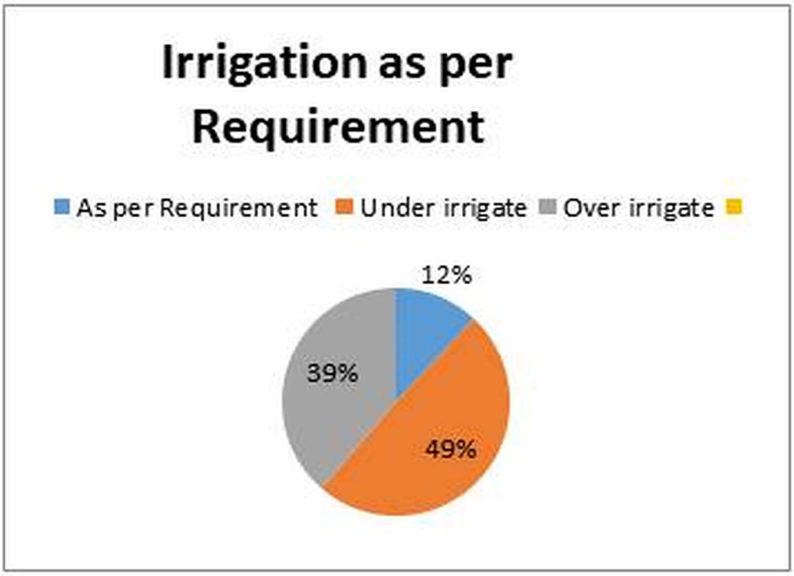
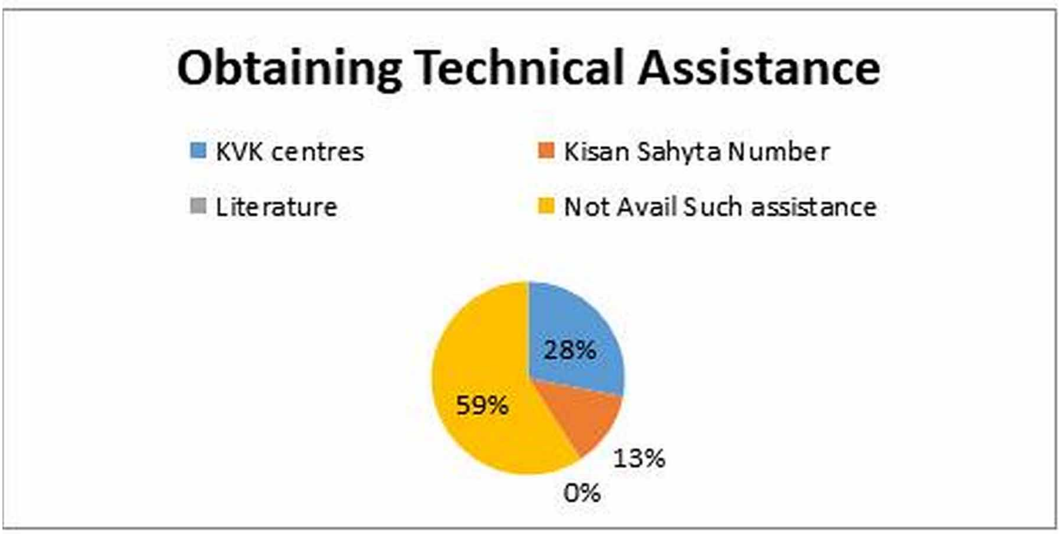


Figure 11. Obtaining technical assistance



5.4.8. Information Technology Friendly

As seen in above section, mostly farmers of Rajasthan are well educated and are comfortable with using mobile phones. Around 73% of farmers use android based mobile phones. None of the famers surveyed use iPhones. Most of the farmers are able to do calling, listing music, watching videos and clicking the pictures from mobile phone camera. Some of the farmers also use agriculture-based applications like *RML, Agribolo,* etc. However, none of the farmers has any sensor in their fields.

6. CONCLUSION AND FUTURE WORK

Nowadays, precision agriculture is not a luxury but the necessity of farmers. Countries like India that heavily depends on agriculture must use ICT enabled services to enhance the production of crops so that more farmers can be benefit. In this paper, authors have reviewed papers to see how precision agriculture is helping farmers in monitoring and taking right decisions using real time data. Most of the work has been done at abroad and best suits with their climate conditions. Authors found a large gap between the literature and actual needs of farmers. In the literature, it has been seen that so many mobile applications, but these applications are not available in India, and once they are available, very typical to use of Indian farmers. Wireless Sensor Network and Geographical Information System are the major components of Precision Agriculture but no farmers have any sensors in his fields. Authors also noticed that under and over irrigation and fertilization are the primary issues of farmers in the Rajasthan. As a result, it is intended to develop decision support system for irrigation and fertilization for Indian Scenario (suitable of Indian climate, soil nutrients and farmer user friendly) so that it can be useful for farmer at ground level.

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