Survey of Impact of Technology on Effective Implementation of Precision Farming in India

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***Abstract*—**The advancements in technology have made its impact on almost every field. India being an agricultural country, proper use of technology can greatly help in improving the standard of living of the farmers. With varying weather conditions, illiteracy of farmers and non-availability of timely assistance, the farmers of this country could not get the best out of their efforts. Precision farming focuses mainly on the aspects that can improve the efficiency based on the data collected from various sources viz. meteorology, sensors, GIS, GPS, etc. The information pertaining to farmland (e.g., soil moisture, soil pH, soil nitrogen) and agro-meteorology (e.g., temperature & humidity, solar radiation, wind speed, atmospheric CO2 concentration, rainfall, climate change and global warming) are used as input parameters to decide the varying requirements of the crop cultivation. Historical farm land data are used as a means to decide on the kind of actions to be taken under a specific scenario.

This paper surveys the existing methods of precision farming and highlights the impact of technology in farming. An overview of different technologies used in precision farming around the world and their implications on the yield are discussed. The methods adopted towards managing different types of crops, the varying environmental conditions and the use of realtime data being collected through sensors are also analyzed. Also, the need for dynamic approaches to assist the farmers in taking context specific decisions has been highlighted.

Keywords- *Farmland data; agro-meteorological data; data analyser; precision farming (PF)***).**

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I. INTRODUCTION

Precision agriculture (PA) or site-specific crop management is a concept based on sensing or observing and responding with management action. It is a scientific approach to improve the agriculture management by application of Information Technology (IT) and satellite based technology to identify, analyze and manage the spatial and chronological inconsistency of agro-meteorology and farmland data.

Earlier in 1929, Linsley and Bauer, drilled the initial seeds of PA, but, Johnson et al. (1983) and Mathews (1983), initiated the works of today's PA. Until the 1980's precise or site specific management was at the farm level and the management unit was the field. The term precision agriculture appears to have been used first in 1990 as the title of a workshop held in Great Falls, Montana, sponsored by Montana State University. Before this, the terms "site-specific crop management" or "site-specific agriculture" were used. In fact, the first two international conferences on precision agriculture referred to site-specific management in the title, but by the third conference in 1996 the term precision agriculture was being used. By the mid 1990s, what we now regard as the new prototype in agriculture was being referred to as precision agriculture. Precision agriculture with the idea, precision time and place management, has established professionally since 1997, now it was applied in many fields in USA, Europe and some of Asian countries [30], [14], [21], [37].

By the year 2050 our estimated world population would be 9.6 billion. To meet the requirement of food to feed the people the food production must be increased by 70%. As the resources are limited so, the only solution is "Smart Farming". Data collection and analysis with information management as well as advance technology in remote sensing, sensor designing and computer processing are changing the agribusiness from which farmers can reap their profits. [7]

A. Scenario of Agriculture in India

Since last ten thousand years, agriculture is the main occupation in India. India holds second position across the world in agricultural production. It contributes a major share in the GDP (Gross Domestic Product) of the country. Despite of gradual fall in its contribution to GDP of the nation, it provides about 50% employment. It also plays a major role in the socio economic growth of the country. Agriculture is currently the biggest industry in India [7].

The total arable area in India is 15,73,50,000 km^2, which is about 52.92% of the overall territory of the country. This area is continuously diminishing because of an ever-increasing number of population and growing urbanization. On the other hand, this puts pressure on the agriculture sector to produce and provide food to all and employment to the large slice of the society. Green revolution began in India in sixties. There has been a rapid expansion in the irrigation facilities. However, even after six decades, about two-thirds of the cropped area is still dependent upon monsoons, which is unpredictable, unreliable, uncertain and irregular. In addition, there is diversity in climate; topography and soil also. Hence, a wide range of crops are grown in India. Throughout the world, there are only few countries including India which experience both tropical and moderate climate and therefore support the cultivation of crops suitable for both these climates. In India, usually small size farms are in practice over 700 years. The produce in this practice are mainly consumed by the farmer and his family with very little leftover for sale in the market [7].

B. Issues and Challenges in Agriculture Sector of India

Agriculture sector is facing certain problems and challenges in India. Some of these are long-standing and some are rising due to the current agricultural practices. Some such problems are:

1) Diminishing arable territory: Arable land is diminishing because of continuous strain from increasing inhabitants and budding urbanization. That puts extra pressure on agriculture sector.
2) Stagnation in production: it is worrisome that some major crops like wheat are getting stagnant in production. It created a huge gap between the demand and supply of growing population and production.
3) Soil Exhaustion: Besides the positive impacts, there are some negative impacts of Green Revolution; one of it is soil exhaustion. It is due to the use of chemical fertilizers. Also, the repetition of same crop degrades the nutrients in the soil.
4) Decline in Fresh Ground Water: Another negative impact of Green Revolution is the declining amount of ground water. In dry regions farming is accomplished with the help of irrigation facilities carried out by the ground water usage. The continuous practice of such agricultural activities has led to an alarming state in context of ground water situation.
5) Increase cost in Farm Inputs: The increase in the prices of farm inputs such as pesticides, fertilizers, farm labor, machineries used in farming etc., put the low and medium land-holding farmers at a disadvantage.
6) Effect of Global Climate Change: Increase in temperature affects the agricultural practices in India also.
7) Farmer Suicides: Farmers are committing suicide, it accounts for a major share of committed suicides in India. It is a major problem facing by agriculture sector of India. The higher suicide rate is reported in areas where there is higher commercialization and privatization of agriculture and higher peasant debt.
8) Refrain from farming: Farmer’s children quitting from their profession is also a major issue. Despite to the very laborious and tedious work, the earning is very less in comparison to its costly farm inputs that are making farmers to head towards other options [7].

C. Role Of ICT in Agriculture

Information and Communication Technology in agriculture or E-Agriculture is an emerging technology to enhance the agriculture sector. It involves the use of information and communication in innovative ways to benefit all farmers.

Precision agriculture is a promising high technology agricultural management system that uses Information & Communication Technology (ICT) to bring multiple sources of useful information for making decision on time. Its fundamental aim is to increase the profitability of crops, to optimize the use of agricultural inputs and to reproduce potentially negative environmental impacts by localized management based on the qualification of in-field spatial and temporal variability. To meet the goal, a suite of tools are used to assess and manage essential agronomic factors. With the progress and application of information technology in agriculture and IT revolution, precision agriculture has been progressively gaining attentions worldwide.

II. LITERATURE REVIEW

Several authors studied about the requirements of application in a PF system. Assessing the performance of literature requires examining the determinants of precision farming in broader perspective. Some existing implementations and related papers are presented here. We briefly describe their aim and focus, and we summarize their technical characteristics.

The literatures related to three major key areas of active research in PF are categorized as impact of farmland & agro-meteorology data on crop production; role of smart technologies in PF and; data management in PF. Literature was collected on broad view basis of related work because limited literature is available in Indian context.

A. Impact of Farm Land & Agro Meteorological Data on Crop Production

Kalra et al., compiled the datasets of 4 years (2000–2004) from the all-India co-coordinated trials, published literatures and crop cutting experiments which are used for cultivars’ characterization (genetic, physiological and phenological), water and nitrogen requirement, and other technical coefficients required for understanding the wheat production under different biophysical stresses. Simulator models WTGROWS and InfoCrop models are highlighted. On the basis of simulated and observed results it is discussed that:

1) Growth and yield of wheat under varying resource inputs (date of sowing, applied Nitrogen and irrigated water) is observed and concluded that the local climate and associated micrometeorological variations are the key factors in deciding the optimum dates of sowings in a particular location, and these vary from one location to another.

2) The yield can be increased by the efficient use of water and nitrogen. Applied nitrogen is usually a variant spatially, depending on the organic carbon content of the soil and subsequently the extent of mineralization for the basal nitrogen availability, which furthermore depends upon the soil pH, soil moisture and thermal characteristics and prevailing climatic conditions. Yield is location and climate specific. Variance in seasonal weather, particularly temperature during various stages of growth does make difference in producing the grain yield.
3) The actual and simulated yields in the farmers' fields under differential inputs of fertilizer nitrogen, irrigation water and variable date of sowing are presented and as expected, wide variation was found in the farmers' fields. This is because the farmers have resource and financial constraints also they fail to maintain adequate levels of inputs [16].

The key areas of PF is explained and categorized in terms of: **Database** on the basis of information related to soil properties, crop characteristics, weed and insect population and harvest data; **Technology** such as Remote sensing, Geographic Information System and Global Positioning System and; **Management** to combine the information generated and the existing technology into a comprehensive and operational system. The authors also discussed the steps to be followed in PF. A comparison of two prominent methods Map based & Sensor based of PF is done and sensor based is proven to be more adequate in terms of time consumption and implementation. However, the effective use of PF is yet to be realized in Indian agriculture [29].

Experiment is performed on soybean field, on collected field data to monitor agricultural practices (e.g., irrigation, sowing, tillage, and harvesting), vegetation parameters (crop height, biomass, dry matter, water content, and yield), and soil parameters [top soil moisture (TSM) and surface roughness] by Betbeder et al., 2016. Each parameter was measured quasi-synchronously with satellite acquisitions [5].

SAFY-WB agro-meteorological model is used to derive the reference evapotranspiration (ET0) according to the FAO method. **Meteorological data** (i.e., air temperature, solar radiation, relative humidity, wind speed, and rainfall) are used as input variables. This model is controlled by optical and/or synthetic aperture radar (SAR) images of leaf area index (LAI) and dry biomass (DB). Images are taken by Formosat-2, Spot-4, Spot-5, and Radarsat-2 satellites. The best results are obtained with the combination of LAI derived from optical or SAR data with DB derived from SAR data which shows the increase in total explained variance by an average of 28% compared to the use of LAI or DB derived from remote sensing alone [5].

A monitoring system which consists of two parts, a Remote Monitoring Platform (RMP) and a Host Control Platform (HCP) are shown in Fig.1. The function of the HCP is to receive and store, display, and analyze the database on line. It also provides functions like inquiries, early warning, and announcements. The RMP is equipped with a TI MSP430F449 microcontroller. This chip can package the sensory data of temperature, humidity, wind speed, and the number of trapped flies into a short message, and then send that message to the HCP at a pre-set time interval by GSM module. The HCP then writes the sensory data into the MySQL database under the control of a program written in LabVIEW. The experimental results demonstrated that large scale, long distance, and long-term monitoring for agricultural information can be achieved by the proposed monitoring system [13].

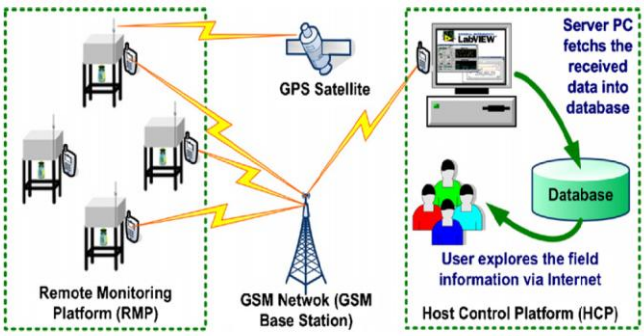

Figure 1: Structural diagram of proposed remote wireless automatic monitoring system [13]

Grisso et. al., stated that Soil electrical conductivity (EC) is a measurement that correlates with soil properties that affect crop productivity and summarized that accurate soil property maps are needed to implement precision farming decisions successfully. The author also mentioned the tips for collecting soil EC data. Soil EC maps can be useful to develop some possible prescriptions, those are:

1) Variable seeding and N rates based on site-specific yield goals based on Cation exchange capacity (CEC) levels.
2) Based on the depth of topsoil seeding rates vary.
3) Variable soil-applied herbicide rates based on texture, organic matter and, CEC.
4) Variable lime rates based on CEC levels found in zone sampling.
5) Control the applications of gypsum to sodic areas [11].

A process-based general Model to capture the Crop-Weather relationship over a Large Area (MCWLA) [40] is applied in Tao, Zhang, Liu, & Yokozawa, 2009; study which simulates crop growth and development in a daily time-step. It is designed to investigate the impacts of weather and climate variability (change) on crop growth. The MCWLA requires daily weather inputs for mean temperature, precipitation, vapour pressure, and fractional sunshine hours.

In this publication the impacts of climate variability (change) on regional agricultural production are discussed. The approach takes account into the uncertainties from CO_2 emission scenarios, climate change scenarios, and biophysical processes in impact assessment models. At most of maize cultivation grids in the regions, relative to 1961–1990, maize yield would decrease approximately by up to 14% with Standard Deviation up to 25% during 2020s, 25% with S.D. up to 35% during 2050s, and 31% with S.D. up to 43% during 2080s. Climate change scenarios could contribute more uncertainties than biophysical processes on crop productivity [39].

Future changes in the productivity of food crops in Europe are estimated by a simple static approach for four scenarios of the IPCC Special Report on Emission Scenarios (SRES). Wheat is taken as a reference crop for the time period from 2000 to 2080 with particular highlighting on the time slices 2020, 2050 and 2080. Estimation of crop productivity due to increase in CO_2 concentration is carried out by the global environment model IMAGE 2.2. The authors estimated increases in crop productivity that ranged between 25 and 163% depending on the time slice and scenario compared to the baseline year (2000). The increases are the smallest for the regional environmental scenario and the largest for the global economic scenario. Technology development was identified as the most important driver but relationships that determine technology development remain unclear and deserve further attention [8].

B. Role of Smart Technologies in PF

While presenting the status of PA in India, the strategies for adoption of PA according to the target sector are explained that can be classified as 'single PA technology', 'PA technology package' (for user to select one or combination) and 'integrated PA technology'. 'Soft' PA depends mainly on visual observation of crop and soil and management decision based on experience and intuition, rather than on statistical and scientific analysis whereas 'Hard' PA utilizes all modern technologies such as GPS, RS, and VRT [23].

Authors focused on the method of collection of geospatial and water quality data. The field data collection system is tailored to sampling biological, chemical and hydrologic parameters along river cross sections. A mobile device application ENVIT- Note is used for Field Data Streaming: data collection process and allows users to rapidly acquire, store, display and transmit data to a broader system infrastructure as shown in Fig.2. The application consists of a graphical user interface (GUI) with features that lead the user sequentially through the following general steps: (1) connection to the database; (2) initialization of the sampling session; (3) selection of environmental and geo location sensors; (4) automated or manual input of selected parameters; and (5) data verification and submittal to local and remote databases.

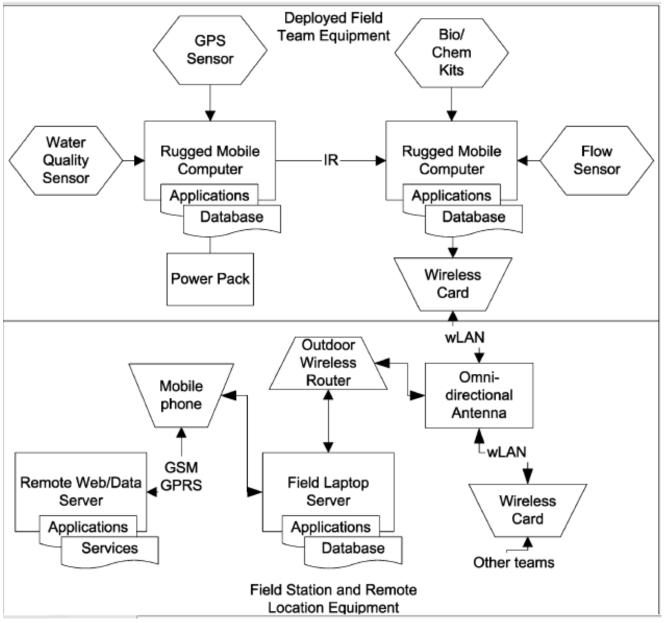

Figure 2: Functional diagram of ENVIT system [44]

The system encompasses advanced mobile, wireless and Internet computing technologies that together facilitate the sharing of field data between the study site and remote locations in real-time.

An experimental campaign is conducted in Williams River and experienced that the ENVIT System improved the efficiency, timeliness and transfer of field data into scientific results. The field data streaming technology can accelerate not only the process of data collection and scientific discovery, but also the incorporation of observations into predictive models. Although the results are satisfactory but can be improvised by including a higher powered radio-frequency network to overcome line-of-sight and range limitations across complex terrain; satellite transmission in remote areas not covered by the mobile network; improved integration of system components including GIS and mobile application user interfaces and; continuous transmission, updating and sharing of raw and processed environmental data products [44].

The need of engineering skills for instrument development, knowledge of optics, understanding of the remote sensing and computer expertise in Precision Crop Management PCM is discussed. Also, the opportunities and limitations of image based remote sensing for PCM applications are discussed. Authors mentioned that limitations are due to instrument design. The satellite based sensors have fixed spectral bands, low spatial resolution and long time periods between image acquisition and delivery to user are inappropriate. However, aircraft based sensors can avoid these limitations but difficult for large area coverage [24].

Strengths and weakness of soil sensing technologies are discussed and concluded that proximal and remote sensing technologies should be implemented to provide high resolution data relevant to the soil attributes of interest. Satellite platforms or airborne are used to deploy the remote sensors. Proximal sensing requires the operation of the sensor at close range, or even in contact, with the soil being measured, allowing *in situ* determination of soil characteristics at, or below the soil surface at specific location. Integrating multiple proximal soil sensors in a single multi sensor platform can provide a number of operational benefits over single-sensor systems, such as: robust operational performance, increased confidence as independent measurements are made on the same soil, extended attribute coverage, and increased dimensionality of the measurement space (e.g., conceptually different sensors allow for an on different soil properties) [3].

Remote sensing applications in agriculture are classified based on the type of platform for the sensor such as Soil sensing, Satellite remote sensing, Proximal remote sensing and Hyperspectral remote sensing of crops. The basic difference among these platforms and their associated imaging systems are based on the spatial resolution of the image, the minimum return frequency for sequential images and the altitude of the platform. Satellite image has improved in spatial resolution, return visit frequency and spectral resolution. Aerial hyperspectral image is able to distinguish multiple crop characteristics, including nutrients, water, diseases, pests, weeds, and biomass and canopy structure. Ground-based sensors have been developed for on-the-go monitoring of crop and soil characteristics such as N stress, water stress, soil organic matter and moisture content [25].

While discussing about Precision Agriculture, authors also explained the Management strategy, philosophy, what PA should be, design to improve the agriculture process, precisely managing each step to ensure maximum production and continuous sustainability of natural resources.

Special tools and methods for Precision Agriculture are discussed. GPS, GIS and RS tools are used to determine variability, different factors and elements of a farm.

- Global Positioning System (GPS) provides the attribute of the spatial coordinates of the farm data. Also, it is possible to determine and record the correct position continuously. Considering that this technology in the field of agriculture has caused that more details already be available, therefore, it provides a larger database for users.
- Geographic information system (GIS) is essential to the storage and handling of data. GIS technology allows us to analysis and process a large amount of data at high speeds and in less time.
- Remote sensing systems provide information and uniform measurements with high-speed for large areas in the digital form.
- Mapping: data can be imported into computer systems and stored in a map. The generated maps are used to obtain information and operate it in strategic decision-making to control variability [41].

Precision Agriculture is all about an innovative agriculture technologies used to improve production with less environmental pollution.

- An RTK-GPS (Real-Time Kinematic GPS, Ag-GPS252, by Trimble) was utilized in order to perform the field topography landscape measurement.
- The data are processed by GIS software (ArcMap, ESRI) to export the field elevation map.
- The EM-38 sensor (Geonics) is used for assessment of soil variability.
- MZA software (ARS, University of Missouri, 2000) was utilized for Fuzzy clustering algorithms to classify data into homogenous zones.
- The wireless sensor parts and equipments are manufactured by 'Libelium sensors' company. The system consists of three main units, the sensors (WATERMARK), the sensor boards (Waspmote sensor devices) and the base station (Meshlium ZigBee-Mesh- AP).

After comparison it is concluded that WATERMARK sensors are reliable and quite accurate and can be used to constantly monitor soil moisture (using datalogger "Meshlium" and wireless sensor network "libelium") for agricultural purposes [38].

Auernhammer described the areas where technology can be used to develop environment friendly agriculture as well as the limitations of technologies. GPS, mobile communication system and online sensor system with geo referenced information can be utilized to calculate the use of fertilizers and water content for PF [4].

The measurement of crop area with GPS and PDA and their use for linkage with other layers of data in GIS is described. Different methods for collecting crop area data including field reporting system, eye estimation, interview of the farmers, objective measurement methods are discussed and concluded that all these methods have their limitations in terms of reliability of crop area data, but the objective method of measuring areas is considered to give the most reliable data. Also, the Position calculation with GPS and sources of GPS signal errors, Steps to follow for using GPS and PDA for crop area measurement, Testing of the GPS devices before use in survey, Conditions in which use of GPS and PDA for crop area measurement is recommended and not recommended, GIS and geo-referenced data basics, GPS and GIS exchange data formats and methods are discussed in detail. And stated that The GPS device also allows integrating geo referenced data collected on the ground in GISs in order to overlay different kinds of spatial data and perform spatial analysis [18].

R. N. Sahoo discussed in his lecture that FAO is preparing a handbook which aims at providing practitioners with a new reference document based on the state of the art in terms of crop area measurement with GPS and PDA and their use for linkage with other layers of data in GIS [32].

Crop simulation models like CERES, CROPGRO, SUBSTOR, CROPSIM, and CANEGRO developed models by researchers from several countries are mentioned who respond to weather, soil water holding and root growth characteristics, cultivar, water management, nitrogen management, and row spacing/plant population. Also, decision support system like, DSSAT incorporates crop/soil/weather models, data input and management software, and analysis programs for optimizing production or profit for homogenous fields. DSSAT also includes links to GPS, GIS and remote sensing information, which allows mapping of spatially variable inputs across a field and mapping of predicted outputs from the models, such as yield, nitrogen leaching, water use, etc. Opportunities, limitations and strategies for Precision Farming in India are discussed [32].

An e-Agriculture Application based on the framework consisting of KM-Knowledge base and Monitoring modules is proposed. Monitoring modules are demonstrated using various sensors for which the inputs are fed from Knowledge base. A comparative study is made among the developed system and the existing systems. Architecture of e-Agriculture Monitoring module consists of TI CC3200 Launchpad, Arduino UNO board with Ethernet Shield, interconnected sensors modules with other necessary electronic devices [22].

ARM LPC2148 Microcontroller and GSM technology is used for monitor and control of irrigation in field. Sensors are used to send the input data to the microcontroller. Those are Temperature, Humidity, Soil moisture, Leaf sensor, pH sensor, Level sensor, Phase sensor. GSM is responsible for controlling the irrigation on field and sends SMS to the farmers [15].

Design and implementation of “Agrisys” an agriculture System is presented that can analyze an agriculture environment and intervene to maintain its adequacy. AgriSys is modeled using Phidget interface8/8/8 which connects to light sensor, environment temperature/humidity sensor, pH sensor, soil moisture sensor for water level, and soil temperature sensor. Moreover, AgriSys system is used to control the temperature, waterfall and sunlight reaching the plants. It is programmed under LabVIEW [2].

An innovative GSM/Bluetooth based remote controlled embedded system is proposed for irrigation. It consists of CC2420 zigbee/RF module as RF Transreceiver core unit of wireless communication system and MSP430 as microcontroller unit. In this proposed work ARM controller (LPC 2148) is used as Central Processing Core unit. It is act as a central part of the system, which connect all other units directly. The Zigbee module is also used which has the range of about 150 meters. The readings of temperature and moisture are recorded and timely sent to farmer’s mobile enabling him to take the proper action. The proposed system is claimed as a low cost system where information is exchange via SMS on GSM network [10].

The radio platform MPR2400CA based on the microcontroller AtmelATmega128L is used to propose an automation system. In order to manage different kinds of sensors, a compliant data acquisition board are adopted namely MDA300CA which is an extremely versatile data acquisition board that also includes an onboard temperature/ humidity sensor. Each sensor node consists of 2.4GHz MICAz mote, MDA300CA data acquisition board, Irrometer Soil moisture sensor, atmospheric pressure sensor MPX4115A, leaf wetness sensor. MICAz motes can be programmed with TinyOS [33].

A wireless datalogger system named “AgroSense” is proposed for remote monitoring of agricultural parameters. Authors focused on mesh wireless protocols for wireless sensors such are *Wireless LAN (IEEE 802.11), Bluetooth (IEEE 802.15.1) and IEEE 802.15.4* [31].

Overview of Precision Farming and Wireless Sensor Networks (WSN) is presented and the several technologies used in the PF are highlighted such as Remote Sensing (RS), Global Positioning System (GPS), and Geographic Information System (GIS). Also, it sheds the light on the agriculture in Egypt and the automation of the agriculture using WSN which help to solve a lot of Egyptian agricultural problems and improve the crops [1].

Mafuta A et al., demonstrated the deployment of Irrigation Management System (IMS) based on WSN. WSN nodes equipped with GPRS module and Zigbee module are used with open source tools: FrontlineSMS, MYSQL, and PHP [20].

A low-cost and environmental friendly Intelligent Greenhouse Monitoring System (IG MS) design based on WSN technology is proposed. IGMS is a web-based technologies using open source comprised of modules that provide [17]:

1) Information about cultivation process
2) Real-time data from the sensors
3) A sensor configuration environment
4) Expert system capabilities and support

A comprehensive report on the design process and implementation of a Wi-Fi based wireless agricultural monitoring system is provided. The agricultural environment monitoring server system collects environmental information such as luminance, temperature, humidity, wind direction, wind speed, EC, pH, CO_2 *etc.* [26].

C. IoT and Cloud Computing in PF

An overview of working and applications of Internet of Things (IoT) and Cloud Computing for agriculture are discussed. Also, geomatics or 3S (RS, GIS and GPS), sensor technology, WSN, RFID are highlighted [28]. In a typical IoT scenario, data can be stored in cloud for monitoring and control. Data can be collected by deployed sensors in fields, green houses, seed storages, cold storages, agriculture machineries, transportation system, and livestock [35].

In [46], the IoT application in agriculture is discussed. Remote monitoring system with internet and wireless communications is proposed. Wireless communication terminal is a GSM modem that supports GPRS (General Packet Radio Service). As shown in Fig.3, the system software includes

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- **Site monitoring system data acquisition software**, made up of user interface module, network communication module, data collection module, data processing module and system configuration module.
- **Remote data acquisition receiver,** made up of user interface module, network communication module, system configuration module, and database access module, which can communicate with the site monitoring system data acquisition software through the network communication module with TCP/IP protocol.
- The **web application software,** include three parts of user authentication, data access, data query and download, which access the database through ADO.NET, and the remote data acquisition can communicate with the database through ADO.NET. The user terminals can get the real time monitoring data from the web page [46].

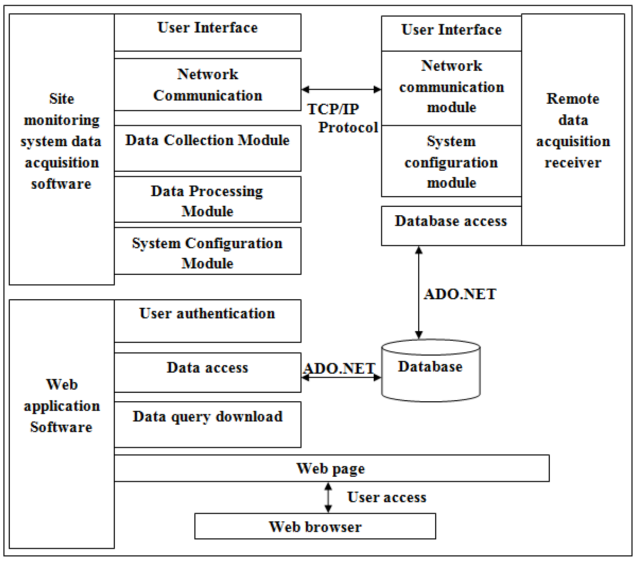

Figure 3: The software function structure [46]

While explaining wireless sensor network and their challenges in precision farming in India, authors proposed cloud based data center for it. It is concluded that in India where poor economic condition and land fragmentation is in general, it seems difficult to implement such data centers in individual levels for poor farmers. In such condition Cloud Based Data Center acts as remedy. Group of such farmer and / or associations of such farmer can implement this Data Centers so that it low the investment per farmer and increases profitability [27].

IoT is an intelligent technology which includes identification, sensing and intelligence. IoT comprises of:

- Cloud computing: Cloud computing management platform is the "brain" of cloud computing and relevant data. It involves management of accession of cloud computing customization application by users of this IoT, computing and processing what is involved in customization service; organizing and coordinating service nodes in the data center.
- Ubiquitous network: Ubiquitous network includes 3G, LTE, GSM, WLAN, WPAN, WiMax, RFID, Zigbee, NFC, bluetooth and other wireless communication protocol technology. It also includes optical cable and other wire communication protocol and technology.
- Intelligent sensing network.

Agricultural information cloud is constructed based on cloud computing and smart agriculture is constructed with combination of IoT and RFID. Hardware resources in agricultural information network are integrated into resource pool by using vitalization technology, achieving dynamic distribution of resource and balance of load, significantly improve the efficiency in resource usage. Large amount of data obtained by using radio frequency identification, wireless communication, automatic control, information sensing techniques of IoT are handled with agricultural information cloud, truly realizing smart agriculture [42].

An algorithm is proposed for monitoring water level in the farm area for precision agriculture. The images of site specific locations are processed in MATLAB and the requirement of water is calculated [43]. An algorithm is proposed and a prototype is developed for proper utilization of water with an increased crop yield [19].

Water management options in irrigated agriculture using RS-simulation modeling and genetic algorithm are presented. The presented method is:

- System characterization by a stochastic data assimilation procedure. In this, estimation of the irrigation system properties and operational management practices are done using Remote Sensing data;
- Optimization of water management. In this fold, they explored water management options under various levels of water availability.

The decision variables are defined by the: (i) water management variable; (ii) crop management variable and soil properties. Yield (Y) is a function of crop and water management. Crop yield is simulated by WOFOST [46], a dynamic, process-based, crop simulation model. WOFOST responds systematically to the stresses caused by the management and water quality variables considered. In the application, the means and standard deviations of the water quality variable and soil properties are assumed to be initially known. The soil system was assumed to be relatively dry during the start of simulations. Several water management scenarios are considered to observe the solutions of the water management optimization model, when water is severely limited, and when it is non-limited [12].

III. DISCUSSIONS

Here, a comparative study has been made among the research papers and research articles referred in literature review for precision farming.

First, we compared their research work based on the criterion of hardware technology used in PF and the proposed or implemented outcomes which are outlined in Table 1.

TABLE I
SUMMARY OF HARDWARE/SMART TECHNOLOGIES USED IN REFERRED PAPERS

Ref. Paper	Microcontrollers	Sensors	Other smart Technology	Proposed Model	Disadvantages
[22]	TI CC3200 Launchpad and Arduino UNO board with Ethernet Shield	Temperature & humidity/ soil moisture/ LIGHT SENSOR/ Ball float liquid level Sensor/ Magnetic Float Sensor	Not used	Demonstrated a model to control the ON/OFF switch of motor	Could be expanded for multitasking.
[15]	ARM LPC 2148 Microcontroller	Temperature, Humidity, Soil moisture, Leaf sensor, pH Level	GSM&WSN	Proposed a model to monitor and control the irrigation system	High Complexity, less reliable due to internet unavailability
[2]	Phidget interface kit 8/8/8	pH sensor/ Light sensor/ soil thermocouple sensor /moisture/ temperature& humidity	proposed an algorithm; LABVIEW	Proposed AGRISYS model to control Fan/pump/motor	Not implemented
[10]	ARM controller (LPC 2148) & ARM7TDMI-S microcontroller	Soil moisture sensor (sensor LM 393)	GSM Module	Implemented a automated system to control Motor pump & sms on Mobile phone	agro-meteorology data are not considered
[33]	RADIO PLATFORM MPR2400CA USED BASED ON AtmelATmega128L	Irrometer Soil moisture sensor, atmospheric pressure sensor MPX4115A, leaf wetness sensor, soil pH.	WSN; MICAz mote/ MDA300CA data acquisition board; Moteview & TinyOS	Designed and implemented a monitoring system to control water sprinkler, intimate soil pH via sms.	High Complexity, agro-meteorology data are not used, less reliable due to internet unavailability, Costly
[13]	Microcontroller (TI MSP430F449 chip)	sensors for measuring wind speed, temperature, humidity	GSM module, GPS receiver. MSP GCC, PHP, LabVIEW, MySQL, Apache server	Implemented RMP and HCP for inquiries, early warning, and announcements on GSM mobile	High Complexity, costly

Microcontrollers (AVR and ARM family) with some sensors (pH sensor, soil moisture, radiation sensor and temperature & humidity sensors) and advance technologies (GPS, GSM, WSN etc.) are used to propose the solutions of some general assignments of farming. The implemented or proposed models are claiming served well in some criterion but there are some parameters (eg., complexity & cost of the devices, dependability on the availability of resources and could do multitasks) which are missing and needed to be taken in consideration.

Next, we compiled the various parameters of farmland and agro meteorological data which are taken in consideration for PF in respective references and their impacts on crop productivity.

TABLE III

IMPACT OF FARMLAND AND AGRO-METEOROLOGY DATA ON CROP PRODUCTIVITY

Key Ref.	Area of implementation	Model	Data collection method	Parameters in consideration	Result	Comment	Drawbacks
[5] 2016	soybean fields	SAFY-WB	optical and/or SAR remote sensing	• Leaf Area Index, Dry Biomass, • air temperature, • solar radiation, • relative humidity, • wind speed, • rainfall	LAI derived from optical/ SAR data with DB derived from SAR data shows increase in total variance of soya bean yield by an average of 28% compared to the use of LAI or DB derived from remote sensing alone	Evaluation of measuring techniques only. Must be considered to implement a system	Historical data are not taken into consideration
[44] 2003	Williams River, Australia	ENVIT an mobile application to integrate the collected data	Record and submit the data by automated or manual	• **Geolocation**, • **Hydrology**, • **Water quality** (pH, Dissolved oxygen, Conductivity, Oxygen reduction potential, Turbidity,Temperature) • **Geometry** • **Chemistry** (Nitrate, Nitrite, Phosphate), • **Biology**	Resource management (eg., water quality) and emergency response.	demonstrated the field data streaming technology	Historical data, sun radiation, rainfall and wind speed parameters are missing
[16] 2007	Wheat Hissar and Karnal (North India)	WTGROWS & InfoCrop	basis of historic datasets or by using simulation models	• applied Nitrogen, • date of sowing, • irrigated water	• influenced the variation in grain yield to the level of 34% variability. • influenced the grain yield production to an accuracy level of 16% • the application of irrigation water influenced the yield prediction to the level of 27% accuracy.	Impact of farmland and agro meteorological data on yield	The best practice which has been used by other farmers in the identically same scenario can be proposed
[43] 2012	Vineyard India	MATLAB	Through wireless sensor networks	• Pictures from database & • Real time pictures	Calculation of water requirement by image processing		Impact of agro meteorology data is missing
[23] 2009	Not implemented	-	-	• Small-scale farming operations.	show a saving of 15–25% in required headland, 20–30% in required work time, and 100–300 e per ha in costs.	PF is not optimized in small scale farms. Virtual land consolidation is the solution.	What else technique which can be good for small scale farming is not proposed
[31] 2013	B.C.K.Vcampus , Kalyani, India	AGROSENSE	Wireless datalogger, routers	• Humidity, temperature & sunshine • soil moisture • soil conductivity • soil Ph	Wireless transmission range varies with humidity and environment condition	Evaluation of measuring technique	How these data could be utilized for decision making is not mentioned.
[11] 2009	Not implemented	-	Sensors for soil EC, historical productivity, soil sample data, and local agronomic knowledge.	• low soil EC • high soil EC	• low yield • high yield	Impact of soil properties on yield	Impact of agro meteorology data and other farmland data are not evaluated.
[39] 2009	Maize crop, CHINA	MCWLA [40]	Obtained from the Climatic Research Unit, UK	• uncertainties from CO_2 emission scenarios, • climate change scenarios, • biophysical processes	Relative to 1961–1990, maize yield would decrease approximately by up to 14% with S.D.* up to 25% in 2020, 25% with S.D.* up to 35% in 2050, and 31% with S.D.* up to 43% 2080.	Climate change scenarios contribute more uncertainties than biophysical processes on crop yield	Real time data are not considered
[8] 2005	Wheat, Europe	IMAGE 2.2	from projections of the future climate based on HadCM3 for Europe. IPCC(SRES) Special Report on Emission Scenarios	• changes in climatic conditions • atmospheric CO_2 concentration • technology development	Estimated increase in crop productivity that ranged between 25 and 163% depending on the time slice and scenario compared to the baseline year (2000).	Importance of Technology outweighing the effects of climate change and increasing CO_2.	Site specific best practices are not mentioned.

S.D.* Standard Deviation

Crop productivity is dependent on various parameters directly or indirectly. How and what amount of these parameters are responsible for yield variation is estimated in some publications compiled in Table 2.

IV. SUMMARY

The study can be summed up as, instead of being stick with the traditional strategies for farming, new and improved methods can benefit from agricultural advancements and sustainable lives. ICT in agriculture can improve the decision making capability, better planning and other community involvement.

According to the various research papers and articles discussed in above section the key parameters which influenced the crop productivity are: Farmland data (soil conductivity / ET0, soil pH, applied Nitrogen, Crop characteristics etc.) and Agro-meteorological data (Rainfall, Temperature, Relative Humidity, solar radiation, wind speed, uncertainties from CO_2 emission scenarios, climate change scenarios, date of sowing etc.). The method of data collections and taking decisions at the appropriate time by the use of Smart technologies (GPS, GIS, WSN, IoT, GSM, cloud computing, different types of microcontrollers & sensors, software & simulators etc.) are also influential factors for proficient implementation of PF.

A comparative study is done among various applications available in agriculture domain and various technologies are identified in developed or proposed system. The main features that are considered in study are the input data, monitoring modules and technologies used to implement the system.

V. CONCLUSION AND FUTURE SCOPE

There are many general reasons why the PF is not implemented in developing countries effectively. The major obstacles are illiteracy, need of technical skill for installation, maintaining and monitoring of devices and, the unavailability of resources or infrastructure such as electricity and internet connectivity. Efficiency & reliability of costly devices are also the limiting factors in the adoption of PF. The adoption of PF cannot be optimized for small size farms. And the other restraining factors include lack of success stories and culture and perceptions of the users.

Assorted methods are proposed and implemented in referred publications but the problems faced to implement the precision farming are yet to be worked out. The challenge remains as to how to produce enormous data sets and process these data to useful suggestions to aid in decision making for the farmers effectively. It is concluded that complexity of the system increases the cost of installation and maintenance of the devices. And also require skilled man power.

A good amount of work on PA has been started in different countries. Knowledge of present status of PA helps to visualize the future challenges. Future research efforts can be done on the key parameters that are majorly responsible for the effective smart e-Farming.

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