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Joli Dutta
Department of Plant Pathology, Assam Agricultural University, Jorhat, Assam, India

Jumi Dutta
Department of Veterinary Biochemistry, AAU, Khanapara, Guwahati, Assam, India

Sukanya Gogoi
Department of Plant Pathology, Assam Agricultural University, Jorhat, Assam, India

Corresponding Author:
Joli Dutta
Department of Plant Pathology, Assam Agricultural University, Jorhat, Assam, India

Smart farming: An opportunity for efficient monitoring and detection of pests and diseases

Joli Dutta, Jumi Dutta and Sukanya Gogoi

Abstract
Smart farming is a key component of the modern agricultural revolutions. The concept of Smart agriculture was first emerged in the United States in early 1980s. Smart farming means application of precise and correct amount of inputs like water, fertilizer, pesticides etc. at the correct time to the crop for increasing its productivity and maximizing its yields. Smart farming comprises of geospatial technology and Internet of Things (IoT). Intregation of Geographical Information System (GIS) and Remote Sensing provide a solution where mapping for the disease incidences can be carried out. Once mapped, the experts can actually understand the causes which led to the crop infestations. Early warnings and forecasting based methods provide appropriate time for managing pest damage and can thus minimize the crop loss, optimize pest control and reduce the cost of cultivation [8]. In the concept of Internet of Things (IoT), every object is connected with each other through a unique identifier, so that, it can transfer data over the network to the human interaction [21]. Therefore, farmers have to be trained adequately so that they can monitor the dynamics of pests and diseases and take right decision at the right moment.

Keywords: Autonomous farming robot, drones, geospatial technology, IoT, remote sensing, smart farming

Introduction
The world's population is about 7.5 billion, and it is expected to rise around 9.8 billion by 2050. To feed those people, we'll need to produce 70 per cent more food. Aware of these issues, in 2016, India's Prime Minister Narendra Modi introduced a new national policy to doubling farmer's incomes by 2022. The objectives of this policy are poverty reduction, food security and climate change. Though precision farming is very much talked about in developed countries, it is still at a very nascent stage in developing countries, including India [22].

Smart farming is the future of Agriculture technology. In the coming years, smart farming is projected to create a massive impact on the agricultural economy. But apart from this, farmer's suicide is a pretty important problem in India. The fact is that, most of the farmers are lacking behind the proper knowledge of better farming techniques. Farmers have to bear huge losses and at times, they end up committing suicide. They are unaware of how today's high technology can be used to get rid of their day-to-day farming problems. 'How to get more from less' should be the mantra behind every agricultural initiative. Smart farming can make agriculture more profitable for the farmer [7, 15].

Smart farming represents the application of modern Information and Communication Technologies (ICT) into agriculture. It includes precision equipment, the Internet of Things [1], sensors and actuators, geo-positioning systems, Big Data [18], Unmanned Aerial Vehicles (drones), robotics, etc. Effective smart farming is based on data analysis. Farmers in every region of the world always struggle to protect their crops from pests and disease. The programme 'Digital India' proposed by honorable Prime Minister Mr. Narendra Modi project to make country more digitized Under the Digital India programme, the government of India have launched several apps towards the welfare of farmers including Farmer's portal, Kisan Suvidha, mKisan, and Pusa Krishi. Smart farming is characterized by a number of sophisticated tools that assist in monitoring variation and managing inputs.

The key components of Smart farming include capturing the data at an appropriate scale and frequency, interpretation and analysis of that data, and implementation of a management response at an appropriate scale and time. Using smart technologies, today's farmers can manage their farm from a laptop to remotely control tractors installed with GPS and instruct distant crop watering systems to turn on and off.

Sensors can be placed in fields to measure soil and air temperature and humidity, and drones and satellites used to collect and analyze data. Farmers inspect the drone images of their crops, discuss interpretation with technical staff and decide when and where to apply fertilizers and other inputs. The data is comprehensive, accurate and provided in real-time; it can also be used to determine crop damage for insurance purposes. Small drones or unmanned aerial vehicles (UAVs) are being used for rapid assessment of crops with high resolution imagery [19]. Smart farming involves the collection of data by observation and measurement, and the subsequent responses. Sensing is key to the collection of data; whether this is remote from space by satellites, by aircraft or drones, or by proximal sensors used on the ground, mounted on vehicles or otherwise Precision (Smart) crop protection requires detailed data on the occurrence and distribution of problems at the earliest possible stage of detection [3]. Some of the key aspects are:

- Identification of crops, targets and beneficial.
- Temporal and spatial distribution: Presence of the target before, during and after the crop growth period.
- Sampling techniques**:** Statistically valid sampling regimes must be used to permit an accurate view of any problem [3].

Components of smart farming:

- Capturing the data at an appropriate scale and frequency
- Interpretation and analysis of that data
- Implementation of a management response at an appropriate scale and time

Pest creates problems in crop production because of monoculture, dense cropping, availability of preferred host, excessive use of fertilizers and indiscriminate use of pesticides [3]

Geospatial Technologies

Smart Farming is an approach of farm management that uses information technology to ensure that the crops and soil receive exactly what they need for optimum health and productivity. An organized collection of computer hardware, software, geographic data, and personnel. It is designed to efficiently capture, store, update, manipulate, analyze, and display geographically referenced information. It can be used in pest monitoring and detection by data visualization and survey data collection, management and analysis [4].

Approaches to Agriculture using Geospatial Technologies

- Climate-Smart Agriculture
- Precision Agriculture
- Conservation Agriculture

The main objectives of geospatial technology are

- To optimizing the use of inputs and resources including water, land, and other inputs which helps to reduce cost of production.
- To improve productivity through more precise use of inputs.
- To minimize agricultural risk due to pests and diseases and climatic variances.

Hence, overall improvement in farm incomes while minimizing risk [11].

Remote Sensing

Remote Sensing is the collection of information about an object without being in direct physical contact with the object. It is a technology for sampling electromagnetic radiation to acquire and interpret non-immediate geospatial data from which to extract information about features, objects, and classes on the Earth's land surface, oceans, and atmosphere. The term “Remote sensing” was first used in 1961, when U.S. Naval project on the study of Aerial photographs was renamed as Remote Sensing [11].

Elements involved in Remote sensing [11]

i. Energy Source or Illumination
ii. Radiation and the Atmosphere
iii. Interaction with the Object
iv. Recording of Energy by the Sensor
v. Transmission, Reception and Processing
vi. Interpretation and Analysis
vii. Application

Scale in remote sensing [11]

- Small scale: 1cm = 5 km or more
- Inter-mediate scale: 1cm = 0.5 to 5 km
- Lage scale: 1cm = 0.5 km or less

Essential component of remote sensing [11]

- Signals from a source/light
- Sensors on a plate form
- Sensing (Signal reception, storage, processing, information extraction and decision making)

Types of remote sensing [11]

- **Passive remote sensing**: When remote sensing work is carried out with the help of electromagnetic radiation (signals) reflected by a natural body(sun and the earth). e.g. Visible, near infrared and microwave remote sensing.
- **Active remote sensing**: When remote sensing work is carried out with a man made source of radiations which is used to illuminate a body and to defect the signal reflected form. e.g. Radar and Lidar remote sensing.

Importance of Remote Sensing [11]

- Large amounts of data needed, and Remote Sensing can provide it
- Reduces manual field work dramatically
- Allows retrieval of data for regions difficult or impossible to reach
- Allows for the collection of much more data in a shorter amount of time
- Digital Imagery greatly enhances a GIS

Application of remote sensing techniques [11]

- Agriculture
- Forestry
- Water resources
- Detection of water pollution
- Geology and mineral sources
- Mapping of land use / land cover
- Monitoring of environmental hazards
- Weather and climatic related applications
- Engineering applications
- Human induced geological hazards

Applications of Remote Sensing in Agriculture [11]

- Crop identification
- Crop acreage estimation
- Crop condition assessment and stress detection
- Identification of planting and harvesting dates
- Crop yield modelling and estimation
- Identification of pest and disease infestation
- Soil moisture estimation
- Irrigation monitoring and management
- Soil mapping
- Monitoring of droughts
- Land cover and land degradation mapping
- Identification of problematic soils

Global Positioning System (GPS): A system designed to capture, analyze, store, manage and present all types of spatial or geographical data. GIS use the space and time dimensions as the key index variable for all other information. It is a satellite system that projects information to GPS receivers on the ground, enabling users to determine latitude and longitude coordinates.

Example: An agricultural producer may use a handheld GPS receiver to determine the latitude and longitude coordinates of a water source next to a field or vineyard [4, 11].

Geographic Information System: An Information System that is used to input, store, retrieve, manipulate, analyze and output geographically referenced data or geospatial data, in order to support decision making for planning and management of land use, natural resources, environment, transportation, urban facilities, and other administrative records.

Example: In a chemical spill, maps obtained from a GIS system can reveal environmentally-sensitive areas that should be protected during response and recovery phases [4, 11].

Basic Functions of GIS [4]

- Data Acquisition and prepossessing
- Database Management and Retrieval
- Spatial Measurement and Analysis
- Graphic output and Visualization

Benefits of GIS [4]

- Geospatial data are better maintained in a standard format.
- Revision and updating are easier.
- Geospatial data and information are easier to search, analysis and represent.
- More value added product.
- Geospatial data can be shared and exchanged freely.
- Productivity of the staff improved and more efficient.
- Time and money are saved.
- Better decision can be made

Basic elements of a GIS are People, Data, Hardware, Software, Procedures. Functions of a GIS are capture data**,** store data**,** query data**,** analyze data**,** display data**,** and produce output. Mapping of hotspots for disease infestations is something like a post disaster management which is carried out when crop is almost destroyed. GIS and RS in integrated form provide a solution where mapping for the disease incidences can be carried out. Once mapped, the experts can actually understand the causes which led to the crop infestations [4].

Internet of Things (IOT)

The Internet of Things is inter-networking of physical devices. This system has the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. The term was proposed by Kevin Ashton in 1999. It means connection of each and every thing to the internet [21]. There are various IOT application used in agriculture such as, Crop water management**,** pest management**,** precision agriculture**,** food production and safety etc.**,** saving fertilizers and chemical crop protection agents**,** boosting soil fertility due to "smart" correction**,** controlling crop state and preventing its loss when stored**,** increasing machinery efficiency**,** monitoring state and location of farm animals**,** tracking processing line equipment condition [1].

Drones

Drones are formally known as Unmanned Aerial Vehicle, which is essentially a flying robot. It can be controlled by either pilot from the ground or it may be autonomous. The drones which are used for agriculture purpose are called as Agriculture drone. In current scenario, it is also being used for surveillance, traffic monitoring and weather monitoring. Different types of sensor are used in drone technology such as**:**

a. Visual sensor: It is used for aerial mapping and imaging**,** photogrammetry and 3D reconstruction**,** plant counting**,** surveillance**,** emergency response and surveying and land use application.

b. Multispectral sensor: It is used for plant health measurement, water quality assessment, vegetation index and plant counting

c. Thermal sensor: It is used for heat signature detection, livestock detection, surveillance and security, water temperature detection and water source detection and emergency response

d. Lidar sensor: It is short range, 270º scanning LASER rangefinder. It is useful in 3D digital surface modelling stockpile calculation and also used for surface variation detection and flood mapping

e. Hyperspectral sensor: It is used for plant health measurement, water quality assessment, vegetation index calculation, full spectral sensing, spectral research and development and mineral and surface composition surveys [16]

Drones can detect problems in plants by scanning a crop using both visible and near-infrared light, drone can identify which plants reflect what amounts of green light and NIR light. When a plant goes into stress, photosynthetic activity decreases. This information can produce multiple images that track changes in plants and indicate their health. As soon as sickness is discovered, farmers can apply the remedies more precisely [22].

Autonomous farming robot [20]

For crop farming, robots need to autonomously navigate their environment and perform actions at set locations, for example, picking a fruit, spraying a pesticide, planting a seed, imaging a plant, or making a measurement. An autonomous

farm robot requires clever controllers, localization and communication systems.

Types of robots used in agriculture [20]
- Demeter robot for harvesting
- Robot for weed control
- Forester robot
- Robot in horticulture
- Fruit picking robot

Farm robot used in pests monitoring
Robot indicates the plant health by observing the colour of the plant parts by image processing. Image processing is done by Raspberry pi. It displays the plant health conditions on the LCD display. The robot takes images of crop and by using image processing in raspberry pi, it can find out the disease or insect present or not on the crop [2]

Methodology of Image processing [16]
- **Image acquisition:** Capture the affected plant parts by using a camera.
- **Image pre-processing:** Histogram equalization is done to increase the contrast of the image.
- **Leaf Segmentation:** It is mainly done for detection of affected areas with the help of various techniques like K-means Algorithm, OTSU, etc.
- **Feature extraction:** Here, colour, texture, etc. are used for matching the test image to the database.
- **Classification:** It is done by using various classifier.

FASAL device: It was developed by Wolkus company which uses Artificial intelligence and data science to make on-farm predictions [2].

How it works?
- **Sense:** It monitors critical microclimatic parameters, including Temperature, Humidity, Rainfall, Soil moisture at various levels, Leaf wetness, Soil temperature etc., 24x7x365 from your farm and uploads it to Fasal cloud platform.
- **Analyze:** The data is then analysed and presented, making your crop's health accessible to you anytime, anywhere on any device for decision making like irrigation management, resource optimization, increasing yield, increasing quality of yield etc.
- **Predict:** Captured data is used by our prediction models to predict the ideal growth conditions, resource requirements including fertilizers, Crop diseases, and microclimatic weather predictions.

Farmer gets notified on his device and actions can be taken directly from it, like switching on drip irrigation etc.

IPM Scope
The IPM Scope combines a digital camera, precision optics and LED lighting into a powerful handheld microscope and imaging software package. Zoom in on fine details of plant disease symptoms, or insects. Instead of straining to look into a tiny eyepiece, place the IPM Scope over the leaf and view the magnified image right on your computer screen [14, 17].

Features
- View live images on the computer screen
- Measures 40X and 140X magnification
- Completely portable when connected to a laptop computer
- Archive still images or send files via e-mail
- Add labels, markers, time stamps and measurement scale
- Draw directly on the live image
- Combines a digital camera, precision optics and LED lighting into a powerful handheld microscope
- Connects to your computer's USB port
- Includes software required to capture and archive your still images
- Software allows you to customize your images with labels, markers, time stamps and measurement scale
- Video software upgrade provides the ability to capture live videos and time lapse sequences of insect movement [14, 17].

Plantect™
It is a smart agriculture solution using sensors and artificial intelligence. Tokyo – Bosch Corporation has started sales of Plantect™ in 2017 – an innovative, Artificial Intelligence-based disease prediction system for greenhouse grown tomatoes. Plantect™ is a service comprising hardware for measuring the environment inside a greenhouse and software for predicting disease occurrence based on the measurement data. The hardware includes sensors for measuring temperature, humidity, sunlight, and carbon dioxide. These are installed inside a greenhouse and the measurement data is sent to a cloud. Users can access the data in the cloud via a web-based app using various devices, such as smart phones or PCs. This enables them to check the inside environment in the greenhouse in real time, or browse past data, at any time and from any location. In addition to the monitoring function, Plantect™ also has a function for predicting the occurrence of disease. Using the data sent to the cloud by the monitoring function, Bosch's proprietary algorithm analyses elements related to disease occurrence, such as leaf wetness, links the analysis with weather forecasts, and displays plant disease infection risk notifications on the app. Plantect™ uses a long-range wireless communication protocol due to low energy consumption. Furthermore, since it is battery-powered, initial installation requires no wiring such as electrical power sockets or communication cables. It can be easily installed in any position within the greenhouse. It uses readily available alkali batteries, which can last for up to one year [7].

Trapview System
It is an automated pest monitoring system that monitors all kinds of insects, which can be lured into insect traps. It works on all continents in any area covered by the GPRS or 3G network. TRAPVIEW system consists of three fully integrated, automated and easy to use tools. The energy independent and weather resistant pheromone traps send pictures of lured pests. The energy independent and weather resistant pheromone traps send pictures of lured pests. All pictures from the traps are gathered, processed and securely archived. The pests that are recognized are automatically marked. An application with powerful analytical tools allows you to efficiently monitor and successfully respond to the situation in the field [7].

Electronic Solutions against Agricultural Pests (e-SAP)
It is an ICT based system developed by UAS, Raichur to help the farmers by providing solutions right in their field and also

extension service workers in enhancing their efficiency. e-SAP targets one of the critical requirements of a crop cycle, pest management. e-SAP consists of the features that brings the farmer, extension worker, scientist and policy maker on the same platform, thereby helping them to find solutions in lesser time that are more practical. It also allows the extension worker and farmers to do survey of pest attack or related problems right in the field, which is then automatically synthesized in the form of graphs and tables [5].

Plantix-Mobile App

It is a mobile crop advisory app for farmers, extension workers and gardeners. It can diagnose plant diseases, pest damages and nutrient deficiencies affecting crops and offers corresponding treatment measures. Users can participate in the online community to network with other farmers, discuss plant health issues and access their local weather reports. Plantix was developed by PEAT GmbH, a Berlin-based AI startup. Plantix is a free mobile application which offers farmers and gardeners the possibility to receive decision support directly on their smart phone. Due to image recognition, the app is able to identify the plant type - as well as the appearance of a possible disease, pest or nutrient deficiency. Plantix takes advantage of deep learning technology which involves neural networks. Furthermore, it provides information on treatment and preventive measures. From the daily new images sent by Plantix users worldwide, the network constantly learns more. This permanent incoming data stream is the basis to providing Plantix users with up-to-date information and alerts in terms of plant diseases, pests and their worldwide distribution in real time. Plantix already cooperates with international research institutes and inter-governmental organizations such as ICRISAT, CIMMYT and CABI. The Agriculture and Horticulture Department of the Government of Andhra Pradesh, India has also already integrated Plantix into its extension services [17].

Other mobile apps

i. **Kheti-Badi:** It is a social initiative App, aims to promote and support 'Organic Farming' and provide important information/issues related to farmers in India. Practicing Natural farming is the need of the hour. Some of the issues include lack of farming information, lack of direct market reach, lack of logistics support and lack of demand forecast while heavily depending on expensive genetically modified (GM) seeds, chemical pesticides and chemical fertilizers. The App can help farmers to convert their chemical farming to Organic Farming, make informed decisions to improve their livelihoods and connect them to consumers to gain bigger pie of the supply chain. The App is available in four languages, and will be available in more languages soon [22].

ii. **Pusa Krishi:** In 2016, Union Agriculture Minister of India, Radha Mohan Singh launched a new mobile app i.e. Pusa Krishi for farmers in order to take the technology to farm fields. The mobile app was launched at the valedictory session of the three-day 'Krishi Unnati Mela' here. With use of this mobile app, farmers can get easy solutions to their problems. Farmers can get information about weather and accordingly they can take measures to save crops. The app will provide farmers with information related to new varieties of crops developed by Indian Council of Agriculture Research (ICAR), resource conserving cultivation practices as well as farm machinery and its implementation will help in increasing returns to farmers [22].

iii. **Smart Krishi:** Smart Krishi, as the name indicates is a revolutionizing smart phone application, caters to every aspect of farming activities and large pool of relevant information for empowerment of professional Nepali agriculture. The main aim of Smart Krishi is to keep up the spirit of farming, bond different regions and help agriculture grow. It inspires the youth to take up agriculture as farming with a lot of emphasis on organic and profitable farming. It keeps in mind the health and prosperity of all i.e. taking mankind and nature together. There are numerous features of this application with a simple to use interface, which makes it much adoptable. Farmers in turn are able to utilize most of the features effectively to earn maximum benefit, such as:

a. Package of Practices: This feature enable farmers to access to all the information related to "High value, low product "category crops from Varieties, soil/ climate to harvesting and storage procedure.

b. Price Information: This section gives daily updated price of Vegetables, Meat, fruits and food grains.

c. Success/failure stories and News: This features let farmers to know about the agriculture related news and success/failure stories which can motivate the early startup farmer.

d. Agro Library: For exploration of large pool information related to agriculture related data, feedings for livestock, manure production, benefits of locally available herbs/fruits for particular disease and many more.

e. Buy and Sell: In this section they can put the details of agro tool, product along with their contact detail. Interested one can directly contact them.

f. Helping institutions: Users can access the contact details of helping intuitions like NGO/INGO, DADO, DLSO, government bodies, research centers, banks.

g. Agro-Vet details: Contact details of agro vets all over the Nepal with phone number and email address. 8. Agro jobs/training and events: Here we will notify users about the agro jobs, training programs or upcoming events (exhibitions, conferences) on a national and international level.

h. Farmer's Community: A pool of agro experts, students, farmers and agro tool traders for discussion on any issues. One can send their queries along with photo of disease their crop is facing and experts will analyze and provide relevant information [19].

iv. **Krishi Gyan:** It is an application aimed at disseminating agricultural information to rural, farming audiences. This application will enable Indian farmers to connect with Krishi Gyan experts and ask their questions related to farming and get the answers within the application through notification. The farmers as well as agriculture enthusiast can also share their answer with each other [17].

v. **Kisan Suvidha:** It is an omnibus mobile app developed to help farmers by providing relevant information to them

quickly. With click of a button, they can get the information on weather of current day and next 5 days, dealers, market prices, agro advisories, plant protection, IPM Practices etc. Unique features like extreme weather alerts and market prices of commodity in nearest area and the maximum price in state as well as India have been added to empower farmers in the best possible manner [19].

vi. **AgriApp:** It is a revolutionary Android based mobile application. It provides complete information on Crop Production, Crop Protection and all relevant agriculture allied services on your Smartphone. In addition to being an information portal, AgriApp is also an online market place bringing farmers, agri inputs, retail & fulfillment services on a common digital platform [21].

vii. **Fasal Salah:** It is an agro advisory path breaking app that provides highly personalized farmer specific crop weather advisories for Indian farmers. This is the first application that provides real-time location specific, crop specific, weather-based agro advisories across India. Fasal Salah advisories are available in Hindi, English and regional languages as well as in audio format for non readers. Inside Fasal Salah [17].

viii. **Krishi Salah:** Personalized farmer advisory is one of the main features of this app. Crop Advisories are available on demand for your crops in your farm: including alerts on adverse weather events, diseases and pests, as well as management practices (irrigation, nutrient management) according to real-time weather conditions at the village level [22].

ix. **Weather information:** Weather is an important factor influencing crop growth. This app provides a 5 day weather forecast at village level which involves several parameters like temperature, relative humidity, wind speed, rainfall. Advisory covers 600,000 villages across India, for nearly all major crops and vegetables [17].

x. **Mandi/Market Prices:** Fasal Salah helps to find and analyze the best Prices for your crops in various mandis [17].

xi. **Audio advisory:** Advisory is available in audio format which is beneficial for non readers.

Fasal Salah provides up to date news for use by farmers like Inputs like crop varieties, fertilizers, pesticides, herbicides availability in their area of operation [22].

Main features of expert system developed in India

I. **Soypest:** A web based fuzzy expert system, developed by ICAR- Indian Institute of Soybean Research, Indore in collaboration with Institute of Int. Management and Technology (IIMT), Gurgaon with an objective to provide IPM decision support to the soybean farmers through internet. This helps to identify active pest and to calculate the activity of active pest followed by their diagnosis [11]. Identification and diagnosis of pest is a knowledge based activity which is done by the system on the basis of damage symptoms, insect-pest morphology and pest images. SOYPEST uses knowledge based inferences for activity calculation [13].

II. **Rice-Crop Doctor:** National Institute of Agricultural Extension Management (MANAGE) developed an expert system to diagnose pests for rice crop and suggest preventive curative measures. The rice crop doctor illustrates the use of expert systems broadly in the area of agriculture and more specifically in the area of rice production through development of a prototype, taking into consideration a few major pests and some deficiency problems limiting rice yield [13].

III. **Agrex:** Center for Informatics Research and Advancement, Kerala has prepared an Expert System called AGREX to help the Agricultural field personnel to give timely and correct advice to the farmers. The Expert System finds its extensive use in the areas of fertilizer application, crop protection, irrigation scheduling, diagnosis of pests in paddy and post-harvest technology of fruits and vegetables [10].

IV. **Pest Management Information System (PMIS) for important crops:** This is a standalone generic database application developed by National Center for Integrated Pest Management (NCIPM), New Delhi to cater the needs of master trainers, KVKs, extension workers and progressive farmers [16]. The software provides information on all aspects of Mustard, Groundnut, Basmati Rice, Cotton, Brinjal, Okra and Tomato crops such as crop general information, agronomic practices, pests, natural enemies, nutrient disorders, resistant varieties etc, Application of PMIS could improve the efficiency of farmers' existing production systems for making farming more profitable [9].

V. **AgriDaksh:** A tool for building online expert system which enables domain experts to build online expert system in their crops with minimal intervention of knowledge engineers and programmers. This is a generic system for all crops with ability to create knowledge models for new crops. It has Ontology based diseases diagnosis, insects identification and variety selection. This also captures location specific variety information with the ability to add multiple pictures for each variety. It has comprehensive plant protection module that provides information on diseases, insects, weeds, nematodes and physiological disorders. The system has been tested on Maize crop and is online for last one year [9].

VI. **Exowhem:** A web based Expert System developed for the wheat growing farmers of India. It provides the complete information about the Wheat Crop Management in the country. The system advises wheat varieties on the basis of area, cultural and climatic conditions and other characteristics of farmer's interest. The system carries detailed information about 300 varieties that have been stored in its knowledge base. It also suggests the appropriate cultural practices like field preparation, fertilizer application, schedule of irrigation etc. It guides them in protecting the crop from insects/diseases/weeds etc [6].

E-Pest Surveillance System for Maharashtra

Pest surveillance or monitoring is the cornerstone of IPM as compared to calendar-based treatments IPM stresses monitoring of pest and determines when the action is necessary to be taken. The basic purpose of surveillance is to determine whether pests are present in the field at a level to initiate pest management interventions. Through regular and systematic pest surveillance, epidemic situations can be avoided by detecting damage before endemic establishment of a pest in any area. Hence in 2009 NCIPM and Maharashtra state agriculture department joined hands to develop and implement ICT based pest surveillance and advisory system also called e-pest surveillance system for Cotton and

Soybeans crops in the state. E-Pest surveillance system is basically an internet based system of capturing pest information from fields and producing instant and customized pest reports to the plant protection experts to advise the state agriculture agencies who further advise concerned farmers and the same information is available for agricultural policy planners [14]. Keeping in view the size of data and internet connectivity in remote areas, system was designed as having offline data entry and online pest reporting & advisory. On the basis of level of pest incidence in farmer's field, experts submit pest advisories which are disseminated by the system to the farmers through SMS. Below mentioned is the Information flow chart of the system [7, 9].

- Data collection
- Offline data entry
- Data verification, compilation and transfer into database
- Online pest reporting & advisory issuance
- Pest advisory dissemination

After successful implementation in Cotton Soybean, Rice, Chickpea and Pigeon pea in Maharashtra, the system has also been extended to horticultural crops; Mango, Pomegranate, Sapota and Banana. This has also been replicated in pulses in Andhra Pradesh, Karnataka, and Uttar Pradesh and Maharashtra states and for Rice in Odisha state [10].

E-National Pest Reporting and Alert System" in pulse crops

It was developed by National Centre for Integrated Pest Management, New Delhi. The useful information is collected, processed, and interpreted, and then the appropriate advisories are sent to the registered farmers through centralized server system. They apply suitable corrective measures as per advisories at right time [7, 9, 16].

Future prospects

The focus of the further research and development should be on how new innovative ideas can be implemented to challenge the pest infestation. The awareness and knowledge about new agriculture technologies are yet to be spread extensively in developing countries. Immense efforts will be required by all the stakeholders to mainstream the use of these technologies in order to capitalize on the benefits:

- Government Agencies: Policy support and resources to support the sector
- Private sector players can support effective business models
- Universities: Special program for training in the sector – graduate/PG programs,
- NGOs: Capacity building of farmers
- Donor agencies: Supporting pilot initiatives
- Finance/Banking sector to support initiatives

Conclusions

Farming is the major source for the survival in this world, here the future farming is moving towards the smarter technologies in order to increase the productivity within a short time. Tools that improve the accuracy on pest and disease diagnosis which will give growers a better ability to spray pesticides when and where required, saving them money on the unnecessary sprays. Decisions that are based on reliable and accurate information increases the quality of farming.

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