Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 8 [12] November 2019 :01-12

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.876
Universal Impact Factor 0.9804
NAAS Rating 4.95

REVIEW ARTICLE **OPEN ACCESS**

Geo-spatial Technology for Plant Disease and Insect Pest Management

Md. Arshad Anwer*[1] and Garima Singh[2]
*[1]Department of Plant Pathology, Bihar Agricultural University, Sabour-813210, Bhagalpur, Bihar;
[2] Department of Agronomy, Bihar Agricultural University, Sabour-813210, Bhagalpur, Bihar
Email: arshadanwer930@gmail.com

ABSTRACT
For the development of any country, food security is essential and it is only fulfilled by ample amount of crop production. The losses in crop production is one of the most important constrains. Various biotic and abiotic factors affect agriculture productivity and production. Among them poor soil, water scarcity, adverse temperature and insect pests, diseases and weeds are the principal causes that reduce the productivity. Only plant diseases, insect pests and weeds cause 30 to 40 per cent loss in production. The losses may be reduced by the noble application of geospatial technology in study of outbreaks and management of insect pests and plant diseases. The production can be further enhanced with precision framing by managing the natural resources. In precision farming there is a necessity for reliable data in apt quantity and quality and location to which geospatial technology can prove as an important tool in acquiring reliable data for agriculture and natural resources information. Geospatial technology includes Geographic Information System (GIS), Remote Sensing (RS) and Global Navigation Satellite System (GNSS). These systems have been used in collecting, mapping, analysing the distribution and predicting the scenario of insect pests and diseases and crop yield. The technology has been used from the very beginning surveying the status of crop in respect of insect pests and diseases until forecasting to be occurred. However, the Geospatial technology has certainly playing a crucial role to decision makers in forming strategies for management of insect pests and diseases of agriculture crops and thus productivity and production.
Keywords: GPS, GIS, Remote Sensing, Global Navigation Satellite System, Insect pests and diseases, Precision farming.

Received 12.09.2019 Revised 20.10.2019 Accepted 02.11.2019

INTRODUCTION

For the sustainable development and economic growth of the country it is necessary that population must not be malnourished or hunger. In India and other developing countries, malnutrition is the only cause of one third of deaths and underweight with retarded growth among children less than 5 years of age. Malnutrition is due to deficiency in macro and micronutrients, is due to imbalance nutritional intake and disease, creating from food insecurity, bad child and maternal care practices with lack of clean drinking water and inadequate quality health and sanitation services [1]. Since past few decades the imbalance between growing food demand of the world burgeoning population and agricultural produce worsened the situation [2]. Biotic and abiotic factors, including unfavourable harsh temperatures, water scarcity, poor soil, and insect pests, diseases and weeds, are main limiting factors that can affect agricultural productivity, production and ultimately food security. Moreover, the climate change or disturbed climate has an enormous negative impact on agricultural productivity and production of the world especially areas of tropical zones [3]. Globally climate is changing day by day and it is anticipated 20% reduction in agricultural production by 2080 and the situation will worsen in developing countries including India. Climate change contributes to extreme event like heat and cold stresses, uneven distribution of rain, drought and flood, storms etc., all have an intense impact on crop yields. These changes and disturbance causes the increase emergence of new insect pests and diseases outbreak [3]. After the establishment of World Trade Organization (WTO) in 1995, there is an increase in global trade of export and import of agriculture produce under liberalisation. The trade globalization has also amplified the movement of invasive alien species which disturb the local and exotic plant ecosystems of different regions. Both liberalisation of trade and climate change have also increased the emergence of new diseases and insect pest outbreak [4]. However, with the development of latest technology, there are many ways to minimise the loss in crop yield. Now these days, the GIS and Remote Sensing are extensively used to collect crop information accurately and to analyse the collected data precisely. This paper reviews the noble role of Geospatial Technology, in emerging and dealing the effects of disease and insect pests on plant/crop. The paper will also visualize the extra knowledge on how geospatial technology would be implemented in agriculture to mitigate the problem.

Effects of insect pests and disease on plant/crop

When a plant is performing its physiological activity to the best of its genetic potential, it is said to be healthy. If plants are disrupted by insect peats or pathogens, their physiological functions are also disturbed from the usual [5]. All the insect pests and diseases hamper the health of the plant, reduce the biomass and, hence, productivity and production. The damage may happen in four ways. Firstly, by killing the plants and predisposing the neighbour plant, for example, different soil fungi, vascular disease or breakdown and several boring insects. Another, by general stunting due to metabolic disruption, nutritional loss or root damage, like caused by aphids, and various plant viruses. Thirdly, by killing of plant's branches, such as, some fungal diebacks and some boring insects. Fourthly or lastly by leaf tissue eradication, such as leaf spots, blights, mildew, rusts and some boring insects. Generally, the insect pests or disease attack in the field, but become more apparent after harvest in the form of yield and quality. The cumulative damage of insect pests and diseases is generally horrible and widespread [6]. It not only harms the agricultural produce but at the same time forest diseases and pests can have major impact on ecosystem services, changing natural landscaping and their cultural value, hampering wildlife habitat and hence biodiversity as well as decreasing the forest ability to sequester carbon, reducing desertification or protect watershed [7,8]. The disease and insect pests outbreak can have many significant negative impacts on forest health, the economies of forest based tribes or communities and on carbon stocks [9]. Therefore, the insect pests and diseases not only hamper crop productivity, but also the economy of the forest community and sustainability of forest.

Effect of insect Pests and diseases on Agricultural crop

Pests in agriculture are known as organisms that kill or destruct plants [10]. Agricultural pests mostly belong to insect species and hence termed as insect pests. Insect pests of agricultural crops can cause harm in different ways by different insects such as sucking, boring and cutting insects etc. All these different types of insects belong to different species under different orders. Agricultural crops/plants of the world are damaged by more than 100,000 diseases (caused by fungi, bacteria, viruses, and other microorganisms) 30,000 species of weeds, 10,000 species of insects, and 1000 species of nematodes [11]. However, less than 10 per cent of the total identified pest species are generally considered as major pest. Insect pest problems in agriculture have shown a considerable shift during first decade of twenty-first century due to ecosystem and technological changes. While there has been an overall decline in the severity of *Helicoverpa armigera* (Hubner), one of the most devastating insect pest, has a severe adverse impact to crop productivity and production, in which it can multiply up to eleven generations every year under optimum suitable condition[12]. The incidences of several other insect pests like mealy bugs, particularly *Phenacoccus solenopsis* Tinsley on cotton; sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner on sugarcane; and tobacco caterpillar, *Spodoptera litura* (Fabricius), on several crops, has shown an increasing trend. The diamondback moth, *Plutella xylostella* (Linnaeus), has consistently remained the most destructive pest of cruciferous vegetables. Now these days, fall armyworm (*Spodoptera frugiperda* J.E. Smith) (FAW), ever most devastating polyphagous pest especially for maize crop, causing economic yield loss to the crop ranging from 22 to 67% in Ghana and Zambia [13] and from 32 to 47% in Ethiopia and Kenya [14]. In several African and Asian countries FAW generations have been continuously observed throughout the year, wherever host plants are available, including off-season and irrigated crops[15]. The main reason pests can be harmful to agricultural plants is the pest hosts on the plants. Pest also can be detrimental to plant health through nesting over planted field or embedding eggs in plant tissues. Damage in plant leaves can lead to shrinkage of the surface area, while also slowing water transportation and nutrition to the other parts due to damage in the stems. If the root parts are damaged, it will affect the absorption of minerals and water from the soil. Thus, it will have a negative impact on the plant's health, slowing down the plant growth and causing parts of the plant tissue to rot. In the majority of cases, the apparent integrity of plants is not damaged by sucker pests. Usually, to identify pathological changes in the affected area, they will identify spots on the surface of the plants as the indicator. A sucking pest is a pest that damages the plant by using their mouthpart and inserting it into the plant tissue and extracting the juice out from the plants [16]. In addition, the biochemicals in plant cells and tissues will be changed when the pest injects its salivary glands' secretion when sucking. Thus, plants that have been infested heavily will wilt, become yellow, stunted or deformed and may eventually die. There are also some sucking insects which, while feeding on the plant, inject toxic materials and transmit disease organisms. A common sucking pest is aphids, blackflies, greenflies, whiteflies or ticks (Trombidiformes), true bugs (Hemiptera) and thrips (Thysanoptera). There are many crops in India and each crop has its own pests that affect its health. For example, brinjal is attacked by more than 70 insect species[17], of which Brinjal Shoot and Fruit Borer (BSFB) (*Leucinodes orbonalis* Guen), leafhopper (*Amraska bigutulla bigutulla* Ishida), aphid (*Apis gossypii* Glover), stem borer (*Euzophera perticella* Ragonotl), Epilachna beetle (*Henosepilachna vigintioctopunctata* Fab.), white fly (*Bemisia tabaci* Gennadius), lacewing bug (*Urantitus hystricellus* Distant) were the major pests. Among them only BSFB causes 80-90% yield loss [18,19,20]. Diamondback moth, *Plutella xylostella*, is an insect pest that infests cabbage and cauliflower [21] and belongs to the Plutellidea family and *Plutella* genus. Fall armyworm becomes serious pest of Indian maize since 2018. Meanwhile, there are about 80 species of arthropods pest that have the potential to feed on oil palms. Each country has its own species that attack. In America, pests that attack palm oil are *Rhynchophorus palmarum* and *Alurnus humeralis*, while, in India, the species is heavy with the population of coccinellidae on the spear region and, in Kerala, the pest recorded was *Rhynchophorus ferrugineus* [22]. Thus, the increase of pests in agricultural activity will cause great economic losses. The global losses due to insect pests have been recorded 10.8 per cent in post-green revolution era to towards the beginning of this century. In India, 17.5 per cent crop losses have been noted during the same era. In terms of monetary value, the Indian agriculture currently suffers an annual loss of about Rs 863.884 billion due to insect pests [11]. Any harmful condition that affects a plant's function or appearance is known as plant disease [23]. The causes of disease in plant can be living or non-living. However, biotic diseases are caused by living organisms such as oomycetes, fungi, bacteria, phytoplasmas, viruses, viroids, virus-like organisms, nematodes, parasitic plants and protozoa [24]. Non-living environmental conditions, such as heat storm, wind, frost, soil salt, soil compaction, damage and girdling roots, cause abiotic disease. However, fungal pathogen is the most destructive plant disease causes major losses to the crop [25]. Standing out among the examples of how damaging a crop disease can be is the Irish famine of 1845/46, which was caused by the failure of the potato crop in Europe because of just one plant disease, the Potato Late Blight caused by a filamentous fungus-like member of the Oomycota, *Phytophthora infestans* (Mont.) de Bary. This is a shocking story of how a crop disease affected the structure of our civilisation and our understanding of nature, while causing the deaths of one in eight of the Irish population. Almost every plant is host for several fungal pathogens and each pathogen can attack one or many kinds of plants. Fungi are an organism classified in the fungi kingdom wherein they lack conductive tissue and chlorophyll. Fungi are known as parasites or saprophytes because they cannot produce their own food, but, rather, feed on decaying organic matter. Fungi damage a plant by killing cell plants or causing plant stress. As an example, *Synchytrium endobioticum* is the fungus that causes potato wart disease and was listed as a weapon on the bioterrorism list in the U.S. in 2002[26]. An example of biotic disease is Moko disease, which attacks the banana plant, caused by *Ralstonia solanacearum* (*Pseudomonas solanacearum*) bacteria [27]. Moko disease is an environmentally and economically important threat that causes large losses in many tropical countries. If there is no emphasis on the disease control, it will lead to a severe loss. On the basis of economic losses, 'Top Ten' fungal pathogens are ranked as (i) *Magnaporthe oryzae*; (ii) *Botrytis cinerea*; (iii) *Puccinia* spp.; (iv) *Fusarium graminearum*; (v) *Fusarium oxysporum*; (vi) *Blumeria graminis*; (vii) *Mycosphaerella graminicola*; (viii) *Colletotrichum* spp.; (ix) *Ustilago maydis*; (x) *Melampsora lini*, with honourable mentions for fungi just missing out on the Top Ten, including *Phakopsora pachyrhizi* and *Rhizoctonia solani*[28]. Generally, the plant pathogenic fungi live under warm and humid conditions.

Meanwhile, abiotic disease is a disease caused by non-pathogenic and abiotic factors, such as wind, frost, soil compaction, etc., but it cannot be transferred to healthy plants from affected plants [29]. The most important reason for an abnormal plant growth is usually, unfavourable environment, such as inadequacy, excess, imbalance or deleterious interaction of the physical or chemical factors essential for healthy plant growth. For example, the disease can be affected by low humidity. When the humidity level decreases, evaporative demand will increase and this will stress on plants' moisture, even when there is plenty of root water supply. Thus, the result is tissue damage. Other than that, atmospheric gases, temperature and light can also be a factor for abiotic disease [30].

Geospatial Technology in Agriculture

Geospatial technology is an organized collection of computer hardware, software, geographic data, and personnel and designed to efficiently capture, store, update, manipulate, analyze, and display geographically referenced information. The term geospatial technology (GST) refers to geographical information systems (GIS), global positioning systems (GPS), and remote sensing (RS), all emerging technologies that assist the user in the collection, analysis, and interpretation of spatial data. It deals with the relationship and condition of manmade and natural objects within space be it on Earth, or beyond. Geospatial technology has made inroads across various sectors in the public as well as private domain in India. The major sectors using geospatial technology in India are: agriculture, telecommunications, oil & gas, environmental management, forestry, public safety, infrastructure, logistics etc. As stakeholders across sectors realize the utility and long term cost effectiveness of using geospatial tools and technologies, the geospatial industry is set to progress exponentially in the coming years. The application of geospatial technology in agriculture began in early 1990s[31] and, now, farmers can measure the spatial and the temporal variability in soil, relief and vegetation through the capability of using global navigation satellite system (GNSS) technology in locating the agricultural machinery and increasing the quality and availability of geographic information in digital form. By using mobile technology, farmers can keep their farm and field records in the device. Thus, farmers can enter and retrieve information on site[32]. GPS and GIS technology are used to generate a georeferenced map for different crop and properties of soil, diseases and insect pests to provide field professionals and growers with a new set of communication tools and management [33]. Today's increasing variety of map production is helping in improving the management of insect pests, diseases and crops. Soil maps for instance, are used to give a better understanding on the property of the land. The basic information related to agriculture parcels, such as yield, and records of operations, such as fertilization and ploughing and usage type, have an inherent spatial and, normally, also temporal reference [34].

Geospatial Technologies in India

The GDP in India is expected to approach $9-10 trillion by 2025 and the Indian economy would be characterized by its transformation to being highly industrialized and technologically advanced. India will therefore require an efficient and advanced information and knowledge regime to arm itself for the anticipated economic growth. Geospatial technologies would be central to information management in India in future and the applications of this technology can have great social as well as national relevance. It can support governance, help prepare sustainable development strategies, enable better management of business process and make geographical knowledge available to the citizens. In India, the market for GIS based technologies has been expanding at such a substantial pace of 13.8% that it is estimated to touch the figure of USD 16.40 billion by 2020-21 (Indian Geospatial Market Report 2017-18). Several Indian states such as Andhra Pradesh, Karnataka, Rajasthan and Tamil Nadu are now using geospatial technology for good governance and efficient management.

Geospatial Technology in Precision Farming

With the introduction of precision framing in Indian agriculture there was a necessity for reliable data in apt quantity and quality and location; satellite data and geospatial technology became important tool in acquiring reliable data for agriculture and natural resources information. These types of data are good in management of resources which are scarce in quantity. Precision farming (PF) or site specific crop management (SSCM) is a sustainable, modern farm management concept that gives opportunities to optimize productivity and reduce pressure on natural resources by observing, measuring and responding to inter and intra-field variability in crops. PF has created the scope of transforming the traditional agriculture, through the way of proper resource utilization and management, to an environmentally friendly sustainable agriculture [35]. It is based on an innovative systems approach, which is a combination of fundamental geospatial technologies such as GIS, GPS, computer modeling, ground-based/airborne/satellite Remote Sensing (RS), variable rate technology, and advanced information processing for timely in-season and between-season crop management [36]. These geospatial technologies are the basis for precise agriculture, which represents a paradigm shift in agriculture [37]. Precision farming is an intelligent technology of 21st century as it epitomizes the efficiency of resource used and manages the spatial and temporal variability of farm. The variabilities of farm are: yield variability, physical parameters of the field, soil chemical and physical properties, crop variability (e.g. density, height, nutrient stress, water stress, chlorophyll content), anomalous factors (e.g. weed, insect, and disease infestation, wind damage), and variations in management practices (e.g. tillage practices, crop seeding rate, fertilizer and pesticide application, irrigation patterns and frequency).

Geospatial technology play important role in PF by assessing crop conditions and yield prediction, detection of crop diseases and pests, mapping and location of disaster, water supply management information, wildlife management, range land, livestock and weather forecasting [35]. Using GIS, GPS and RS analytical capabilities, variable parameters that can affect agricultural production can be evaluated. RS is considered potentially a practical management tool for site-specific crop management [38]. Geospatial technology tool used in precision farming are shown in figure 1.

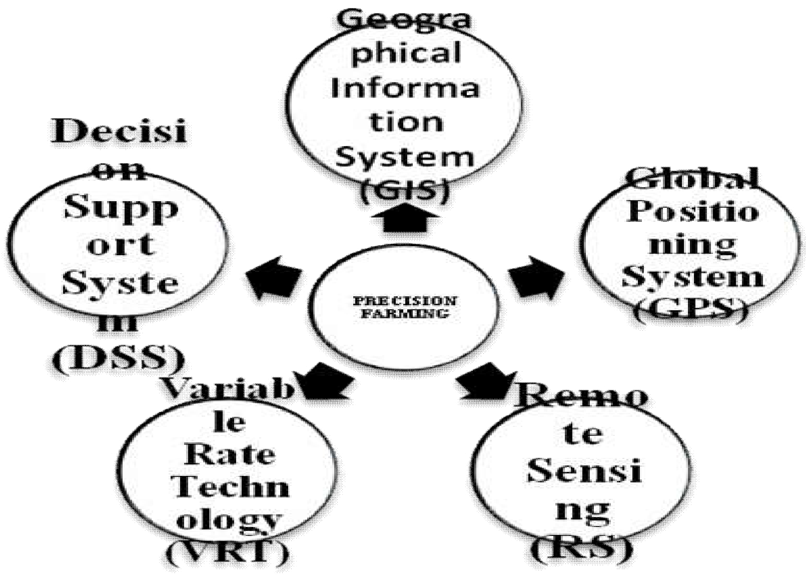

Figure 1: Geospatial technologies used under precision farming.

Firstly, Remote sensing technologies are used to gather information about the surface of the earth from a distant platform, usually a satellite or airborne sensor. Remote sensing has been used in soil mapping, terrain analysis, crop stress, yield mapping and estimation of soil organic matter. Most remotely sensed data is collected as reflected electromagnetic radiation (EMR) and are used for mapping and spatial analysis. Reflected EMR are in infrared spectra which is normally invisible to the human eye but is of great importance for vegetation study. The spectral properties of vegetation in different parts of the spectrum can be interpreted to reveal information about the type of vegetation, health status of crops, rangelands, forests etc. These spatial data are then captured, stored, manipulated, analyzed and managed in GIS system. GIS is the key to extracting value from information on variability as it is the brain of precision farming system and its spatial analysis capabilities enable precision farming. A GIS can manage different data types occupying the same geographic space. The ability to depict different, spatially coincident features is unique to GIS. For example, distribution of biological control agent and its prey across a variety of plant types in an experimental plot. Although predator, prey, and plants occupy the same geographic region, they can be mapped as distinct and separate features. GPS is a satellite and ground-based radio navigation and locational system that determine the accurate locations on the surface of the earth. Simple and inexpensive GPS units with high accuracy are available for more sophisticated precision agriculture systems.

The use of these geospatial technologies in precision farming enabled everyone to collect information from various sources and Internet of Things (IoT) establishes a communication to the entire world through an Internet bringing an evolution in global agricultural scenario. This type of smart agriculture with the application of information and communication technologies will be helpful in the maintenance of the farmland making it more resource-efficient and productive. By combining the Geospatial technology with IoT for precision, main goal is to monitor and predict the critical parameters such as water quality, soil condition, ambient temperature and moisture, irrigation, and fertilizer for improving the crop production [39].

In North eastern Colorado, users of site-specific management zones under irrigated corn have maintained or increased grain yields, increased N use efficiency by 20 to 200%, and increased net economical return to land and management by $17 to $30 ha-1 [40,41]. Ground based remote sensing, GIS and a revised N Reflectance Index (NRI)[42] was used to improve in-season N management of corn in a commercial sprinkler-irrigated field. This site-specific N management system applied 52% less N than that used by the farmer (214 kg N ha-1 yr-1) in commercial field operations during the growing season [43]. The Bausch and Delgado (2003) method saved 102 kg N ha-1 yr-1 with equivalent savings of about $55.00 ha-1 per season. The use of GPS/RS/GIS tools can significantly maximize N efficiency of corn systems without reducing grain yield for commercial applications and minimize NO3-N leaching and offsite transport of N [43]. Magalhaes and Cerri in Brazil developed a special yield monitoring system specifically designed for the implementation of precision agriculture in sugar cane crops [44].

In India, Tamil Nadu State Government has sanctioned a scheme named ''Tamil Nadu Precision Farm-ing Project" to be implemented in Dharmapuri and Krishnagiri districts covering an area of 400 ha. High

value crops such as hybrid tomatoes, capsicum, baby corn, white onion, cabbage, and cauliflower are proposed to be cultivated under this scheme.
A computer-aided software named 'CROP9 -DSS' has been developed, which will aid as a DSS for calibrating water and fertilizer requirement, crop protection and identification of implements for the leading crops of the state of Kerala.

Geographical Information System in Crop Health, Plant Disease and Insect Pest

Geographical Information System (GIS) is a technology used to store, capture, analyse and visualize data that describe a part of the Earth's surface, the technical and administrative entities, as well as the findings of geoscience, economics and ecological applications [45]. Typically, GIS offers functions for retrieval and storage, visualization, query, geometrical and thematic analysis, transformation etc[46]. GIS can be categorized into four categories: data capture systems, analysis systems, administration systems and presentation systems. Parallel with the vast of technology development, there are many options which can be chosen to capture the data. For example, Global Positioning Systems (GPS) and Geodetic Surveying, laser scanning, photogrammetry and satellite-based remote sensing, etc.; therefore, we can say that monitoring of plant health has become easier with the development of geospatial technology.
GIS has been used in various farm operations and widely in accommodating the biosecurity assessment of plant health (figure2) [47]. According to Mandal *et. al* [48], to face the problem of production of monoculture cotton loss up to 40 % caused by *Rotylenchulus reniformis* infestation, Brazil employed geo-statistics technique to produce a spatially differentiated nematode risk map in the field. Whereas, this method is less cost rather than using protection by nematicides.

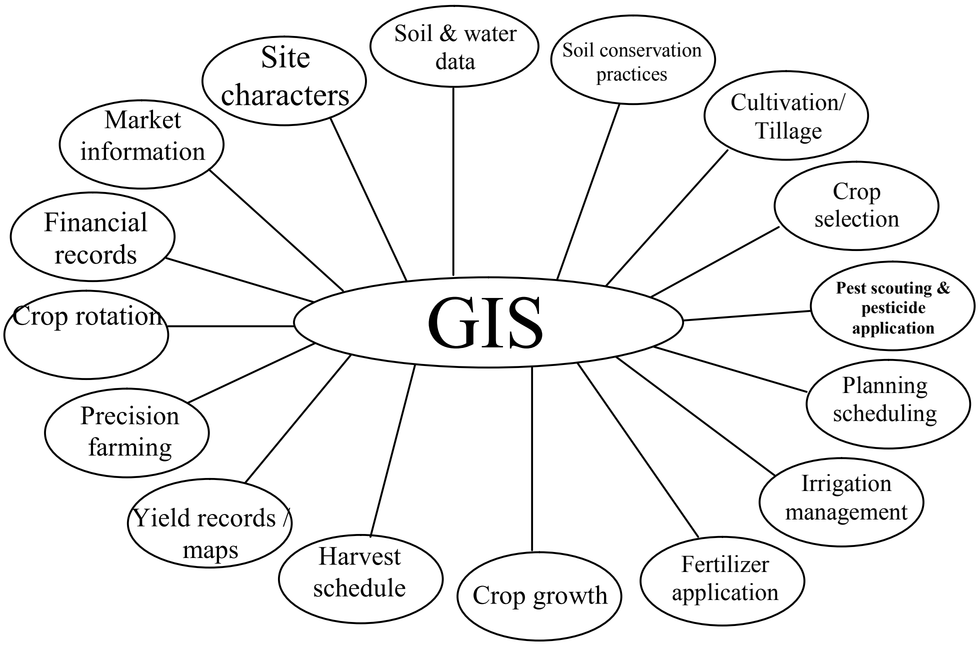

Figure 2. Application of GIS in various farm operations

In some cases, GIS is also used to improve the way New Zealand farmers manage their inputs[49]. Ravensdown, known as one of New Zealand's largest manufacturers and distributors of fertilizers, is using geospatial technology to guide the farmers in decreasing the amount of wasted resources that can potentially cause harmful runoff into streams and waterways. This method not only can save the environment, but also, at the same time, save their total fertilizer expenditure by up to 10% per year.
Moreover, GIS is known as a software application that is used to manage and analyze spatial data. It is able to store, retrieve and transform spatial information relating to productivity and agronomy including disease and pest. Case studies in India have proven that, by using the GIS Based Decision Support System, it will help all farmers in taking the day-to-day decisions whereby agricultural experts suggest the selection of crop based on geography through an understanding of all the risks. In addition, this system helps in analyzing past records or databases with reference to the geographical maps which can be used in producing various models for agricultural practices. Thus, GIS acts like a tool that can help the decision-makers in identifying the sites which are already being used for cultivation and

analysing the details of potential sites that can be used for various means of agriculture, such as floriculture, etc[50].

Use of GIS/GPS technology for semi-automated data analysis was used in northern California, Washington, Oregon, Idaho, and Arizona. Ground-based weather, plant-stage measurements, and remote imagery were geo-referenced in GIS software using an integrated approach to determine insect and disease risk and crop cultural requirements. Weather forecasts and disease weather forecasts for agricultural areas were constructed with elevation, weather, and satellite data. Models for 6 insect pests and 12 diseases of various crops were calculated and presented daily in georeferenced maps for agricultural surveyed areas. Grape harvest dates and yields also were predicted with high accuracy. The data generated from the GIS global positioning system (GPS) analyses were used to make management decisions over a large number of acres of the study area and information was distributed daily over the Internet as regional weather, insect, and disease risk maps[51].

In Malaysia, Pohl et al. (2016) GIS has been implemented in support of decision- making and monitoring to increase sustainability of oil palm plantation[52], whereby all spatial layers collected from various sources are geo-coded and fed into the GIS. Then, an appropriate method in GIS is used to analyze all the data. Yahayaet. al. (2015) GIS was also used for paddy cultivation management[53]. Their study developed a web-based system to monitor growth of the paddy in which all the data collected were converted into spatial information and stored. Then, a map was created and published into the ArcGIS server. The database is available in Internet Information systems as a web browser and ArcGIS servers are used to publish spatial layers as map series.

Remote Sensing in Insect Pest and Disease Management

Remote sensing is the approach of getting information about an object without direct contact with the object. Electromagnetic radiation is the information carrier in remote sensing, whereby it travels in a vacuum in the form of waves of various lengths and at the speed of light. There are two types of remote sensing, active and passive remote sensing. Passive remote sensing sensors record incident rays reflected or emitted from objects while active sensors emit their own radiation by interacting with the target to scrutinize and return to the measuring device [54]. The spectrometer field in remote sensing is usually used in agriculture to solve problems in the nutritional requirement of plants, detection of disease and pest damage, forecasting yield, water demands and weed control. The factors which favor the development of pests and their effect on plant parameters that are detectable by remote sensors are shown in Figure 3.

Remote-sensing technology has a variety of applications, including environmental monitoring, site-specific agronomic management (SSM), land cover classification, climate- and land-use-change detection, and drought, disease and pest monitoring. The ability of a remote sensor to detect ultrafine differences in vegetation makes it a useful tool for quantifying within-field variability, evaluating crop growth and managing fields based on current conditions that may be overlooked using typical ground-based visual scouting methods.

According to Wojtowicz et al. (2016), remote sensing can also be used to determine the nutritional requirements of plants [55]. A study of two sets of cucumber plants (*Cucumis sativus*) grown in a controlled environment was performed wherein one set was inoculated with bacterial wilt causing pathogen, *Ralstonia solanacearum* and the other set was the experiment control. During the pre-symptomatic stage, both sets of cucumber plants were subjected to changes that can be applied in the field, such as nutrient content, water content and light exposure. Spectral reflectance of the cucumber was measured using a spectro-radiometer. In this case, remote sensing instruments measure electromagnetic radiation that is reflected or emitted from an object of interest. If two different objects reflect the same electromagnetic energy, these two objects would appear the same in a remotely sensed image. Meanwhile, when a plant is infected by bacteria, virus or fungi, there is a period during which there are no visible symptoms of infection on the plant. This is usually because the plant has a resistance mechanism against infection or the pathogen takes time to establish and develop within the plan [56].

Additionally, remote sensing has also been used to forecast crop yields based primarily upon statistical–empirical relationships between yield and vegetation indices. Information on expected yield is very important for government agencies, commodity traders and producers in planning harvest, storage, transportation and marketing activities. If this information is available, the lower the economic risk, translating into greater efficiency and increased return on investments [55].

In China, Liu et al. characterized and estimated fungal disease severity of rice brown spot with hyper spectral reflectance data[57]. The result not only confirms the capability of hyper spectral remote sensing data in characterizing crop disease for precision pest management in the real world, but also testifies that the ratios of crop reflectance is a useful method to estimate crop disease severity.

In Australia, Apan et. al. detected pests and diseases in vegetable crops using hyper spectral sensing with a comparison of reflectance data for different sets of symptoms[58]. Another study was conducted in the same country using hyper spectral remote sensing as a tool for early detection of leaf rust in blueberries.

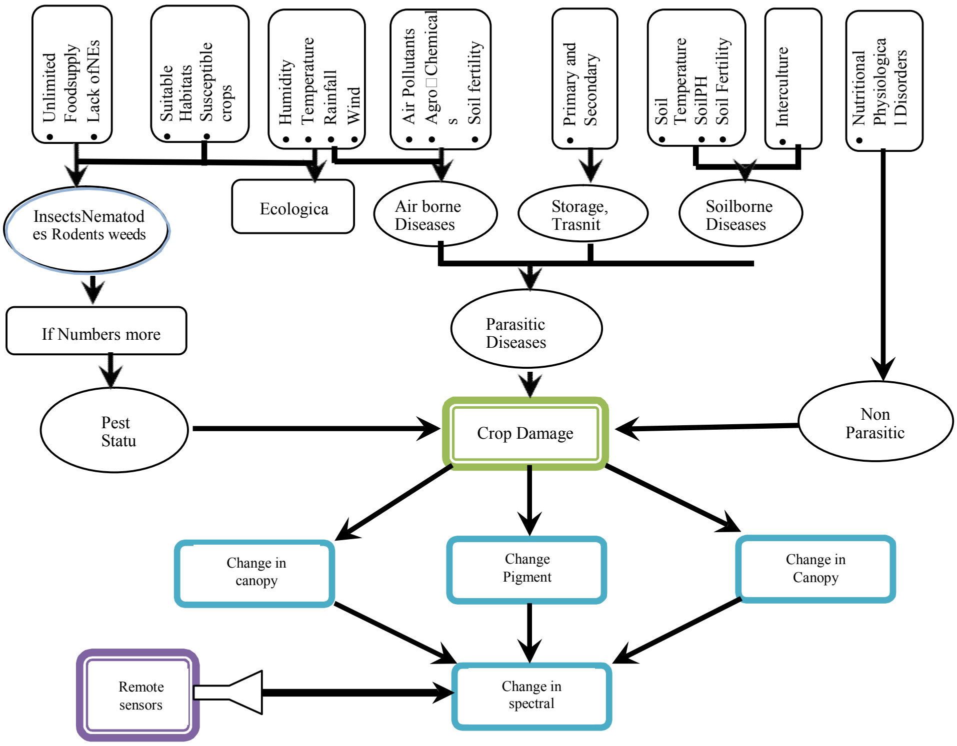

Figure 3.Development of diseases and pests of crop resulting crop damage and its detection through remote sensing *(Source: Rao, 1988).*

In Malaysia, remote sensing technique was used in soil use by Tayari et. al. (2015)[59] to track the dynamic conditions of a plant in a glimpse form and it was measured visible and invisible features of a farm or a group of a farms and turned it into point estimation of continuous spatial information (Phol et. al., 2016) used a multitemporal and multisensory approach to monitor oil palm plantations[52].

FAO has developed an Android app (FAMEWS) for recording field scouting and pheromone trap data. Research on remote sensing, automatic counting of trap catches, image analysis of insects and damage, and radar, will all improve monitoring and contribute to understanding fall armyworm (*Spodoptera frugiperda*) biology, as well as provide opportunities for forecasting.

Remote sensing technology has also been implemented in other studies like precision farming in Rice Field Management. In the study Ishak and Sutha (2014) used high-resolution satellite image with resolution of 0.5m-1.0m overlaid with an integrated cadastral map [60] to define the actual planted area and differentiate which were the paddy and non-paddy fields, such as roads, fishponds and others. The purpose of this study was to use high-resolution images to manage rice field management. Satellite imagery has not only been used for mapping, but also to keep track and observe the activities during the growth phase, starting from land preparation to harvest.

Global Navigation Satellites System (GNSS) in Plant Disease and Pest Management

The Global Navigation Satellites System (GNSS) has been used for various types of applications, such as location, navigation, tracking, mapping and timing. The Global Positioning System (GPS) is the common GNSS that was developed in the 1980s and becoming fully operational in 1995[61]. The ground receiving units can receive this location information from several satellites at a time for use in calculating a triangulation fix, thus determining the exact location of the receiver [62]. GNSS has now become of significance to the agricultural sector not only for research, but also in practical use. Accurate and current information, either spatial or non-spatial data, is needed in agricultural management to help in planning and executing activities to improve the efficiency in productivity of the land and input use [63].Typically, GNSS technology is used in precision farming to collect point of data, georeferenced and more. Usually, DGNSS or RTK-GNSS is chosen due to their ability of precision up to submeter accuracy. In management of plant pest and disease, Jiannong et al. (2009) used advanced digital imaging technology embedded with GPS coordinates and timestamp to produce geo-tagged images [64]. This technique enables to the monitoring or mapping of pest and plant disease locations through time and space, whereby a geo-coded image can be seamlessly transferred to a computer through metadata called Exchangeable Image File Format (EXIF) for a mapping system. The mapping process can be performed seamlessly with integration mapping software, combining web mapping with digital imaging technologies and can enhance the ability to track pest and plant disease through time and space. In managing plant pest and disease, Gougherty et al (2015) employed GPS technology in providing the location of areas with positive Plum Pox Virus (PPV) and all PPV-negative prunus block [65]. PPV is one of the most threatening pathogens, as it will cause a huge reduction in the production of fruit yield and quality. Meanwhile, to combat Panama disease that infected banana in the Middle East, Ploetz et al. (2015) used GPS to obtain the location of the areas infected with Panama disease and non-infected areas and mapped the data [66]. Aguilar et al. (2014) used a geo-location method with GPS technology for in situ habitat characterization in managing banana insect pest in Mindanao, in the Philippines [67]. Every month for six months, the area was monitored for insect pest incidence. Then, each location was compared to analyze insect pest that infest on the crops. In Malaysia, Idris et al. (2015) used handheld GPS for data collection enabling locations identified as areas infected with pest and disease [68].

CONCLUSION

In these modern days Geospatial technology like GPS integrated with GIS are being used in precision agriculture for integrated pest management (IPM). Remote sensing and spatial analysis and other tools like Global Navigation Satellite System (GNSS) are of additional value in planning crop management practices. On other hand, these technologies have some limitations; firstly, high spatial resolution imagery is not easily available for all areas, especially rural. Whereas as hyper-spectral imagery is required; secondly, there is a lack of technical knowledge about geospatial technology by consultants and end-users / farmers; and finally this technology depends on time sensitive mapping and near real time image acquisition and product delivery. However, facing these challenges, Geospatial Technology can provide valuable information in an IMP context, allowing for a complete understanding (via remote mapping or spatial modeling) of the spatial complexity of the biotic and abiotic characteristic of a field and its crop, and providing information about the disease and pests populations that are present or likely to occur. The technology is highly effective for forestry where increasing and large-scale pest and disease attacks are increasingly reported. Geospatial technologies are making forestry management more precise and spatially comprehensive to better yield, insect pests and diseases control dynamics. New access to data and technology will likely promote the transition of these tools from a research to an applied domain across both sectors.In this way geospatial data and technology plays a significant role in improving the production of yield and overcoming food security issues. As the population grows, the production of crop needs to be increased as well to ensure all the people in whichever country or region get enough nutrients. Various methods and techniques are used in agriculture production to make it safer and diminish their harm impacts on environment to make agriculture sustainable. Precision agriculture is important tool to bring successful conclusion.Precision farming is a micromanagement system to obtain better decisions on agricultural and territorial management deriving from the use of information provided by geospatial technology. This paper has reviewed the role of geospatial technologies to tackle the issue of pest and disease affecting plant health that has a big impact on crop yield production in producing food for the world population. Global trade liberalisation and climate changes have warranted for the local crops to produce good products and to secure food for the world population generally. Nevertheless, the advancement of geospatial technology has made the activities of combating various pests and diseases affecting plant health much easier than before.

REFERENCES

1. Tirado M. C., Crahay P., Mahy L., Zanev C., Neira M., Msangi S. & Müller A. (2013). Climate change and nutrition: creating a climate for nutrition security *Food and Nutrition bulletin* **34:** 533-547.
2. Savary S., Ficke A., Aubertot J. N. & Hollier C. (2012). Crop losses due to diseases and their implications for global food production losses and food security *Food Security* **4:** 519-537.
3. Masters G., Baker P. & Flood J. (2010). Climate change and agricultural commodities *CABI Working Paper* **2:**9-11.
4. Masters G. & Norgrove L. (2010). Climate change and invasive alien species *CABI Working Paper* **1:** 8-11.
5. Azoulay J. P. (2017). European Crop Protection Association *Impact* **1:** 92-93.
6. Clive P. & Julie U. (2016). Tree Disease and Pest Epidemics in the Anthropocene: A Review of The Drivers, Impacts and Policy Response In The UK *Forest and Economics* **79:** 61-68.
7. Boyd I., Freer-Smith P., Gilligann C. & Godfray C., (2013). The Consequences of Tree Pests and Diseases for Ecosystem Services *Science* **342:** 823-840.
8. Anonymous (2009). FAO 2009 *Global Review of Forest Pest and Diseases, FAO Forestry Paper 156* Food and

Agriculture Organization of The United Nations [online] Available: http://www.fao.org/3/a- i0640e.pdf [Accessed Feb2018].

9. Trevor Q. M., Stephen W. T., Aquila F., Alan M., Alvaro M., Francis W. Z., Rene A. & David L. S. (2012). Pest outbreak distribution and forest management impacts in a changing climate in British Columbia *Environmental Science & Policy* **26:** 75-89.
10. Jolivet P. (1988). Interrelationship Between Insects and Plants (Boston: CRC Press).
11. Dhaliwal G. S., Jindal V. & Dhawan A. K. (2010). Insect Pest Problems and Crop Losses: Changing Trends. Indian Journal of Ecology, 37 (1): 1-7.
12. Prabhash K. P., Duhyant S., Ranjan S., Mrityunjay K. S., Sangram S. & Farrukh J. (2016). Cassia Fistula seed's trypsin inhibitor(s) as antibiosis agent in helicoverpaarmigera pest management *Biocatalysys and Agricultural Biotechnollogy* **6:** 202-208.
13. Day R., Abrahams P., Bateman M., Beale T., Clottey V., Cock M., Colmenarez Y., Corniani N., Early R., Godwin J., Gomez J., Moreno P. G., Murphy S. T, OppongMensah B., Phiri N., Pratt C., Richards G., Silvestri S., Witt A., (2017). Fall armyworm: impacts and implications for Africa. Outlooks Pest management **28**: 196–201.https://doi.org/10.1564/v28.
14. Kumela T., Simiyu J., Sisay B., Likhayo P., Mendesil E., Gohole L., Tefera T., (2018). Farmers' knowledge, perceptions, and management practices of the new invasive pest, fall armyworm (*Spodoptera frugiperda*) in Ethiopia and Kenya.Int. J. Pest Manag. 0874, 1–9. https://doi.org/10.1080/09670874.2017.1423129.
15. Prasanna B. M., Huesing J. E., Eddy R. & Peschke V. M. (2018). Fall Armyworm in Africa: A Guide for Integrated Pest Management, First Edition. Mexico, CDMX: CIMMYT
16. James F.D. & Clay A. K. (2016). Umaine Cooperative Extension: Insect Pests, Ticks and Plant Disease [online] Available: https://extension.umaine.edu/ipm/ipddl/publications/5040e/ [Accessed Jan2018].
17. Subbarathnam G. V. & Butani D. K. (1982). Chemical control of Insect pest complex of brinjal.Entomon **7**:97-100.
18. Patnaik H. P. (2000). Flower and fruit infestation by brinjal shoot and fruit borer, Leucinodes orbonalis Guen damage potential vs. weather. Veg. Sci. **27**:82-83.
19. Misra H. P. (2008). Bio-efficacy of chlorantraniliprole against shoot and fruit borer of brinjal, *Leucinodes orbonalis* Guenee. Journal of Insect Science **24**(1):60-64.
20. Jagginavar S. B., Sunitha N. D., Biradon A. P. (2009). Bio efficacy of flubendiamide 480 SC against brinjal shoot and fruit borer, *Leucindoes orbonalis* (Guen.). Kar. J. Agri. Sci. **22**(3):712-713.
21. Robin A. H. K., Hossain M. R., Park J. I., Kim H. R. & Nou I. S. (2017). Glucosinolate profiles in cabbage genotypes influence the preferential feeding of Diamondback moth (*Plutella xylostella*) *Frontiers in plant science* **8:** 1244.
22. Kalidas P. (2012). Pest problems of oil palm and management strategies for sustainability Agro technology **11:** S001.
23. Anonymous. Tamil Nadu precision farming project. http://www.tn.gov.in [12.06.2007].
24. Busby P. E., Ridout M., & Newcombe G. (2016) Fungal endophytes: modifiers of plant disease *Plant molecular biology* **90:** 645-655.
25. [24]. Van alfren N. K. (2001). *Fungal pathogens of plants,* ed K. Roberts (Encyclopedia of life science: Wiley inter science, Chichester).
26. Nutter F. W. & Madden L. V. (2009): *Plant Pathogens as Biological Weapons against Agriculture* In: Lutwick S., Lutwick L. (eds) (Humana Press) p 1-29. DOI https://doi.org/10.1007/978-1- 59745-326-4_17.
27. Blomme G., Dita M., Jacobsen K. S., Pérez Vicente L., Molina A., Ocimati W. & Prior P. (2017). Bacterial diseases of bananas and enset: Current state of knowledge and integrated approaches toward sustainable management *Frontiers in plant science* **8:**1290.
28. Dean R., Kan J. A. V., Zacharias A., Pretorius Z. A., Hammond-Kosack K. E., Di pietro A., Spanu P. D., Rudd J. J., Dickman M., Kahmann R., Ellis J. & Foster G. D. (2012). The Top 10 fungal pathogens in molecular plant pathology. Molecular Plant Pathology **13**(4): 414–430.
29. Zandalinas S. I., Mittler R., Balfagón D., Arbona V. & Gómez-Cadenas A. (2018). Plant adaptations to the combination of drought and high temperatures *Physiologiaplantarum***16: 2**2-12.
30. [30]. Crandall S. G. & Gilbert G. S. (2017). Meteorological factors associated with abundance of airborne fungal spores over natural vegetation *Atmospheric Environment* **162:** 87-99.
31. Kunal S., Sharda S., Ranbir S. R., Aditya R., Vaibhav Kalia & Arun Kaushal (2015). Application of GIS in Precision Agriculture.
32. Qu Y. & Tao B. (2014). The constitution of vegetable traceability system in agricultural IOT *J. of Chemical and Pharmaceutical Research* **6:** 2580-2583.
33. Deleon L., Brewer M. J., Esquivel I. L. & Halcomb J. (2017). Use of a geographic information system to produce pest monitoring maps for south Texas cotton and sorghum land managers *Crop Protection* **101:** 50-57.
34. Bill R., Nash E. & Grenzdörffer G. (2011). GIS in Agriculture in: KresseW, DankoD(eds) *Springer Handbook of Geographic Information* (Springer: Berlin, Heidelberg) p 461-476.
35. Praveen B., Sharma P. (2019). *A review: The role of geospatial technology in precision agriculture* Academic paper *Journal Public Affairs*. 2019; e1968.
36. Jensen, J. R. (1996). *Remote sensing of the environment: An Earth resource perspective* (3) (pp. 1–28). USA: Prentice Hall.
37. Mandal D., Ghosh S.K. (2000).Precision farming - The emerging concept of agriculture for today and tomorrow. *Current science* **79**(12): 1644-1647.
38. Casady, W. W., & Palm H. L. (2002). Precision agriculture: Remote sensing and ground truthing. MU Extension,

University of Missouri-Columbia.
39. Bhanumathi V., Kalaivanan K. (2019). The Role of Geospatial Technology with IoT for Precision Agriculture. In: Das H., Barik R., Dubey H., Roy D. (eds) Cloud Computing for Geospatial Big Data Analytics. Studies in Big Data, vol 49. Springer, Cham.
40. Khosla, R., K. Fleming, J. Delgado.T. Shaver, & D. Westfall. (2002). Use of Site Specific Management Zones to Improve Nitrogen Management for Precision Agriculture. *Journal of Soil Water Conservation* **57**(6): 513-518.
41. Koch, B., R. Khosla, M Frasier, & D.G. Westfall. (2003). Economic Feasibility of Variable-Rate Nitrogen Application in Site Specific Management. *In Proceedings of the Western Nutrient Management Conference,* March 6-7, 2003 Salt Lake City, Utah **5**:107-112.
42. [42]. Schleicher, T. D., W. C. Bausch, & J. A. Delgado. (2003). Low Ground Cover Filtering to Improve Reliability of the Nitrogen Reflectance Index (NRI) for Corn N Status Classification. *Journal Transactions American Society Agricultural Engineers.*
43. Bausch, W.C. & J.A. Delgado. (2003). Ground-Based Sensing of Plant Nitrogen Status in Irrigated Corn to Improve Nitrogen Management. In: T. VanToai, D. Major, M. McDonald, J. Schegers, and L. Tarpley (eds). *Digital imaging and Spectral Techniques. Applications to Precision Agriculture and Crop Physiology. Agronomy Society of Americ*a, Madison Wisconsin
44. Magalha˜es P. S.G., Cerri D.G.P. (2007). Yield monitoring of sugar cane. Biosyst Eng; **96**(10):1–6.
45. Murray A. T. (2017). GIS in regional research *In Regional Research Frontiers* Vol. 2 ed Randall J and Peter S Springer International Publishing p169-180 DOI10.1007/978-3-319-50590-9.
46. Barleme N. (2011). Geographic information system *Springer Handbook of Geographic Information* ed Kresse W. & Danko D. (Springer: Berlin, Heidelberg).
47. Lindgren C. J. (2012). Biosecurity policy and the use of geospatial predictive tools to address invasive plants: updating the risk analysis toolbox *Risk Analysis* **32:** 9-15.
48. Mandal D., Ghosh P. P. & Dasgupta M. K. (2013). Appropriate precision agriculture with site- specific cropping system management for marginal and small farmers *Plant Sciences Reviews 2012* ed Hemming D (CAB international 2012) p 121 DOI 10.1079/PAVSNNR20127029.
49. Meeta P. M. (2017). Geo Spatial Technologies for Agriculture [Online] Available: https://geospatialworldforum.org/speaker/SpeakersImages/geo-spatial-technologies-for- agriculture. pdf [Accessed Jan2018].
50. Manas J. (2017). Gis Resources: Geospatial Technologies for Sustainable Agriculture Development Issue 3. [Online] Available: [Accessed Jan2018].
51. Thomas C. S., Skinner P. W., Fox A. D., Greer C. A. & Gubler W. D. (2002). Utilization of GIS/GPS-Based Information Technology in Commercial Crop Decision Making in California, Washington, Oregon, Idaho, and Arizona. Journal of Nematology **34**(3): 200–206.
52. Pohl C., Kanniah K. D. & Chong K. L. (2016). Monitoring Oil Palm Plantation in Malaysia.*2016 IEEE International Geoscience and Remote Sensing Sympossium (IGARSS)* (IEEE: Beijing China) 10-15 July2016.
53. Yahaya S. M., Musa N. C., Mansor Z., Siham M. N. & a/p Veloo S (2015). Remote Sensing and GIS Web-Based System for Paddy Cultivation Management in Malaysia. *Paper presented at 36th Asian conference of remote sensing 2015* Manila, Philippines: ACRS
54. Lillesand T. M. (2014). Concepts and Foundations of Remote Sensing *Remote Sensing and Image Processing* 7thed, Lillesand T M, Kiefer R W &Chipman J W (eds) (United states : WILEY)
55. Wójtowicz M., Wójtowicz A. & Piekarczyk J. (2016). Application of remote sensing methods in agriculture *Communications in Biometry and Crop Science* **11:** 31–50.
56. Elbattay A., Hashim M. & Sutra. (nd). Induced Em-Spectral Response for an Early Detection of Vegetation (Crop) Biotic Stress Natural Science and Natural Heritage [Online] Available: http://eprints.utm.my/18630 /1/PROJECT_PROFILE. Pdf [AccessedJan2018].
57. Liu Z., Huang J., Tao R. (2008). Characterizing and Estimating Fungal Disease Severity of Rice Brown Spot with Hyperspectral Reflectance Data. Rice Science **15** (3): 232-242.
58. Apan A., Datt B., & Kelly R. (2005). Detection of pests and diseases in vegetable crops using hyperspectral sensing: a comparison of reflectance data for different sets of symptoms. Proceedings of SSC 2005 Spatial Intelligence, Innovation and Praxis: The national biennial Conference of the Spatial Sciences Institute, September 2005.
59. Tayari E., Jamshid A. R. & Goodarzi H. R. (2015). Role of GPS and GIS in precision agriculture *J. of Scientific Research and Development* **2:** 157-162.
60. Ishak & Sutha, (2014). GIS For Rice Field Management [online] Available: https://issuu.com /geospatialworld/docs/combined_pdf_august_2014[AccessedJan2018]
61. Hofmann-Wellenhof B., Lichtenegger H. & Collins J. (2001). *Global positioning system: Overview of GPS* Springer-Verlag Wien p 11-24 DOI10.1007/978-3-7091-6199-9.
62. Thompson R. B. (1998). Global Positioning System: The Mathematics of GPS Receivers. *Mathematics Magazine* Vol. **71** 4.
63. Palaniswami C., Gopalasundaram P. & Bhaskaran A. (2011). Application of GPS and GIS in sugarcane *Agriculture. Sugar Tech* **13:** 360–365.
64. Jiannong X., Harmon C. L., Vegot P. & Huafeng J. (2009). Tracking pest and plant disease through space and time using geo-tagged digital images. *proc. Conf. 7th world congress on computers in agriculture* 22-24 june 2009, reno,Nevada.

65. Gougherty A. V. & Nutter Jr F. W. (2015). Impact of Eradication Programs on the Temporal and Spatial Dynamics of Plum pox virus on Prunus spp. in Pennsylvania and Ontario, Canada *Plant Disease* **99:** 593-603.
66. Ploetz R., Freeman S., Konkol J., Al-Abed A., Naser Z., Shalan K. & Israeli Y. (2015). Tropical race 4 of Panama disease in the Middle East *Phytoparasitica* **43:** 283-293.
67. Aguilar C. H., Lasalita-Zapico F., Namocatcat J., Fortich A., & Bojadores R. M. (2014). Farmers' perceptions about banana insect pests and integrated pest management (IPM) systems in SocSarGen, Mindanao, Philippines *IPCBEE* **63:** 22-27.
68. Idris N. H., Said M. N., Fauzi M. F., Yusri N. A. M. & Ishak M. H. I. (2015). A Low Cost Mobile Geospatial Solution to Manage Field Survey Data Collection of Plant Pests and Diseases *Presented in IEEE Workshop on Geoscience and Remote Sensing*, Kuala Lumpur Malaysia: IWGRS2015.

CITATION OF THIS ARTICLE

Md. ArshadAnwer and Garima Singh. Geo-spatial Technology for Plant Disease and Insect Pest Management. Bull. Env. Pharmacol. Life Sci., Vol 8 [12] November 2019: 01-12