Chapter

Precision Vegetable Farming Technologies: An Update

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Abstract

The efficiency of precision vegetable farming cannot deny in the current of climate change. As compared to west adoption of reliability precision agriculture approaches in developing world is a gradual procedure. The small scale of farms limits economic benefits from currently accessible precision farming technologies. Nevertheless, horticulture interventions like geographical positioning system (GPS), geographical information system (GIS), artificial intelligence (AI), robotics, sensor technologies, etc., are being utilized for precision vegetable farming to improve production and quality of vegetables. This retains excellent promise for developing vegetable crops within the present farming scenario when climate change makes the whole rethink agriculture practices. Overall, this chapter will provide useful information about precision vegetable farming technologies for vegetable growers, enthusiasts, farmers, and researchers.

Keywords: precision, vegetable farming, GIS, GPS, robotics, AI, sensors

1. Introduction

The demand for vegetable crops is continuously increasing. Sustaining this demand requires the infusion of technologies for efficient utilization of sources for deriving higher result per product of inputs with a superb quality of produce [1]. It will be possible only through the deployment of hi-tech applications and precision farming. Precision agriculture is among the most modern technologies for sustainable agriculture, which has gained impetus in the 21st Century [2, 3]. Precision farming consists of using products and principles to control temporal and spatial variability regarding all factors of gardening generation for bettering crop performance and setting quality [4]. Precision farming calls for effective management of resources through location unique hi-tech interventions. Precision vegetable farming provides a new solution using a systems treatment for today's farming issues, such as the necessity to balance efficiency with ecological problems [5]. It offers to describe and model variation in soils and plant species combining farming methods to meet up with website specific needs. It seeks to improve economic return shipping and delivery and lessen the power feedback and the environmentally friendly impact of farming. Precision agriculture approaches can help both large scale farmers as well as small farm holders. Moreover, precision vegetable farming offers the promise of enhancing productivity while reducing production costs [6].

With the precision vegetable farming describing the variability is going to be the primary key concept. Primarily, it is affected by variation within each region [7]. In comparison, hi-tech horticulture will be the deployment of today's technology

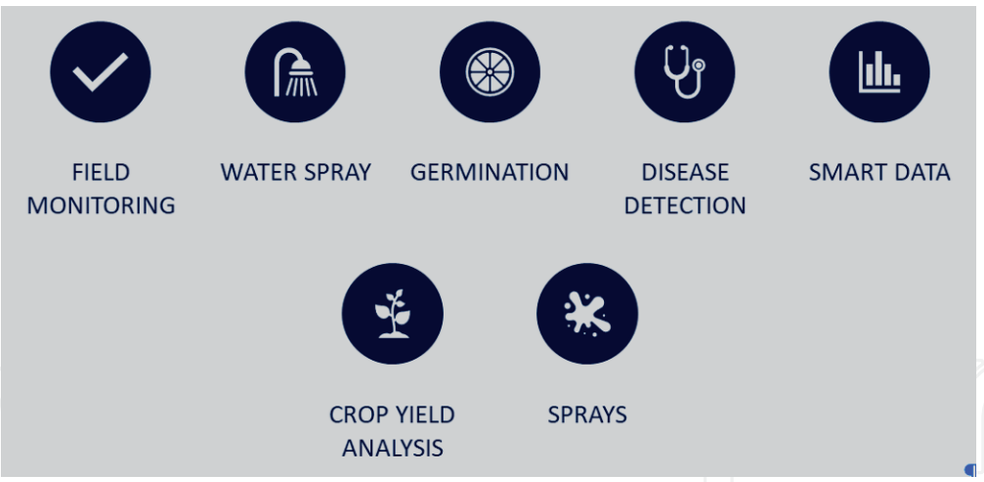

Figure 1.
Application of precision vegetable farming technologies to different aspects of vegetable production.

that is capital intensive, much less environment-dependent, capable of enhancing the output and quality of produce. Utilization of these interventions orchestrated together, keeping the goal of obtaining higher output in granted time results in precision vegetable farming, which is knowledge-driven. Precision vegetable farming aims to enhance crop performance and setting quality [8]. The actual benefit of precision vegetable farming is that the farmer can conduct much more regular tillage, adjust sowing rates, fertilizer application based on soil conditions, plan even more crop protection programmes with increased precision, and understand the yield variation area. These benefits may improve the real cost-effectiveness of harvest production; nonetheless, the grower should be prepared to make changes in his management types to work [9, 10]. Precision vegetable farming is a modern-day procedure utilized to improve crop productivity using the newest technologies, cloud computing, information technology (IoT), WSN, i.e., artificial intelligence (AI) machine learning (ML). Thus far, the majority of research suggests that PA-based methods possess a good impact on productivity and sustainability [11]. Nevertheless, a few obstacles are associated with the growth and deployment stage of these methods. Since the primary goal of precision agriculture is producing surplus yield by optimizing the materials such as for instance water, pesticide sprays, plant foods, etc., for source, prescription maps play a crucial role, that allows farm owners to quantify information needed for useful plants at any specific development stage. The application of precision farming technology to various aspects of the vegetable farming process is presented in **Figure 1**. In general, this chapter is going to provide information that is useful about precision vegetable farming solutions for vegetable growers, farmers, enthusiasts, and scientists.

2. Role of global positioning system (GPS) in precision vegetable farming

Along with its simplicity of using and worldwide all the weather procedure, GPS owes its acceptance on the superior, dependable precision with what place, time, and direction might be determined. This information is provided in healthy time, meaning that continuous place information is supplied while in motion [12]. Having exact location information at any time permits harvest, soil and liquid dimensions being mapped. GPS receivers perhaps have with the spot or possibly mounted on implements enable owners to return to places to sample or perhaps deal with those areas. GPS component in precision vegetable farming is implementing the

most significant factor [13]. At the correct spot, at the proper time, understanding the most significant thing to perform may involve all kinds of hi-tech equipment and fancy statistics or other analysis. However, making the perfect point starts with excellent supervisors and new operators doing an excellent job of employing everyday resources as planters, fertilizer applicators, harvesters no matter what else is needed [14, 15]. In this specific context, GPS is going to become part and parcel of perfection agriculture. For analysis and processing of remote Sensed images must have ground-truth information, collected in the region, at many sites and often at several times throughout the crop paper season [16]. Precision farming is an incorporated harvest management method that attempts to enhance inputs' kind and quantity with the actual crop requirements for small regions within a farm region. We have produced an interactive, portable telephone system to gain field info right away into a digital database containing yield, soil, road, water alongside contour maps [17]. The system additionally allows anyone to save GPS info from widening and tracking field exercise at a later working day. Data captured in the field, like the location of weed patches, region boundaries, and harvest quality pointed out, are moved readily to others. Spreadsheet along with image processing techniques to enhance datasets plus much better analysis [18]. GPS-based precision farming applications have been used for farm preparation, region mapping, soil sampling, tractor guidance, harvest scouting, flexible rate programs, and yield mapping. GPS permits farm owners to function during low visibility field problems, for instance, rainfall, particles, fog, and darkness. Growers can achieve additional benefits by pairing better utilization of some other soil amendments and fertilizers, identifying the economic threshold for combating pest and weed infestations and protecting the organic energy sources for future use. Nowadays, GPS derived items are utilized by many growers to enhance organizations within their farming companies. GPS receivers gather location information for mapping region borders, roads, irrigation systems, and problem areas in plants as weeds or disease. The accuracy of growers is permitted by GPS to create farm maps with extremely accurate acreage for subject areas, street places, and ranges between tourist attractions. Farm owners are allowed by GPS to successfully review to particular spots in the area, season after season, to collect soil samples or perhaps monitor crop conditions. GPS likewise allows pilots to provide farmers with precise maps. Growers, together with farming service providers, are in a position to foresee more changes as GPS regularly modernize. With the present civilian service provided by GPS, the nation is focused on using a second together with a third municipal signal on GPS satellites.

3. Role of sensor technologies in precision vegetable farming

Optical and thermal sensors will be the most favored sources in plant phenotyping. Sensors are classified based on the amount and wavelength selection of measured wavelengths, the taller the detection ability [19]. The more comprehensive the band range assessed around a specific wavelength, the diminished the measurement reliability because of the overlap of different wavelengths, even if several indices will most likely be steadier when estimated in broader bands. For a clear understanding of how sensors fixes are positioned to complement breeders' needs in vegetable crop phenotyping, it looks like far more valuable to describe the different PRSs, contemplating their working principles distant relative to how plant life speaks with the electromagnetic light [20]. The use of the evaluation and stereo system camera rigs by computer programs of photographs taken by several angulations enable drawing sophisticated versions because of the reconstruction of growing constructions in 3D. Nevertheless, sensors reliant on reactance

measurement can provide a lot more valuable information to develop physiology studies. Multispectral imaging consists of computing leaf reactance at numerous wavelengths, thus providing details for calculating important vegetation indices [21]. In Solanaceae, numerous scientific studies say hyperspectral sensing items for early detection of various symptoms relating to biotic stresses. Results indicated how spectral imaging is a lot more suitable for classifying ripeness stage, lessening the error as an outcome of variations which are easy in ripeness. These studies demonstrate hyperspectral items' power to choose parameters and plant diseases related to quality, thus enhancing synthetic substances in horticulture in the various phases of the supply chain [4]. Spectrophotometry was also utilized to assess chlorophyll concentration. These two phenomena are related to the development of H20, which is free in the tissue and mild penetration. Results evidenced how lettuce has a drop-in plant growth triggered by severe salinity, while no improvement rate decrease was confirmed under temperature stresses [22, 23]. Data gathered from sensors will better offer smallholder farmers, various other stakeholders, and extension workers with updated information about their plant life to enhance productivity. Improved data and information will optimize farming inputs and time invested by farming extension employees along with different actors on the floor, ultimately leading to great utilization of electrical power and cost savings. Finally, information is necessary to allow the private sector and various other intermediaries to make decision-making methods that might get smallholder farmers like financial and insurance applications. Consequently, leaders, technology vendors, farming businesses, academics and funders should commit to coming also and together finding the potential for these technologies. Agricultural receptors gather a significant quantity of info, but they usually must run in shallow connectivity environments when

Vegetable	Character	Instrument with Sensors
Solanum lycopersicum	Leaves damaged by leaf miner	Nexus FT-NIR spectrometer
Solanum lycopersicum	Ripeness	ImSpector V9
Leafy vegetables	Chlorophyll content	ASD Fieldspec FR spectroradiometer
Spinacia oleracea	Crop canopy under water	Specim V10 spectrometer
Citrullus lanatus	Lycopene, -Carotene, and Total Soluble Solids	NIR On-Line® X-One
Lactuca sativa	Plant traits under extreme temperature and salinity stress treatments	Series VNIR Micro-Hyperspec Sensor; Fluor Cam 800 MF
Solanum lycopersicum	Harvest time	AgroSpec VIS–NIR spectrophotometer
Cichorium intybus	Cold stress	CF Imager
Phaseolus vulgaris	Photosyntetic traits, morphological parameters and shoot architecture	Growscreen Fluoro
Brassica rapa subspecies pekinensis and chinensis	Quality	FluorPenFP 100 fluorimeter
Cucumis melo	Grafting compatibility	Imaging-PAM fluorometer
Leafy vegetables	quality in post-harvest storage	SPAD-502; Agriexpert CCN 6000
Solanum melongena	Fruit morphology and shape	Scanner imaging

Table 1.
Non-destructive compact sensors for field use and data procuration in vegetables [22].

applied to the developing world. Agricultural details are being collected through satellites, weather stations and ground sensors. Yet these options do not consult one another, and therefore there is just no centralized method to level data. For the info being genuinely useful in decision making, know-how vendors need to work toward interoperability and discover efficient ways to integrate it. Examples of sensor technologies used for the precision vegetable farming are presented in **Table 1**.

4. Role of geographic information system (GIS) in precision vegetable farming

The advance GIS solutions enable checking, picture, and analysing geographical contents to facilitate information consumption. Furthermore, the mobile version will allow farmers to keep informed about all their plots through information on soil analysis, the crop's problem, and the managing of evapotranspiration [24, 25]. With using remote sensing, GPS and GIS, farmers might be prepared to see site-specific demands of the farms. With this information, they can formulate and implement control techniques that will ensure the perfect use of inputs to enhance their output and profits. Therefore, geospatial technologies give you a farmer with an information resource that he/she can use generating educated decisions that guarantee effective and efficient managing of the farm to enhance its efficiency. Thus, growers need to understand and implement these ways together with their expertise and experience getting the best advantages of their farms [26]. GIS has a hardware-software repository unit used to capture, store, enter, influence, analyze, screen, map as sort, and spatially referenced geographical information. GIS maps are energetic. On the computer display screen, map computer users can check out a GIS chart in almost any program, zoom in or out, and modify the characteristics of the information discovered within the chart. The capability of GIS to evaluate and imagine farming environments and work has shown to be genuinely beneficial to each of those connected with the agriculture business [27]. GIS is a crucial element of automated field operations, known as precision agriculture or possibly satellite farming. Using info collected from remote receptors and sensors installed on farm machinery, farmers have raised decision-making abilities to cook their growing to enhance yields. Last crop yields, surfaces particulars, natural material content, pH, moisture, and nutrient quantities of the grime most help in appropriate preparation for real farming. Combine harvesters constructed with GPS tracking devices are able to evaluate crop yields along with crop quality values as grow water content and chlorophyll levels in time which is genuine and at the particular place in the region from which they are harvested. Adjustable velocity engineering (VRT) will be the element of accuracy agriculture, which really allows the info being placed right to apply. It joins farm machinery, management methods, and application products to don precise amounts of cultivating inputs at specific times or locations. Precision farming with VRT has both economic and environmental benefits. Applying seed, fertilizer, nutrients, and perhaps insecticides, only where and when they are needed, might have sizable cost savings due to the farmer and boost revenues. Furthermore, harmful environmental impacts from overusing of numerous synthetic materials are relieved, and the use of specific chemical compounds might probably be eliminated wholly based on data analysis. Persistent dilemmas as nitrogen program may additionally be dealt with, helping the farmer obtain the appropriate length between excessive and insufficient.

Public, individual, together with non-profit sectors, use GIS to handle public utilities to control the movement and the dispersion of goods and services. GIS is very purposeful in typical map making, to plot items as fire hydrants along a

freeway, and maybe to sketch boundaries, like the area of different crop parts on a farm. Real examples of this within the realm of agriculture will be a map showing the range of farm crashes by county, or perhaps the number of crop acres fallen to flood by tax chart parcel. The best benefits of remote sensing are that it is non-invasive and does not negatively affect the spot that is now being observed.

5. Role of grid soil sampling and variable-rate fertilizer (VRT) application in precision vegetable farming

The usual soil test P or K of control strips frequently was Less or perhaps optimum in responsive areas. When GIS strategies were used to analyze yield responses on the consistent P or K program, an incredibly high yield reply variation became obvious. Approximately these outcomes show an exceptionally high potential in numerous fields for dense soil sampling to identify areas with contrastingly several soil tests values. The outcomes also demonstrate an excellent chance for VRT, because this technology place on the strips, hardly ever there's undoubtedly a statistically significant [28]. The standard amount of P or K fertilizer applied per acre by each method varied considerably among fields but generally was a lot less for just about any variable-rate method. Many factors might explain infrequent, small, in addition to inconsistent differences observed between uniform and variable fertilization methods, very possibly for minimal testing field areas [29]. Nevertheless, it might just explain an absence of distinction between application methods for the 1st harvest (because extra P or K likely was utilized by every method) however, not for the following harvest. Therefore, disparities in small field places will be diluted by no response or random differences in larger area areas. Hence, although varying rate program hardly ever improved harvest yield in contrast to a consistent application, it did offer with P application significantly better [30]. The results endorse that adjustable-rate P method will reduce P loss from places compared to a regular application over low-testing or high-testing field areas and may wind up in much better water quality. Moreover, these on-farm trials' results say that the most significant problem to utilize variable-rate fertilization effectively is the dirt sampling method and the soil test chart exactly where it should be seated. The results suggest that a major issue is if the significant small-scale P and K variation can really be calculated cost-efficiently [31, 32]. The convenience of increased cost sampling and fertilizer application methods increases profitability advances only if the view of fertilization is converted to a much more demanding effect-based philosophy. Nevertheless, outcomes indicating VRT does reduce both fertilizer application.

6. Recent developments and tools in precision vegetable farming

Newest solutions in precision vegetable farming include various technologies. In this direction, self-steering tractors have existed for very a while. These tractor types do a great majority of the works; these are establishing toward driverless gadget customized by GPS to spread manure or maybe to furrow land. Novel developments feature a solar fueled scanner which distinguishes weeds and executes them with a portion of herbicide or lasers.

Robots: Farming robots, otherwise referred to as AgBots, as of today, are existing. However, advanced harvesting robots now are being developed to realize fresh fruit, which is ready, comply with their shape and size, and cautiously pluck them from limbs. Recent light aircraft models can take aerial photographs with information from satellite records to foresee coming yields based on the current subject biomass

level [33, 34]. Collected pictures can produce maps to follow where water stations, decide adjustable rate seeding and produce yield maps of nearly productive regions.

Smartphone applications: Tablet and cellular phone apps are starting to be steadily well known in precision farming. Cell phones accompany numerous helpful applications earlier published, GPS, like accelerometer, etc. Personal computer only at that information is created by that time and sends linking activities to these items [35]. This involves considering robots to impart the perfect way of computing manure or IoT products to help make the ideal amount of water legally to the environment. The fate of farming pushes a lot more the last machine learning methods each year. It is seen as progressively proficient and exact cultivating with less human labour [36]. Greenhouses are among the most effective techniques for precision agriculture. Sensors, actuators, drones, robots each are IoT items that are meant to improve the effectiveness and precision of greenhouses. With the aid of IoT and a few AI, reliable, unique, innovative farming methods are created right from irrigating to harvesting, which involves forecasting the lifetime of the crop [37]. These days, the farmer can have complete control over his crop worldwide by utilizing the internet finally, which improves the financial system of the nation and is going to save a huge amount of time.

7. Conclusions

In vegetable farming, probably the latest quick adoption of precision agriculture, approaches provide growers with quality solutions and notice food quality and security issues. With automation products recording parameters concerning product quality such as color, size, shape, external defects, sugar content, acidity, and other inner characteristics. Additionally, checking field functions as synthetic substances sprayed and fertilizers can easily provide complete vegetable and fruit processing methods. This information might be disclosed to clients for risk management and food traceability and makers for precision agriculture being much better quality and larger yields with enhanced inputs. Recently many new methods were developed that consider the specific size of the tree, the crop issue, and the ecological variables. Vegetable quality and yield maps are of excellent worth during crop to avoid mixing grapes of several potential wine qualities. Precision vegetable farming will continue to be a concept in many developing nations, and strategic guidance from the public and private sectors is essential to promote its quick adoption. Successful adoption, nevertheless, comprises at least three phases as execution, evaluation, and exploration. Precision vegetable farming can focus on both economic and environmental issues that surround modern farming practices nowadays. Queries remain about cost-effectiveness and the most remarkable techniques to use the technical resources we today have. However, the thought of "doing the best thing in the correct area on the appropriate time" offers an excellent intuitive appeal. Ultimately, precision agriculture's success hinges largely on how properly and how easily the information should point the new solutions might be found. Precision vegetable farming provides a new choice utilizing systems utilized for current-day agricultural issues, such as the necessity to balance efficiency with ecological problems. It is reliant on sophisticated information technologies. The polygons that stand for different ownership or municipalities can impart values in various approaches, most regular being a changing style ramp. GIS can help a farmer change to these different variables, monitor specific plants' health, appraisal yields originating from a particular region, and enhance crop production. There are many choices for GIS info at no cost as well as for a rate. Colleges, federal organizations, and individual business owners tend to be repositories of spatial information.

Figure 2.
Most frequently used precision vegetable farming approaches.

But, based on the development of a country resources and reach some precision farming approaches are more frequently used than others (**Figure 2**). Using land-use and primary food crop information, together with info collected by mobile devices and satellites to identify locations in need root causes of food insecurity, GIS is essential to end around the world hunger. Satellites, drones, plus human-crewed aircraft are used for remote sensing, in addition to that's the gathering of information about the planet's surface area by scanning it from high altitudes. Based on the exterior temperature, the intensity of the wavelengths created by different vegetation types and various manmade and natural landscapes differs. The captured info is transformed into explicit electronic imagery and maybe set on to popular objectives like managing water for watering consumption or planting disease detection. It's competent to besides, be placed onto objectives like analyzing the maturity of fresh fruit. It offers to describe and model variation in soils and plant species and mix farming methods to meet up with website specific needs. It seeks to increase monetary return delivery and lessen the considerable feedback and the environmentally friendly impact of farming.

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