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The role of precision farming in sustainable agriculture: An overview

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Abstract

The most fundamental requirements of humanity are met by agriculture: food and fiber. In the last century, new farming methods have been introduced, such as during the Green Revolution, which has enabled agriculture to keep up with the rising demand for food and other agricultural goods. But as the price goes up a rise in population, an increase in food demand, and rising income levels are projected to place extra strain on resources in nature. As the detrimental effects of agriculture on the environment become more widely acknowledged, Future food demands should be met through innovative methods that maintain or reduce environmental impact. Modern agriculture's growing field of precision farming aims to optimize output (i.e. crop production) while minimizing input (i.e. fertilizer, pesticide, herbicide, etc.). Application of a holistic management approach is what is meant by precision farming. A method that collect data from numerous sources using information technology to make choice regarding agricultural production, marketing, financial, and personnel decisions. The Precision farming's primary goals are to improve production efficiency and to increase product quality, minimize environmental damage, save energy, and protection of the groundwater and soil. The following are crucial elements of precision farming: Management, Information & technology. Precision Farming technologies can be categorized into five primary groups: Computer, Global positioning system (GPS), Geographic information system (GIS), Sensors & Application Control. By improving agriculture management and reducing waste and labour, Precision Farming has the potential to boost yields and lower input cost. Furthermore, it aids in the reduction of environmental pollution.

Keywords: Sustainability, agricultural development, precision, GPS, GIS

Introduction

Man has been employing Agri inputs derived from natural resources to care for his field and crops ever since agriculture emerged as a profession millions of years ago to increase his agricultural productivity. According to Upanishads, Vedas and in ancient Hindu literature water, soil and air as essential resources and it need to be maintained its purity. The incredible increase in human and animal populations over the past century, as well as the rapidly expanding industrialisation and the last two decades have seen rapid urbanization which extremely use of natural resources and the resources are become degraded. However, increased use of agricultural inputs also contributes to eutrophication, reduced surface fluxes, and loss of groundwater (Konikow *et al.*, 2015) [18]. Excessive and/or ineffective use of soil, water, pesticides & fertilizers for agricultural purposes, agricultural production results in greater water and nutrient losses as well as financial losses causing environmental deterioration (Hendricks *et al.*, 2019) [13]. For a sustainable economy and environment development of methods that can boost crop productivity through the existing production system increased input effectiveness and decreased environmental losses (Delgado *et al.*, 2019) [10].

Consequently, there is a need to innovate in agriculture and increase production to satisfy the demands of the growing population. Here comes precision agriculture's significance. Precision farming is utilize of technology and guiding concepts to control spatial and the temporal variability related to all production of agricultural to boost output and the state of the ecosystem (Patil Shirish, S., and Satish A. Bhalerao 2013) [26]. Precision agriculture in simple terms is the identification, analysis, and management of variability within fields for maximum sustainability, profitability, and conservation of the land resource. With this agricultural technique, fresh information technologies can be utilized to improve decision-making in many aspects of crop production (Singh AK 2012) [30]. Precision agriculture requires accurate measurement of variability, its control, and evaluation in the space-time continuum throughout crop production. Precision agriculture's agronomic viability has been easy to use mostly reliant on the adoption of conventional arrangement advice at smaller sizes. Precision agriculture has had impressive agronomic results with crops like sugarcane, tea, sugar beet and coffee.

There is no magic wand in precision agriculture. Numerous things affect the chance of success. Computers, the Geographic Information Systems (GIS), Remote Sensing (RS), Global Positioning System (GPS) and Application Control are the five main categories into which the use of technologies of precision agriculture can be divided. Precision agriculture is defined as the art and science of utilizing innovative technologies for increasing crop production while reducing potential environmental pollution

(Khosla, 2001) [17]. This method acknowledges the inherent geographical variation associated with the majority of crop fields. After the in-field variability (both geographical and temporal) has been identified, localized, quantified, and recorded, it can be controlled farm inputs application in a particular amount and at a particular location (Khosla, 2001) [17]. It determines basic spatial variability and the essential factors where yield is constrained by changeable constraints. In basically, current technology has enabled more precise farm management.

The degree of management in precision farming sets it apart from traditional agriculture. Rather than supervising entire fields as a single entity, within, management is tailored for tiny areas fields. This higher level of management highlights the importance of good agronomic methods. A strong farm management system must already be in place before considering the switch to precision agriculture. Precision farming offers three benefits. First, it gives farmers helpful information that can affect how they use farm inputs such as seeds, fertilizer, pesticides, irrigation, and other things. Second, increased agricultural input efficiency optimizes economics. In the final, the environment is maintained by adjusting the quantity of agricultural inputs (insecticides, fertilizers and irrigation) required for crop production and applying those agricultural inputs precisely where they are needed.

Why Precision Farming?

One of the farming methods including the acceptance of technology for better managing field variability is precision farming. This technology allows for a reduction in the amount of work that must be done by humans, which saves time and trying to complete a task (Aziz *et al*., 2008) [4]. Precision agriculture, commonly referred to as precision farming, is the use of cutting-edge technology to collect data from the field. Farmers can use precision farming to apply fertilizer based on the needs of a particular sub-field rather than the average demands of the field. The term "Precision Farming" or "Precision Agriculture" has drawn the attention of many people who are concerned with the production of feed, food, and fiber. It aims to boost productiveness while lowering production costs and reducing environmental effect (NRC 1997) [24].

The decline in overall productivity, reducing and deteriorating natural resources, stagnant farm incomes, shortages of an ecoregional strategy, decreasing and dissipated holdings of land, liberalization of trade on farming, limited employment opportunities in non-farm sectors, and worldwide climatic variation are major factors in agricultural growth and development. Therefore, implementing recently created technology is one strategy to increase farm output in the future. Instead than managing a whole field based on some fictitious average situation that may not exist across the field, a precision farming technique takes site-specific variances within fields into account and adapts management measures accordingly.

After noting and mapping the variations in crop or soil parameters within a field management measure are implemented as a result of ongoing evaluation of the within that field, spatial variability (Patil and Bhalerao, 2013) [26]. These variations may be attributed to soil characteristics, management practices, or environmental conditions. It is difficult to maintain the level of understanding of field conditions because of huge dimensions and annual changes in agreements for lease in the farming area. As a result, the whole farm needs to be divided into small farm units, each of which must be worth a maximum of fifty cents. Precision agriculture has the ability to automate and simplify data collection and processing. It makes it possible to quickly and effectively apply management decisions on smaller fields inside of larger fields. Precision farming, which is growing in popularity as a crop production technique, aids in the development of a sustainable, ecologically friendly agriculture. Site-specific farming seeks to increase production while minimizing environmental effect. Additionally, there will be a rise in interest in automated information processing and data collection, which will be another step toward improved management of farms and general sustainability in the food production process. The capacities of the technology being employed have a significant impact on the benefits and effectiveness of precision farming techniques (Markus Her *et al*., 2002) [22].

The main motive of precision agriculture is to increase farming output, prevents soil erosion on land that can be farmed, decreasing the usage of chemicals in crop production, utilizing water resources effectively, the adoption of cutting-edge farming methods to boost production, quality, and affordability of agricultural crop production (Mandal, S. K., & Maity, A. 2013) [21]. Precision farming is a systems-based method of farming. Benefits to the environment and the economy must be considered for a project to be viable as well as the practical problem with field-level management and the required collaborations to deliver support systems for technologies. Some of the crucial factors in a precision agriculture system are shown in Figure 1. Issues with precision agriculture management include perceived advantages as well as obstacles to its widespread adoption (Davis, Undated).

Sustainability and Precision Farming

There has been much discussion over what sustainability means. The word "sustainable" was first utilized for agricultural and industrial innovations that decreased or prohibited the environmental degradation that is frequently connected to economic activity. Environmental sustainability was described (Pearce and Atkinson, 1993, 1995) [39] by arguing that natural resources and manufactured capital complement one other in the process of production and that, because they are the production's limiting element, they must be protected. In 1972, the United Nations offered a simpler explanation of sustainability, noting that it aimed to satisfy present needs without hampering the ability of the next generation to meet their own.

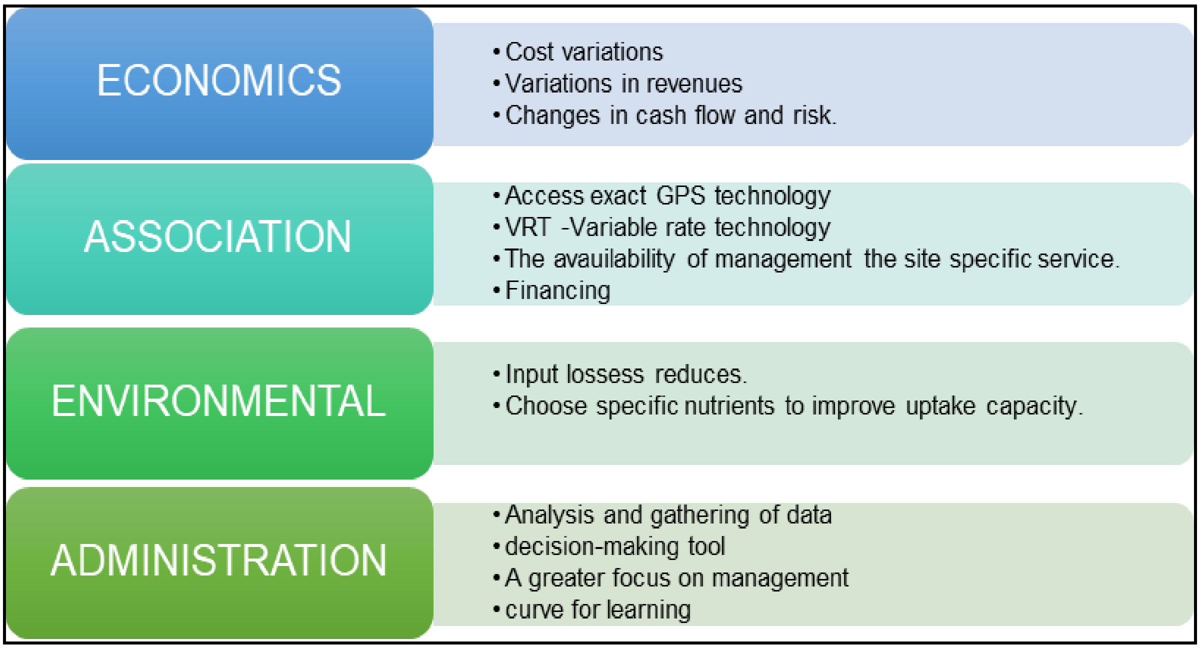

Fig 1: Issues with precision agriculture management include perceived advantages as well as obstacles to its widespread adoption (Davis, Undated)

The American Society of Agronomy applies the idea to agriculture and defines sustainable agriculture as a practice that, over the long term serves human demands for basic food and fiber, enhances the environment's quality and the resource basis on which agriculture depends, and is commercially viable, and improves the standard of living for farmers and society at large. The concept of doing the right thing, at the right place, at the right time is known as site-specific management (SSM). While this idea prior to farming itself, it came under great economic pressure with the modernization of agriculture in the 20th century to manage vast fields in an organized way. SSM may be mechanized using information technology via precision farming, which makes it valuable in commercial farming. All agricultural production methods that employ information technology to monitor or adjust input use to achieve desired results are referred to as precision agriculture (PA). Examples include yield monitors, variable rate application (VRA), and remote sensing (Patil and Bhalerao, 2013) [26]. The electronic monitoring and control used in data collecting, decision support & information processing for the temporal and geographical allocation of inputs for agricultural production is known as SSM. Producers may benefit from better management tools from precision agriculture for the inputs they must bring to the farm. Precision Agriculture enables farmers to more precisely focus applications of pesticides or fertilizer rather than distributing them uniformly over vast areas. It is frequently maintained that Precision Agriculture can replace certain external physical inputs with information and knowledge, potentially bringing the farm closer to the ideal of biological balance. Of course, external inputs such as information technology and knowledge are necessary for Precision Agriculture to function. With Precision Agriculture, it is hoped that natural systems will be less disrupted than they have been with the uniform use of physical inputs.

Global status and status in India

There are disparities in the status, limitations, and crucial components of sustainable agricultural growth for many countries that are developing. Due to the rapid socioeconomic changes taking place in various emerging countries, new chances for PA are being generated. The world's urban population doubled over the 20th century, and the majority of this growth is currently taking place in countries with low or middle incomes like India. (Mondal, P., & Basu, M. 2009) [23].

The US is a world leader in several modern fields of technology. This also holds true for Precision Agriculture technologies. According to Fountas *et al*. (2005) [40], the US operated about 90% of the world's yield monitors. Around 45.000 combines had yield monitors in 2003; these combines gathered 46% of maize, 15% of wheat, and 36% of soybeans. Around 90% of yield monitors in the world were in the US. In various states and regions recently, the adoption rate of automated guidance technology has reached 60-80%. While variable rate and yield monitoring technology previously dominated (Norwood & Fulton, 2009) [41], automatic section control and auto directing systems have become more and more commonplace during the past ten years. GNSS-based automatic guidance systems supply farmers with several advantages, such as more precise field work, faster & easier operation, working at night, reduced sensitivity to bad weather, reduced operator fatigue, quick setup, fewer overlaps, and skips, working without foam markers, and lower input costs. (Fuel, insecticides, fertilizer, seeds, etc.). Auto guiding may soon be regarded as a standard function for modern, very effective agricultural tractors. Additionally, some industrialized nations, notably the US, are actively testing driverless autonomous tractors.

Along with the US, Canada, Australia and a few European Union nations, such as Germany, Finland, Sweden, and Denmark, have adopted PA technologies to some extent. In particular, Leonard (2014) [42] noted that in Australia, roughly 80% of grain growers adopt computerized assistance. Additionally, Steele (2017) [43] reported that 98% of inquired farmers in western Canada used GPS guidance. The biggest resemblance between these three nations (the US, Australia, and Canada) is the scale of the farms, which makes the farmers in these nations more competent and ready to accept new technologies. One of the most important variables affecting Precision farming technologies is farm size. According to (Keskin 2018) [29]. Farmers owning a minimum of a few hundred hectares seem to be more receptive to costly new technologies. According to Fountas *et al*. (2005) [40], farmers are more likely to be the first to invest in new technologies if their fields are larger than 300 ha. PA adoption in Germany was negatively impacted by characteristics including having a land with less than 100 ha and growing barley. According to Keskin *et al*. (2018) [29], most Turkish farmers in the Adana area (56.4%) who used tractor auto guidance had fields larger than 100 h.

South Africa, Argentina, Brazil, and Turkey are among the countries using Precision Agriculture technologies to some extent. It should be noted that there may be other nations that use Precision Agriculture technologies but were not mentioned in publications. In Canada/Western 98% of farmers surveyed reported using GPS instruction, 84% reported using at least one Precision Agriculture technology, yield monitoring capacity are 84% reported, 73% reported using auto section control, and 75% said they planned to utilize more Precision Agriculture in the future. Significant progress is being made in the adoption of PF in Asian countries like India, Korea, Bangladesh, Sri Lanka, China and others where the average land holding is fewer than 4 ha. The agricultural sector in India is characterized by tiny and inefficient holdings. Approximately 85% of all agricultural land has been divided into areas fewer than 10 hectares. In the world, 60% of cropland is smaller than 4 hectares. Because of land limit laws and, occasionally, family disputes, the general size of holdings land is quite modest (less than 4 hectares). Such tiny holdings are frequently overstaffed, leading to covert unemployment and low labour productivity. Some low-tech, low-cost gadgets may prove helpful for small farms in underdeveloped nations. The leaf colour chart (LCC) and chlorophyll meter (SPAD) are straightforward, diagnostic tools that are accessible that may be used to assess rice crops in real time to identify the best time to use Nitrogen top putting, which is very helpful for underdeveloped nations. GIS has begun to be used on small farms. Better information results in better judgments, and this is certainly true for GIS. GIS is currently being updated for use on small Asian farms in Japan, Taiwan Province of China, & The Republic of Korea where government programs are fostering the use of web-based GIS systems (Mondal, 2009, Mandal & Maity, 2013) [23, 21].

Successfully Implemented PF in India are"

Tata Kisan Kendra (TKK): The TKKs provide farmers with TCL's extension services, which use remote sensing technologies to examine soil, provide information on crop health, pest infestations, and crop coverage in order to anticipate ultimate output. Farmers can more easily adjust to shifting conditions thanks to this. Higher yields, better crops, and higher farmer earnings are the end results. Finance is one of the main concerns for small farmers in India. This requirement is also met by the Kendra's. Farmers have access to buyback facilities, loans, and insurance to protect their crops from catastrophic disasters.

Tamil Nadu Precision Farming Project: In Tamil Nadu, the Precision Farming Project was launched in 2004-2005. Initially, 250 acres were used in 2004-2005, 500 acres in 2005-2006, and 250 acres in 2006-2007.The Tamil Nadu Agricultural University had been given this responsibility by the Tamil Nadu government. with financial assistance for crop production and drip irrigation installation. The farmers had planted five crops in three years. Farmers were initially hesitant to embrace this initiative because of their unhappiness with agriculture as a result of the region's ongoing drought, which has lasted for four years and started in 2002. However, after witnessing the achievement of the initial 100 farmers and high Farmers started joining in great numbers as soon as the scheme's produce reached market pricing (India Development Gateway. 2012).

Step/Requirement of Precision Farming

Precision farming's fundamental steps are:

1. Evaluating variation
2. Controlling variation
3. Assessment

With the help of the available tools, we are able to control the improbable characteristics of precision agriculture by providing site-specific agronomic suggestions. Finally, evaluation is a crucial component of every precision farming system. A graphic clearly illustrates all the specific processes that are involved in each operation.

Evaluating variation: Assessing variability is an essential first step in precision farming. Since it is obvious that you can't control what you do not recognize. There are numerous variables that affect crop performance in terms of yield over time and space. Assessing the variability of these elements and processes and determining when and where different combinations are responsible for the spatial and temporal variation in crop output are challenging tasks for precision agriculture. It is unusual to publish both temporal and spatial variation at the exact same time, despite the existence of specific methods for analyzing temporal variation. Both the temporal and spatial statistics are necessary. We can observe the variation in crop yield from space, but we cannot foresee the causes of the variation. It just takes a short amount of time to observe crop growth and development over the duration of the growing season. As a result, in order to use precision agricultural techniques, we also require time statistics and spatial data. However, not all variations or factors that affect crop production share this trait. Some variables are more created in area than in duration, making them more appropriate to the precision management techniques currently in practice.

Controlling variation: Farmers must use management guidance to match agricultural inputs with existing conditions once variance has been appropriately quantified. These are site-specific and use exact application control technology. Controlling site-specific variability is the most effective use of the technology. By using a GPS tracker, we can improve site detail while making maintenance easy and economical. When gathering soil or plant samples, we must note the coordinates of the sample location so that we may utilize them later for maintenance. This leads to the effective use of inputs and eliminates waste, which is what we desire. A manageable soil property's potential worth and ability for precise management increase with a property's degree of spatial dependence. However, the degree of difficulty rises as the geographical variability's temporal component rises. This theory would support the idea that soil fertility in terms of phosphorus and potassium is particularly responsive to precision management because of the low temporal variability. In other circumstances, precision N management can be significantly more challenging since the temporal component of variability for N can be greater than its geographical component.

Assessment: Regarding the assessment of precision agriculture, there are three crucial considerations:

a) **Economics:** When analyzing the profitability of precision agriculture, the most important factor is how the data are applied rather than how technology is used.
b) **Environment:** Potential improvements in environmental quality frequently serve as incentives for precision agriculture. Environmental advantages are commonly mentioned, including decreased usage of agrochemicals, increased nutrient utilization effectiveness, increased efficiency of regulated inputs, and increased production of soils from degradation.
c) **Technology Transfer:** The key term here is managed because precision farming does involve the application of technological innovations and agronomic concepts to manage spatial and temporal variability. How to interact with the farmer has received a lot of interest in what is known as technology transfer. As precision agriculture advances, these difficulties relating to the operator's managerial skills, the infrastructure's spatial distribution, and the technology's suitability for specific farms will drastically change (Patil and Bhalerao, 2013) [26].

Tool and Technology used in precision Farming

Technologies cover a wide range of hardware, software, and apparatuses. Which are:

Global positioning system (GPS): With an accuracy range of 100 to 0.01 meters, the Global Positioning System (GPS) is a navigation system based on satellites that enables users to store location information (longitude, latitude, and elevation) (Lang L 1992) [20]. Farmers can use GPS to locate field data such as type of soil, insect appearance, weed transport, water holes, limitations, and obstructions precisely. In addition to a DGPS, an antenna, and a receiver for light or sound, there is an automated operating system. GPS devices may use the signals that the observatories provide to establish their location. The method enables farmers to precisely pinpoint fields so that resources (seeds, herbicides, fertilizers, insecticides and irrigation water) may be applied to each distinct field based on its performance requirements and prior input applications (Batte MT and Van Buren FN 1999) [6].

Differential Global Positioning System (DGPS): A technique for improving GPS accuracy that takes advantage of the virtual range faults found at a specific site to improve readings obtained from various GPS receivers situated roughly in the same geographic region. In addition, the usage of DGPS is necessary due to the precision, which is a crucial aspect of PF. GPS can pinpoint the location of farm equipment in the field to within a meter using an international constellation of military satellites. Knowing a location to within inches of accuracy is useful because: To evaluate the positions of the soil samples with laboratory findings, utilize a soil map; To meet soil characteristics (clay and organic matter concentration) and conditions of the soil (relief and drainage), fertilizer and pesticide recommendations can be made; You can adjust tillage in reaction to shifting field conditions, and you are able to record yield information as you move over the field.

Geographic information systems (GIS): This system consists of software, equipment, and processes to support feature properties and location gathering, storage, data retrieval, and analysis to create maps. Through GIS, data is connected in one location so that it may be expanded as required. Several layers of information (such as yield, maps of soil surveys, rainfall, crops, soil nutrient levels, and pests), which are not present on conventional maps, are present on computerised GIS maps. GIS is a form of computerised map, but its real use is for geographical analysis and statistical analysis of people and locations. Through GIS, data is connected in one location so that it may be expanded as required. Several layers of information (such as yield, crops, soil nutrient levels, maps of soil surveys, rainfall and pests), which are not present on conventional maps, are present on computerised GIS maps. GIS is a form of computerised map, but its real use is for geographical analysis and statistical analysis of people and locations. Information on the cultivation of crops, field topography, types of soil, surface water drainage, subsurface water drainage, evaluation of soil, and irrigation can be found in an agricultural GIS database. This data is analyzed and used to understand the relationships between the various elements influencing a crop in a certain area (Trimble, 2005). The GIS can be used to analyze various management situations in addition to preserving and displaying data by combining and altering various data layers.

Remote Sensing: Remote sensing is the process of acquiring data about an object without physically touching it. Remote sensing has been used in mapping soils, geography evaluation, crop stress, output mapping, and computation of organic matter in the soil, however on a larger scale than what is required for precision agriculture. Precision farming can greatly benefit from the use of high-resolution remote sensing due to its ability to track spatial variations. In PF, the purpose of satellite remote sensing is to gather geographically and temporally dispersed data in order to recognize and assess crop and soil variability within fields.

Variable rate technology: According to Mandal and Maity (2013) [21], the variable rate applicator consists of three parts. Actuator, locator, and control computer are some of these. The application map is loaded onto a computer that sits on a variable-rate applicator. In order to modify the quantity and/or kind of product, as indicated by the application map, for example, a goods-delivery controller is controlled by the device itself using the applications map and a receiver for GPS. Sync yield monitors with harvesters. Here the flow of grain in a combine's clean grain elevator is continuously measured and recorded by yield monitors. Yield monitors can supply the information required for yield maps when connected to a GPS receiver.

Sensors Technology: A number of techniques, including electromagnetic waves, electrical conductivity, photo electricity, and ultra vibrations, are used to measure moisture, greenery, temperature, appearance, construction, physical character, and conductivity. Remote sensing data can be used to identify between different crop species, locate stress sites, locate weeds and pests, and track a lack of moisture soil, and vegetation conditions. Large amounts of data can be collected with sensors without the requirement for a laboratory analysis. (Chen F *et al*., 1997) [8].

Soil and Plant Sensors: Sensors are employed to provide information on soil properties, plant growth, and water condition, as has been widely documented. A crucial part of precision agriculture technology is sensor technology. A complete review of the sensors that are in use today as well as features that should be included in future sensors (Adamchuk VI *et al*., 2004) [1]. Surveying the field with soil actual electrical conductivity (ECa) sensors, which continually capture data when moved over the field surface, is one of the most common methods for describing soil variability. These sensors offer a great starting point for implementing site-specific management because ECa is sensitive to variations in soil texture and salinity.

Rate Controllers: The delivery rate of chemical inputs like fertilizers and insecticides, whether they are liquid or granular, can be regulated using rate controllers, which are devices. These rate controllers monitor the rate of flow and the pressure of the material (if it is a liquid), as well as the tractor/sprayer's movement as it travels over the land, and they adjust the supply in real-time to reach the target rate. Rate controllers have been around for a long and are frequently used as separate systems.

Softwares: Precision agricultural technologies are widely used to carry out a variety of jobs, such display-controller interface, data layer mapping, pre and post data processing assessment and comprehension, farm accounting of inputs per field, and many more duties. The most common types of software are those that filter obtained data, create variable rates of applications maps (for fertilizer, chemicals, lime, etc.), create yield and soil maps, overlap numerous maps, and provide significant geostatistical characteristics.

Yield Monitoring: Yield monitors are composed of several components. A range of sensors are typically included in the task computer, which is frequently located in the tractor's cab and regulates the interaction and combination of numerous sensors and other components. It also serves as an information storage device, interface to the user (display and keypad), and other components. The sensors determine the grain itself, the weight or capacity of the grain flow, the separator speed, the ground speed. Grain yield is continuously monitored by calculating the impact force of the grain flow when it collides with a sensible plate in the combine's clean grain elevator. A freshly created mass flow sensor measures the amount of energy reflected after contacting the stream of seeds flowing through the chutes. It works by sending microwave radiation beams. All output monitors use GPS receivers to map production data and keep track of its location. Another sort of monitoring of yield system is equipment used in fodder crops to measure volume, humidity, and other information per bin (Davis G and Massey 2005) [9].

On-line resources for precision Agriculture: On modern technology for agricultural production, there is a variety of information online. Most producers of agricultural machinery, GPS units, sensors, and other PA technologies use this medium to update growers on new goods, technical details, troubleshooting advice, software updates, and a range of services.

Grid Sampling: It is the method of breaking a field into grids of 0.5-5 hectare. Sampling soil within the grid is useful or determining appropriate amount of fertilizer requirement.

Application of Remote Sensing

The use of remote sensing technology is very useful for gathering a lot of data at once. It is the remote collection of data. Simple portable gadgets, attachments for airplanes, or satellite-based systems can all be used as data sensors. Crop health can be evaluated using data collected using remote sensing technology (Table 1). Plant stress brought on by nutrients, moisture, compression, diseases of crops, and other problems with plant health are frequently observed in aerial pictures. Remote sensing can assist managers make modifications that will raise the earnings of the crop that is now being harvested by identifying in-season variability that affects agricultural output.

Because each field has different characteristics, such as the length of time and frequency of midseason drainage, the timing and amount of nitrogen-rich fertilizers application, and the timing of harvest, it may be difficult to identify the most crucial management element even though remote sensing technology may collect a lot of information. For this kind of research, GIS, or geographic information systems, are the best tool. They generally evolved as a result of improvements achieved in one Geographic Information Systems (GIS) application being shared and improved upon in other applications. GIS are important management and research tools for natural management of resources. The evaluation and regionalization of the replenishment of groundwater, the planning and control of irrigation supplies for rice irrigation systems, and the construction of geographic distribution mapping for heavy metals are common applications of GIS in agriculture (Patil &

Bhalerao, 2013) [26].
The primary uses of remote sensing in agriculture are crop identification by collecting data on reflection patterns, stress plant identification using NDVI, detection, diagnosis, and control of plant diseases using pathogen-given reflections in infected zones, weed identification management, and yield forecasting by observing fields where no stress is present.

Table 1: Application of precision Agriculture

Sl. No.	References	Area Of Work	Signification
1.	Available: http://agropedia.iitk.ac.in/?q=node/4550	Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal.	Tata Kisan Kendra (TKK): Through the TKKs, TCL offers extension services to farmers that assess the soil, provide data on crop health, infestations of pests, and crop protection, and forecast the yield of different crops.
2.	Available: http://www.indg.in/agriculture/agricultural-best-practices/precision-farming	Tamil Nadu	Tamil Nadu Precision Farming Project: With funding for drip irrigation installation and crop production
3.	Mondal and Basu 2009 [23]	India	Effective tools for rice production include laser-based land levelling and N management based on leaf colour charts (LCC).
4.	Lowenberg-DeBoer 2015 [44]	USA	Variable-rate technology (VRT) services are provided by more than 60% of agricultural input dealers.
5.	Leonard (2014) [42]	Australia	More than 80% of grain growers employ autonomous guidance systems.
6.	Steele (2017) [43]	Canada / Western	98% of farmers asked said they used GPS guidance, 84% said they used at least one PA technology, 84% said their combines could monitor yields, 73% said they used auto section control, and 75% said they planned to employ more PA in the future.
7.	Borghi *et al.* (2016) [45]	Brazil	The most popular technology among survey respondents were yield maps (56%), GPS guidance with manual control (89%), and GPS guidance with automatic control (56%)
8.	Armagan (2016) [46]	Europe	Smart or ISO-Bus enabled equipment is installed in 70% of all fertilization and spraying devices.

Advantages and disadvantages of Precision Farming:
Advantages

Agronomic perspective: The exact agricultural procedures to be utilized for a crop are influenced or determined by the diverse requirements of the crop. The agricultural viewpoint on precision farming is mostly founded on the implementation of some conventional advice that has been practiced for millennia. Those who adhere to these traditional recommendations or practices should completely change their mindset. The crucial agronomic issues that must be addressed in the Precision Farming movement are reducing soil degradation and making efficient and cost-effective use of water resources.

Technical Perspective: Farmers need to be trained and educated on how to use technology to grow crops and save valuable time. According to the National Micro-Irrigation Mission (NMMI). India must implement micro-irrigation on a big scale due to the unpredictable monsoon, a water constraint, and the abundance of arable land. The five types of technologies GPS (Global Positioning System), computers, GIS (Geographic Information System), RS (Remote Sensing), and application control are recommended for use in precision farming. In addition, modern farmers have access to a wide range of technical advancements. For the digitalization of plot boundaries, they are aerial and indipendent agriculture. Prescriptive Planting, Phytogeomorphological Approach, Orthomosaic Maps.
The Phytobiome, Plant Phenotypin Mobile Technological Platforms, and the Internet of Things.

Environmental perspective: Agricultural products should be produced utilizing a variety of eco-friendly techniques that harm a region's ecology as little as possible. According to the Indian viewpoint, the country attained food self-sufficiency during the green revolution of the 1960s. The Green Revolution, however, was unable to focus on this distinctive feature of Precision Farming or Precision Agriculture. During the Green Revolution farming 11 era, the adoption of varieties with high yields (HYVs), intensity of cropping, and agricultural mechanization of farms received increasing attention. All resources are used by pesticides, fertilizers, chemical substances, and water. There was a lot of environmental pressure. Hence, in the current situation, it is crucial to overcome the green revolution's exhaustion by concentrate on Precision Farming. Although the Green Revolution increased food security and, to some extent, independence, it also put tremendous demand on natural resources, particularly the land. Out of the entire 328.7 million hectares in India, 182 million hectares have been degraded, including 141,33 million hectares owing to water erosion, 11,5 million hectares due to wind erosion, 12,63 million hectares due to water logging, and 13,23,000 hectares due to chemicals and other factors. The need to reduce environmental pollution while preserving the priceless natural resources land, soil, and water is another part of the environmental approach.

Economic Perspective: Making agriculture profitable, sustainable, scalable and achieving economies of scale through various techniques are the goal of economic thinking. The agricultural inputs must be used effectively to lower production costs, boost output, and improve output quality. Combining agricultural land for efficient and precise farming lowers operating expenses. Aggregation of land parcels is crucial since deploying precision agricultural equipment on the two platforms, Land and Arial, is quite expensive. Some of the more important concerns to be addressed as part of precision farming include improving purchasing power, fortifying the "Supply Chain Infrastructure," and streamlining the "Supply Chain Governance" laws at the national and international level (Soma *et al*., 2019) [34].

Limitation

A few of the obstacles to the adoption of these high-tech precision farming technologies in India include the high cost of obtaining location-specific satellite imagery, the unwillingness of different organizations to share spatial data, the multifaceted nature of the methods and instruments requiring new skills, and the culture, perspective, and viewpoints of farmers, including their against adopting new techniques and their lack of understanding about agro-environmental problems. India's adoption of this cutting-edge precision agricultural technology is hindered by a variety of problems, some of which include Lack of PF adoption success stories and no proof of yield impacts, a lack of local technical experience, uncertainty about the returns on expenditures in new technology and data management systems, inability to communicate technical knowledge to farmers in their native tongue, and technological gaps, including an absence of understanding of agronomic issues and their interactions and a shortages of understanding of geostatistics, are just a few of the problems that need to be addressed. (Patel *et al*., 2004) [25].

Future Prospect

Along with raising productivity, the green revolution has had a number of negative environmental consequences, including the depletion of land, loss of soil fertility, salinization of the soil, soil erosion, degradation of the environment, deterioration of the environment, and health hazards. Sustainability has been put in danger by excessive application of fertilizers, irrigation, and pesticides. However, factors including decreasing input use efficiency and a decreasing output-to-input ratio have made agricultural cultivation less lucrative. According to Mandal and Ghosh (2000) [47], sustainable agriculture is the effective use of resources to meet changing human requirements while preserving or improving the environmental quality. Although it is frequently a tested technique, precision farming is still largely limited to industrialized (American and European) nations. The extent of its adoption in India is not well documented, with a few exceptions. The short field size, in our opinion, is one of the main issues. More than 57.8% of operating properties in India are smaller than 1 hectare in size. However, more than 20% of agricultural lands in the key agricultural states of Gujarat, Punjab, Rajasthan, and Haryana have operational holding sizes of more than 4 hectares. These are distinct field dimensions. However, the field sizes (or rather, simulated field sizes) are high when we consider contiguous fields with the same crop (usually under identical management approaches). Using aerial data, it was discovered that more than half of continuous field sizes in the Punjabi district of Patiala are larger than 15 h. For the sake of implementing precision farming, these adjacent fields can be treated as a single field. Important food grain crops like rice and wheat could benefit from precision farming, especially in the states of Punjab and Haryana. However, a lot of high-yielding horticultural crops in India provide ample opportunity for precision farming.

Until and unless it is marketed for widespread usage as a service mode, any technological improvement does not offer a complete answer for the user. The popularity of PF and its adoption have led to a vacuum between scientific knowledge of the link between input materials and output goods and technological capabilities. Although the market has mostly propelled PF's development, both the public and private sectors must work together for it to continue growing.

According to Mandal and Ghosh (2000) [47], the private sector must assume responsibility for market expansion, product legitimacy, and client happiness. In contrast, the public sector must supervise the processes of creating and putting into practice PF by helping programs to attain the goals. For end consumers to transfer and embrace technology there must be connections between the public, private, and academic sectors. Although the technology's potential has previously been shown, substantial delivery in reality is challenging because it requires extensive commercial use to truly experience the rewards (Patil and Bhalerao, 2013) [26]. Users and farmers could need to pay for high resolution satellite data, which might be prohibitively expensive, particularly for small farms. For small farm operations, a low-cost alternative may be provided by photos captured by UAVs, but (Candiago, *et al*., 2015) [7]. The usage of UAVs and tractor-mounted sensors necessitates expert operators (such as drone licensing) and requires the use of specialized software for data analysis. The cutting-edge sensors deployed on some of the most recent satellite launches and unmanned aerial vehicles (UAVs) produce hyperspectral images that contain a wealth of data on crop biophysical parameters. However, these sensors (UAVs) are expensive, and picture processing is difficult (Khanal *et al*., 2018) [15].

Machine learning and other artificial intelligence approaches have the ability to produce spatially and temporally continuous information from real-time satellite data at the scale required for many PA applications (Reichstein *et al*., 2019) [28]. Such AI techniques can be complemented by hybrid methods, which use the information from physically based models to build methodologies helpful in PA decision making (Reichstein *et al*., 2019, Weiss *et al*., 2020) [28, 36]. Given the complicated nature of image processing methods and the amount of knowledge and ability required for application, it is necessary to explore and create a simple and trustworthy workflow for image prior processing, analysis, and use in real time.

There are still many obstacles and limitations in the development of devices and structures that allow end users to exploit satellite information for real-time applications. The creation of precise, user-friendly innovations is likely to result to a higher usage of data from remote sensors in both commercial and non-commercial PA activities.

Conclusion

Optimal input use is a challenge that will be solved by the emerging concept of precision farming, which combines new technology from the computer age. If implemented correctly, it can address the issue of food security while keeping agriculture sustainable. Precision agriculture can help minimize the economic and environmental issues that affect agriculture. It goes without saying that the newest tools of science and technology should be used to distribute our nation's natural resources in a sustainable and fair manner. Although industrialized nations employ this technology more frequently, developing nations like India can also benefit from it. Precision farming is still largely an idea in numerous developing nations, thus strategic support from both the public and private sectors is needed to promote its rapid adoption. The initial three stages of an effective adoption are investigation, evaluation, and application. Precision agriculture can address the financial and environmental issues that now surround generating agriculture. Although the concept of "doing the right thing in the right place at the right time" has a strong intuitive appeal, there are still concerns about affordability and the most effective ways to employ the current technology. In view of the current urgent need, a full-scale effort should be launched to leverage new technical inputs to convert the "Green Revolution" into a "Evergreen Revolution". Precision's prospects the field of agriculture offers promise and has the potential to develop into a technology with broad impacts. Agriculture's future path will depend on the research community's capacity to carry out in-depth investigations in this field, with the support of the producer and environmental communities who are certain that reforms will improve the environment and boost the productivity of agricultural production**.** In India precision farming research is still in the early stages. Precision farming technologies are effective at increasing crop productivity and the effectiveness of input utilization while lowering production costs and environmental impacts. It is necessary to standardize, develop, and use affordable, farmer-friendly tools and methodologies for evaluating soil and yield variability. Therefore, precision farming may enable farmers to take advantage of the benefits of modern technology without sacrificing the quality of their crops or the soil. The necessity of the hour is for India to undergo a techno green revolution, which would be brought about by precision farming.

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