A Review on Precision Cultivation: The emerging modern and scientific concept for sustainable agriculture.

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Abstract: Recently in the agricultural sector Precision cultivation also known as precision agriculture has emerged as the most influential concept. Precision agriculture can be defined as "Use of Information Technology for designing effective management strategy of the collected data from multiple sources and make decision relating agricultural yield, product marketing , funds and labour". The main objectives of precision cultivation are to increase yield efficiency, to improve quality, to reduce environmental degradation, to conserve energy and protection of soil and water. Key components of precision farming are: Information, Technology and Management. Precision crop growing technologies are classified into four major areas: Sensors and Instrumentation, Global positioning system (GPS), Geographic information system (GIS) and Data management. Precision cultivation promises higher yield and lower input cost due to reduction in labour and waste. It also helps to minimize environmental degradation and pollution.

Keywords: Agriculture, GPS, GIS, IT, Soil science and Environmental degradation.

[I] INTRODUCTION

Since millions of years, human race has been in the profession of agriculture through natural resources like water, soil and light. Practice of periodic management of these resources are mentioned in various ancient Hindu literature[1, 2]. The population explosion in the last century and the rapid rise in industrialization with urbanization in last few decades have divested the natural resource base, which are getting degraded at the alarming rate[3]. Thus, to meet the needs of ever increasing population (Fig.1) it is must to improve agricultural methods to produce enough. But at the same time the enormous use of the technology in the last few decades has invited environmental degradation where the natural resources are deteriorated physically, chemically, biologically and ethically. This is a huge menace to sustainable farming. Irrigation development and technological progression in India[4] have achieved unparalleled food grain production[5]. But to achieve the day by day increasing demand will not be easy as many of the existing production systems are exploiting the resources. Agricultural researchers all over the globe are concerned with the insufficient output as compared with the agricultural inputs.

Precision Agriculture is the application of technologies and principles to manage spatial and temporal variability associated with all aspects of agricultural production for improving production and environmental quality[6]. The success in precision agriculture depends on the accurate assessment of the variability, its management and evaluation in space-time continuum in crop production[7, 8]. The potential for economic, environmental and social benefits of precision agriculture is largely unrealized because the space-time continuum of crop production has not been adequately addressed[9, 10]. Precision agriculture is based on information technology, which enables the producer to collect information and data for better decision making. Precision farming technologies[11] are classified into four major classes: Computers, Global positioning system (GPS), Geographic information system (GIS) and Sensors and Instrumentation Control.

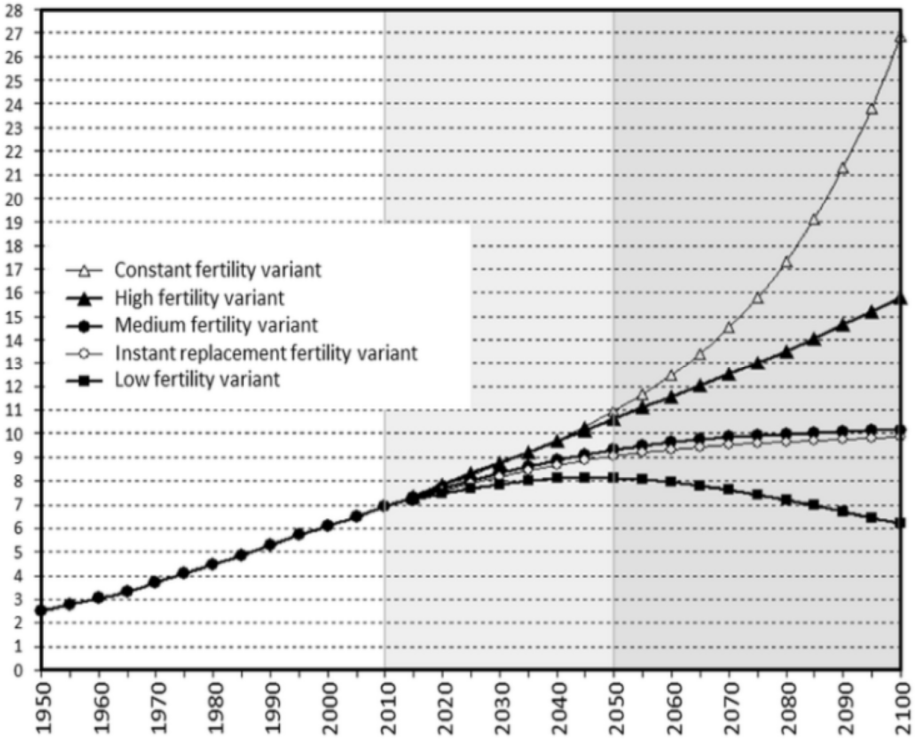

Fig. 1 : Estimated and projected world population (billions) according to different variants, 1950-2100. (Source: UN 2010 Revision)

[II] CONCEPTUAL DEFINITIONS

1. Precision Cultivation:

Precision cultivation also known as precision agriculture is defined as the scientific art of utilizing advanced technologies for enhancing crop production while minimizing environmental pollution[12]. The technology identifies the spatial and temporal variables associated with land under crop production. The variations occurring in crop or soil properties within a field are noted, mapped and then management actions are taken as a consequence of continued assessment of the variables within that field[13]. Development of geoinformatics technology has helped in the implementation of management of agricultural sites using remote sensing (RS), global positioning system (GPS), and geographical information system (GIS). This approach is called site specific management (SSM) [14]. Site-specific management (SSM) is the idea of doing the right thing, at the right place, at the right time. Precision farming provides a way to automate SSM using information technology, thereby making SSM practical in commercial agriculture. Precision cultivation distinguishes itself from traditional agriculture by its class of management. Instead of managing whole fields as a single unit, management is adapted for small areas within fields[15].

2. Sustainable agriculture:

Precision agriculture and sustainability are interlinked[16]. There are many definitions of Sustainability. Initially it referred to agricultural and industrial technologies that prevented the environmental degradation mainly associated with economic activity[17]. Sustainability was defined as economics of resources or resources of economics[18]. Here it was discussed how technology can be used to sustain resources. Sustainability was defined environmentally by stating that natural resources and manmade capital complement each other in a production process and natural resources must be preserved as the limiting factor[19]. In 1972, the United Nations defined sustainability as approach to meet the needs of the present without compromising the ability of future generations to meet their own needs. Recently Sustainability has been associated with the economic, environmental, and sociological impacts of any development (fig. 2)[20].

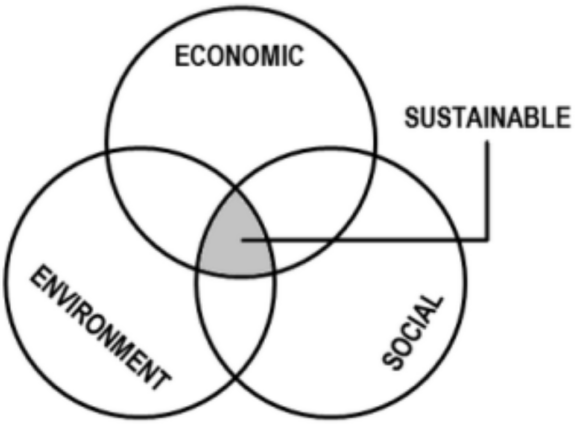

Fig. 2: Sustainability associated with three disciplines: environment, economics and sociology (Wood P., 2012)

[III] METHODOLOGY

1. Work culture in Precision Agriculture:

The work flow in precision agriculture can be realized as
a) Identifying variations.
b) Managing variations and
c) Analysis

a) Identifying variations:

Factors such as soil, water and climate affecting the crop performance vary in space and time. We need both the physics and chemistry of the soil for spatial and temporal statistics. Techniques for assessing spatial variability in soil are used widely in precision agriculture. Techniques for assessing temporal variability also exist but the simultaneous reporting a spatial and temporal variation is not much studied. Variability in crop yield can be studied for a specific space and time but predicting causes is a tough job. Climate variability is another important factor to be identified[21]. Major climate variables that affect crop production are rainfall variability[22] **(fig. 3)** and temperature variability.

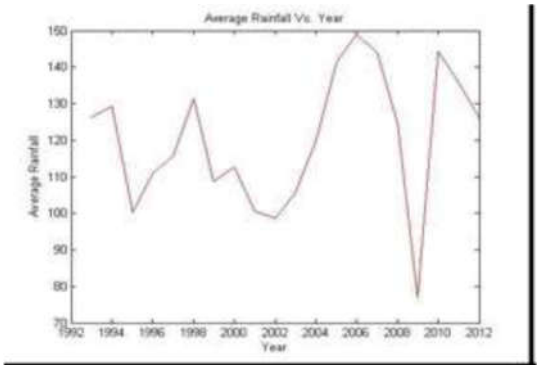

Fig. 3: Avg Rainfall Vs. Year (over Maharashtra state during 1993-2012, source: Mahajan P., et. al)[22]

b) Management:

For successfully managing the variables, we can easily record the sample site coordinates[23] with the help of GPS. Soil variability is accurately identified and interpreted, for both quality and quantity crop yield. Potential precision management is easily achieved. The inputs can be applied in a way to maintain good environment. However managing temporal variability is very complex task. The climate variability plays an important role in increasing the difficulties for management. The knowledge of regional variations in rainfall and temperature play crucial role in management of crops in that region.

c) Analysis:

Once the variables are identified and managed we use them in analysing and making decision[24]. Advanced technologies can make precision agriculture possible and enhance the production efficiency to make it a profitable profession. Reduced agrochemical use, higher nutrient use, increased efficiency of managed inputs and preventing soil degradation are the important parameters for healthy environment.

2. Advance Technologies:

Precision agriculture is based on Information Technology for designing effective management strategy of the collected data from multiple sources and makes decision relating agricultural yield, product marketing, funds and labour. The advance technologies used are GPS, GIS, RS and VRA.

a) Global Positioning System (GPS) receivers:

Global Positioning System (GPS) provides the possibility to point the spatial coordinates of the land. Having precise location information at any time facilitates recording and mapping of soil and crop measurements. GPS receivers with electronic yield monitors are generally used to collect yield data across the agricultural land accurately. Global positioning systems (GPS) are widely available in the agricultural community as different packages like mapping yields (GPS + combine yield monitor), variable rate planting (GPS + variable rate planting system), variable rate lime and fertilizer application (GPS + variable rate controller), field mapping for records and insurance purposes (GPS + mapping software), and parallel swathing (GPS + navigation tool) [25].

b) Geographic information systems (GIS):

GIS is a useful tool for the assessment and management of agricultural resources. GIS plays an important role in the development of expert systems in different fields of agriculture as an essential technology for the decision support system. An important function of an agricultural GIS is to store layers of information, such as yields, yield maps, soil survey maps, remotely sensed data, crop scouting reports and soil nutrient levels. Application of GIS generally includes various types of spatial and description data. Maps are in both raster and vector formats and descriptive data are preserved in the database format of Oracle TM, Sybase TM, Informix TM, SQL server and so on[26]. GIS can be used in three levels of Workstation GIS, Desktop GIS, and Enterprise GIS. Geographic information systems (GIS) are computer hardware and software that use feature attributes and location data to produce maps.

c) Remote sensing (RS):

This technique monitors the dynamic conditions of the soil and the plant in glancing form. It measures the visible and invisible features of a farm or a group of farms and also reveals continuous spatial information. Visual observations are recorded and fed to GIS database[27] through an electronic device which is geo-referenced. Though aerial photos and videos recorded by drones can be used in precision agriculture, satellite images are a powerful tool for estimating the area under cultivation within a month or two with 90% accuracy and estimating performance during couple of weeks for the single crop cultivation area with more than 90% accuracy.

Data sensors can be hand-held devices[28], mounted on aircraft or satellite-based. Plant responses related to moisture, nutrients, complexes, crop diseases and other concerns are easily detected by these sensors. Remote sensing can reveal in-season variability affecting crop yield, and can be helpful in making timely decisions that improve profitability for the crop. GIS has been employed in other applications such as scheduling and monitoring of irrigation systems, regional groundwater recharge estimation and distribution maps for heavy metals present in soil and water.

d) Variable Rate Applicator (VRA):

The variable rate applicator has three components[29]. These include computer, locator and actuator. The application map is loaded into a computer mounted on a variable-rate applicator. The computer uses the application map and a GPS receiver to direct a product-delivery controller that changes the amount and/or kind of product, according to the application map. Here Yield monitors continuously measure and provide data necessary for yield maps.

[IV] CONCLUSION

Sustainable agriculture is the successful management of resources to satisfy the ever increasing human needs, while maintaining or enhancing the quality of environmental and conserving natural resources[30]. Precision agriculture can address economic, social and environmental issues of today and tomorrow. The green revolution has undoubtedly increased productivity, but has threatened sustainability with several depressing ecological consequences such as decreasing soil fertility, causing soil erosion, depletion of agricultural lands, Arbitrary use of pesticides and fertilizers has promoted health hazards, decline of environment and degradation of biodiversity. There is a scope of implementing precision farming for major food-grain crops such as wheat in the states of Punjab and Haryana and rice in the southern India. The precision cultivation beyond doubt can increase yield efficiency, improve soil quality, reduce environmental degradation, conserve energy and protect Biodiversity.

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