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Precision Farming: An Introduction

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Precision farming is an approach where inputs are utilised in precise amounts to get increased average yields compared to traditional cultivation techniques. Hence it is a comprehensive system designed to optimize production by using a key elements of information, technology, and management, so as to increase production efficiency, improve product quality, improve the efficiency of crop chemical use, conserve energy and protect environment [1]. Thus, precision farming is an appealing concept and its principles quite naturally lead to the expectation that farming inputs can be used more effectively, with subsequent improvements in profits and environmentally less burdensome production. The precision farming developments of today can provide the technology for the environment friendly agriculture of tomorrow. Especially in the case of small farmers in developing countries, precision farming holds the promise of substantial yield improvement with minimal external input use.

Need of Precision Farming

The global food system faces formidable challenges today that will increase markedly over the next 40 years. Much can be achieved immediately with current technologies and knowledge, given sufficient will and investment. But coping with future challenges will require more radical changes to the food system and investment in research to provide new solutions to novel problems. The decline in the total productivity, diminishing and degrading natural resources, stagnating farm incomes, lack of ecoregional approach, declining and fragmented land holdings, trade liberalization on agriculture, limited employment opportunities in non-farm sector, and global climatic variation have become major concerns in agricultural growth and development.

Therefore, the use of newly emerged technology adoption is seen as one key to increase agriculture productivity in the future. Instead of managing an entire field based upon some hypothetical average condition, which may not exist anywhere in the field, a precision farming approach recognizes site-specific differences within fields and adjusts management actions accordingly. Farmers usually are aware that their fields have variable yields across the landscape. These variations can be traced to management practices, soil properties and/or environmental characteristics. The level of knowledge of field conditions is difficult to maintain because of the large sizes and changes due to annual shifts in leasing arrangements in the farm area. So the entire farm area has to be divided into small farm units of 50 cents or less. Precision agriculture offers the potential to automate and simplify the collection and analysis of information. It allows management decisions to be made and quickly implemented on small areas within larger fields (Hakkim *et al*. 2016)

Components of Precision Farming

In Precision agriculture, the field is broken into "management zones" also called 'grids' based on soil pH, nutritional status, pest infestation, yield rates, and other factors that affect crop production. Management decisions are based on the requirements of each zone and precision agriculture tools such as GIS, GPS, etc., are used to control zone inputs. The exact location can be identified with the help of one of the main precision farming technology of Global Positioning System (GPS), while application on the exact location can be made with the help of advanced equipments available. To accomplish this, the farmer must mount a GPS receiver on the tractor/system applying the chemical so that the equipment knows its location in the field. An in-vehicle computer must contain the fertilizer/pesticide (or whatever needs to be applied) – need map,which compares to the field position data recorded from the GPS receiver. In addition to fertilizer/pesticide requirements, plant population can also be chosen to optimise soil nutrients and plant variety selection can be chosen to take advantage of the field conditions. Crop yield can also be monitored to create maps that show the high and low production areas of a field for improved management decisions**.**

Technologies used in Precision Farming

In order to collect and utilize information effectively, it is important for anyone considering precision farming to be familiar with the modern technological tools available. The vast array of tools include hardware, software and the best management practices. These are described briefly in the following paragraphs.

Mapping

The generation of maps for crop and soil properties is the most important and first step in precision agriculture. These maps will measure spatial variability and provide the basis for controlling spatial variability. Data collection occurs both before and during crop production and is enhanced by collecting precise location coordinates using the GPS. The data collection technologies are grid soil sampling, yield monitoring, RS and crop scouting. During crop production, the data are collected through sensing instruments such as soil probes, electrical conductivity and soil nutrient status. Mapping can be done by RS, GIS and manually during field operations.

Global Positioning System (GPS) Receivers

Global Positioning System satellites broadcast signals that allow GPS receivers to compute their location. This information is provided in real time, meaning that continuous position information is provided while in motion. Having precise location information at any time allows soil and crop measurements to be mapped. GPS receivers, either carried to the field or mounted on implements allow users to return to specific locations to sample or treat those areas.

Yield Monitoring and Mapping

In highly mechanized systems, grain yield monitors continuously measure and record the flow of grain in the clean-grain elevator of a combine. When linked with a GPS receiver, yield monitors can provide data necessary for yield maps. Yield measurements are essential for making sound management decisions. However, soil, landscape and other environmental factors should also be weighed when interpreting a yield map. Used properly, yield information provides important feedback in determining the effects of managed inputs such as fertilizer amendments, seed, pesticides and cultural practices including tillage and irrigation.

Grid Soil Sampling and Variable-Rate Fertilizer (VRT) Application

Soil cores taken from random locations in the sampling area are combined and sent to a laboratory to be tested. Crop advisors make fertilizer application recommendations from the soil test information. Grid soil sampling uses the same principles of soil sampling but increases the intensity of sampling. For example, a 20-acre sampling area would have 10 samples using a 2-acre grid sampling system (samples are spaced 300 feet from each other) compared to one sample in the traditional recommendations. Soil samples collected in a systematic grid also have location information that allows the data to be mapped. The goal of grid soil sampling is to generate a map of nutrient requirement. Grid soil samples are analyzed in the laboratory, and an interpretation of crop nutrient needs is made for each soil sample. Then the fertilizer application map is plotted using the entire set of soil samples. The application map is loaded into a computer mounted on a variable-rate fertilizer spreader. The computer uses the application map and a GPS receiver to direct a product-delivery controller that changes the amount and/or kind of fertilizer product, according to the application map.

Remote Sensing

Remote sensing is collection of data from a distance. Data sensors can simply be hand-held devices, mounted on aircraft or satellite-based. Remotely-sensed data provide a tool for evaluating crop health. Plant stress related to moisture, nutrients, compaction, crop diseases and other plant health concerns are often easily detected in overhead images. Electronic cameras can also record near infrared images that are highly correlated with healthy plant tissue. Remote sensing can reveal in-season variability that affects crop yield, and can be timely enough to make management decisions that improve profitability for the current crop. Remotely-sensed images can help determine the location and extent of crop stress. Analysis of such images can help determine the cause of certain components of crop stress. The images can then be used to develop and implement a spot treatment plan that optimizes the use of agricultural chemicals. Satellite Remote sensing has provided a tool for acreage estimation one month in advance, with more than 95% accuracy and in mono-crop area yield estimation with more than 90% accuracy ten days in advance. The most popular procedure is to take images from satellites such as LANDSAT or SPOT. Finally, images are used for generating maps and calibration of the measurement, assuming that measurements are taken in field to ground-truth accuracy. These images allow mapping of crop, pest and soil properties for monitoring seasonally variable crop production, stress, weed infestation and extent within a field.

Geographic Information Systems (GIS)

Geographic information systems (GIS) are Computer hardware and software that use feature attributes and location data to produce maps. An important function of an agricultural GIS is to store layers of information, such as yields, soil survey maps, remotely sensed data, crop scouting reports and soil nutrient levels. Geographically referenced data can be displayed in the GIS,adding a visual perspective for interpretation. In addition to data storage and display, the GIS can be used to evaluate present and alternative management by combining and manipulating data layers to produce an analysis of management scenarios.

Quantifying on Farm Variability

Every farm presents a unique management puzzle. Not all the tools described above will help determine the causes of variability in a field, and it would be cost-prohibitive to implement all of them immediately. An incremental approach is a wiser strategy, using one or two of the tools at a time and carefully evaluating the results.

Soil Variation

Soil variation is a spatial variable. Water-holding capacity or organic matter variation, along with topography, provides even a more interesting view of a field in which a producer places inputs or disturbs the soil. Other variables could be layered within this field to create a series of interacting elements. The central question is how to quantify soil variation. Collection and analysis of the samples only provides one portion of the base layer of information. Individual samples represent points; to be of value, they must be interpolated. There are as many interpolation schemes as there are sampling schemes. These schemes include central tendency, proximal, inverse distance methods, splines, and geostatistical. None of these methods or schemes are described herein, but all have been used to determine variability across a field. Topographic variation within fields can be collected from topographic maps, but the resolution on these maps is often insufficient to provide the necessary detail about variations within fields. Topographic maps can be generated from differential or kinematic geographic positioning systems. The role of topographic variations on water use, plant growth, soil processes, yield, surface runoff, and groundwater hydrology has not been quantified for agricultural fields.

Variability of Soil Water Content

It is well established fact that soil water content in a field varies over time and location and this temporal and spatial variability in soil water content patterns may have profound implications for Precision Farming in general, and water management in particular. Knowledge of the underlying stable soil water distribution could provide a useful basis for precision water management and lead to savings in energy, water, equipment cost, labor, and improved production efficiency.

Opportunities and Challenges

Precision Agriculture can have a positive impact on environmental quality. The opportunity exists to show producers how changing production practices will not place crops at risk and produce positive economic and environmental benefits. Conducting experiments on precision agriculture will require field or farmscale studies and perhaps watershed-scale adoption of new management practices.

Completing this type of study will require:

1. Appropriate questions that can be addressed at the field scale.
2. Methods for measuring environmental endpoints that will demonstrate the efficacy of management practices.
3. Commitment to multiple years of study to overcome meteorological variation.
4. Adequate monitoring equipment for crop production, soil properties, and environmental quality in order to understand the changes occurring due to the management practices.
5. Use of comparison fields or farms in which no changes are made to provide a validation of the improved practices.
6. Cooperation of producers to implement the practices with minor modifications across years so that variations can be isolated to the management practice and not producer influence.
7. Data base structure that includes geographic information layers and accurate global positioning system equipment to position any treatments in the same area across years.
8. Funding sources that will allow for long-term studies across large areas.
9. Interdisciplinary teams that will address the critical problems in experimental design,implementation, and evaluation of results.

Precision Farming within the Fruits & Vegetables and Viticulture Sectors

In fruit and vegetable farming the recent rapid adoption of machine vision methods allows growers to grade products and to monitor food quality and safety, with automation systems recording parameters related to product quality. These include colour, size, shape, external defects, sugar content, acidity, and other internal qualities. Additionally, tracking of field operations such as chemicals sprayed and use of fertilizers can be possible to provide complete fruit and vegetable processing methods. This information can be disclosed to consumers for risk management and for food traceability as well as to producers for precision agriculture to get higher quality and larger yields with optimized inputs. In recent years several new approaches were developed that take into account the actual size of the tree, the condition of the crop, but also the environmental conditions. The development and adoption of PA technologies and methodologies in viticulture (termed Precision Viticulture, PV) is more recent than in arable land. However, driven by the high value of the crop and the importance of quality, several research projects already exist in wine production areas of the world . Grape quality and yield maps are of great importance during harvest to avoid mixing grapes of different potential wine qualities. The parcels with greatest opportunities for PV are those which reveal a high degree of yield variation. A high degree of variation will mean higher VRA of inputs and, therefore, greater economic and environmental benefit in comparison with uniform management (Hakkim *et al.*2016).

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