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Remote sensing (RS) and geographical indication system (GIS) techniques in precision agriculture

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Abstract
Agriculture provides for the most basic needs of humankind: food and fiber. Precision agriculture is based on information technology, which enables the producer to collect information and data for better decision making. Precision agriculture is an emerging farm management strategy that is changing the way people farm. Precision farming (PF) refers to the use of geographical information to determine field variability, ensure optimal use of inputs and maximize the output from a farm (yield). Large tracts of land usually have spatial variations of soils types, moisture content, nutrient availability and so on. Therefore, with the use of remote sensing (RS), geographical information systems (GIS) and global positioning systems (GPS), farmers can more precisely determine what inputs to put exactly where and in what quantities. This information helps farmers to effectively use expensive resources such as fertilizers, pesticides and herbicides, and more efficiently use water resources.

Keywords: agriculture, precision farming, GIS and RS

Introduction
Precision farming is one of the most scientific and modern approaches to sustainable agriculture that has gained momentum in 21st century. Precision farming aims to improve crop performance and environmental quality (Ray, 2010) [12]. It is said, "Precision agriculture is a phrase that captures the imagination of many concerned with the production of food, feed, and fiber". The concept of precision agriculture offers the promise of increasing productivity while decreasing production cost and minimizing environmental impacts. Precision agriculture conjures up images of farmers overcoming the elements with computerized machinery that is precisely controlled via satellites and local sensors and using planning software that accurately predicts crop development. This image has been called the future of agriculture. (Elham *et al.* 2015) [5]. Precision Farming (PF), also called Precision Agriculture (PA) or site specific crop management (SSCM) is an integrated information- and production-based farming system that is designed to increase long term, site specific and whole farm production efficiency, productivity and profitability while minimizing unintended impacts on wildlife and the environment" (Earl *et al*., 1996) [4].
It is clear that precision farming has several advantages, but it can make farm planning and management both easier and more complex. It does not happen as soon as a farmer purchases a GPS unit or a yield monitor. It occurs over time as the farmer increases his level of knowledge regarding precision farming technologies and realizes that PF is an integrative approach to manage the whole farm and not only increase yields. What is perhaps the most important for the success of precision farming, at least initially, is the increased knowledge that a farmer needs of his natural resources in the field. This includes a better understanding of soil types, hydrology, microclimates and aerial photography. A farmer should identify the variance of fact or within the fields that affect crop yield before a yield map is acquired (Dra. Veronica Andreo 2013) [3].
The PA database generally includes (Venkataratnam, 2001) [13]:
- Crop information such as growth stage, health, nutrient requirement.
- Soil physical and chemical properties, depth, texture, nutrient status, salinity and toxicity, soil temperature, productivity potential.
- Microclimatic data (seasonal and daily) such as canopy temperature, wind direction and speed, humidity.
- Surface and sub surface drainage conditions, Irrigation facilities, water availability and planning of other inputs.

Geographical information system (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 (IDMAS16) (Mandal, 2000) [8]. A *geographical information system* (GIS) consists of a hardware-software database system used to capture, store, retrieve, manipulate, analyze, and display, in map like form, spatially referenced geographical information. In the simplest terms, GIS is the merging of cartography, statistical analysis, and data base technology. GIS maps are interactive. On the computer screen, map users can scan a GIS map in any direction, zoom in or out, and change the nature of the information contained in the map. Balancing the inputs and outputs on a farm is fundamental to its success and profitability. The ability of GIS to analyze and visualize agricultural environments and workflows has proved to be very beneficial to those involved in the farming industry (Orellana *et al*., 2006) [10].

GIS has two different roles in precision farming vehicles, First, a combination of GIS and simulation models is highly relevant for precision farming. There are many simulation models for different purpose like the flow of water, crop growth, soil erosion, nutrient and pesticide leaching. GIS helps in integrating geographical data on various aspects such as soil, crop, weather and field history along with simulation models. Another aspect of GIS support to precision agriculture is the engineering component, in which the research findings are translated into operational systems for use at farm level. GIS can support this engineering activity by providing a good platform for storage of base data, simple modelling, presentation of results, development of a user interface, and, in combination with a GPS, controlling the navigation of farm. On the basis of GIS, a decision support system can be developed for operationalisation of precision farming at farm level (Bregt, 1997) [2].

Yield monitors are crop yield measuring devices installed on harvesting equipment. The yield data from the monitor is recorded and stored at regular intervals (of time or distance) along with positional data received from the GPS unit. They also track other data such as distance and bushels per load, number of loads and fields. Using GIS software it is possible to produce yield maps.

Several tools to quantitatively assess spatial relationships within and between layers of environmental information have been developed in the last years. These tools allow to quantitatively establish if a certain variable has some sort of spatial pattern or structure, or if it can be related to other (s) and in that way explain and/or predict the productive and quality behavior of a crop. Undoubtedly, the mere graphic representation of data has important implications in our capacity to understand or visualize probable associations between, for example, environmental variables and yield. However, we are neither able to see if those associations are meaningful, nor if associations or patterns are obscured by different sources of error or stochasticity. Therefore, here is where the statistical analysis play their most important role, allowing to quantify and numerically characterize the spatial associations present in the field.

Interpolation

To represent the variables of interest we have to fill the spaces without information with estimated or interpolated data. For the interpolation to be plausible, data of the variable of interest must have a spatial structure, i.e.: places that are closer should have more similar values than those that are far away in geographic space. This is what is termed as spatial autocorrelation. Only if this correlation exists, the interpolation is possible. There are several indexes to establish if a variable shows spatial autocorrelation. The most used are “G” (Geary index) and “I” (Moran index). Once it has been established that there is indeed autocorrelation among values of the variable under study, the next step is to model it through an interpolation technique in order to get a surface map of the variable of interest.

Geo-statistics

All of the above described interpolation methods do not assume any parametric distribution for data. There is another technique, however, that assumes a continuous and normal distribution of values of a variable in the geographic space of a field. This technique is called *Geo-statistics*. Mapping of the variables sampled using geo-statistical methods and a reference grid (raster map or surface map), is a recommendable measure (Plant, 2001) [11].

Spatial Econometry

The generalized spread of GIS has generated the need for a methodology that allows to manage spatial models and autocorrelation. Anselin (2001) [1] has defined Spatial Econometry as the collection of techniques that addresses the peculiarities caused by space in statistical modeling. This technique differs from geo-statistic in its basic principles. Geo-statistics assumes that spatial variationis continuous while spatial econometry assumes that the covariance is a result of the interaction among discrete objects. This premise requires the specification of a spatial stochastic process represented by a matrix of spatial weights (Anselin, 2001) [1].

GIS Software currently used in Precision Farming

Aside from the widely known proprietary GIS that has developed special plug-ins or modules for PF applications (ArcGIS, MapInfo, etc.), there is a growing market of especially designed GIS for PF. The most used of these latter are Farm works (http://www.farmworks.com/), SST Toolbox software (http://www.sstsoftware.com/), geoagro GIS (http://geoagro.com/en/content/geoagro-gis), Map Shots (http://www.mapshots.com/), etc. Some of them also have on-line access and mobile and tablet applications. Some free and open source software with general and specific GIS applications for PF are also available and used mainly in the academic field, such as: GeoDa (which also includes geostatistical analysis tools), QGIS, GRASS GIS and R.

Remote sensing technology

Precision farming needs information about mean characteristics of small, relatively homogeneous management zones. These mean characteristics may be obtained from soil tests for nutrient availability, yield monitors for crop yield, soil samples for organic matter content, information in soil maps, or ground conductivity meters for soil moisture. Generally, the fields are manually sampled along a regular grid and the analysed results of the samples are interpolated using geostatistical techniques. Geostatistical modelling of soil, water and crop variability requires that large number of samples at close intervals are collected throughout the agricultural landscape. Such samplings are costly and time consuming. Various workers have shown the advantages of using remote sensing technology to obtain spatially and temporally variable information for precision farming. Remote sensing imagery for PF can be obtained either through satellite-based sensors or CIR video digital cameras on board small aircraft.

Remote Sensing (RS) is the science of obtaining and interpreting information from a distance, using sensors that are not in physical contact with the object being observed (Jensen, 1996) [6]. The science of remote sensing includes aerial, satellite and spacecraft observations of the surfaces and atmospheres of the planets in our solar system, while the Earth is noticeably the most frequent target of study. RS is usually restricted to methods that detect and measure electromagnetic energy including visible and non-visible radiation that interact with surface materials and the atmosphere (Moran *et al*. 1997) [9].

RS and GIS technologies have been of great use to planners in planning for efficient use of natural resources at national, state and district levels. Application of these technologies in the management of natural resources are increasing rapidly due to great strides made in space-borne RS satellites in terms of spatial, temporal, spectral and radiometric resolutions (Venkataratnam, 2001) [13].

Remote sensing has several unique advantages (Jensen, 1996) [7]:

- RS technology is well-known as a non destructive method to collect information about earth features.
- RS data may be obtained systematically over very large geographical areas rather than just single point observations.
- RS data can reveal information about places that are inaccessible to human exploration
- The systematic (raster) data collection in RS can remove sampling bias.
- RS can provide fundamental biophysical information that can be used in other sciences
- RS is independent from the data produced elsewhere, in comparison with the other mapping sciences such as cartography or GIS.

Conclusion

Precision farming is essential for serving dual purpose of enhancing productivity and reducing ecological degradation. With increasing population pressure throughout the world and the need for increased agricultural production, there is a definite need for improved management of the world's agricultural resources. To make this happen, it is first necessary to obtain reliable data on not only the types of resources, but also the quality, quantity and location of these resources. Satellite-or aerial-based RS technologies will become important tools in improving the present system(s) of acquiring and generating agricultural and natural resource data.

Fast processing by GIS systems and increasing the accuracy of satellite images data with the help of data collected from location experimental data provide appropriate solutions. Pest and disaster control, crop estimation and evaluating the status of plant growth are provided at a very wide level by satellite data and reduce the adverse effects of plans on the environment and smooth the ways to achieve sustainable, environmental, and dynamic agriculture development.

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