GENERAL CONSIDERATIONS ABOUT PRECISION AGRICULTURE

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Introduction

The homogeneous application of production factors takes to its over or sub - application, leading the first to the environmental pollution and the second to the decrease of its efficiency; only the right amount allows to maximize its action, minimizing the environmental impact.

Can have the inside plot areas different soils types, with different potential production, the application of factors medium doses to the all plot leads to underestimate the needs of part of the soils and overestimate other ones, why the agronomical entity should not be the plot, but the sub - units inside it, that has homogenous characteristics.

The use of the new agriculture technologies has been allowing to quantify the variability inside the plots regarding the characteristics of the soil (physical, mechanics and chemistries characteristics), of the cultivated plants (state development, diseases, production, quality, etc.), of the weeds and diseases and, seldom, the climate, what has leading to the improvement of the efficiency of factors application.

The spread of the resulting advantages of these means, as well as the computer science in the management of agricultural enterprises, has been contributing to its acceptance by the farmers and society.

1 - The traditional agriculture vs the precision agriculture.

The traditional agriculture is an activity that tends to disappear, because today, the highly competitive technology, aren't compatible with the "standard" use of techniques, established in function of the plot reference conditions. Although these techniques have minimum risks, they don't have in consideration the differences inside the plot areas that are fundamental to specify the right techniques for each situation and for the modulated management culture activity.

So, to face the new agriculture challenges, it is fundamental the use of new technologies that include GPS - Global Positioning Systems, to makes possible the determination of the equipments position and the all information collected in the plots, sensors, for information determination and the GIS - Geographical Information Systems, for analysing the spatial variation of all information collected. Besides this, it is necessary to have equipments that permit a modulated factors application, without any operator intervention, to face the spatial variation of inside plot information. The agriculture, when use these techniques, is called precision agriculture (PA), production factors located management or variable production factors application.

The technology, when makes possible the execution of right interventions, in the right time and right place, and have in consideration the characteristics of the environment and the identification of variability among and inside of the plots, allow to adjust the cultural techniques to those conditions.

Table 1 - Comparison between the technology used in the traditional agriculture and the precision one

Decision criterion	Actual technology	Future technologies
Soil work: Technical choose in function of the soil type and crop rotation	Couple tractor - equipment right choose and rational actuations	Automatic equipments regulation, in function of soil conditions and culture type
Sowing: Variety and doses choose in function of different situations	Confirmation of distributed dose, use of certified seed, maintenance of the sowing machine	Dose modulation during the sowing, according to the inside plot variability
Fertilization: Doses choose in function of the production objectives; use of nitrogen balance	Confirmation of the right width work, use of fertilizers with appropriate physical characteristics, confirmation of debit machine	Inside plots doses modulation according to the characteristics of the soil (type, depth), of the identified places and the culture development.
Cultures protection: Doses and volumes modulation; reduction of drift losses; risks estimation using forecast models	Appropriate parameters choose (speed, pressure), periodic nose control, regulation before each application, sprayer adaptation to the culture	Selective products application; optical sensor for leafs identification, etc.
Agriculture	Traditional agriculture	Precision agriculture

As we can verify in table 1 the tools used in precision agriculture implicates great changes relatively to the traditional systems because, besides the necessary modifications of the cultural practices, it is fundamental to update the educational system and the rural world formation. It is important to have informatics knowledge for cultures and environment data acquisition and its analyses and management; this kind of information must be accomplish with experimental trials done close to the farmers.
Considering the costs of the necessary technology used in precision agriculture, only with large areas it can be justified although some tools that can be used in small ones. The use of this technology should have in consideration some aspects, such as:
- the variability degree of potential production;
- the percentage of production variation that can be controlled by the farmers;
- the area that will be used in precision agriculture;
- the cost of this technology.

The farmer knowledge about the areas with variability is important, but insufficient, because it is necessary to calculate the profitable critical productions to justify its cultivation or to improve its potential.

2 - Precision agriculture; general aspects.
The precision agriculture, not being a recent idea, has been coming to be accept with the emergence of new technologies, especially GPS, because it is, basically, a tool that allows the space and temporary management variability and improve the understanding forms and control of environmental factors.
The collected information, from production, soil maps, satellites images, etc., and from management and decision (fertilization, drainage, pulverization, etc.), can be used for different purposes, what helps its implementation.

2.1 - Precision agriculture objectives
The main objectives of precision agriculture are:
- the production maximization, which implicates that the homogenous fertilization models based in soil uniformity characteristics don't be used. The factors application must have in consideration the potential of different areas inside the plots;
- the "inputs" minimization, for which it is necessary to know witch are the factors that limit the plants growth, to calculate the necessary amount of it to the different places according its potential production;
- the maximization of economical advantages, to obtain the same production, with less inputs;
- the minimization of the environmental impact, for witch we can't made uniform treatments that lead to pesticides application doses bigger than the necessary, which pollute the environment.

In conclusion we can say that the purpose of precision agriculture is the management of the different plots parts based in information about the needs of the plants and environmental characteristics, to increase the farmers' incomes, the competitiveness of the agricultural activity and the environmental protection.

2.2 - Different ways of doing precision agriculture.
The precision agriculture can use technologies based in preconization (production) maps or sing real time technology.
The first of these methodologies includes samples field collection and its analysis, being the georeferenciated data used for maps elaboration, which are used by the controlled application equipments; during the sample collecting and equipments use a GPS identify its localisation.
The second methodology uses sensor that measure, in real time, the value of several parameters, especially related with soil and plants, which are immediately used for the equipments regulation, in a way to apply the amount of production factor necessary to a specific situation; this methodology doesn't need the use of any DGPS.

2.2.1 - Applications based in georeferenciated characteristics maps
The use of maps with georeferenciated characteristics is the most frequent situation of doing precision agriculture, because the easiness of laboratorial characteristics determination, namely that ones related with soil. The inexistence of sensor to determine some important environmental characteristics justifies, equally, its largest use.

The detailed maps, with the respective characteristics are, at present, with specific software which allow interpolations among data to smooth its variations.
The main maps advantages are the possibility of planning the activities in a medium - long term and the detailed analysis of each situation. Its use is especially indicated for collecting data that don't present great variations among the several seasons, like the organic matter, soil texture etc. Some parameters, as the soil fertility, especially the phosphorus and potassium, that can present important variations during the vegetative cycle, should be determined every 2 - 3 years but, for the nitrogen, the determinations should be done every year.
The maps use, generated in computer, involve its conversion for a recognizable format to the application systems, so these can calculate the amount of income factor to apply in each moment; the presence of a DGPS is necessary to relate the equipment and input field location.
Using the modulation systems that permit the equipment speed determination, we can, through the previous map analysis, to synchronize the amount of input to apply with the equipment position in the field.
In some equipment, namely the sprayers with booms, it is necessary that the debit of each nose can be controlled individually because, otherwise, the distribution would be uniform in the whole work width; the use of a system of noses individual control it is only possible with high resolution maps.
So, we can say that the main advantage of using preconization maps is the possibility of previously knowing the amount of products to apply in each homogenous inside plot area during a operation, in other words, to work in a similar way used when a constant volume is applied.

2.2.2 - Applications based on sensor determinations
The technologies that allow the determination, in real time, of different environmental characteristics and the control of inputs systems application, has been coming gradually to impose. The electrodes use for determination of the soil type, its organic matter level, cationic capacity exchange, humidity, amount of nitrates, etc., during the cultural operation work, are possible without the maps preconization; if we want to get the records of the amounts of input applied for later use, it is necessary to create the maps with the georeferenciated inputs.
One of the main problems related to the use of this methodology is concerned with the difficulty in synchronizing the measurements of the sensors with the amounts of factor to apply, why it is necessary to put the sensor in the front part of the tractors, for the controlled application systems "have time" to be regulate, before it pass the place in which the sensor made the measurement.
Of the several types of sensor the more used are that ones that permit the measurement of soil organic mater, that use fotodiodes surrounded by LED's that emit light against the soil, which is reflected and measured by the fotodiodes; the amount of reflected light depends on the amount of soil organic matter and its humidity.
Besides this type of sensors are being in development other ones for nitrates determination, pH, potassium, phosphorus, soil texture, etc., that can be mounted in the agricultural equipments, aircrafts or satellites. The analysis of resulting images of aerial pictures to "observe" the inside variation characteristics in a plot, it is one of the most promising ways of obtaining data for AP use.
So the obtained information got from preconization maps or directly from sensor, together with the agricultural ones, makes possible the adaptation of the production system to the variability of the plot characteristics, in other words, it allows to adjust the equipments regulations to the specific needs of each point plot.
The use of the new technologies is equally important in the behaviour determination of the cultures in different situations, because it makes possible to get some indicators and define methods to improve its management and its modulation.

2.3 - Different phases of precision agriculture
The cultural operations in precision agriculture, presents four different phases, that can be presented as:
- collecting information;
- analysing information;
- take decision;
- execution of cultural operations.

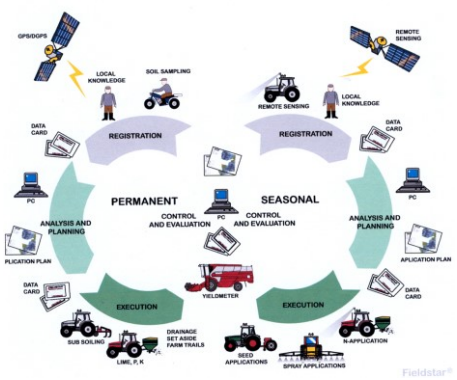

Figure 1 - The different phases of precision agriculture

2.3.1 - Collecting information

Collect information consists in data acquisition that determine put in evidence the plot variability; this information can be obtained directly from the field as, for example, the culture revenue, infestation degree, etc., or through meteorological stations, satellites, soils analysis laboratories, etc.

This phase begins, usually, in the crop collecting, because the use of production maps, allows the identification of critical areas being, however, necessary to have available information concerned about soil characteristics, meteorological conditions, etc., to get decisions about the amount of factors to use. The creation of new maps during the vegetative cycle plants is important to estimate the temporal variability, to identified the inside plot areas that present the same response, which allow to reduce the number of measurements that must be done.

This phase is, nowadays, since we have the right tools, a stage technically simple, but the volume of data implicates that they must be easy to obtain without lost of precision; at the present the limitation to collects data is, mainly, economical.

The information must include, in the beginning, the data that the farmers have about the plot, that are fundamental for the characterization and valorization of plot heterogeneity and, in a second phase, its cartography with the necessary parameters to the execution of cultural operation.

The data related to the environmental conditions must allow the quantification of agronomical variables, in other words, the variables that characterize the climate, soil and plant, which must be associated with the coordinates of the place where they were measured.

The cartography of the inside parts of a plot, must be based on space and temporary indicators, being the first ones permanent or related to the actual culture development and, the seconds ones, related with the cultures heterogeneity in a given moment, or during its vegetative cycle.

2.3.1.1 - Permanent space indicators

The permanent indicators characterize the main environmental variables, especially those ones related with soil, namely, its depth, type, topography, organic matter level, etc. The permanent nature of this information allow its measurement to be executed once and used, as a map soil or a map production, for the rationalization of the next cultural operations.

2.3.1.2 - Space indicators of culture state

The space indicators of the cultures state are obtained by observation or collecting samples and have, due to the frequency of its measurement and number, a limited use. For example, the number of measurements to do in plants and soil for the nitrogen manure, make this a very costly operation, why it has little used.

2.3.1.3 - Temporary indicators of cultures heterogeneity.

The temporary indicators of cultures heterogeneity indicate the changes that are verified in these as result, for example, of the emergence of diseases, "stress" in water or in nitrogen, damages resulting from frosts, etc., or for the evaluation of the culture conditions in different phases.

2.3.1.4 - Temporary indicators of the cultures evolution.

The temporary indicators of cultures evolution allow to follow, in continuous, its cycle, to foresee its development and to determine its productivity.

Considering the volume of possible information that can be collected, it is usually that the file data size, doesn't be a problem, but the different origin of this information, can make necessary to ignore some parameters or reduce the number of measurements. Take in account several elementary units inside a plot the amount of collected data increases proportionally to the number of those units.

Another aspect that has been a problem is what is related with the information use in different equipments, because that one has several origins and the programs for its analysis and for equipments modulation are very different.

To simplify the use of different income information it is important to transfer it for personal computers that make its analysis sending it, after have been analysed, for the equipments.

The solution to turn compatible the information among the several equipments must be based in the normalization devices, in a way similar to other situations as, for example, the PTO. The technical group "Electronic in Agriculture" of ISO - International Standard Organisation, have been studyng norms to overcome the compatibility lack among equipments.

2.3.2 - Information analysis

The information used in precision agriculture has to be georreferenciated, so the measured parameters (production, pH, etc.) should be associated to a precise point, that it obtained by a DGPS - System of Differential Global Positioning. The management and analysis of this information is done using a GIS - Geographical Information System, that is a program that establish the relationship between those parameters and a database with all information available for that situation. The elements used can be points, lines or surfaces, being the informatics system responsible for the organization, management and lineal or crossed data analysis, to present the information geographically located.

The SIG programs used in precision agriculture, that are usually associated with the sensors, change the different types of data in production maps, soil characterization maps, etc., whose files are saved in a informatics support, that will be used by the board computer or personal one. These maps, together with the information introduced by the operator, permit to create preconization maps, that will be used in the equipments informatics systems turning possible the modulated application factors.

Relatively to the programs SIG operation, the elements space identification is done by the attribution of coordinates to locate its position. So, for example, the plot drawing can be made using a grill in which are identified the points ("raster" representation), or drawing its limits, using lines, to form a polygon (vectorial represenation). In this case to draw, for example, a square, it is enough to know the coordinates of the four corners.

The "raster" representation, using a grill in which each elementary unit (pixel) has a value, translating the stored information the related area, permit an easy and low cost space analysis, but turns the files to big and generates graphic representations of low quality; the aerial picture and the digitalized images are examples of this kind of representation.

The vectorial representation, representing the elements in different layers, as drawings done with geometric shapes like points, lines, polygons, etc., allows, when are overlay, to represent the area to be analysed. Considering the example of a plot, the points will represent wells, houses, etc., the lines the rivers, roads, etc., and the surfaces the cultures, being each one of these elements, associate to their attributes.

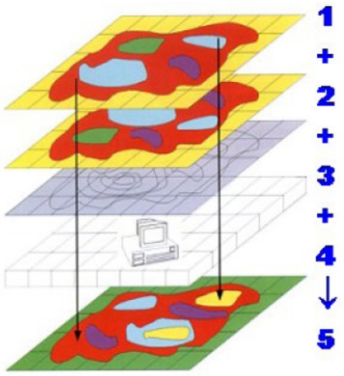

Figure 2 - Vectorial representation of a plot.
1- Production map 2- Fertility map 3- Soil and topography map 4- System to help make decisions 5- Application map

In this representation SIG consider each information types, after have been converted in a map (production map, pH, etc.), as being a layer that, when overlapped with other maps (other information type), permit to put in evidence the relationships or lacks of it, the different aspects, to take the decisions about the amount of income factors to apply at the different places.
The vectorial representation allows to obtain good quality graphic representations, but with a more difficult space analysis, with small files, and it has a more expensive and demanding technology in time.
The choice for one or another of these representation isn't very important because, at the present, SIG integrate the raster and vectorial representation, although only one graphic representation it is possible. These programs can analyze important volume data and, inclusively, it can work with data with different space and temporary resolutions; for example, the data production can be done every 10 m and the soil analyses every 100 m, the production can be measured once a year but the pants weeds several times, etc.

These informatics cartography and space analysis programs are used today in all activities that is need to manage georeferrenciated information, relatively to the inside variation plot.

2.3.3 - Taking a decision
The taking a decision to face the variability of the inside plot characteristics needs a knowledge of the variation origin and its impact in a cultural operation (operational decision) and in the exploration (economical and environmental impact). The interpretation of maps variability, especially the culture production, is generally quite complex, because can exist several factors that influence the results (production).
The collected data, after having been structured and converted in plot maps, are used by SIG that, together with the appropriate agronomical software, help the results interpretation with the purpose of defining the equipments operation conditions.
The agronomical software to help taking the decisions related with the cultures, were initially developed considering the plots as to be uniform, why it has to be adapted and validated for the new situations. When inside plot variability is not considered just a measurement of each factor is necessary but, for the other situations, the model should consider all the heterogeneous areas inside the plot.
The agronomical models should use parameters easy to measure in a quantitative and qualitative way, and that translate the characteristics more or less stable in time as, for example, the physical and mechanical soil parameters, or that one that change in a short time like, for example, the soil water. The first data can be got with a systematic study of the different inside plot areas, that permit to elaborate the preconization maps but, the seconds ones, must be determined by sensors and will be used to elaborate preconization maps; this last situation will allow a previous program actuation, or real time actuation, using sensors, not being necessary the georeferentiation systems. For the first situation we have, for example, the use of fertilization maps and, for a second one, the weed detection and its control.
The use of the two solutions at same time, maps preconization and real time actuation, is more and more used because they allow, for example, to correct the maps information in real time, to take in account the development state of a culture or some problems that have happened later to the maps creation like irregularity germination.

Taking agronomical decisions is a farmer responsibility task although it is advisable some technical support, because the tools used to take decisions aren't easy and some models aren't adapt to the modular plot production.
The production data, together with data georeferenciated information got with external sensors must be analyzed with software that makes available the information that will support taking decisions that will be used for the equipments regulation. This information together with the DGPS data, permits the factors differentiated application. The data should include the agronomical information for the situation, relative to soil, climate and plant.

2.4 - Cultural operations execution

The cultural operations execution has the purpose to implement in the land the decisions taken after the data analyse, so the equipments regulations permit the factors modulation application, according the variability of the inside plot.
The regular equipment operation, that is a builder's responsibility, is practically settled for all the situations, not happening the same with the information compatibility for which are used different programs from several marks. The cultural operation execution can be done in real time, in which the right sensors actuate directly in the equipment during the work or, later with the use of maps preconization. In this situation, that is the most frequent, the maps accuracy depends from the information collected, from the statistical data analyses and from the quality of the agronomical models used.

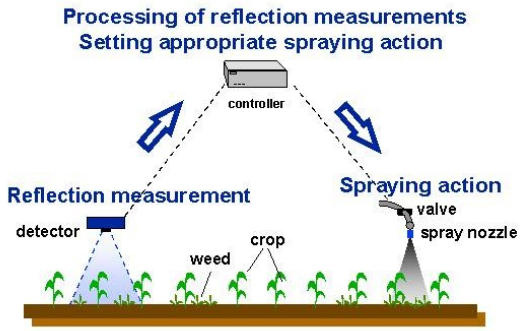

Figure 3 - Optical weeds detection for herbicides application in real time.

These methods can be used in a same culture as, for example, in the nitrogen spread, in which the first applications can be done based in the cartography information and the remaining one according the data measured by the sensors relative to the real needs of the culture during the application.

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