Precision agriculture

New tools to improve technology management in agricultural enterprises

Evandro Chartuni[1], Francisco de Assis de Carvalho[2], Daniel Marçal[2] and Emilio Ruz[3]

KEY WORDS

Spatial and temporal variability
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Remote sensing
Variable rate technologies
Geo-statistics

The modernization of agricultural practices is emerging as a new challenge given the need to ensure the environmental and economic sustainability of production. The response on the part of the research, innovation and extension sectors linked to agriculture has been to generate technologies that will make it possible to quantify the variability that occurs naturally in fields, so that inputs can be applied in the right amount, at the right place and at the right time. Further, the effective use of new agricultural machinery and equipment to till the land and plant, grow, harvest and process agricultural products has resulted in significant increases in food production. As a result, the 1990s saw the adoption of a new approach to agricultural land management that is based on the identification and interpretation of in-field spatial variability, known as precision agriculture.

The Cooperative Program for the Development of Agrifood and Agroindustrial Technology in the Southern Cone (PROCISUR) and IICA have been working together for years, promoting the adoption of new technological discoveries and advances in the region. For some six years, since people first began talking about this topic, PROCISUR and IICA have been supporting cooperation actions aimed at disseminating and developing precision agriculture technologies that are suited to conditions in the countries of the region. Experts from more advanced countries have contributed different visions and experiences related to this technology, which is relatively new in the region. This first stage culminated with the publication of the book *"Agricultura de Precision: Integrando conocimientos para una agricultura moderna y sustentable,"* which was used as the basis for preparing the present document, the objective of which is to present the basic concepts of precision agriculture and information related to the development and adoption of this technology around the world.

1 Brazilian Agricultural Research Corporation (EMBRAPA), Brazil, evandro.mantovani@embrapa.br
2 UFV, Brazil, facpinto@ufv.br, queiroz@ufv.br
3 PROCISUR-IICA, emilio.ruz@iica.int

All of this led to precision agriculture being defined as a number of techniques aimed at optimizing the use of agricultural inputs based on the quantification of in-field spatial and temporal variability.

Application of the concept of precision agriculture

In the 1970's, a new type of agriculture began to take shape thanks to studies on the automation of agricultural machinery. When global positioning systems became available for civilian use in the late 1980s and early 1990s, it was possible to develop intelligent equipment that allows for the localized management of cultural practices, with more efficient application of inputs. This reduced the environmental impact and, as a result, the cost of producing food decreased.

All of this led to precision agriculture being defined as a number of techniques aimed at optimizing the use of agricultural inputs (seeds, agricultural chemicals and corrective treatments) based on the quantification of in-field spatial and temporal variability.

The technology does not consist only of measuring the existing variability in a field, but also of adopting management practices based on that variability. According to Robert (1999), the practice of identifying in-field variability or the factors that affect production in agricultural ecosystems is not new. What is different is the possibility of identifying, quantifying and mapping that variability. Furthermore, it is possible to geo-reference fields and apply inputs in different amounts and only when and where needed.

Precision agriculture calls for a more precise application of inputs based on the localized management of variations in yield in a given area. In contrast, in traditional agriculture, inputs are applied on the basis of average values.

The use of precision agriculture technologies can be divided into three stages (**Figure 1**):

1. Data collection
2. Processing and interpretation of information
3. Application of inputs

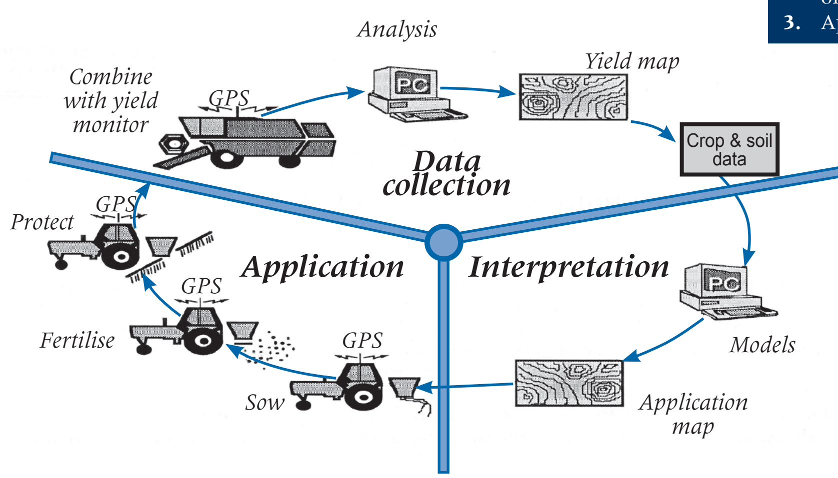

Fig. 1. *The three stages of precision agriculture*

Source: *AGCO 2005*

The application of precision agriculture technologies can begin, for example, at harvest time, with a yield map or the identification of soil variability represented on yield and/or soil fertility maps, respectively (**Figure 2**).

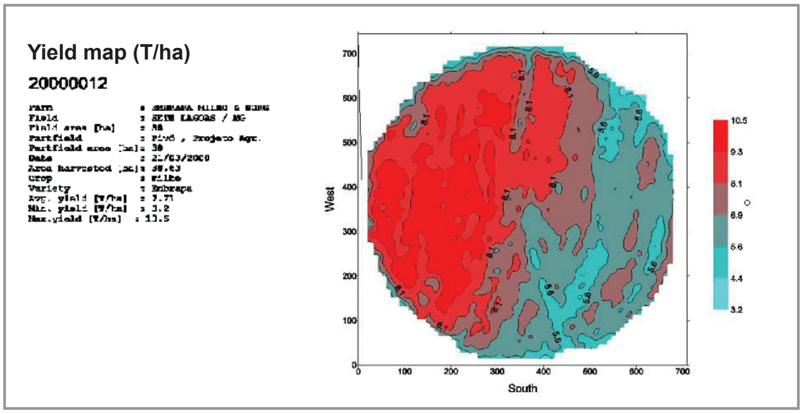

Fig. 2. *Corn yield map, 2002 planting season*

Source: *EMBRAPA, Corn and Sorghum Experimental Station, Sete Lagoas, MG, Brazil*

The study of soil and crop variability makes it possible to determine trends in yield in a single area over time, taking into account variations in climate and changes in soil. When the yield and/or fertility of a field do not vary, there may be little incentive for adopting precision agriculture techniques in order to increase production. This is not the case, however, in terms of managing agricultural enterprises.

When production levels vary considerably, it may be beneficial to adopt these techniques because they reduce the distortions normally found in fields.

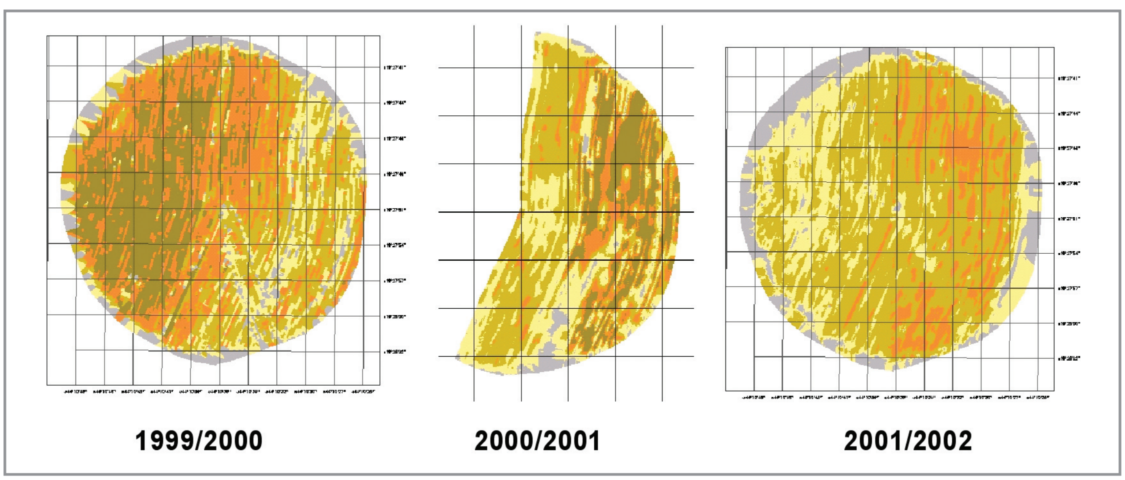

Fig. 3. *Temporal variability of corn yield, 2000, 2001 and 2002 harvests/seasons.*

Source: *EMBRAPA, Corn and Sorghum Experimental Station, Sete Lagoas, MG, Brazil*

To understand and apply precision agriculture, it is necessary to define the following basic concepts:

- ***Spatial variability:*** differences in production in a single field, for a single season and harvest (**Figure 2**)
- ***Temporal variability:*** changes in production in a single field, in different seasons (**Figure 3**).

Localized management practices are not based solely on productivity or soil fertility maps. Decision making in precision agriculture can be based on data displayed on a map, or on information obtained as an action is carried out, using real-time sensors.

Sampling may take place in intervals of months or years, as in the case of soil correction. When a soil characteristic changes rapidly, the producer can measure the variability in real time and provide the necessary input immediately, without prior sampling. An example of this would be the application of nitrogen based on information from real-time sensors (**Figure 4**).

Precision agriculture is possible thanks to the development of five technologies:

1. Global positioning system (GPS)
2. Geographic information system (GIS)
3. Remote sensing
4. Variable rate technologies (sensors, controllers and others)
5. Analysis of geo-referenced data (geo-statistics, spatial econometrics, multi-factor analysis, cluster analysis and CART, among others)

This new information technology-based approach to agricultural production has been adopted in response to the demands of a competitive market, which include increased production and lower prices as well as techniques and systems that are more environmentally friendly.

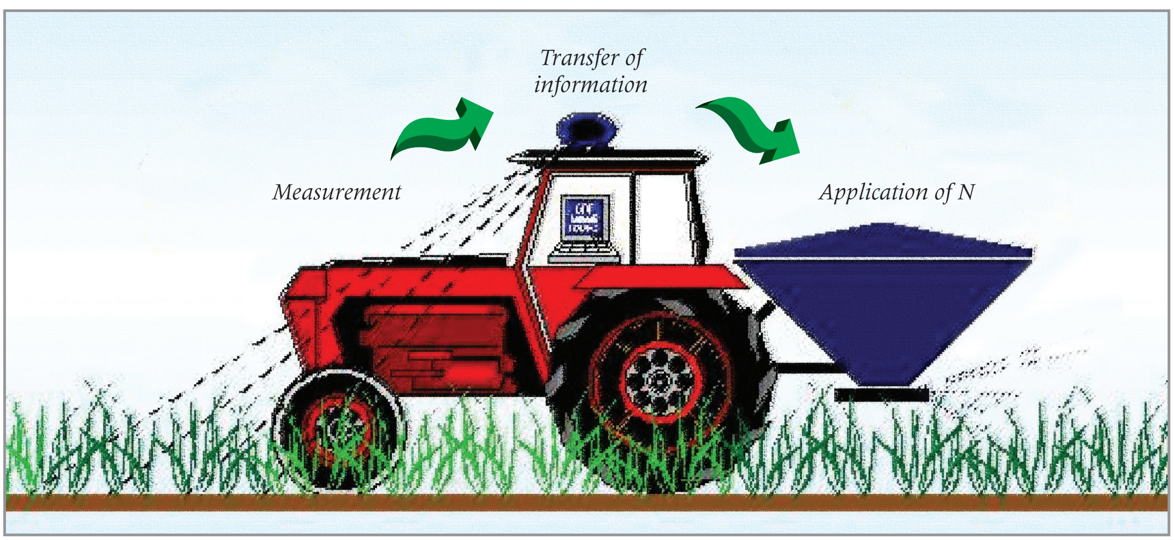

Fig. 4. *Real-time sensor for variable-rate application of nitrogen.*

Source: *Yara 2005*

Applications of precision agriculture in traditional cropping systems

In traditional production systems, fields are considered as a whole. Based on average conditions of the field, actions are undertaken to correct limiting factors. In an effort to develop production systems that are more competitive and efficient, new techniques aimed at increasing and/or maintaining crop productivity of crops and lowering production costs have been adopted. Precision agriculture is a new way of managing information on crops, based on the existence of in-field spatial and temporal variability (Saravia *et al.,* in Borém *et al.* 2000).

Cigana (2003) offers some examples of the application of precision agriculture technologies. Both increased productivity and lower costs were reported in two fields, totaling 265 hectares, in the region of Planalto Medio Gaucho, in Rio Grande del Sur, Brazil, planted in soybeans and corn. One of the fields, 132 hectares planted in corn, yielded 5,880 kg/ha, which exceeds the regional average of 4,680 kg/ha by 20%. This figure is also 13% above the average of 5,100 kg/ha obtained with other crops on the same property, Hacienda Anna, where conventional methods were applied. On the 124 hectares planted with soybeans, the yield was 2,800 kg/ha. The average for the region was approximately 2,040 kg/ha (29% less), and that of Hacienda Anna, 2,520 kg/ha (12.5% less). According to Cigana, the cost of inputs for these crops vs. the other crops grown on the property was lower. In the field planted with corn, there was a savings of 18% in the application of fertilizers, and in the 124 hectares of soybeans, 23%.

Applications in intensive agriculture: viticulture-viniculture

In terms of intensive farming, precision agriculture has been used most in viticulture-viniculture. Grape growers in the United States, Australia and, more recently, Chile have found these techniques to be helpful in managing grapevines more efficiently.

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Until recently, grape growers and winemakers did not have the tools they needed to identify the spatial variability of the vineyard and display it on a map, specifically as regards:

- Soil characteristics (depth, moisture, nutrient content, acidity, etc.).
- Plant characteristics (m^2 of leaves per m^2 of soil [or leaf area index], leaf/fruit ratio, among others).

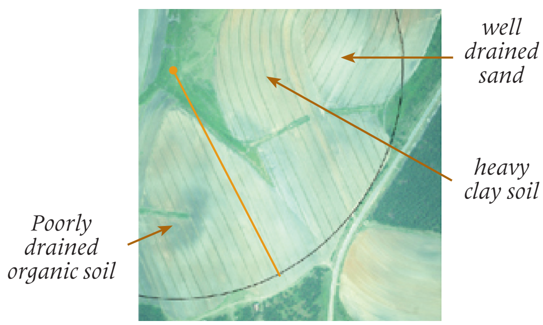
Today, precision agriculture enables grape growers to identify more precisely sub-areas for the production of high-quality, uniform grapes through the use of aerial images known as "multispectral images" obtained with special cameras and GIS technology. The images are then analyzed to produce what are known as "vegetation vigor indexes," which include the Normalized Difference Vegetation Index (NDVI). This index is used to identify obtain a variable closely associated with the quality of the grape to be processed. The indexes are displayed on "vigor graphs" for different sectors.

Applications in irrigation systems

A high degree of spatial variability in terms of soil conditions translates into the inefficient application of irrigation water, a problem generally not considered in the design of new irrigation systems (sprinkler, drip and surface irrigation). Such inefficiency leads to the loss of nitrogen fertilizer and the subsequent contamination of underground aquifers via leaching (Best and Duke 2001).

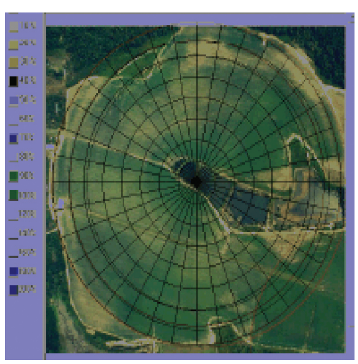
The identification of uniform areas within fields and the use of computer models will lead to improved management water and more efficient use of water and nitrogen fertilizer, which in turn will protect the underground water from contamination.

Center pivot irrigation systems are the variable rate technology most commonly used to apply water and fertilizers. These systems have become an important factor in the development of agriculture because they make maximum use of a limited resource and do not over-apply or under-apply inputs to crops.

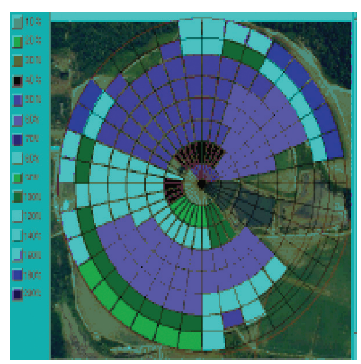


a) Lack of soil uniformity

b) A FarmScan Canlink3000 controller, used to program differentiated irrigation via center pivot systems.



c) Example of aerial view and subdivision of irrigation areas based on the variable rate application system installed.



d) Map of application of water based on crop requirements in the different parts of the area under irrigation.

Fig. 5. *Center pivot variable rated irrigation system.*

Source: *Best and Duke 2001*

Final thoughts

There is still work to be done if precision agriculture is to become a widely-accepted and fully viable solution for all subsectors of agriculture. Its adoption holds great potential for streamlining modern agricultural production systems because it:

- makes maximum use of the agricultural chemicals, fertilizers or corrective treatments applied to soils and crops;
- establishes clearly the correlation between spatial and/or temporal variability and among the factors associated with soil and crop development;
- determines the existence of nutrients, organic matter, acidity, water, texture, diseases/pests, weeds, etc.;
- reduces production costs and environmental contamination; and
- improves the quality of harvests.

Even though the topic of precision agriculture is relatively new, significant advances have been made that others can use, especially in the development of machinery and implements that allow for localized management based on maps. Every day, more advanced information technologies are appearing on the market, such as global positioning systems (GPS), geographic information systems (GIS), data acquisition and management systems, sensors and controllers, etc.

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Resumen / Resumo / Résumé

Agricultura de precisión: Nuevas herramientas para mejorar la gestión tecnológica en la empresa agropecuaria

La agricultura de precisión es un concepto agronómico de gestión de predios o terrenos agrícolas, basado en el conocimiento e interpretación de la variabilidad espacial en el campo. Para ello requiere del uso de una serie de tecnologías relacionadas con los sistemas de posicionamiento global (GPS), sensores, imágenes satelitales e imágenes aéreas junto con sistemas de información geográfica (SIG). Esta publicación permite compartir con los lectores una serie de conceptos y aplicaciones de estas tecnologías en distintos ámbitos, con el objeto de difundirlas, estimular su análisis y comprensión, presentar sus beneficios, complejidades y limitaciones para su uso.

Agricultura de precisão: novas ferramentas para aprimorar a gestão tecnológica na empresa agropecuária

Agricultura de precisão é um conceito agronômico de gestão de edificações ou terras agrícolas, baseado no conhecimento e na interpretação da variabilidade espacial no campo. Para tanto, requer o uso de uma série de tecnologias relacionadas com os sistemas de posicionamento global (GPS), sensores, imagens de satélite e imagens aéreas, juntamente com os sistemas de informação geográfica (SIG). Esta publicação apresenta aos leitores uma série de conceitos dessas tecnologias e sua aplicação em diferentes âmbitos com vistas a difundi-las e incentivar sua análise e compreensão, bem como apresentar seus benefícios, suas complexidades e as limitações para seu uso.

Agriculture de précision : nouveaux outils pour améliorer la gestion technologique dans l'entreprise agricole

L'agriculture de précision est un concept agronomique de gestion des domaines ou terrains agricoles, fondé sur la connaissance et l'interprétation de la variabilité spatiale dans la parcelle. Elle requiert l'utilisation d'une série de technologies liées aux systèmes de positionnement mondial (GPS), aux capteurs, aux images satellitaires et aux images aériennes, conjugués aux systèmes d'informations géographiques (SIG). Le présent article vise à présenter aux lecteurs une série de concepts et d'applications de ces technologies dans divers domaines, dans le but de les faire connaître, de stimuler leur analyse et leur compréhension, et de montrer leurs avantages, leurs complexités et les limites de leur utilisation.