DEVELOPMENT OF A TRAINING PROGRAM FOR ENHANCING THE USE OF ICT TOOLS IN THE IMPLEMENTATION OF PRECISION AGRICULTURE

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Training package 1

Introduction to Precision Agriculture

Tutor instructions

Authors: UPC

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1 Objectives

The objectives of the lesson are:

1) Create awareness of basic concepts of Precision Agriculture (PA)
2) Define the main benefits and costs of using PA
3) Describe main tools to achieve PA and expose current examples
4) Overview of the current legislative framework in Europe

2 Tutor instructions

This lesson should takes 1h30min. The presentation will lead the attendant to get an overview of the Precision Agriculture through recognized definition for the main stakeholders, some examples and the impact on the benefits and to environment and the current legislation framework in Europe.

2.1 What is Precision Agriculture

To create awareness of basic concepts of Precision Agriculture (PA), the first part of the lesson will be divided in 3 steps:

1) Discussion by groups on what they think PA.
2) Statement of several definitions on Precision Agriculture coming from relevant organizations and researchers of PA environment.
3) Description of the main terms that defines the PA.

2.1.1 What do you think about PA?

(Slide 4 from document *Lecture_PA_introduction.pptx*)

A small activity will be used before start to aware attendants on what could be PA. For that, attendants will be divided in small groups of 3 people to write down a definition in 25 words in 5 minutes. After that, each group will read the definition and the instructor will write on the blackboard the key words of each definition read. They should spend 15 minutes (5 minutes to create the definition and 10 minutes for the discussion).

Once the activity is finished, the words will remain on the board. In this way, during the course of the session, each time a word appears on the board, it will be indicated, thus reinforcing the intuition of the attendees and highlighting their previous knowledge.

2.1.2 Definition of Precision Agriculture

(Slide 5 to 14 from document *Lecture_PA_introduction.pptx*)

The following definition was sated by McBratney and Whelan (2001):

"Site Specific Crop Management may be defined as: Matching resource application and agronomic practices with soil attributes and crop requirements as they vary across a field."

The goal of this sentence is to define Site Specific Crop Management (SSCM) that can be understand as *variation across the field*. This is a key term PA concept.

Variability in field basically come from the soil characteristics that some time could come from unification of parcels, giving soil variability in spite of being one single parcel.

The following definition was sated by Khosla (2008):

"*Applying inputs at the Right time, the Right amount and the Right place, with the right source and at the Right manner."*

In this definition it's important to put the focus introducing the word *input* (that is the only thing it is possible to vary in field) and the word *right*, leading farmers and stakeholders to a best management practices.

An example of that is to apply pesticides at the right moment (where the product will eliminate the disease), with the right dose per hectare need, at the right place considering variation across the field, with the right calibrated sprayer following best management practices like using low drift nozzles to prevent pesticide drift.

The Precision Agriculture Laboratory from the University of Sydney suggest the following definition (US, web reference):

"Precision Agriculture (PA), in the form of Site-Specific Management (SSCM), offers a remedy to many of these concerns. The philosophy involves matching resource application and agronomic practices with soil properties and crop requirements as they vary across a site.

Collectively, these actions are referred to as the "differential" treatment of field variation as opposed to the "uniform" treatment underlying traditional management systems."

With this definition, the term of Site-Specific Management is reinforced considering not only variation across the field as well as management concept like soil properties and crop requirements. The second part of the definition, allows to point out the precision agriculture as an opposite of uniform systems like traditional management systems.

SSCM implies that the variations in the parcel have to be identified and, of course, a classification of this continuous variation has to be done.

This Precision Agriculture (PA) definition has recently been recognized by the Board of directors as the official definition of the International Society for Precision Agriculture (ISPA):

"*Precision Agriculture is a management strategy that gathers, processes and analyzes temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production."*

ACtually, this definition is the most complete since it includes all the fundamental terms of PA, which can be explained in the following way:

- *Management* of resources and inputs.
- *Gather* information from field trough sensors (on board or remote) or even measures obtained by scouting.
- *Process* information gathered with GIS (Geographical information Software).
- *Analysed* by an agronomist or farmer with PA skills.
- *Temporal, spatial and individual* in relation to the variation over the years, the variation in the plot itself as well as the variation between individuals.
- *Combined with other information* coming from field sensors or from other sources like research institutions or governmental services.
- *To support management decisions* regardless of own experience or using decision support software.
- *According to estimated variability* as Site Specific Management.
- *For improved resource efficiency*, that means minimizing wasting resources as well as optimizing its usage.
- *Productivity*, by increasing yields
- *Quality* of products
- *Profitability* of the farms by doing more with less and doing an economic sustainable activity.
- *Sustainability of agricultural production* for next generations of farmers who could carry on this activity.

At that point we can ask the following questions:

- What about all the electronics embedded on the tractor that helps farmer do more precise operations?
- All electronics embedded on the tractor with expensive GNSS systems, are not Precision Agriculture?

The reality is that, as long as this technology is used to vary the inputs according to the variability of the field, it can be considered as AP.

Some topics that most of the time are presented as Precision Agriculture, needs to be reviewed or discussed deeply because can be considered as high technology to increase the efficiency of the operation.

One of the technologies that is difficult to separate from Precision Agriculture is automated guidance or auto pilot systems that automate the steer of the tractor for an exact path. On a really large fields with low variation of different paths, it is a really helpful tool because any deviation generates a large deviation at the end of the journey. In addition, according to Terry Griffin (Cropping system economist from the Kansas State University), “Automated guidance has improved the live of farmers and their families. Equipment operators are less fatigued and tired at the end of the work day when technologies such as automated guidance has been utilized”.

Similar situation are held in variable dose systems adapted to forward speed. The objective of this systems is to allow a uniform input distribution. As higher is the forward speed the flowrate should increase and in the opposite, if the forward speed is reduced also de flowrate should be reduced, maintaining constant the dose per hectare (no matter what the forward speed varies).

For example, if a fertilizer spreader is used, high technology is needed to reach this objective with electric servo motors to adjust the dose regulator, sensors to measure the weight of the hopper, a sensor to measure the forward speed and an electronic systems to control all this sensors and actuators. But the final objective of this systems is to maintain a constant dose per hectare. All these connected systems mounted on the spreader, together with a prescription map, will allow the application of variable fertilizers adapted to the variability of the parcel.

Another clear example is on spraying pesticides operation in field crops. The market is plenty of automated systems that controls the boom sections to avoid overlapping between passes to prevent overdose of products. As the fertiliser spreader example, a large investment must be made in the sprayer. A GNSS receiver with high accuracy (less than 0.5m) is needed, plus an automated control system to switch off the spray. Off course other devices should be add to avoid over pressures on the sprayer. The objective is to maintain a constant dose per hectare in all field, but all this technology is ready to be used for an application based on prescription maps as well as based on embedded sensors.

An example applied to an irrigated system is that implementation of sensors on field to determine the right time to irrigate, also software dedicated to detect water stress of the field or plants. As previous examples, all this systems/technologies are not precision agriculture as far as they not take into consideration field variability.

Translating the previous definitions to a process which we will call cycle, then the cycle of the PA can be reduced to 4 stages. First step is to gather information about the crop, soil, environment and if it is possible, from yields of the previous seasons. This information, that means data, has to be processed with dedicated software to convert it to a valuable information for the farmer, which generally end on a map. With this information (maps), farmer could take decisions based on own experience or assisted by Decision Support Systems tools. This decision making generally is expressed on a prescription map.

To go through these stages, information from several inputs is required, that can goes from Global Navigation Satellite Systems to Geographical Information Systems or Variable Rate Technology. When information and prescriptions are displayed as maps and the cycle takes several days to be completed that is the case of the so-called map-based Precision Agriculture. When information is not mapped and the cycle is completed in some milliseconds, it is the case of real-time sensor-based Precision Agriculture (Arnó *et al* 2016).

2.1.3 Description of PA main terminology

(Slide 15 to 20 from document *Lecture_PA_introduction.pptx*)

Once the definition of PA is clear, let put the focus on the key elements of the PA to better understand then the main tools and examples of PA used on this lecture. To do so, subfield, variability, efficiency, variable application, technology and benefits will be described.

1) Subfield. A smaller portion of a field. Conventional/traditional agriculture considers the field as a one single piece. PA starts consider the field as a lot of fields inside the field. Besides, with the suitable technology, it is possible to reach every individual plant of the field. No matter how large is the field, the detection is individual for each plant.
2) Variability: All the fields are heterogeneous, and this heterogeneity (soil, water, slope, nutrients, etc.) is always reflected in the crops (growth stage, vigour, stress, etc.). However, in most cases the human eyes' perspective not allows to realise about these differences. Variability is the driving force behind PA. Without variability there is no reason to subdivide fields. (In the past it was an easier management decisions if you can apply decisions to entire field). So a question could be asked: Should we manage the field with the same dose?

3) Efficiency: In the past, it was difficult for farmers to correlate production techniques and crop yields with land variability. This limited their ability to develop the most effective soil/plant treatment strategies that could have enhanced their production. Today, more precise application of pesticides, herbicides, and fertilizers, and better control of the dispersion of those chemicals are possible through precision agriculture, thus reducing expenses, producing a higher yield, and creating a more environmentally friendly farm. It is possible to distinguish between:
    - Management Efficiency is the ability of the producer to use PA Technology for fundamental management of the operation.
    - Decision Making Efficiency is the ability to use financial and production records to make decisions such as: No till vs. conventional tillage or which crops give higher return.

   The most common case for increased efficiency is variable application of fertilizers/chemicals.
4) Variable application: Variable rate technologies are based on electromechanical equipment controlled by computer systems that enable and adjust the application of an input in near real time. The goal is to have 100% of the field having the correct amount of product. With the appropriate variable rate technologies (VRT) it is possible to do variable rate application (VRA) at any field operation. This variations can be carried out from a prescription map or from an embedded sensor.
5) Benefits: Cost savings is the biggest benefit of using PA products. But there are other important benefits like: Environmental – ability to reduce or strategically place inputs or make decisions that will reduce impact on natural resources (buffer strips, products at lower rate, etc.); Economical – decisions that result in higher monetary return.

2.2 Main tools and examples

To better understand the opportunities to implement PA, it is necessary the define tools or technologies that provides PA. In the following slides, a definition, description and some examples are proposed for each tool.

2.2.1 GIS

(Slide 21 to 24 from document *Lecture_PA_introduction.pptx*)

What is GIS? (Geographic Information Software) *GIS* refers to computer software that provides data storage, retrieval, and transformation of spatial (field) data. Fully functional *GIS* can be used to analyze characteristics between layers to develop prescription application maps or other management options like selective harvesting (Glens *et. al.* 2009).

Generally the data gathering is obtained discontinuously, for instance, when soil sampling, it is very difficult to determine the soil texture of whole field surface, unless you are using an Veris3100 sensor (Uribeetxebarria, 2018). To analyze the results of soil samples and correlated with other variables like yield, a GIS tool it is used to transform this discrete data to a continuous map.

It is possible to use this software as well from aerial image (that generates continuous map) to discrete map, to guide scouter through the field for sampling different variables (canopy characteristics, fertility, disease, etc.)

There are several software available on the market. An example are: QGIS (https://qgis.org/en/site/), a Free Open Source Software (FOSS), or ArcGIS (https://www.esri.es/arcgis/). These platform are common used in geospatial analysis.

2.2.2 GNSS

(Slide 25 to 28 from document *Lecture_PA_introduction.pptx*)

What is Global Navigation Satellite System (GNSS)? A GNSS is a constellation of orbiting satellites together with ground based equipment enabling a user to determine his position, with respect to a given coordinate system, using signal transmitted by satellites

There are several constellations around the world: Global Positioning System (GPS) developed by United States of America; Global'naya Navigatsionnaya Sputnikovaya Sistema (GLONASS) developed by Russia, Galileo developed by European Union together with European Space Agency; BeiDou + COMPASS developed by China.

These constellations are available for any receiver. GPS and GLONASS could be disabled or degraded by their operators at any time because of its military purpose.

The Agriculture industry can benefit from this constellations by: Improving parcel yield from customized treatment; More efficient property management; Improving traffic control in the fields.

Depending on the operation to be carried out farmers need more precision. For instance, to determine de position of a field low precision is needed (around 20m precision). This precision is quiet inefficient when ground sampling or when the field has to be divided in zones, then a precision around 1m is more appropriate. For operations like spraying and fertilizing, a 30 cm precision is most accurate than 1m. For tractor guidance (5 cm) or guidance inter-row plants (< 2 cm) like for mechanical weed control in field crops.

But how can a farmer reach this levels of precision? It is possible by using Satellite Based Augmentation Systems (SBAS) like WAAS, EGNOS, OmniSTAR) or Ground Based Augmentation Systems (GBAS) like Beacon/commercial DGPS, RTK/ Network RTK, etc.

A sub-metric precision could be reached by means of SBAS. This is a good solution to get introduced in Precision Agriculture. Some of this correction signals are free and other needs a subscription. For a higher precision, public or private nets, radio signal or internet connection should be used. High precision step, with less than 5 cm, will be assisted by GBAS like RTK systems. These are the most expensive systems but offers the highest precision.

2.2.3 SENSORS

(Slide 29 to 35 from document *Lecture_PA_introduction.pptx*)

It is considered that the beginning of Precision Agriculture starts through yield maps. This maps were obtained by a sensor mounted on the combine. But nowadays the use of remote sensing embedded in satellites, aircrafts or Unmanned Aerial Vehicles (UAV) allows to obtain information about the landscape and its variation.

What are sensors? A sensor is a device that responds to a physical stimulus (such as heat, light, sound, pressure, magnetism or particular motion) and transmits a resulting impulse (as for measurement or operating a control). A simple example of a sensors could be a water flowmeter or an ultrasonic sensor.

In Precision Agriculture, sensors are being developing to determine crop stress, soil properties, pest incidence, canopy structures, etc. The measurement can be obtained as the tractor passes over the field, as a scout goes over the field on foot, or as an airplane or satellite photographs the field from the sky.

In this field of Precision Agriculture is possible to distinguish two types of sensor classification: embedded and remote sensors. Which are the differences? Embedded sensors (like weed detection or ultrasonic sensors) are mounted on the tractor, implement attached to a tractor or combine, to measure field/crop characteristics. This information can be uploaded on a GIS to be process it or directly transferred to a Variable Rate Technology (VRT). Remote sensors (like optical sensors) are generally categorized as aerial or satellite sensors in spite of remote sensing means the acquisition of information without physical contact.

Regarding to remote sensors, the most common sensors used are the photographic and multispectral cameras. With a photographic camera farmers will obtain data about Red, Green and Blues reflection of the field. An example of data output from a photographic camera could be an ortho-photography. To obtain more useful information, more spectral bands are needed, like Infrared. With this information NDVI index, linked to water stress or crop vigor, can be calculated.

On the other hand, an example of embedded sensor it the ultrasonic sensors. For instance, it can be mounted on a tractor to determine de variation of the canopy along the row. An example of data output is a variation of the canopy volume detected by each sensor mounted at three different heights. Next step, and really easy to adapt, is the variable rate application adapted to canopy variation determined by the sensors.

2.2.4 VRT

(Slide 36 to 42 from document *Lecture_PA_introduction.pptx*)

What is Variable Rate Technology (VRT)? VRT are the technologies that allows to modify the actuation according field variability VRT allows Variable Rate Application (VRA), that adjust the dose to the field. Then VRT includes computer controllers and associated hardware attached to implements or directly to the tractor that vary the output. This systems use the variation map obtained with a GIS, or information provided by on the go sensors to modify characteristics of the actuation of the operation that farmer is carrying out.

An example applied to spraying process is explained here below:

- Variable Rate Application based on prescription maps. In this example a sprayer (in this case adapted for vineyard crops) is adjusted to upload a prescription map and take decisions according to data of the map (Campos *et al* 2019). In this case the map contains information about spraying rate. For that, the sprayer uses the localization of the tractor and actuates over the pressure system to modify the flow rate. After the spray process, an application map is obtained, from where traceability can be obtained as well as verify that the procedure is accomplished.
- Variable Rate Application baser on embedded sensors. In this example, a vineyard sprayer is fitted with ultrasonic sensors and solenoid valves to adjust the flow rate to the variation of the canopy (Gil *et al* 2007). A GPS receiver is add to the system for traceability of the spray process. On the figure add on the presentation is possible to observe the variation of the flowrate according to the variation of the canopy volume and the savings obtained in comparison to a constant spray application.
- Variable Rate Application based on embedded sensors and adjusted according to a prescription map. In this case, an orchard sprayer adjusts the dose rate as explained on the previous example, based in ultrasonic sensors data. A prescription map is uploaded with information related to sensitive

areas were liquid/air flow rate can be adjusted to reduce pesticide contamination (Doruchwski *et al* 2009).

2.3 Benefits and costs

(Slide 43 to 46 from document *Lecture_PA_introduction.pptx*)

Benefits from Precision Agriculture goes far beyond from profitability. It supposes as well as benefits for the environment and for the sustainability of the farms. Then many times deciding to invest in PA is not just a simple matter of costs and returns.

Decide the investment on PA it is not an easy task. Since there are different technological levels (from high precision GNSS receivers to simple screen and a manual button to switch dose rate) and different ways of doing PA (from design of irrigation systems to VRT), farmers must choose for those technologies that best suit their farms. PA applications that can work in a specific farm may not be the most appropriate for another farm. (Arnó *et al*, 2018). Then field characteristics and farmers expectations should lead to a profitability option. In this sense, it has to be considered what skills has farmer. As it is stated right above, there are a lot of levels of technology and that means that farmer plays a relevant role. The skills needed change when using a VRT embedded on the tractor + implement or when using GIS to generate a prescription map and upload it on an implement controller.

Since PA adjust inputs to field variability an environmental impact can be assumed by reducing losses. Since uniform application does not consider variation of crop need, in some subfield will be overdosed (wasting inputs and contaminating the environment) and other subfield will be under dosed (with associated risks of reduce production or repeat the application).

At least, the sustainability of the farm depends on a balance between investments on new technologies adapted to the market (optimization of inputs, traceability, safer food, etc.) that makes life works easy and is safe for the environment. Benefits from implementation of Precision Agriculture goes from short term like economics to long term like sustainability of farm companies. Positive impacts on environment, farm company logistics or social value of farming work can be attributed to PA.

As it is mention previously there are different levels of technologies, so costs depends on: Time dedicated to analyse data from all sensors, availability to transform data to decisions (need to increase training programs on AP uses) and evaluate impacts further than profit (social and environmental impacts).

2.4 Police and legislative framework

(Slide 47 to 53 from document *Lecture_PA_introduction.pptx*)

Precision Agriculture methods promise to increase the quantity and quality of agricultural output while using less input (water, energy, fertilizers, pesticides, etc.). The aim is to save costs, reduce environmental impact and produce more and better food.

The definition of a legislative framework for the promotion of precision agriculture is an important aspect that the European Union is considering. The Commission's communication on the Common Agricultural Policy (CAP) post-2020 (COM, 2017) notes the significance of the potential contribution that innovation can make to agriculture and rural areas is being increasingly recognized, not least through the difference investment in research and development can make to productivity growth in agriculture, as well as in terms of sustainable development.

The CAP should play a larger role in helping farmers make more money from the market. There is a clear need to boost investments into farm restructuring, modernization, innovation, diversification and uptake of new technologies and digital-based opportunities such as precision agriculture.

In addition, the potential role and opportunities that precision farming can offer European agriculture have been presented in a study undertaken for Members of the European Parliament by Parliament's Scientific Foresight (STOA) unit on 'Precision agriculture and the future of farming in Europe' (STOA, 2016).

On this study four main guiding themes are identified: Food security and food safety, environmental sustainability of farming, societal changes and technology uptake in agriculture, Skills and education for farmers.

Irrespective of what the economic context might be in the next decades, PA will be needed by EU farmers to improve their yields on less available arable land. Nowadays the EU is putting efforts on take steps addressing the Precision Agriculture challenge, trough Horizon 2020 program, under specific theme "Societal Challenge 2" which partially relates to PA.

Sustainability is another central pillar of the STOA PA study and expert discussions. The study recommends that PA should be one of the key issues to be addressed by the next CAP. For instance enticing farmers to invest in PA technologies through Pillar 1 and a renewed greening scheme. It could take the form of a 'sustainability bonus' linked to investment in PA technologies. In this sense, developing PA standards focusing on transparency, sustainability and interoperability through the Centre Européen de Normalisation (CEN), the International Organization for Standardization (ISO) and the European Telecommunications Standards Institute (ETSI) is necessary.

Similarly to the way in which PCs, internet, smart phones and satellite navigation have changed our ways of life, PA will trigger societal changes in rural communities and will initiate new business models A policy option is to build an appropriate infrastructure for keeping and attracting young farmers.

Like every new technology, the introduction and uptake of PA will require new skills to be learned by farmers. Encouraging new forms of learning or reaching out to smaller farms by new educational and mentoring mechanism, are presented as a policy options.

Some of the STOA Panel Members tend strongly to encouraging support for the transition towards precision agriculture in the EU through the Common Agricultural Policy (CAP). However, MEPs also expressed concerns about possible loss of jobs in the sector in countries highly agriculture-dependent for employment, through the introduction of precision farming and automation in farming practices.

Further from CAP framework, other initiatives on the European Commission environment are focused to help Precision Agriculture development:

- EIP-Focus group on Precision Farming
- Legislation regarding UAV (EASA recommendations)
- Horizon 2020 (research priorities on PA)
- Directive 2009/127/EC of requirements for sprayers related to environmental protection
- Directive 2009/128/EC of a sustainable use of pesticides

One of the challenges that EU has to face is related to data ownership. From the STOA 2016 report it is noted that the lack of broadband infrastructure in rural areas and connectivity to devices, ensuring effective data ownership in the context of big data and the lack of standards, and the limitations on the exchange of data between systems, all constitute further barriers and challenges that need to be addressed. Precision agriculture also raises questions in relation to the terms of interaction between humans and machines – particularly regarding the lack of independent advisory/consultancy services, technology push, food security and whether precision agriculture would further aggravate the employment situation in the field of agriculture.

As far as non-personal data is concerned, the identification and specification of 'data ownership', 'trade secrets' or 'intellectual property issues', competition law aspects, public data and usability, access to machine generated and machine-to-machine data, constitute some additional data-related challenges. For example, details on soil fertility and crop yield have historically been considered akin to a trade secret for farmers, and suddenly this information is being gathered under the guise of technology and miracle yield improvements. A management system like precision agriculture, which heavily depends on data, maps and images, is likely to create new concerns about data management, access to data, the ownership of aggregated data, control of the data generated, assimilated, and manipulated through precision agriculture activities, raising a series of tricky questions: Who owns the data? Do you own the data (as an individual or a business) or does another organisation own it? Does using a particular software service mean that ownership is transferred to the service provider? Who ought to have access to the data generated by precision agricultural equipment? Who owns the secondary and tertiary uses of the data; can this ownership be limited or expanded, and in what way? Who is the owner if the data is collected under a separate contract (e.g., custom harvesting or custom applicator)?

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