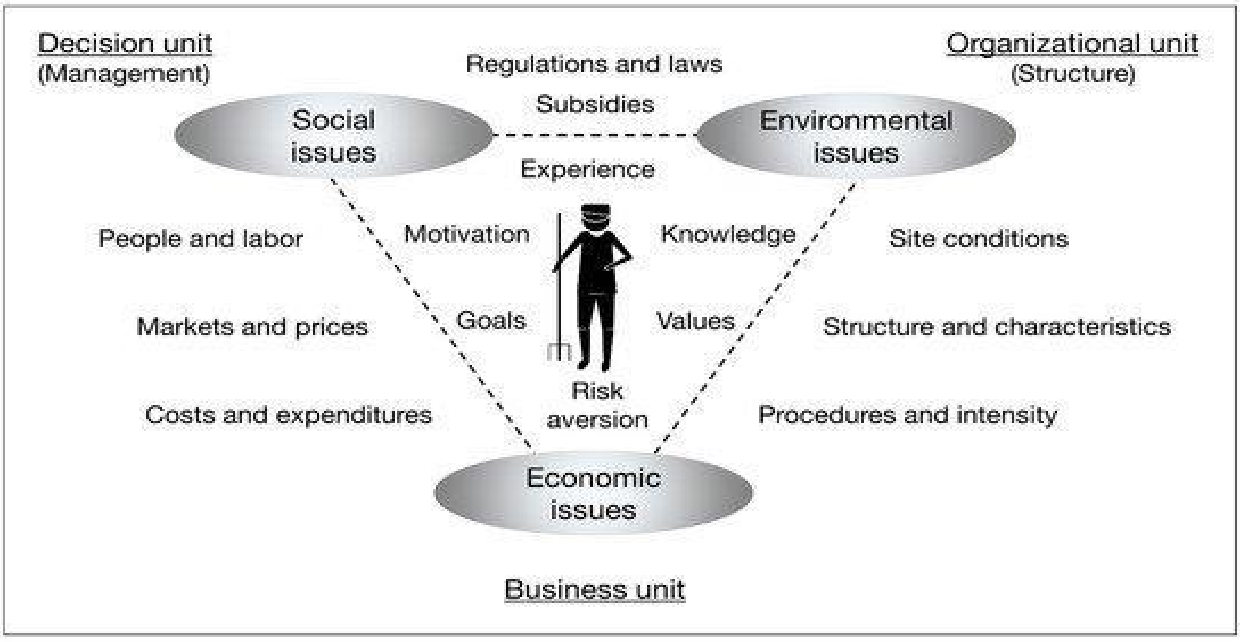
Lesson 1

General agriculture

Introduction

The terms 'agriculture' and 'agricultural system' are used widely to encompass various aspects of the production of plant and animal material for food, fibre and other uses. For many, the terms are limited to the cultivation of soil and growth of plants. But for others the terms also include the financing, processing, marketing, and distribution of agricultural products, farm production supply and service industries, health, nutrition, and food consumption, the use and conservation of land and water resources and related economic, sociological, political, environmental and cultural characteristics of the food and fibre system. Thus, agriculture involves economics, technology, politics, sociology, international relations and trade, and environmental problems, in addition to biology.

In recent years there has been growing demand for a more multidisciplinary and holistic content to agricultural research and development. Responses to this demand include farming systems research, integrated rural development, agricultural system analysis, agro ecosystem analysis and food production system appraisal. Although most of these approaches employ frameworks with sufficient flexibility for interdisciplinary interaction, there is little agreement on the meaning of 'agriculture'. Definitions of agriculture vary according to the dimension (e.g. resource base, crop production, management and economics, rural community) and the spatial scale (e.g. plot, field, farm, region) which are being considered.



Interventions in the territorial environment

1. Fertilization

The major agricultural products can be broadly grouped into foods, fibers, fuels and row materials (such as rubber). Food classes include cereals (grains), vegetables, fruit, oils, meat, milk, eggs and fungi. Over one-third of the word's workers are employed in agriculture, second only to the service sector, although in recent decades, the global trend of a decreasing number of agricultural workers continues, especially in developing and mechanization that brings an enormous yield increase.

Organic fertilizers and amendments can be derived from animal and vegetable origin processed in accordance with relevant organic certification rules. Two of the approved processes developed to transform organic materials into organic fertilizers are:

Aerobic digestion

- The aerobic transformation of organic wastes results in a stabilized, rich, humic-like substance generally characterized by slow mineralization rates in the soil.

Anaerobic digestion

- Anaerobic digestate is composed of organic substances in a chemically reduced form at low molecular weight, which, depending on the characteristics of the starting materials, can supply N and other nutrients at greater mineralization rates than compost.

Several studies have shown promising yield results from the application of compost, municipal solid waste, and anaerobic digestates for different crop species.

2. Green fertilization

Cover crops play an important role in green fertilization and in properly designed rotational systems, are able to provide fundamental ecological services to enhance agro-ecosystem sustainability. Indeed, soil covered with plants is an effective way to suppress weed growth and reduce soil erosion and nutrient leaching while increasing soil organic matter and sustaining long-term soil fertility and crop production. Legume cover crops are N sources and can reduce or replace off-farm N fertilizers. In particular, the use of common vetch (*Vicia sativa* L.) as a cover crop may improve soil fertility and increase the yield of subsequent crops in the rotation. These positive effects may be the result of the roots and/or aboveground plant biomass, which contain a considerable amount of N and a relatively low carbon-to-nitrogen ratio (C/N) that results in a rapid release of plant-available N. To allow the timely production of subsequent crops, the crop cycle of this type of crop is terminated before normal maturation by chemical or mechanical methods. In organic farming, the termination of cover crop is achieved by mechanical cutting or plowing.

3. Inorganic fertilization

Chemical (inorganic) fertilizers are frequently accused of everything from "poisoning" the soil to producing less tasty and nutritious food. Chemical fertilizers supply only nutrients and exert no beneficial effects on soil physical condition. The advent of granulated and chemically uniform inorganic fertilizer salts with high nutrient content, reduced labour during application (there was no need to incorporate by tilling) as compared to organic fertilizers.

Cultivation methods

1. Cultivation machinery

There has been a widespread adoption of mechanized harvesting, in which the crop residues are no longer burnt, but are left on the surface of the soil. However, the modern machinery can result in soil compaction. Specific causative agents are:

- increases in the number of passages of machines through the same location,
- the high per axle loading of the machines,
- and traffic on wet soil.

The degradation of the structure of the soil is one of the principal negative consequences of the modernization of the agricultural systems and intensive cultivation.

2. Intensive cultivation

Intensive agriculture is the most typical method of soil cultivation. It relies on reaping high yields with strong and often extreme land exploitation and often extreme inputs. The main benefits of intensive farming include sufficient food supplies at affordable prices. However, advantages never come for free. Increased chemical applications are dangerous both to nature and human body. Intensive farming causes environment pollution and induces major health issues due to poisonous agents.

3. Non-cultivation

In the last few years the possibility of growing crops without any soil disturbance has been demonstrated. On many soil types crop yield has been unaffected and has sometimes shown a slight increase compared with traditional cultivation. Advantages of non-cultivation include:

- the possibility of increasing crop uniformity and yield by using closer row spacings and completely new methods of crop production,
- the avoidance of injury to surface-feeding roots,
- decreased risk of frost
- easier mechanical harvesting of some crops.

4. Crop rotation

Crop rotation is the agronomic practice of growing crops on the same field in sequence. It has several benefits for soil and crop systems. Beneficial effects include lower incidence of weeds, insects, and plant diseases, as well as improvements of soil physical, chemical, and biological properties. The selection of crops used in rotations is often determined by the crop's commodity price. Farmers often return to continuous cropping systems despite the numerous advantages provided by rotating crops, especially if the specific crop prices are high. This decision has been an error over the long term. Crop yields have declined in continuous cropping systems, and there have been increases in input demands, leading to lower overall farm profitability.

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Assessment test

Lesson 1

1 - Multiple Choice Questions

1) **Which is the aim of this lesson?**
    a) The aim of this lesson is reducing field inputs and consequently reducing pollutants.
    b) The aim of this lesson is the understanding of the participants in general knowledge concerning the agricultural systems of land exploitation, the growth and development of plants.

2) **The terms "agriculture" and "agricultural system" are widely used to include what is included?**
    a) Agriculture involves economics, technology, politics, sociology, international relations and trade, and environmental problems.
    b) Agriculture includes biology.

3) **Organic fertilizers can be derived from animal and vegetable origin. Which processes developed to transform organic materials into organic fertilizers?**
    a) Aerobic digestion.
    b) With chemical interventions.
    c) Anaerobic digestion.

4) **Crop rotation is the agronomic practice of growing crops on the same field in sequence. It has several benefits include lower incidence of weeds, insects, and plant diseases, as well as improvements of soil physical, chemical, and biological properties.**
    a) Yes
    b) No

Lesson 1 - Answers

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    b) No

Lesson 2

Introduction to Precision Agriculture

Introduction

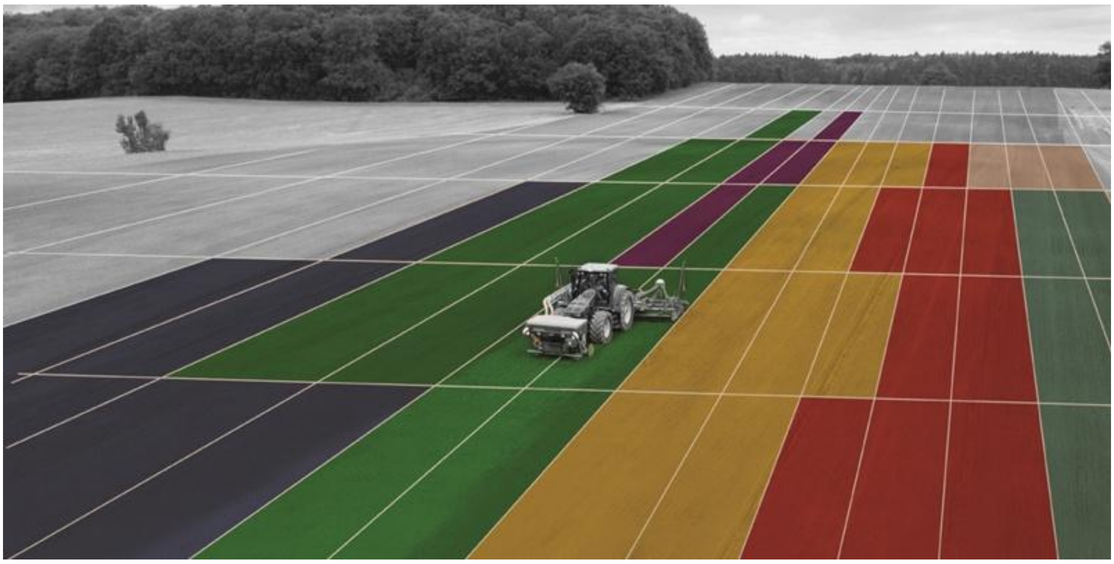
Precision Agriculture is a new method of field management according to which inputs (pesticides, fertilizers, seed, irrigation water) and cultivation practices are applied according to the needs of the soil and crops, as they vary in space and time.

The main objectives of Precision Agriculture are:

- increasing crop yields,
- improving the quality of products produced,
- the most efficient use of agrochemicals,
- energy saving,
- the protection of soil and water from pollution

The idea of managing the parts of the field as a separate unit is not new. This is what the farmers did in the old days, when they sowed every plant by hand. Today the cultivated areas have increased due to the possibilities provided by mechanization, so in order to be

managed at the plant level, advanced technology is needed. The development of technology and electronics has given impetus to the development of precision agriculture.
The prerequisite for the application of precision agriculture is the knowledge of spatial variability. Spatial variability is the variability in measured characteristics of the crop and the soil. Variability exists in all fields and can be observed in soil fertility, moisture, soil mechanical composition, topography, plant growth and populations of pests and diseases.

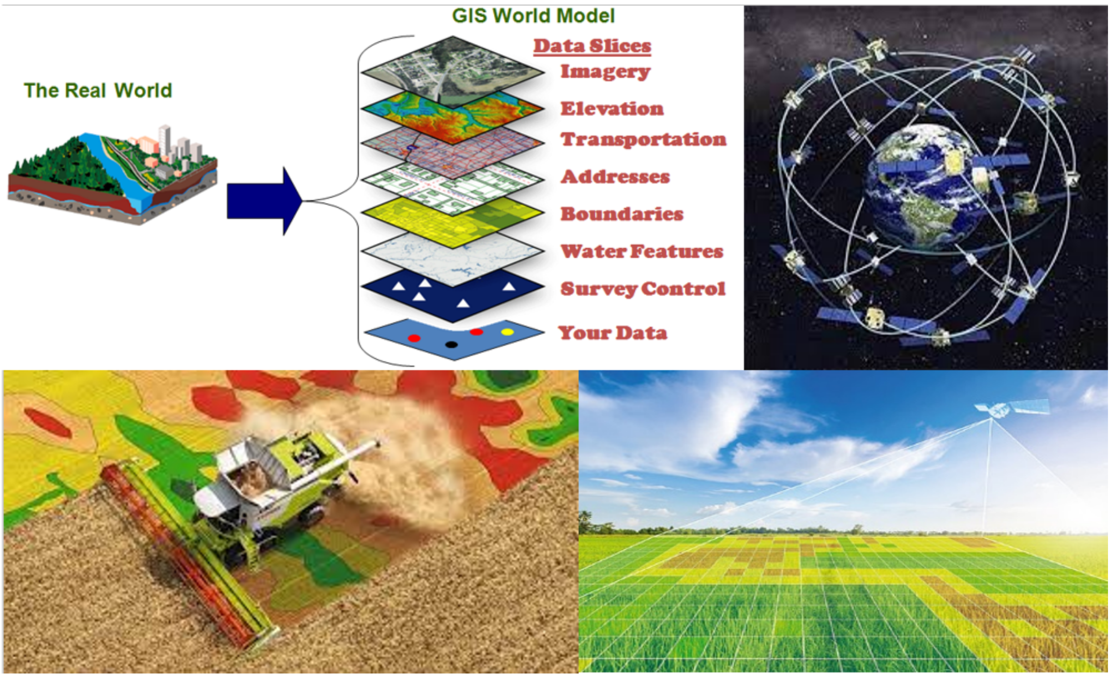


Apart from being spatial the variability can also be temporal. For example, some soil properties are stable over time or change slightly from year to year, such as soil organic matter and mechanical composition. Other properties, such as nitrate levels and soil moisture can change greatly over time. Also, the condition of the crop can change within hours.
Economics is one of the most important reasons for moving from traditional farming to precision agriculture. Precision farming can affect production costs and crop yields. Thus, there is a possibility for higher returns using the same inputs but redistributed, for the same returns with reduced inputs or for higher returns with reduced inputs. The producer must decide on the most appropriate management method. It is known that lack of nutrients can reduce plant growth and worsen product quality. On the other hand, the excess of nutrients can lead to poor fruit quality, also can cause problems in the plantation (grain inclination, susceptibility to enemies.
However, the fact that a field has variability does not always mean that it makes sense to apply precision agriculture. The magnitude of the variability first must be measured, then the causes of this variability must be found, and finally a way must be found to manage the

variability. The inputs currently applied in variable doses are fertilizers, pesticides, irrigation water and seed.

One more important goal of implementing variable dose inputs is to protect the environment. For example, the application of variable dose nitrogen can reduce the nitrogen applied and reduce the nitrogen in sensitive areas, without reducing production and possibly with a better economic result. Also, with the application of insecticides and herbicides with variable doses the quantities that can be applied can be reduced, since they are applied only where they are necessary.

Technologies in Precision Agriculture



The technologies used by precision agriculture are related to all production stages from sowing to harvest. These are:

- GPS and GIS. They are systems that allow accurate mapping of fields and interpretation of field variability.
- Yield mapping. Yield mapping collects production data from specific locations in the field.
- Mapping of soil properties with which the fertility of the fields is recorded.

- Electrical conductivity mapping of the soil. The electrical conductivity of the soil unifies a wider set of factors that affect the production of a crop.
- Remote sensing. The simplest way to explain the meaning of remote sensing is the collection of information about an object without contact. The two most common methods of remote sensing are aerial photography and satellite imagery.
- Variable Rate Application technology. With this technology the inputs are applied to the field in different doses according to the needs of each specific area of the field.

Precision Agriculture vs Conventional Agriculture

The main differences between conventional farming and precision agriculture are:

1. Management of the field in smaller parts based on the variability of the field

With the conventional agriculture the producers exploit their land as a whole whether they know the peculiarities and the different needs of each part of it. In the same field the soil type, the nutrients, the water and drainage etc. may differ. Precision agriculture uses new technologies and provides information for the management of the field on a smaller scale. These technologies provide data of high spatial and temporal analysis, i.e. information on the variability and needs of the field at each point, so that the application of inputs is more accurate and more efficient.

2. Providing more detailed, accurate and more frequent information

At the present, all the information on soil fertility, plant nutritional status and their clinical picture in terms of pests are obtained based on sampling and they concern the whole field. In most cases the sampling method used by the producers is not always correct and the analytical techniques in their current form are slow and expensive, making dense and frequent sampling prohibitive. On the contrary, with the mapping techniques the data that are obtained highlight the variability of each part of the field. Thus, precision agriculture reduces the uncertainty of producers in making decisions because the collection and analysis of data is more frequent and more detailed. Therefore, the solution is in time and specific. In addition, precision agriculture allows management performance to be quantified.

3. Reduction of crop inputs

In conventional agriculture, the application of crop inputs (water, seed, fertilizers, pesticides, etc.) is based on sampling. So, the field is treated as a whole and the doses that being applied represent the averages. As a result, the application of input is larger than the necessary quantity increasing production costs and burdening the environment. In contrast, precision agriculture addresses the variability of the field and applies the appropriate inflow, where needed, at the right dose and at the right time. This achieves a reduction in crop inputs and therefore a reduction in production costs.

4. Increase of production efficiency and improvement of the quality of the products

The division of the field into zones according to their variability and needs and respectively the correct application of inputs spatially and temporally, lead to the development of robust and more productive plants because their needs are met exactly. On the other hand, the application of inputs in the right dosage provides quality products suitable for the modern needs of consumers, increasing the income of the grower.

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5. Environmental protection

In recent years, the waste of water, fertilizers and pesticides has caused enormous negative effects on the environment. These include degradation of the soil to a degree of desertification, reduction of water resources in aquifers, penetration of sea water in coastal areas, salinization and pollution of soils and finally the production of lower quality products and in many cases hazardous for consumption. With the Precision Agriculture the relationship and interdependence between agriculture and the environment is direct and dynamic. Proper management and implementation of inputs minimizes the harmful effects of agriculture on the environment and human health.

In conclusion, precision agriculture can help farmers make the most of their resources without adding to their workload. It helps to lower a farmer's costs by reducing the need for fertilizer, pesticides, and herbicides. Having in mind that the pressure for higher yields is increasing rapidly, an investment in precision farming would be a wise decision by farmers as it would ultimately lead to increased profits, a healthy climate, and the promotion of sustainable farming.

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Assessment test

Lesson 2

1 - Multiple Choice Questions

1) **Which is the aim of this lesson?**
   a) The aim of this lesson is present the basic principles of precision agriculture, the benefits and technology required to implement it.
   b) The aim of this lesson is to show participants the steps to adopt precision agriculture.

2) **Which are the main objectives of the Precision agriculture?**
   a) Aims to increase crops production without taking into account environmental costs.
   b) The main objectives are: increasing crop yields, improving the quality of products produced, the most efficient use of agrochemicals, energy saving and the protection of soil and water from pollution.

3) **Are the technologies used by Precision Agriculture are related to all production stages from sowing to harvest?**
   a) Yes
   b) No

4) **The main differences between conventional farming and precision agriculture are: Management of the field in smaller parts based on the variability of the field, environmental protection, reduction of crop inputs.**
   a) Yes
   b) No

Lesson 1 - Answers

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Lesson 3

Precision Agriculture Tools and Methodologies

Global Positioning System (GPS)

GPS is a satellite system for locating position, speed and time distribution. This system uses radio signals from satellites orbiting the Earth.
The main purpose of the system was to control the movement of vehicles, ships and airplanes on a global scale and initially for military purposes. However, over time and with the improvement of the accuracy of the system, its applications have expanded to other areas, such as the monitoring of movements of the Earth's solid crust (Geodynamics), the monitoring of small movements of large technical projects (Geodesy), hydrographic applications, applications in space sciences, applications in transport, etc.
GPS provides:

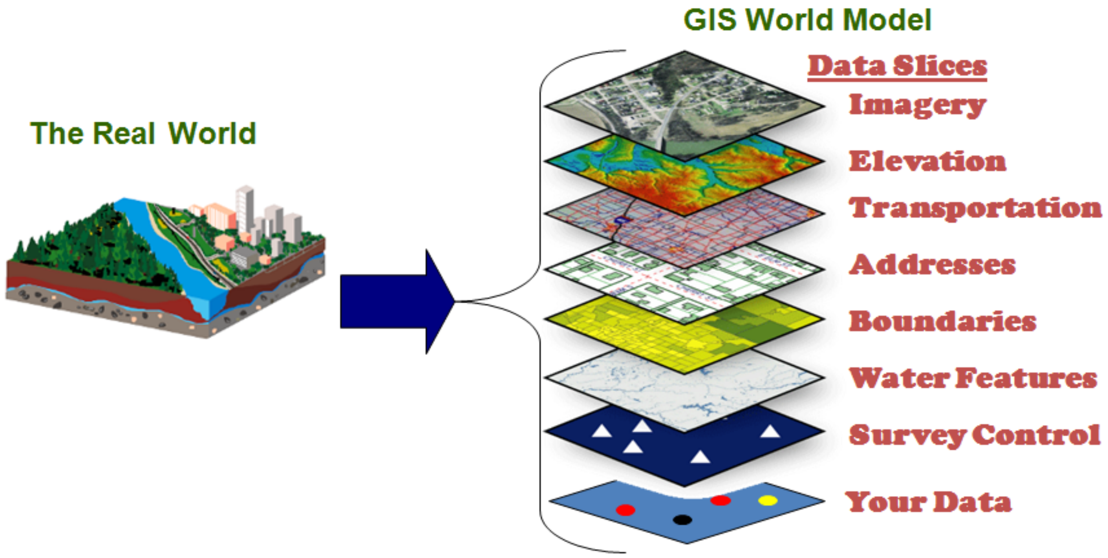
- 24-hour coverage worldwide
- 3D positioning with high accuracy
- A global reporting system
- Continuous operation in real time
- Use without restrictions
- Civil use with slightly reduced accuracy, but suitable for many applications

GPS consists of three parts: the satellite part, the control part and the user part.
The satellite section consists of 24 satellites orbiting the earth at a distance of 20,200km above the earth's surface. Each satellite orbits the earth every 12 hours. The satellites follow 6 orbits with 4 satellites in each orbit. This arrangement of satellites ensures that at least 4 satellites will send a signal to any part of the earth 24 hours a day.
The control section consists of ground stations which are of three types: a central control station, 5 monitoring stations and 3 control stations. The monitoring stations are equipped with receivers that receive the signals continuously transmitted by the satellites, which after some processing are transmitted to the central control station. The central control station uses this information to calculate the exact orbits of the satellites and to update the navigation signals.
The user section consists of users, who are civilians and the military who use GPS to determine the position of a person or vehicle on earth. GPS receivers used by citizens do not need a license, because they do not send signals but only receive signals. Also, there is no financial charge for using GPS satellite signals.

GPS applications in Precision Agriculture

There are various GPS applications in Precision Agriculture, such as field contouring, crop tracking, soil mapping, yield mapping.
To create an outline of the field, the producer simply walks or drives around the field with GPS and a laptop to record the data.
With the same equipment used for the outline, the producer walks in the field and records during the growing season the areas where there are weeds, problems with enemies and diseases or nutrients deficiency problems. By recording the locations of the above problems the farmer can return and apply the appropriate agrochemical or other crop care.
For soil mapping GPS is used to record the location where soil samples are taken and then after analyzing the samples in the soil laboratory, the corresponding maps are created using appropriate mapping software.
To yield mapping GPS along with material flow sensors on the harvesting machine, can record production at any location in the field and then create the corresponding production maps.
In addition to recording the location of a vehicle, GPS can be used to assist in navigating and guiding a vehicle in the field. In precision agriculture, auto guidance systems support tractors. Thus agrochemicals can be applied to the soil and to the crops, without gaps or coatings. That last one, lead to over-application which has as a consequence the higher costs, the destruction of crops and the risk of environmental pollution.

Geographic Information System (GIS)



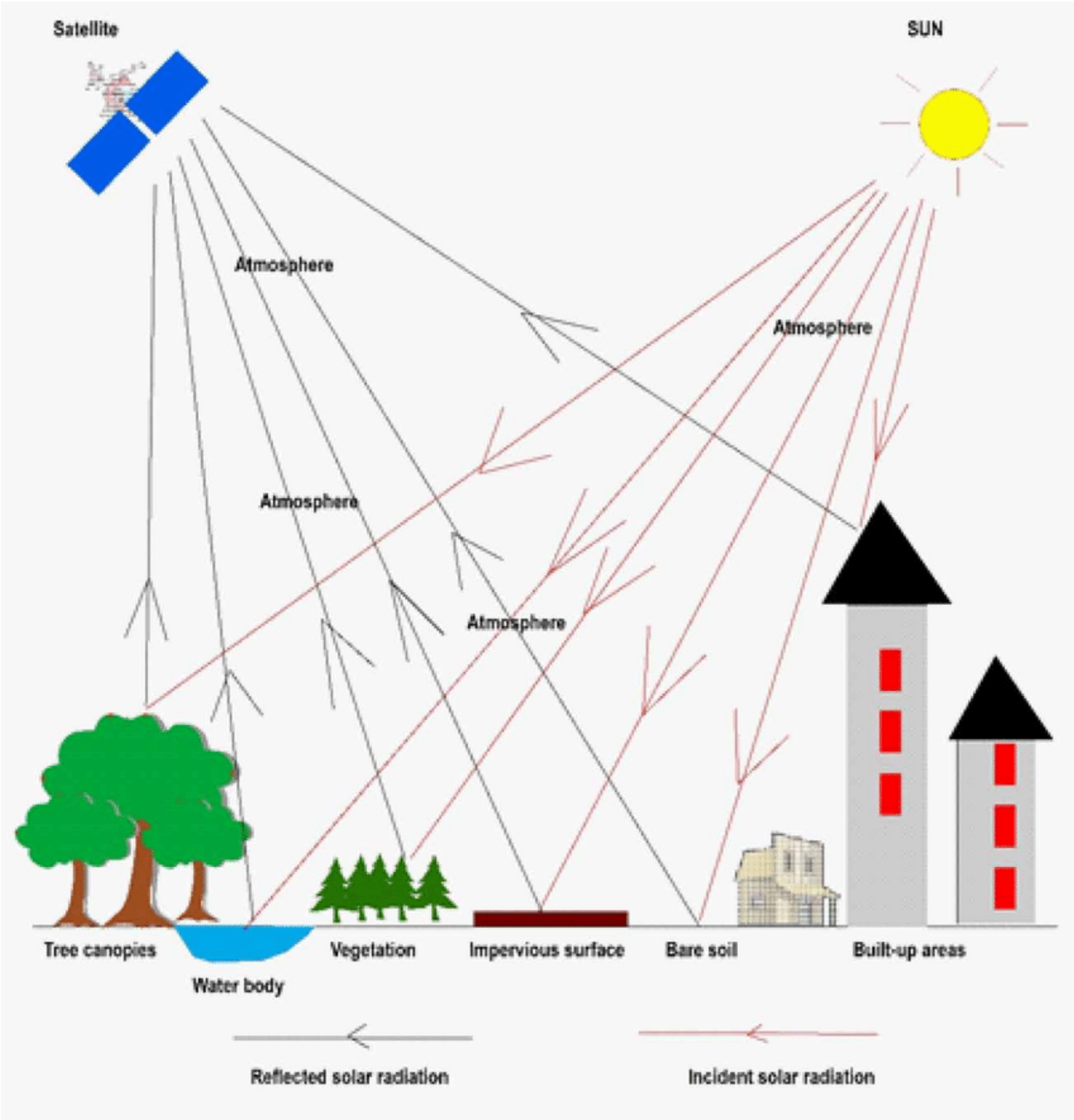
Geographic information systems are systems for managing spatial data and associated properties. They collect, manage and analyze data for specific geographical locations with the help of a software. They provide an interactive data map for a geographical location (thematic map) that can relate to altitude, slope, annual rainfall, average temperature and humidity, crops, nutrients, soil electrical conductivity etc. With the help of these systems the farmer can monitor the production and keep a record of their inputs and results in a spatial order.

The result of data processing by a GIS program is displayed in the form of a map for better understanding by the user. The main advantage of using GIS over plain maps is that the data interacts with the maps at the user's command. Thus, we can process the data of a field and the result of the processing will appear directly on the map.

Specialized GIS software gives the user features such as:

- The ability to predict production.
- The more efficient use of inputs (fertilizers, irrigation) that leads to reduced production costs and sustainability.
- The ability to harvest according to quality standards, improving the income of the producer.
- To help ensure quality according to various protocols (ISO, HACCP).
- Managing large amounts of data easily and quickly.

Remote Sensing (RS)



Remote sensing is the science that observes and studies the characteristics of the earth's surface from distance with the help of electromagnetic radiation. For example, it can record, by aerial or satellite means, how vegetation reflects the different wavelengths of sunlight. Every farmer can get useful information from digital images taken using remote sensing, about his crops, the state of plant health and how he will deal with any problems. The aim is to capture in this way the spatial variability of the field, so that cultivation practices and inputs (fertilization, plant protection, irrigation, harvesting) are localized. When the data are organized in a Geographic Information System (GIS) along with other types of data, we have an important tool that helps in making decisions about crops and agricultural strategies.

Variable application systems (VRA or VRT)

Variable application systems are agricultural engineering systems that are installed on agricultural machinery and change the amount of application of inputs (water, seed, fertilizers, pesticides, etc.). Also they are able to change the type of inputs (seed variety, fertilizer type) the same time as they apply the inputs, according to the needs of each point of the field. This technology is based on mapping techniques or sensors.

Yield Monitoring System

Yield monitoring systems are systems for measuring and recording the yield of a crop at harvest point. The data obtained, in combination with the global positioning system (GPS) and the geographic information systems (GIS), are giving important information about the performance of every spot of the field depending on the location (production map). Yield monitoring systems consist of sensors, a GPS receiver and a management / computer console.

Crop and soil sensors

Sensors are mechanisms of automatic sampling and rapid measurement. There are several categories of sensors such as crop sensors, field sensors, soil sensors, plant sensors, weed or infestation sensors. The special sensors are placed in the fields and collect information on temperature, humidity, weather conditions, diseases, etc. By using such sensors, each farmer can have direct access to a range of field-critical information related to normal growth and crop needs.
The adoption of new technologies opens new roads in agriculture. With the help of technology the digital display of a map becomes a useful tool for providing information for the optimal management of the agricultural holding.

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Assessment test

Lesson 3

1 - Multiple Choice Questions

1) **Which is the aim of this lesson?**
   a) The aim of this lesson presents the negatives of conventional agriculture.
   b) The aim of this lesson is to present the tools, technologies and methods for applying Precision Agriculture to standard production systems.

2) **Which is the main purpose of the GPS system in Precision Agriculture?**
   a) Field contouring, crop tracking, soil mapping, yield mapping.
   b) Collect information on temperature, humidity, weather conditions, diseases.

3) **Can yield monitoring systems are systems for measuring and recording the yield of a crop at harvest point?**
   a) Yes
   b) No

4) **GIS is a satellite system which provides: 24-hour coverage worldwide, 3D positioning with high accuracy, a global reporting system, continuous operation in real time, use without restrictions, civil use with slightly reduced accuracy, but suitable for many applications.**
   a) Yes
   b) No

Lesson 3 - Answers

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   a) Yes
   b) No

Lesson 4

Economic-Business Benefits

Introduction

While precision agriculture (PA) has enormous potential for reducing the environmental footprint of farming, awareness is growing with respect to the social implications of the technology and the widespread adoption of PA depends on economics. Farming is a business and technology is adopted if it provides benefits for the farmer and farm household. Sometimes those benefits are qualitative (e.g., more time for recreation, reduced fatigue, less stress), but often those benefits are in monetary terms (i.e., more stable cash flow, higher and less variable profits). Farming is subject to what has been called 'economic physics' in the sense that someone must pay the bills regardless of the ideological framework within which the farmer is functioning just as everyone is subject to gravity whether or not they approve or think it is fair. Labour and capital must be compensated. The opportunity costs of land and other natural resources must be covered. That compensation might be in cash or in kind.

Precision agriculture can be characterized as a solution leading to reduction in agrochemical inputs and reduction of adverse environmental impacts of agriculture, where the basic benefits for the farmer are seen in the economic area (reduced costs by means of controlled application of agricultural inputs), in increased yields (targeted management of field variability) and, last but not least, a favourable environmental impact in the sense of precise application of agrochemical products.

Precision agriculture is one of the ways to increase competitiveness of agriculture while also better combining application of scientific results and techniques directly in agricultural businesses. It thus helps eliminate the weaknesses of agriculture (reduction of production costs in particular) and contributes to increasing profitability/competitiveness of businesses.

The investment and capital costs of machinery used for precision agriculture are very different. Some technologies (e.g., auto-steer or yield mapping) are usually a standard equipment of new machines and mean very low capital costs. Some new technologies (e.g., GreenSeeker technology, camera spraying technologies) are associated with higher investment. The precision agriculture technique brings a number of favourable effects in practice. They contribute, for example, to reduced soil compaction thanks to targeted movement of machinery on plots and more efficient traffic control methods, and bring a saving of time and costs expended on individual work operations. In summary, the techniques in question also contribute to increased labour productivity.
The benefits resulting from using of PA technologies are derived from many key drivers, capital and annual operating costs associated with acquiring the technology, impact of the technology on labour demand, impact on yield, product quality, cost savings, environmental benefits etc. The profitability of PA and benefits from PA technologies varies from farm to farm, in line with farmer preferences and circumstances.

The impacts of precision agriculture to agricultural production are:

• Time savings: evident in a number of work operations, particularly in harvesting, soil preparation and spraying

• Savings in labour costs (harvesting, soil preparation, spraying, sowing, fertilizing), equipment costs, chemical plant protection products, seed stock, fertilizers, fuels
• Increased crop yields.

The primary objective of this lesson is to provide the simulation of precision agriculture (PA) impact on crop production economy. The primary objective is achieved by means of secondary goals:
• Description of techniques and work operations in PA
• Study of structure of agricultural crop production costs
• Simulation of effects of selected techniques PA on production economy

Analysis and management of exploitation

Precise agriculture is an intersection in which meet high technologies, knowledge of the earth, soil, climate and good practices in agricultural activity. Economic aspects with precise agriculture are related to the introduction of those practices that can help improving the optimization of costs and achievement of higher quality products and better crop collection rates. In order to introduce the practices and techniques of precise agriculture specific investments are required in: information assurance, agro -technical procedures, monitoring services, and the use of GPS devices for mapping the field and planning the production process according to the specific needs of the farm. There are a wide variety of techniques that could be introduced in the production process, but only in certain cases these practices could be viable and could lead to real pay-back in a reasonable period of time and of course, could lead agricultural production to optimization levels, reducing costs of exploitation and improving financial statements of the farm.

Precision agriculture is structured on several principles that underlie the management of the farm:

- Obtaining information on the state of natural resources: climatic and microclimatic features, the state of the soil cover of the areas, the state of the vegetation index of plant crops, monitoring the conditions for keeping animals in agricultural buildings (temperature, humidity, lighting).
- Systematization of the collected data in statistical tables and their aggregation in mathematical models.
- Presentation of the state of the farm, as clearly as possible through the use of maps and graphs indicating the state of the farm.
- Technologies for application of fertilizers and plant protection products with the possibility of "variable rate" according to the collected information.
- Real-time monitoring of the farm, using mobile meteorological stations - control of temperature, humidity, and precipitation in specific points of agricultural land. Periodically take a "medium sample" to monitor the condition of the soil.
- Opportunity to implement timely and adequate measures using optimal resources and preserving the vitality of natural resources for as long as possible.

One of the most ambitious and interesting aspects that emerge from PA is, therefore, an attempt to combine two apparently divergent goals: maximize productivity by reducing both the environmental and economic costs. To pursue this target, a detailed knowledge of cultivation parameters, topographic and weather environmental is required.

Planning and decision making

The economic applicability of precision crop production depends on several factors. Among them the following aspects must be emphasized:

- The size of the farm, the characteristics of the production structure, the current input-output prices and their tendencies, the investment needed.
- For transitioning to precision technology and its capital source, the level of professional knowledge and the managerial attitudes of the farm.

The majority of farms characterized by greater output and size can be based on their own equipment but it might as well be presumed that smaller farms can turn to precision farming not based on their own investment. They can buy the technical service from providers, they can establish producer cooperation, for example in the frame of machinery rings.

At a certain farm size and farming intensity precision crop production is a real, environmentally friendly farming strategy, with the help of which the farm can reach earnings that cover at least the economic conditions of simple reproduction.

Financial planning

With a successful implementation of the techniques of precision agriculture, optimizations in agriculture are achieved in two aspects. On the one hand, an improvement in the revenue side is achieved by achieving higher levels of the biological potential of the cultivated crops. On the other hand, tangible savings are achieved in the expenditure part of the farm due to the reduction of the use of fuels, fertilizers and plant protection materials.

In the crop sector, these "small changes" in the cost per acre of arable land can lead to large differences in total costs and thus have a positive effect on the finances of the farm. The main challenges in the crop sector are to achieve the necessary scale of activity so that the changes in the way of growing crops and the costs that are invested in the production process have a business purpose. It is also very important for the farmer to have modern agricultural machinery in order to be able to integrate the collected information about the farm into the navigation system of the machines.
On the one hand, the scale is needed to be able to make investments in the field of precision agriculture, and on the other hand, the benefits and savings to lead to real optimization of income and expenses in the economy.

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Assessment test

Lesson 4

1 - Multiple Choice Questions

1) **Which is the aim of this lesson?**
   a) Participants will be able to know the financial benefits they will have by adopting precision agriculture.
   b) Participants will acquire all the necessary introductory and basic knowledge related to the modern way of cultivation and the application of good agricultural practices.

2) **The impacts of precision agriculture to agricultural production are?**
   a) Time saving: evident in a number of tasks, especially in harvesting, soil preparation and spraying.
   b) Labor cost savings (harvesting, soil preparation, spraying, sowing, fertilizing), equipment costs, chemical plant protection products, seed stocks, fertilizers, fuels.
   c) Cultivation methods (intensive cultivation, reduced cultivation, non-cultivation).

3) **How economic aspects related with precision agriculture?**
   a) To provide participants with general knowledge of precision agriculture.
   b) Can improving the optimization of costs and achievement of higher quality products and better crop collection rates.

4) **With a successful implementation of the techniques of precision agriculture, optimizations in agriculture are achieved in two aspects. On the one hand, an improvement in the revenue side is achieved by achieving higher levels of the biological potential of the cultivated crops. On the other hand, tangible savings are achieved in the expenditure part of the farm due to the reduction of the use of fuels, fertilizers and plant protection materials.**
   a) No
   b) Yes

Lesson 4 - Answers

1 - Multiple Choice Questions

1) **Which is the aim of this lesson?**
   a) **Participants will be able to know the financial benefits they will have by adopting precision agriculture.**
   b) Participants will acquire all the necessary introductory and basic knowledge related to the modern way of cultivation and the application of good agricultural practices.

2) **The impacts of precision agriculture to agricultural production are?**
   a) **Time saving: evident in a number of tasks, especially in harvesting, soil preparation and spraying.**
   b) **Labor cost savings (harvesting, soil preparation, spraying, sowing, fertilizing), equipment costs, chemical plant protection products, seed stocks, fertilizers, fuels.**
   c) Cultivation methods (intensive cultivation, reduced cultivation, non-cultivation).

3) **How economic aspects related with precision agriculture?**
   a) To provide participants with general knowledge of precision agriculture.
   b) **Can improving the optimization of costs and achievement of higher quality products and better crop collection rates.**

4) **With a successful implementation of the techniques of precision agriculture, optimizations in agriculture are achieved in two aspects. On the one hand, an improvement in the revenue side is achieved by achieving higher levels of the biological potential of the cultivated crops. On the other hand, tangible savings are achieved in the expenditure part of the farm due to the reduction of the use of fuels, fertilizers and plant protection materials.**
   a) No
   b) **Yes**

Lesson 5

Environmental Benefits

Introduction

Over the last years the waste of water, fertilizers and pesticides has caused enormous negative effects on the environment. The degradation of the soil to a degree of desertification, the reduction of water resources, the penetration of sea water in coastal areas, the salinization and the pollution of soils and finally the production of lower quality products that in many cases are hazardous for consumption, are some of the results. Precision agriculture and environmental quality protection are inseparably linked. However, the impacts of precision agriculture on environmental quality have been poorly documented, and most scientists believe that judiciously applying agricultural inputs only when and where needed will reduce the impacts on the environment.
Five key environmental benefits were identified to be quantified as a result of precision agriculture technology adoption. These are:

- Fertilizer use
- Pesticide / Herbicide / Insecticide use
- Water use
- Fuel use
- Productivity

Fertilizer use

Nitrogen (N) and phosphorus (P) are two nutrient elements that are applied regularly to agricultural crops, as well as, commercial and residential landscaping. Phosphorus and N are the primary nutrients that in excess can cause detrimental effects on the environment. Agricultural pollution comes from inputs that are not utilized by the target crop.
Fertilizer N can be lost due to gaseous plant emissions, soil nitrification and denitrification, volatilization, surface runoff, and leaching. In addition, N fertilizer can be immobilized into microbial biomass and build soil organic matter.
Nitrate–N is not held tightly by soil particles, and thus vulnerable to movement with percolating water. Nitrate–N that moves below the root zones can enter the groundwater, potentially causing health issues if consumed.
Phosphorus, being strongly sorbed to the soil matrix, is generally lost through soil erosion and surface runoff, although P leaching can also occur where soil P sorption is low as in sandy soils and with repeated P fertilizer application.
Precision, or site-specific nutrient management (SSNM), involves better utilization of fertilizer inputs by following the 4Rs– applying the right nutrient source, at the right rate, at the right time, and in the right place (International Plant Nutrition Institute, 2012). For efficient and effective SSNM, use of soil and plant nutrient status sensing devices, remote sensing, geographic information systems, decision support systems, simulation models, and machines for variable application of nutrients play an important role. While, traditional practice of farmers is to apply the same fertilizer management over whole fields and even whole farms, SSNM recognizes the inherent spatial and temporal variability associated with most fields by incorporating as much information as possible and employing the appropriate tools and technologies to account for this variability. Matching supply with temporal and spatial plant demand and balancing N, P, and K fertilizer application can improve use

efficiency of fertilizers, thus lowering the potential for environmental impacts. Optimizing these factors helps ensure that fertilizers are used as efficiently and effectively as possible. Precision farming, through efficiently matching fertilizer application with actual soil nutrient needs, has been shown to increase nutrient use efficiency and reduce nutrient. Optimizing nutrient inputs results in multiple ecosystem benefits including enhanced aquatic bio-diversity, healthier fish stocks, aquaculture improvement, fewer algal blooms, reduced biochemical oxygen demand, and maintains ecosystem balance.

Pesticides / Herbicides / Insecticides

Pesticides are chemicals that are applied to control a variety of agricultural pests that damage crops and reduce farm productivity. Despite the numerous benefits of using pesticides, their use can have negative consequences. Many pesticides are capable of harming life other than the targeted pest species. As soon as a pesticide is applied, it may be taken up by the intended target pest, be bound to the soil, be degraded, be volatilized, or be transported with percolating water to the groundwater.

Precision agriculture provides an enabling set of technologies to help reduce potential environmental problems from pest management. These technologies include automatic guidance and map-based automatic boom section control on agricultural sprayers that can reduce over application of pesticide by turning off application equipment sections when the boom passes over previously covered areas or passing over areas outside cropped regions of the field such as grassed waterways and buffer strips.

Herbicides are chemicals used to control weeds and unwanted vegetation. The most frequent application of herbicides occurs in agricultural fields, where they are applied pre-emergence or post-emergence of weeds. Precision weed management matches site-specific conditions (i.e., weed densities and soil properties) with proper herbicide and application rate to reduce the risk of creating weed resistance and improving environmental quality. Benefits of site-specific weed management are reduced herbicide use and better matching of chemicals to the problem. By controlling weeds site-specifically, herbicide reductions could be reduced up to 100%. As a result of a significant reduction in herbicide use, positive ecological effects of site-specific weed control are expected. Moreover, reduced herbicide use has been suggested as means of slowing the development of herbicide resistance in weeds.

The amount of herbicide lost to leaching is affected by soil texture, herbicide adsorption to soil colloids, and water movement through the soil. As a general rule, herbicides leach more in sandy soils that are low in organic matter than in soils with high clay and/or organic matter content. Therefore, it would be sensible not to apply pre-emergence herbicides at field sections with high organic matter and clay content.

Site-specific insecticide application has demonstrated success in reducing total insecticide applications in numerous fields. Studies showed that site-specific application can reduce total insecticide use by 20 to 44% compared to uniform applications without a yield loss. Another beneficial effect of site-specific insecticide application is creation of spatial refuges of susceptible pests unexposed to the toxins and conserve natural enemies that slow the rate of selection of resistant pest populations, resulting in reduction in the appearance of resistant pest populations.

Water use

Irrigation is an important player in agriculture production. Irrigated lands produce approximately 40% of the world's total food on 17% of its cropped lands. Irrigation systems draw water from rivers, lakes, or streams, and distributes it over an area to overcome water stress. Direct consequences of water movement and distribution are reduced downstream river discharge, increased evaporation in the irrigated areas, increased groundwater

recharge (deep drainage or deep percolation), and increased water table level and drainage flow. Other effects include waterlogging and soil salinization.
Variable-rate irrigation (VRI) is precision agriculture applied to irrigation. It is the site-specific management of water so that individual parts of a field receive the amount appropriate for specific soil and crop conditions at that location.
The major benefit from VRI system is the reduction of the total irrigation water volume used to grow field crops. Variable-rate irrigation enables farmers not to irrigate ditches, waterways, wetlands and other non-farmed areas within the field. Through the use of electromagnetic and electrical sensors, topography information, and soil property data, farmers now have the capacity to precisely map their fields and create irrigation management zones to customize water application.
Reducing water use can also reduce energy requirements, resulting in reductions of combustion related emissions. Energy-related CO_2 emissions can be reduced as a result of the lower required pumping volume.

Fuel use

The adoption of precision agriculture has a major benefit in fuel saving. Fewer field passes for tillage, application of chemicals, irrigation, fertilization and harvesting are needed. This machine optimization leads to improved fuel efficiency and finally to reduction of economic and environmental costs.

Productivity

According to all the benefits of precision agriculture techniques we already analyzed, it is more than clear that the productivity of the farm is increasing.

Precision agriculture and Climate Change

During the last years, there has been a trend of reducing greenhouse gas (GHG) emissions in the agricultural sector, but more effort in this direction should be made in order to fulfil global climate commitments. In fact, the agriculture sector is still one of the larger contributors to global GHG emissions both directly and indirectly. Agriculture is liable for climate change, as the sector's activities account for nearly 13.5 % of the total global anthropogenic GHG emissions. The major GHGs produced in the agricultural sector are methane (CH4), nitrous oxide (N_2O) and carbon dioxide (CO_2).

Carbon dioxide emissions arise from pre-farm and post-farm energy use and from changes to above- and below-ground carbon stocks induced by land use and land use change. Methane is mainly produced from anaerobic decomposition of organic matter during enteric fermentation and manure management, but also from paddy rice cultivation. Nitrous oxide arises from the microbial transformation of nitrogen (N) in soils and manures.

Precision agriculture technologies (PAT) optimize the use of agricultural inputs (e.g. fertilizers, fuel) by accounting for the spatial and temporal variability of the field. They have the potential to reduce GHG emissions from agricultural activities and maintain or improve productivity.

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Assessment test

Lesson 5

1 - Multiple Choice Questions

1) **Which is the aim of this lesson?**
   a) The aim of this lesson is for participants to be aware of the environmental benefits of Precision Agriculture, by reducing field inputs and consequently reducing pollutants.
   b) The aim of this lesson is for participants will acquire all the necessary introductory and basic knowledge related to the modern way of cultivation.

2) **Which environmental benefits were identified to be quantified as a result of precision agriculture technology adoption?**
   a) Increase production, increase quality.
   b) Collect Fertilizer use, Pesticide / Herbicide / Insecticide use, Water use, Fuel use, Productivity.

3) **Can Precision agriculture provide an enabling set of technologies to help reduce potential environmental problems from pest management?**
   a) Yes
   b) No

4) **Precision farming technologies (PAT) have a negative impact on the use of agricultural inputs (e.g., fertilizers, fuels). They increase GHG emissions from agricultural activities.**
   a) Yes
   b) No

Lesson 5 - Answers

1 - Multiple Choice Questions

1) **Which is the aim of this lesson?**
   a) **The aim of this lesson is for participants to be aware of the environmental benefits of Precision Agriculture, by reducing field inputs and consequently reducing pollutants.**
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3) **Can Precision agriculture provide an enabling set of technologies to help reduce potential environmental problems from pest management?**
   a) **Yes**
   b) No

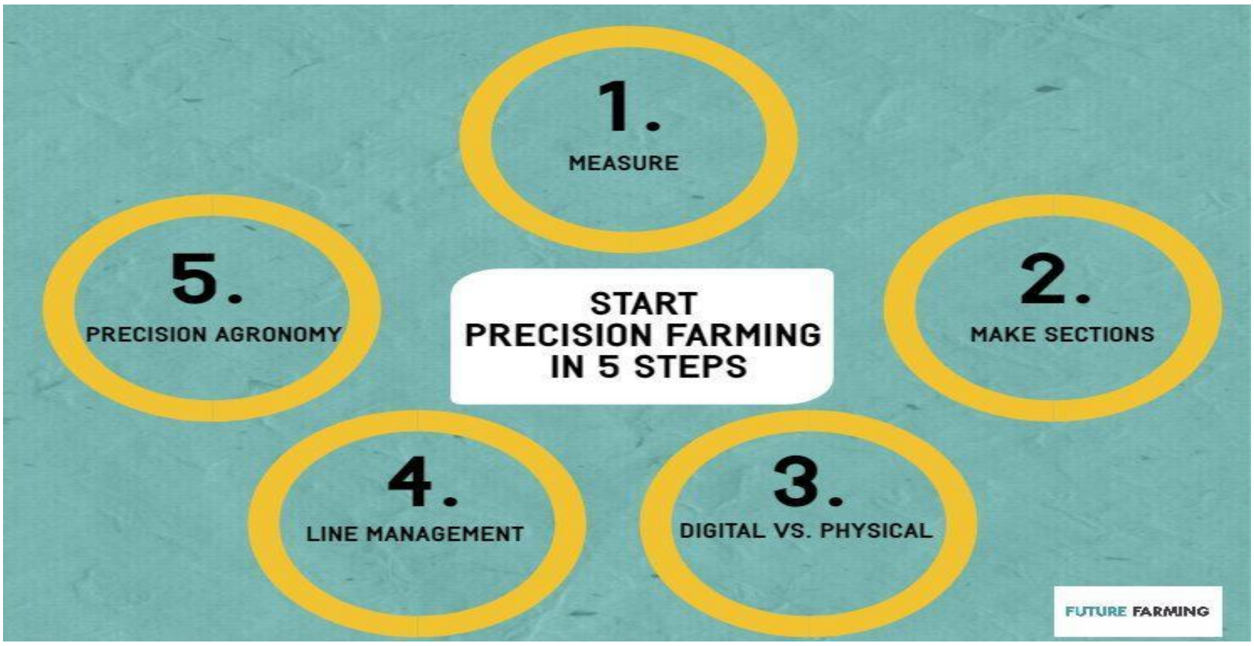
4) **Precision farming technologies (PAT) have a negative impact on the use of agricultural inputs (e.g., fertilizers, fuels). They increase GHG emissions from agricultural activities.**
   a) Yes
   b) **No**

Lesson 6

Ways of Introducing Precision Agriculture into Cultivation

The adoption of new technologies in agriculture is rarely immediate. Even though much effort is placed into in persuading users to adopt new ICT tools, adoption is a complex activity and many factors influence these decision-making processes. The most important aspects influencing the adoption of PA technologies are:

- Farm size
- Costs reduction or higher revenues to acquire a positive benefit
- Total income
- Land tenure
- Farmer's education
- Familiarity with computers
- Access to information (via extension services, service provider, technology sellers)

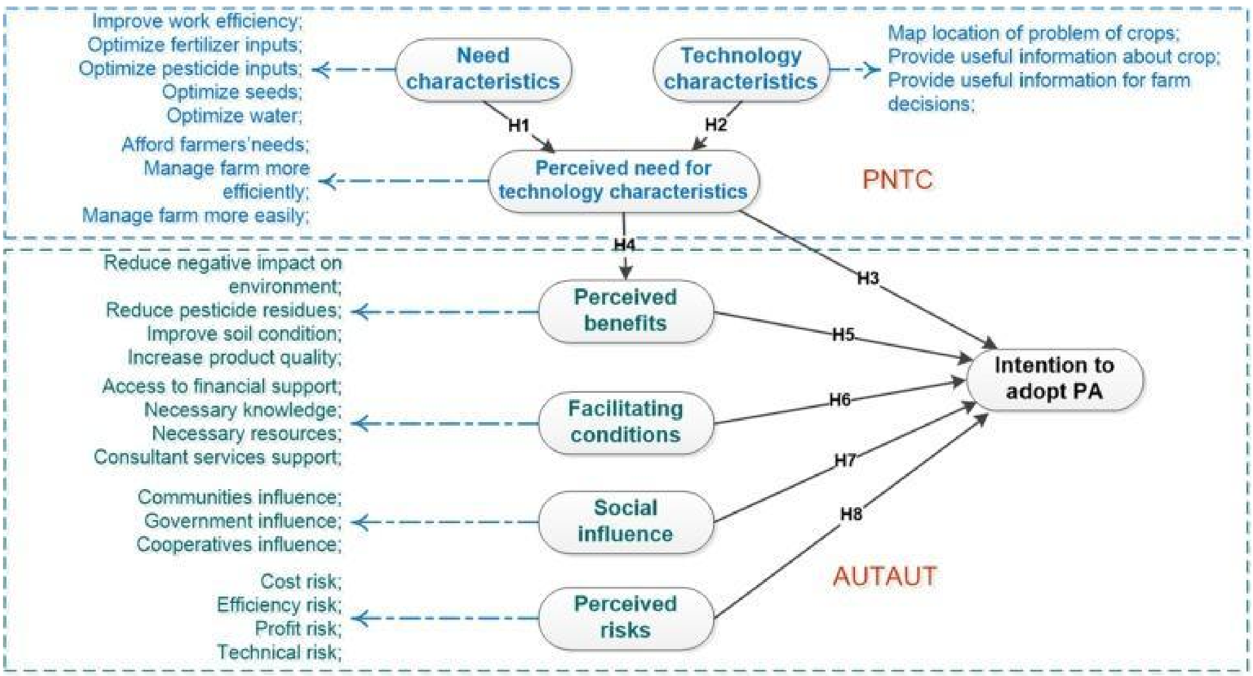


The typical PA adopter is indeed depicted as an educated farmer, owner of a larger farm with a good soil quality, and aiming to implement more productive agricultural practice to face growing competitive pressures. Farm size is the most frequently cited parameter affecting the use of new PA technologies. Although in Europe research about PA adoption is less diffuse, evidences seem to support that younger (<50) and graduated farmers of larger companies are more inclined to use PA technologies, thus reaffirming the role of farm size and education in characterizing the potential PA technology user. However, small farms could become PA adopters thanks to contractors or cooperation. Usefulness and Ease of Use are central aspects for technology adoption, provided that these aspects do not cause a significant increase in the production cost.

Barriers to PA adoption include:

- Technical issues with equipment
- Access to service software
- The lack of compatibility of equipment to current farm operations
- Concerns regarding service providers misuse of agricultural data
- Challenges of managing the amount of PA data

Extension participants' knowledge increased when taught PA innovations through hands-on experiences with software, coupled with instructor guided and self-directed instruction. The perceived need for a technology depends on the alignment between the perceived capabilities of the technology and the task requirements. A good "task-technology fit" will promote users' adoption and a "poor task technology fit" will decrease the user's intention to adopt.



Basic steps to adopt precision agriculture are:

- Sensing variability
- Managing variability
- And evaluating the decisions based on the management of variability

Sensing variability is the most critical step in precision agriculture because proper management and better decision making cannot be done without proper knowledge. After adequately assessing variability, it can potentially be managed by matching required inputs in spatial and temporal context.

Via PA technology we can monitoring the efficiency of resource inputs while reducing chemical use to avoid environmental damage and produce high quality products to satisfy growing demand on food. Precision farming is a holistic, innovative systems approach that assists farmers in managing crop and soil variability to decrease costs, improve yield quality and quantity, and enhance farm income. PA applies traditional farming practices with new technology, practices, and economic drivers to enhance sustainability in a dynamic balance. Ensuring that the specific quantity of required farm input resources like fertilizers, insecticides, herbicides, water to plants and the reduction in farm labour activities are the key areas where the technology is effective.

PA should reduce environmental loading by applying fertilizers and pesticides only where they are needed, when they are needed. PA benefits to the environment come from more targeted use of inputs that reduce losses from excess applications and from reduction of losses due to nutrient imbalances (K deficiency reducing N efficiency, for example), weed escapes, insect damage, etc.

By increasing the efficiency of machinery and input use, precision agriculture provides an opportunity to simultaneously reduce environmental impacts and improve productivity and profits on the farm. For example, navigational aids can reduce overlap in multiple passes of farm machinery, thereby decreasing the use of fossil fuels and other inputs. Variable-rate application of nutrients or pesticides can potentially reduce the use of those inputs, thereby saving on costs, as well as reducing the amount of harmful runoff into waterways.

The carbon footprint includes direct emissions from the operation of farm machinery, as well as indirect emissions embodied in the production of inputs (fertilizer, herbicide, insecticide, seed, etc.).

 Greater sustainability and environmental protection	 Higher productivity	 Economic benefits

Environmental Benefits

The **five key environmental benefits** achieved through precision agriculture technology adoption are:

- Yield benefit through increased efficiency.
- Fertilizer reduction by more precise placement.
- Pesticide reduction by more accurate application.
- Fuel savings due to less overlap and better monitoring.
- Water savings through more accurate sensing of needs.

Significant increases in yields and further input savings can be reached as precision agriculture technologies become more widely adopted:

- Productivity has increased an estimated 4% and has the potential to further increase 6% with broader adoption.
- Precision agriculture has improved fertilizer placement efficiency by an estimated 7% and has the potential to further improve an additional 14%.
- Herbicide use has been reduced by an estimated 9% and has the potential to further decrease 15% at full adoption.
- Fossil fuel use has decreased an estimated 6% with the potential to further decrease 16%.
- Water use has decreased an estimated 4% because of current precision agriculture adoption with the potential to further decrease 21% at full adoption.

Precision agriculture technology improves environmental stewardship while providing economic return for farmers. Precision agriculture leverages technologies to enhance sustainability through more efficient use of critical inputs, such as land, water, fuel, fertilizer, and pesticides.

Farmers who use precision agriculture equipment use less to grow more.

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Assessment test

Lesson 6

1 - Multiple Choice Questions

1) **Which is the aim of this lesson?**
   a) The purpose of this lesson is to show participants the simple steps to adopt precision agriculture.
   b) Economic benefits of precision agriculture.

2) **How participants knowledge can increase from PA innovations?**
   a) Only with theoretical knowledge.
   b) Through hands on experiences with software, coupled with instructor guided and self-directed instruction.

3) **What environmental benefits are achieved through the adoption of precision agriculture?**
   a) Waste of water.
   b) Fertilizer reduction by more precise placement.
   c) Pesticide reduction by more accurate application.

4) **Precision agriculture technology improves environmental stewardship while providing economic return for farmers. Precision agriculture leverages technologies to enhance sustainability through more efficient use of critical inputs, such as land, water, fuel, fertilizer, and pesticides.**
   a) Yes
   b) No

Lesson 6 - Answers

2 - Multiple Choice Questions

1) **Which is the aim of this lesson?**
    a) **The purpose of this lesson is to show participants the simple steps to adopt precision agriculture.**
    b) Economic benefits of precision agriculture.

2) **How participants knowledge can increase from PA innovations?**
    a) Only with theoretical knowledge.
    b) **Through hands on experiences with software, coupled with instructor guided and self-directed instruction.**

3) **What environmental benefits are achieved through the adoption of precision agriculture?**
    a) Waste of water.
    b) **Fertilizer reduction by more precise placement.**
    c) **Pesticide reduction by more accurate application.**

4) **Precision agriculture technology improves environmental stewardship while providing economic return for farmers. Precision agriculture leverages technologies to enhance sustainability through more efficient use of critical inputs, such as land, water, fuel, fertilizer, and pesticides.**
    a) **Yes**
    b) No