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MANUAL OF BEST MANAGEMENT PRACTICES

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2016

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ISBN: 978-84-09-09651-0

Introduction

The objective of the project LIFE ClimAgri is to contribute to the adaptation of irrigated annual crops to climate change while mitigating the effects of this phenomenon.

For this, the project proposes the implementation of a Decalogue of Best Managament Practices (which have already proved to be effective at an experimental level) in the network of demonstration farms linked to the project.

This publication aims to explain what each of these Best Management Practices (BMPs) is. It presents some guidelines on how to implement the BMPs and state the way in which each of them brings benefits for mitigation and/or adaptation to climate change.

BEST MANAGEMENT PRACTICE 1
USE OF PERMANENT SOIL COVER

What is meant by vegetation cover?

The implementation of a cover crop, is a practice which allows farmers to protect the soil and introduce a supply of nutrients to it, enhancing soil structure and supporting life in the soil. In annual crops, the soil is kept covered throughout the whole year, either by crops (commercial or those planted with the sole purpose of keeping the soil covered) or by the residues of the harvest of the previous year, which is left scattered on the ground.

What benefits are obtained with the implementation of soil covers?

The implementation of this practice creates benefits for the soil where crops are located, influencing their sustainability. Living or inert cover provides a protective armor on the ground, acting as a protective layer which prevents the direct impact of rainfall against the bare surface. By blocking impact, physical erosion is avoided and therefore soil loss, one of the most pressing problems of agriculture in Mediterranean environments is prevented. In addition, ground cover provides a physical barrier to surface runoff on slopes. Thus, soil loss caused by the erosive effects of water flowing on the surface, which creates trails and gullies, is avoided.

The presence of cover on the soil surface also provides a screen, protecting against the harshness of direct sunlight, reducing heat stress on it. The result of this protective action includes decreased evaporation of water held in the soil, administering maintenance of moisture levels. This is particularly relevant in irrigated crops, especially those established in areas with a Mediterranean climate, assuming an important role in preserving water and hence proving to be financially beneficial for the farmer.

In addition to the protective functions on the ground, another benefit of the application of this practice is the supply of nutrients and biomass to the soil. The residues from the previous year's harvest are broken down and absorbed by the micro organisms that inhabit the ground, causing a recirculation of nutrients as well as increased organic matter in the soil profile.

Finally, the disposal of crop residues on the soil surface and the implantation of cover crops, provide shelter and food for a variety of wildlife, ranging from microscopic creatures to communities of steppe birds. This not only increases the biodiversity of the agricultural system, but also favors self-regulation, preventing the appearance of pests and promoting sustainability.

How to keep the soil covered in annual crops?

The techniques which are focused on keeping the soil protected, should be selected depending on the factors affecting the degradation of plant material serving as cover, such as weather conditions or the nature of the plant material.

Therefore, in areas where the weather does not degrade plant material quickly (areas with dry periods between crops), it may be sufficient to adequately spread the crop residues at harvest which will remain on the surface up until the seeding of the next crop.

However, if conditions favor the activity of microorganisms that decompose crop residues (high humidity, for example) and these residues decompose while protecting the soil during the period between crops, and taking into account that high moisture is motivated by rainfall which can in turn cause erosion problems, it is recommended the implementation of a cover crop that complements the protective action of crop residues. The selection of the species used as cover crops can be made by choosing those that can help in the management of the farm, depending on their characteristics.

Grasses

- The cost of the seed is low, as being a cover crop without commercial purposes, it can be implemented with non-certified planting seed.

- The control is simple. Grasses can be easily removed by applying small doses of low hazard herbicides.
- Adequate C/N ratio. Grass residues in the soil have great persistence because the stems of grasses have a high C/N ratio which slows down decomposition.
- Surface roots. Grass roots don't delve deep into the ground, so they will not extract water from deep horizons.

Leguminous plants

- They have the advantage of the ability to hold nitrogen in their structures, the nitrogen remains in the soil available for future crops.
- The C/N ratio of legumes is low, so that degradation occurs quickly once they are controlled and therefore fail to protect soil before other types of cover.

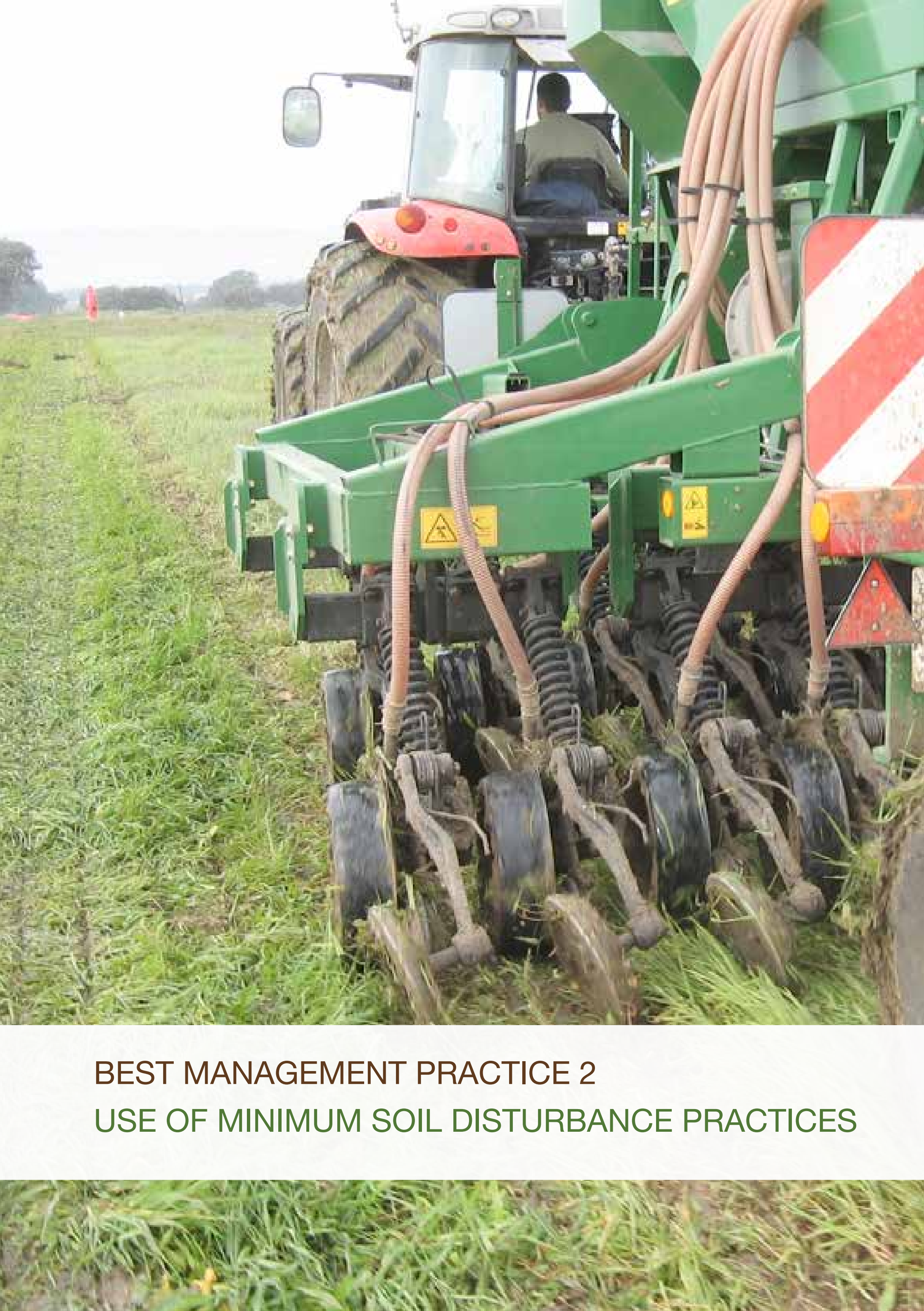
Cruciferous vegetables

- Its tap root can be useful for solving problems regarding deep soil compaction.

Influence of soil covers on mitigation and adaptation to climate change

One of the advantages obtained after the implementation of the ground cover is the “atmospheric improvement.” This signifies the positive effect that this agricultural technique has on climate change.

Agriculture can play an important role in mitigating emissions. Agricultural soils, if properly managed, can act as carbon sinks, mainly in the form of organic matter. The carbon input into the system is through photosynthesis, incorporating atmospheric carbon to the plant structure, thus any agricultural technique to increase these inputs, and/or decrease its return to the atmosphere, will increase the carbon stored in the soil, sequestering atmospheric CO_2 and as a result increasing its sink capacity.



BEST MANAGEMENT PRACTICE 2
USE OF MINIMUM SOIL DISTURBANCE PRACTICES

What it is meant by minimum soil disturbance?

The establishment of annual crops was made from the first steps of agriculture, through tilling of the soil surface. This process, which traditionally reached shallow levels within the soil profile, was intensified with industrial development and the arrival of powerful machinery to the agricultural world. The end result is less protected soil, which is vulnerable to erosion, leading to net soil loss, and nutrients leaching.

Minimum soil disturbance is one of the pillars on which Conservation Agriculture rests. It is to avoid, insofar as possible, mechanical soil disturbance for the development of agricultural activity.

For this purpose, it was developed the so-called direct seeding, which is an agricultural system that does not require the performance of any work to prepare the seed bed before seeding. This is made possible by machinery which has been developed to allow sowing on plant residues, although it is necessary to select the type of machine best suited to the conditions of each farm.

How do we carry out direct seeding?

In order to seed correctly, it is necessary to ensure that the combine adequately chops and distributes plant residues during the harvest of the preceding crop, because if they are left in a central cord, it will occur a lack of homogeneity that will adversely affect the seeding operation. It is therefore recommended that the combine harvester counts on residues chopper and spreader.

In the period between the harvesting of a crop and the seeding of the next one, the farm must be kept free of weeds, paying special attention to the control of unwanted vegetation in the period immediately prior to the seeding. Crop residues on the ground, coupled with proper crop rotation helps achieve this, although the use of herbicides is necessary in most cases. These products will always be used in accordance with authorised doses and only when conditions of the plot demand it.

Regarding fertilization, it is recommended to do it localized and simultaneously with sowing. The market offers direct seeding machinery incorporating the localized fertilization system.

To carry out the seeding, it is essential to have a drill adapted to the soil characteristics and the type and volume of residues on which the seeding takes place. To achieve a proper implantation of the seed on a soil covered with plant remains, row units count on several mechanisms. Usually, a direct seeder has:

- A row cleaner, consisting of toothed wheels which remove excess residue from the row.
- Furrow opener: single or double discs inclined with respect to the soil surface and to the forward direction, or hoe openers which act on the ground exerting vertical cutting.

- Seed firming element to fix seeds in the ground.
- Finally, to close the furrow, closing wheels are placed at the end of the row unit.

During the development of the crop, if necessary, they can be applied selective herbicides (authorized for the crop and at authorized dose) to control weeds.

If the crop requires top dressing fertilization during its development, it will be carried out following the same pattern as in conventional agriculture.

What are the advantages of direct seeding?

Direct seeding has direct implications for sustaining soil structure, reducing vulnerability to erosion that occurs when plowing. But the reduction in the loss of soil and nutrients are not the only advantages of implementing these techniques. By reducing/suppressing the number of tillage operations and therefore using less machinery, the farmer decreases fuel costs, increasing the economic efficiency of agricultural activity. In addition, soil compaction phenomena decrease due to the reduction of agricultural works.

Biodiversity also improves when systems on which mechanical disturbance of soil is reduced are used. The no soil disturbance allows edaphic fauna to be more diverse and the food chain to be more complex. This is particularly relevant for soil quality, as these organisms cause its aeration and promote water infiltration. But its greatest advantage is the work of decomposing crop residues, releasing nutrients to the soil.

As mentioned above, the implementation of direct seeding practices on agricultural land, usually carries with the maintenance of the cover remains of the previous year's harvest during the crop growth. This is because of the sowing process, which barely interferes with the crop residue remains which are deposited on the surface. Therefore, beneficial effects on soil nutrients, moisture, biomass and biodiversity provided by the soil cover are in addition to the ones provided by direct seeding. The combination of both practices has a synergistic effect, whereby its effects are enhanced, resulting in a greater benefit for the farmer and the environment that if independently developed.

Influence of tillage on mitigation and adaptation to climate change

Historically, intensive tillage of agricultural land has caused substantial losses (from 30% to 50%) of soil carbon. These carbon losses are due to soil fragmentation caused by tillage which facilitates the biological activity, resulting in the exchange of CO_2 and O_2 soil with the atmosphere and vice versa. The operations of traditional agriculture (inversion tilling with mouldboard or disc plough, disc harrow or rotovator) bury plant residues and left the soil in an optimal condition for CO_2 losses to occur, while reducing the sink effect of soil.

By reducing the work on the ground, there is less exposure of soil aggregates into the atmosphere, which reduces the weathering of organic compounds and maintains higher moisture, which in turn promotes microbial activity. Both processes tend to increase the concentration of organic carbon in the soil reducing the volume of CO_2 released into the atmosphere.

The implementation of direct seeding or no tillage practices, brings benefits not only limited to the farmer, but also has major implications on an environmental level. The use of these techniques reduces the emission of greenhouse gases (GHGs) by agricultural machinery, due to less use of it. In addition, by not carrying out the process of tilling the soil, the gas exchange between soil and atmosphere is impeded and carbon is stored in the soil.

BEST MANAGEMENT PRACTICE 3

PERFORM SUITABLE CROP ROTATION/DIVERSIFICATION

What are crop rotations?

Crop rotation is the successive planting of different crops on the same land, following a defined order. This concept is opposed to monoculture, which consists of repeated planting of the same species in the same field year after year.

What are the problems with monoculture?

When a rotation is not established, an increase in the problems arising from specific pests and crop diseases become evident overtime, because the organisms that cause them remain stable in a habitat that favors their development.

Additionally, species thrive on those weeds whose cycle is adapted to the conditions of exploitation (timing of plant protection products)

Another problem mentioned is the depletion of nutrients extracted to a greater extent by the crop, since there will always be the same crop, it systematically extracts the same nutrients and from the same depths. As a result, the roots will encounter difficulties in their development and production will be affected.

What are the advantages of crop rotations?

The introduction of appropriate crop rotations brings a number of improvements which result in increased yields:

- Reduces the incidence of pests and diseases: changing the crop means a change of habitat, so the life cycles of pests and diseases are interrupted.
- Weeds can be kept under control by using asphyxiating crop species, via cover crops, which are used as green manure, or by sowing winter crops when it is allowed by temperature conditions, soil moisture or irrigation.
- Provides a more appropriate distribution of nutrients in the soil profile (crops which are more deeply rooted extract nutrients at a greater depth).
- Helps reduce economic risk, if any eventualities occur affecting any of the crops.
- Allows regulation of the amount of crop residues, since they can be alternated crops that produce negligible residues, with others that generate an abundance of them.

Recommendations for carrying out crop rotations:

- It is recommended to alternate the most demanding species of inputs with less demanding species, or even species which improve soil (enriching and increasing its fertility, as with legumes).

- Crops with different root systems must be alternated to explore and extract water and nutrients from different soil layers.

- If a fallow season is included in the rotation, during this time it is advisable to introduce a legume in order to protect the soil against erosion and improve soil fertility.

Influence of this management practice on mitigation and adaptation to climate change

The introduction of crop rotations has a beneficial effect on mitigation of climate change, given that it significantly improves the control of weeds, pests and diseases, the number of treatments and/or doses of them will be reduced. This optimization in the use of products ensures lower energy consumption derived from their production and a decrease in fuel consumption required for their application in the plot.

Moreover, this practice is also helpful for the adaptation to climate change, since it will allow the implementation of crops with different cycles and characteristics adapted to climatic conditions as the climate evolves.

BEST MANAGEMENT PRACTICE 4
OPTIMIZATION IN THE USE OF AGROCHEMICALS

What is the optimal use of agrochemicals?

Optimizing the use of agrochemicals is not just about using the necessary active ingredients at the right time and dose, but also using equipment which are in optimum conditions of maintenance and calibration (a subject which will be covered in Best Management Practice 5). It is a concept in line with the management of pesticides and fertilizers developed through integrated production. This practice contrasts with the carrying out of applications, year after year, using the same products, with the same dose and the same date of application, regardless of the real needs of the crop.

What problems are presented with the conventional application of agrochemicals?

The inappropriate use of agrochemicals creates serious problems both on the farm where they are applied and beyond. The use of excess fertilizer, not applying what the crop really needs, the use of excessive doses of herbicides, fungicides and pesticides and implementing applications at inappropriate times, causes not only an important economic decline in the farm (more product is being used than necessary and, if used outside of the right time, will not be as effective as it should), but can also cause environmental problems, since these products can be harmful to the environment if used improperly.

What are the advantages of optimizing the use of agrochemicals?

The benefits achieved through the implementation of this practice are not only for the farm but it also positively affects to the environmental surrounding of the agrosystems.

- Cost reduction regarding agrochemicals in general, because dose to be applied can be reduced by knowing the exact demand of the crop and the optimal time and application conditions.

- Increased production of crops by improving their nutritional and health status.

- Increased economic benefits on farms by reducing their production costs and increasing revenue from the sale of the harvest.

- Reduction of diffuse pollution of water because there is no loss of products due to a misuse in the application.

- Reduction of nitrous oxide emissions as a consequence of volatilization associated with misuse of fertilizer.

- Increase of auxiliary soil fauna due to the use of fungicides and pesticides only when needed and with the right dose.

Recommendations for optimum performance in the use of agrochemicals

- It is convenient not only to have an empirical knowledge of the farm by knowing which are richer and more productive soils, often waterlogged areas, etc., but we must also rely on soil analysis which would allow us to know the actual variability of the farm and its physico-chemical conditions.

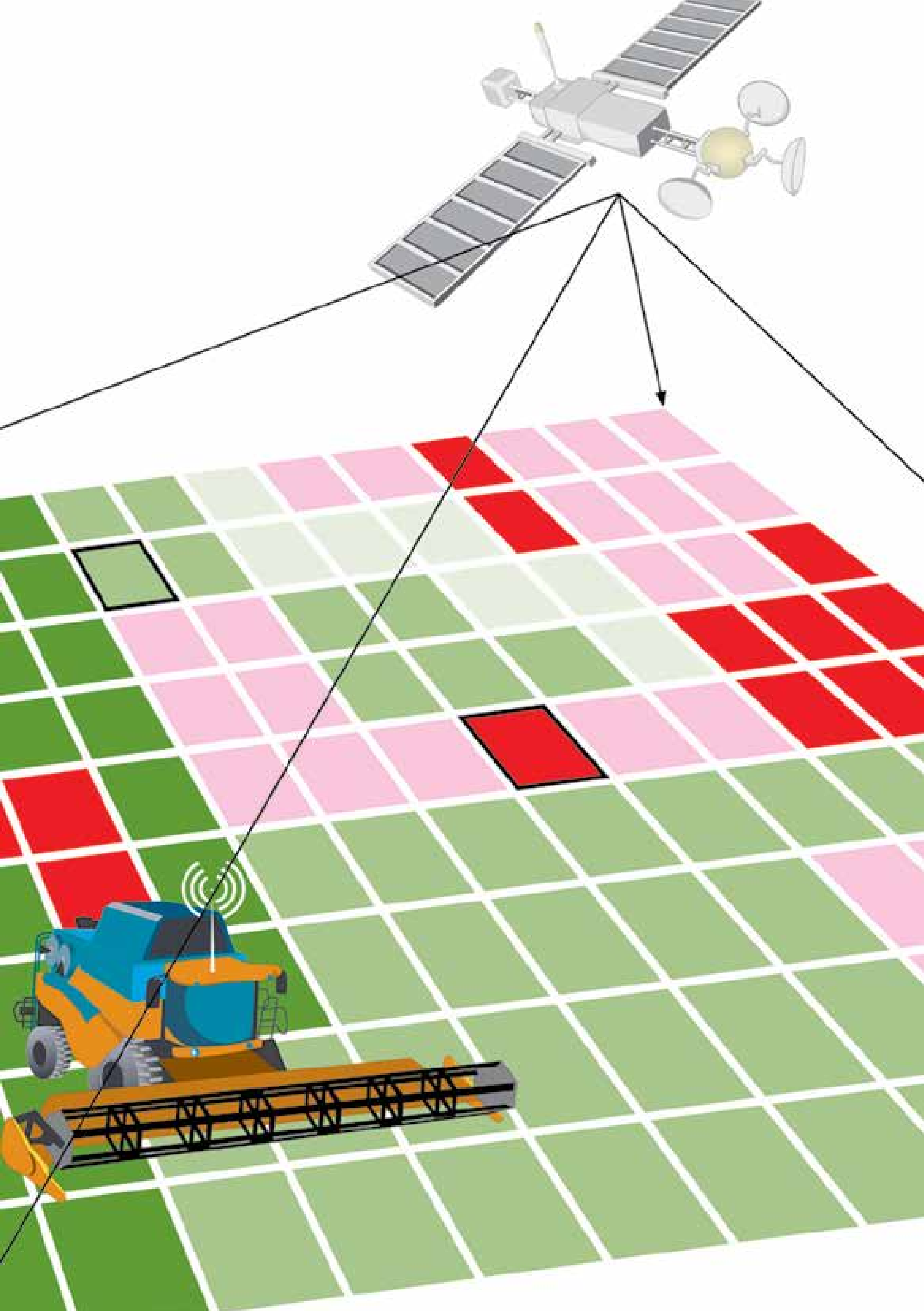
- Making harvest maps that, each year, allows the farmer to know the productive variability of the farm to try to deduce the reason (soil conditions, crop type, weather, etc.) and correct existing problems in areas of lower productivity.

- Use of decision support systems that, based on all the data collected annually –soil analysis, harvest maps, rainfall, etc.–, can help farmers to make decisions and optimize crop management and use of agrochemicals.

Influence of optimizing the use of agrochemicals on mitigation and adaptation to climate change

The application of these techniques has a direct influence on the mitigation of climate change in two ways:

- Reduction of superfluous nitrous oxide emissions by reducing volatilization processes of fertilizers and improving its field application.
- Reduction in the energy consumption of farms due to the reduced use of agrochemicals, and therefore the consequent reduction of GHGs in the manufacturing process.



BEST MANAGEMENT PRACTICE 5

APPROPRIATE MANAGEMENT OF AGROCHEMICAL PRODUCTS

What is the appropriate management of agrochemical products?

Agrochemicals are one of the essential tools needed to maintain the production of crops at a level capable of feeding a constantly increasing world population. However, improper use can cause a significant decline in the profitability of farms and serious problems regarding environmental pollution and loss of biodiversity.

To avoid these issues, equipment to be used must be in a correct state of calibration and maintenance. At the same time the use of these products should not be done in those areas and periods which may cause contamination, as described below:

1. **Calibration and maintenance of agrochemical application equipment**

   There are basically two types of machines: Fertilizer spreaders and pesticide application equipment (sprayers for application in soil and crops, and mistblowers for tree crowns). Fertilizer spreaders have no specific maintenance other than the correct state of the distribution system (final distributor in pendulum spreaders and disc paddles –which have a specific position for each type of fertilizer to ensure its correct distribution on the ground- in disc spreaders. Regarding pesticide application equipment, it must meet the requirements imposed by Directive 2009/128/EC on the inspection of equipment in use. Among the actions to be taken into account it is worth highlighting:

- Care and maintenance of nozzles: It is advisable to change them annually and, if possible, use anti-drift nozzles.
- Manometer: Ensure that it is in proper operating condition and that the scale range is adequate.

2. Basic rules for the use of plant protection products

- With regards to fertilizers it is to be initially taking into account the location of the farm, because if it is included in a vulnerable area to pollution by nitrates, there are specific restrictions on the use of nitrogen.
- In the case of a fertilization before a rain, there should be used products that are not mobile in the water, the use of nitrates is inadvisable because they can cause leaching problems and contamination of aquifers.
- In the opposite case, if it is necessary to apply fertilizers and no rain is expected, the use of urea is not recommended because it is very volatile and high losses due to emission to the atmosphere will happen.
- The use of both fertilizers and plant protection products must be avoided in the vicinity of watercourses even if they are temporary, like streambeds.
- The use of plant protection products should always be conditioned by the existence of auxiliary fauna. For example, in the

case of hives in the farm, use of hormonal herbicides against broad-leaved weeds must take place at sunset, off-peak period of bees.

- Finally, the use of any product before heavy rain is inadvisable.

3. Management of containers

Another point to consider in reference to agrochemicals is the containers management. According to current legislation (Directive 2009/128 / EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides), they must be rinsed after use and stored in an appropriate place for collection by authorized companies, for further processing or delivery.

What problems can occur due to the improper handling of agrochemicals?

Agrochemicals which are used improperly can cause environmental problems and can be financially detrimental to farmers:

Environmental problems

They can derived from the following issues:

- Incorrect distribution of products due not to maintain equipment in proper working order. In many cases although the total quantity of product applied is correct, its distribution within the plot is incorrect, concentrating the product in some areas (which prevents its degradation over time and desirable manner) and eliminating application in other. This is common when it is not performed a proper maintenance of the application

nozzles the paddles of the fertilizer spreader are not correctly positioned.

- It is also essential to make a proper handling and storage of pesticides and fertilizers and their packaging and remains. Not to do so may result in the appearance of source point of contamination by these products.

Financial loss

- When treatment is not correctly performed, the efficacy of the product is not as expected, what means that the incurred expense will not have the desired impact in yields. This will produce a decline in the farm revenue.

What are the advantages of proper handling of agrochemicals?

The benefits achieved through the implementation of this practice are not only for the farm but it also positively affects to the environmental surrounding of the agrosystems.

- Cost reduction regarding agrochemicals in general, because dose to be applied can be reduced by knowing the exact demand of the crop and the optimal time and application conditions.

- Increased production of crops by improving their nutritional and health status.

- Increased economic benefits on farms by reducing their production costs and increasing revenue from the sale of the harvest.

- Reduction of diffuse pollution of water because there is no loss of products due to a misuse in the application neither contamination due to an incorrect handling of containers.

- Reduction of nitrous oxide emissions as a consequence of volatilization associated with misuse of fertilizer.

Recommendations for carrying out proper management of agrochemicals

1. Many of the equipment for the application of pesticides do not comply with the requirements imposed by legislation, so it is useful to ask manufacturers for proof that their machines comply with the regulations.

2. Change application nozzles annually, and whenever possible it is advisable to use anti-drift nozzles.

3. Manometers are very sensitive instruments and need periodic calibration, although this is difficult to do. So because of their low cost, it is advisable to change them every three years.

4. Never use pesticides/fertilizers before heavy rains and even less close to water streams.

5. In order to favor proper distribution of fertilizers it is recommended to check that the pellets' size is homogeneous and stable.

Influence of a proper handling of agrochemicals on mitigation and adaptation to climate change

The application of these practice has a direct influence on the mitigation of climate change in two ways:

1. Reduction of superfluous nitrous oxide emissions by reducing volatilization processes of fertilizers and improving its field application.

2. Reduction in the energy consumption of farms due to the reduced use of agrochemicals, and therefore the consequent reduction of GHGs in the manufacturing process.

BEST MANAGEMENT PRACTICE 6

USE OF ADVANCED TECHNOLOGY

How are advanced technologies used?

Numerous technological advances are available today that allow farmers to optimize the management of their farms, although their use is not yet widespread. GPS-guided tractors is the first step in these technologies, which makes it possible to perform operations with great precision, avoiding overlaps or untreated areas. There are other technologies at a higher level, which have revolutionized the decision making process and the possibilities to carry out farming operations. So, information and communications technology (ICT) supported by a network of sensors located in the farm, in the machinery, or in other items such as unmanned platforms “drones” and even satellites, can generate a lot of knowledge about meteorology and characteristics of the farm: the variability of types of soil, harvest maps and the quality, nutritional status and water status of the crop, etc.

With this information and supported by specific for agriculture Geographic Information Systems (GIS), they can be obtained recommendations for the carrying out of field operations. The decisions are based on the generation of a large amount of information from the farm during several seasons, what allows the farmer to have accurate knowledge, based on no empirical but real data, for example, of the soil type distribution of the farm, its physical and chemical conditions, the most productive areas or the variability of yields.

With this information they can be produced maps of harvest, soil types, moisture, weeds, etc., which will serve as a basis for prescription maps for treatments, such as fertilization or herbicide applications, which are the most common.

As an alternative to this system, they can be used real-time sensors that measure the desired parameters, perform the relevant calculations and act on the machinery without intervention of the driver. These systems are less accurate but faster and cheaper. They normally use sensors which rely on NIR technology and they measure, for example, the nutritional state of the crop and calculate the amount of fertilizer to apply based on its state. They can also be used to detect weeds in real time and perform site-specific treatments only where they are.

What problems are presented with conventional agricultural management?

Conventional agriculture, as a general rule, is based on empirical knowledge, in the mere observation of the farmer. Generally, the same dose of product is applied to all the surface, regardless of soil fertility, crop requirements and climatic conditions. This causes the efficiency in the use of plant protection products to be low, often below 50%, which results in not only a decline in the profitability of farms due to loss of products and yield (since the desired effect from products used is not obtained), but also in a risk of environmental pollution. The product is not absorbed by plants which typically creates some potential pollution.

What are the advantages of using advanced technologies?

- Better knowledge of the farmer of his own farm and better ability to make decisions.
- Optimization of the use of inputs.

- Better vegetative state of crops and therefore increased production.
- Increase the economic benefits of the farm.
- Reduction in the agriculture environmental footprint.

Recommendations for use of advanced technologies

- It is recommended to perform soil analysis of the farm. The number of samples may vary, but very homogeneous large farms, a sample every 5-10 hectares may be sufficient whereas in small or very heterogeneous farms, this should be done every 1-2 hectares.

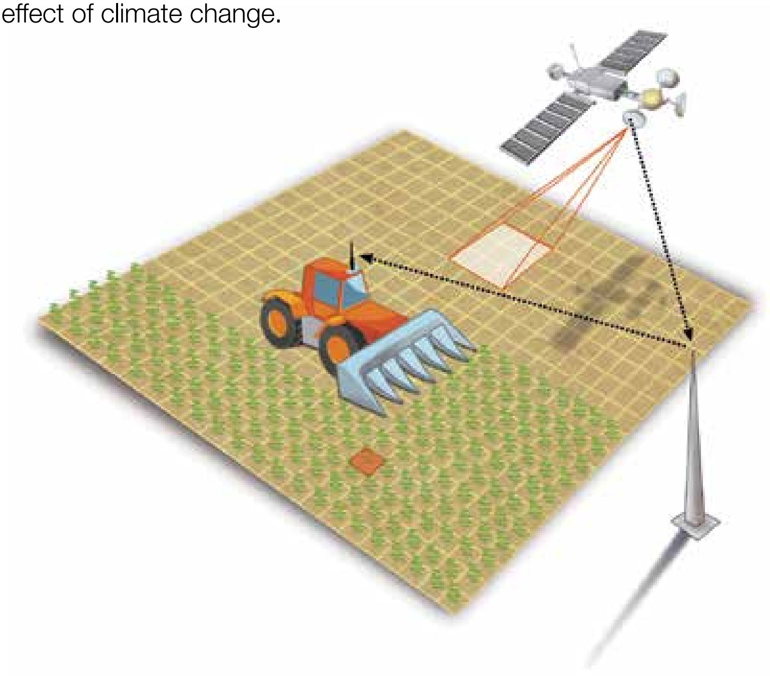
- In order to start seeing reliable results of the information obtained by harvesting, soil and moisture maps, it is recommended to have at least 3 crop seasons, even more if weather conditions are changeable or if crop rotation is carried out.
- Prior training in these sensors and technologies is advisable, in order to get the most out of them.

- If possible, it is advisable to start using these techniques with the support of a company which provides services or technical specialists in the area.

Effect of the use of advanced technologies for mitigation and adaptation to climate change

These technologies, like any other aimed at improving the use of plant protection products, has a dual effect on mitigating climate change by reducing GHG emissions both by decreasing energy needed to grow crops as by a lower volatilization of fertilizers.

Regarding adaptation to climate change, the introduction of new technologies will allow to perform treatments and provide the necessary inputs to crops based on their actual needs, which can vary due to the effect of climate change.



BEST MANAGEMENT PRACTICE 7
IMPLEMENTATION OF REGULATED DEFICIT IRRIGATION STRATEGIES

What is regulated deficit irrigation?

Deficit irrigation strategy means to reduce the total irrigation water supply to the crop in certain periods of low sensitivity to water deficit, reducing water consumption, without producing significant yield losses.

What are the advantages of regulated deficit irrigation?

Regulated deficit irrigation manages to improve water use efficiency by crops, reducing, in addition, water losses from surface runoff or deep percolation. In the case of crops such as cotton, applying irrigation below the optimum, does not lead to significant drops in yield, improving water productivity, which helps to ensure the sustainability of farms.

Recommendations for carrying out the deficit irrigation

Proper implementation of deficit irrigation strategies requires a comprehensive climatic, physical and agronomic characterization. Thus, to determine the irrigation needs of crops, an analysis of the weather conditions of the area will be necessary. This analysis will reveal the reference evapotranspiration (ET_o), a key instrument for the implementation of irrigation scheduling. On the other hand, the phenological cycle of the crop under study is critical, because it will determine the sensitive and non-sensitive periods to heat and water stress. For example, in the case of maize, the blooming phase is the most sensitive to water stress, resulting in reductions of aerial dry mass, yield and harvest index. However, in experiments on deficit irrigation at grain filling stage, growth and grain yield have not been significantly affected. In the case of sugar beet, it has been found that a greater efficiency in the use of water can be achieved, without significantly decreasing the production of sugar or the industrial quality by applying water at the end of the cycle. To carry out this characterization work, the use of simulation models and remote sensor techniques that enable accurate local characterization is recommended.

Scheduling deficit irrigation strategies also requires the development of specific studies for each crop. It is important to determine the water stress that is being generated to the crop in order to prevent moderate and potentially beneficial water deficit from becoming too severe.It is also necessary to have previous experience in the area and crop, to determine the impact of deficit irrigation on the farm. To this end, it is necessary to have tools available to evaluate the water status of the soil and the plant. Therefore, it is recommended to perform pre local level experimentations of deficit irrigation strategies. Obviously the implemen-

tation of these experimental activities should be promoted by research organizations, although the collaboration of farmers and technicians is also essential.

In recent years, advances in irrigation management and support systems, have contributed to the development of tools for monitoring crops and determining deficit irrigation schedules. For example, one of the partners of this project, the Institute for Agricultural and Fisheries Research and Training of the Andalusian Government (IFAPA), is currently developing an advice platform to irrigators. This tool enables to monitor the crop in real time, detecting incidents such as water stress, low irrigation uniformity or improper handling, by combining simulation models and remote sensing techniques.

Influence of this farming practice on mitigation and adaptation to climate change

The implementation of deficit irrigation strategies is a measure of adaptation to the expected decrease in water resources resulting from climate change. Cultivation systems must be adapted to this limitation, carrying out a reduction of water consumption without significantly affecting yields. This will imply a significant increase in irrigation water productivity, improving the sustainability of agricultural systems.

BEST MANAGEMENT PRACTICE 8

JOINT CONSIDERATION OF OPTIMISED AGRICULTURAL, TECHNICAL AND FINANCIAL PRACTICES TO IMPROVE IRRIGATION WATER MANAGEMENT

What is this management practice?

Given the growing limitations on the use of water resources for agriculture, it is essential to have a detailed knowledge of agricultural systems, so that proper irrigation management can be carried out. This type of knowledge is often not accessible to farmers, resulting in irrigation management which is performed without adequate information about crop conditions, soil or irrigation systems. In recent years, the implementation of public and private advisory services to irrigators is helping farmers and technicians to better meet the needs of their farms, making it possible to apply water in a timely way and correct amount and, consequently, saving water and energy resources. These advisory services should serve as transmitters of knowledge generated by research organizations to the end user. The aim of this agricultural practice is to provide the farmer with a series of agronomic, technical and economic recommendations to ensure proper use of resources in order to make their management more efficient.

What are the recommendations for efficient irrigation water management?

Factors such as the availability of water (based on time and volume), the irrigation method or the reliability of water supply, are key concepts to irrigation scheduling which are frequently omitted. This omission creates significant imbalances between irrigation demand and volume applied. This can lead to severe water stresses or over irrigation, which reduces crop yield or causes significant water losses through deep percolation and/or runoff.

Further critical factors to take into account for efficient irrigation management, is the correct design of irrigation systems. Choosing the right system (depending on the crop, soil characteristics, weather conditions, water quality and availability) and the irrigation management are other components that are often not considered.

Should equally be considered a prior scheduling of the agronomical practices to develop in the farm (such as early seeding and harvest or soil management), what would enable significant improvements in the efficient use of resources. In fact, an advance of the date of seeding of various crops would avoid carrying out irrigation during drier periods of the cycle (at the end of spring or summer), consequently saving water. In the opposite case, if winter or early spring are dry, bringing forward the irrigation season, prevents stresses that create significant limitations on the vegetative development of crops. Nevertheless, the planning of irrigation scheduling is sometimes restricted by the basin management authorities, which limit the application of irrigation in certain periods.

For those irrigated areas where traditional water resources are very limited, the use of alternative resources is recommended, such as underground water or reclaimed wastewater. However the consideration of these resources is not always easy, requiring specific tools to determine their optimal management in the most efficient possible way.

An additional recommendation is to consider the irrigable area (in addition to the plot) as the management unit. Thus, the overall irrigation efficiency is significantly improved when managing irrigation comprehensively for all crops and plots of the irrigated area, seeking to maximize the overall benefit of the whole zone.

Influence of this management practice on mitigation and adaptation to climate change

The implementation of these recommendations has a beneficial effect on adaptation to climate change, given that, with a more efficient management of resources, decreased water consumption with regards to irrigation is achieved. This is essential to make more sustainable agricultural systems and adapt them to future restrictions. Moreover, reducing the volume of irrigation also contributes to the mitigation of climate change, as it means less energy consumption is required for application on the plot.

BEST MANAGEMENT PRACTICE 9

IMPLEMENTATION OF MULTIFUNCIONAL MARGINS AND RETENTION STRUCTURES

What are multifunctional margins?

Multifunctional margins are vegetation strips that are introduced on farms whose main objective is the formation of infiltration zones and the retention of the flow of runoff water.

These margins are considered as an infrastructure measure within a basin, and is a highly recommended measure to reduce soil loss by erosion and reduce the amount of water lost in the farm.

What are the advantages of the introduction of multifunctional margins?

The introduction of multifunctional margins involves a number of environmental benefits that increase the sustainability of farms. The most significant advantages of the implementation of this measure are:

- Decrease of the energy of runoff water flow.
- Creation of zones of surface water infiltration.
- To provide habitats for increased biodiversity.
- Reduction of waterways pollution due to sediment from erosion.

How to carry out the implementation of margins?

Due to the complexity and variability of the factors that control the effectiveness of a security strip, recommendations for the location and size of these infrastructures must be based on an assessment of the needs

of each farm. It is recommended that this analysis is developed at basin level, since the benefits provided by the implementation of this measure will be enhanced.

To decide the location of these strips it must be taken into account the flow of surface water in the basin in which the farm is located. These areas will vary in length and size depending on the characteristics of the area on which they operate. They must be preferably placed close to the source of the runoff problems, in the high part of farms, and on the water banks, both perennial and seasonal.

Proper positioning of these vegetation strips is much more important than their width.

To implement this measure it is necessary to first decide the type of vegetation. Different types of margin strips can be established:

- Herbaceous.
- Woody.
- Combination of woody and herbaceous.

Water infiltration is better in areas planted with woody vegetation, as the root system of trees increase soil porosity. Herbaceous, densely vegetated strips are more efficient to reduce velocity of surface water flow, thereby improving the capture of the particles from eroded soil. Combinations of both systems increases the efficiency of these measures. The selection of plant species for buffer strips of vegetation must take into account the characteristics of the area and the contribution to increased biodiversity this may involve, being recommended the use of non-invasive and easy to manage native species.

It is necessary to seed the margin strip at the beginning of the season, so that the germination of selected species occurs before the emergence of weeds, which can cause more problems in controlling it. Also, if species selected for the margin are annual, their mechanical control should be performed once they are fully developed, to ensure the availability of the seed bank of the selected species for the next season. The cycle of the selected vegetation must be such that it is controlled at the beginning of the season of increase of temperature and decrease of precipitations, in order to avoid fire risks and minimize the likelihood of having to perform more than one mechanical control because of regrowth of vegetation.

In order for adequate effectiveness of these areas, it is necessary to avoid soil compaction. The use of machinery should be limited, by not being used as pathways between plots of the farm. The use of these areas as grazing lands can be an alternative to mechanical control, provided that the access of excessive livestock is avoided, as this may lead to compaction problems. The margins should not be fertilized or treated with pesticides.

Where can the multifunctional margins be placed?

The most suitable places for the implementation of these margins are:

- The boundaries between plots, whose purpose is to intercept the possible runoff from adjacent plots.
- In the side of the paths of the farm.
- Along banks of rivers and streams, preventing water runoff which can cause contamination by pesticides draining directly into the channels.

- In the stream beds, where runoff flows are concentrated, it is kept from increasing the current velocity.
- In areas of water concentration, in order to promote natural infiltration.

Influence of this management practice on mitigation and adaptation to climate change

The implantation of multifunctional margins has a beneficial effect on the mitigation of climate change, given that they are areas where no tillage operations are carried out and, consequently, the CO_2 emissions that occur when performing work are eliminated. Also, by establishing this zones, there is a reduction of emissions from the use of inputs, since machinery traffic and its corresponding fuel consumption and the application of fertilizers or plant protection products is suppressed or greatly reduced.

Additionally, the increase of biomass due to the vegetation in multifunctional margins also increases the CO_2 in these areas, what contributes to climate change mitigation.

BUENA PRÁCTICA AGRARIA 10

MEASURES FOR THE PROMOTION OF BIODIVERSITY

What is biodiversity?

Biodiversity is defined as the variety of animal and plant species in their environment.

How does agriculture affect biodiversity?

Agriculture, like any other human activity has an impact on the environment since natural resources are used and natural space is occupied. With the intensification of agriculture the impact on ecosystems has been increasing, threatening biodiversity due to the transformation of ecosystems.

What are measures for the promotion of biodiversity?

They are practices that are carried out in order to improve the biodiversity of the farm mainly by improving habitats.

- Maintenance and implementation of edges between plots with various plant species in order to improve/provide habitats for auxiliary fauna (mainly invertebrates).
- Maintenance of walls, heaps or structures made of stones without mortar that provide shelter for small vertebrates (reptiles and small mammals).
- Maintenance and vegetal restoration of slopes and gullies.
- Creating copses-island in unproductive or very steep areas.

How to make improvements in habitats?

The establishment of a vegetative cover at the edges of the plots, especially in borders and close to waterways, acts as a security zone in plant protection products applications and as habitat for species.

The walls and heaps of stones that are often present on farms as borders or as a consequence of the de-stoning of the plots, act as wildlife habitat especially for small vertebrates. The maintenance of these structures creates a permanent shelter.

The slopes and gullies have their surface often unprotected, what increases their instability and erosion risk. Maintaining a vegetative cover, both herbaceous and bushy, in addition to significantly reduce erosion, will provide shelter for auxiliary species.

Likewise, the introduction of copses-island or natural vegetation patches in steep and/or unproductive areas improves the ecosystem.

Influence of this best management practice on mitigation and adaptation to climate change

Maintaining areas with permanent vegetation cover fix atmospheric carbon in the biomass, increasing the content of soil organic matter.

The increase and / or conservation of genetic variability in ecosystems improve its ability to adapt to changes (resilience). A more diverse ecosystem is more stable and can better withstand environmental stress.

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With the contribution of the LIFE financial instrument of the European Community

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