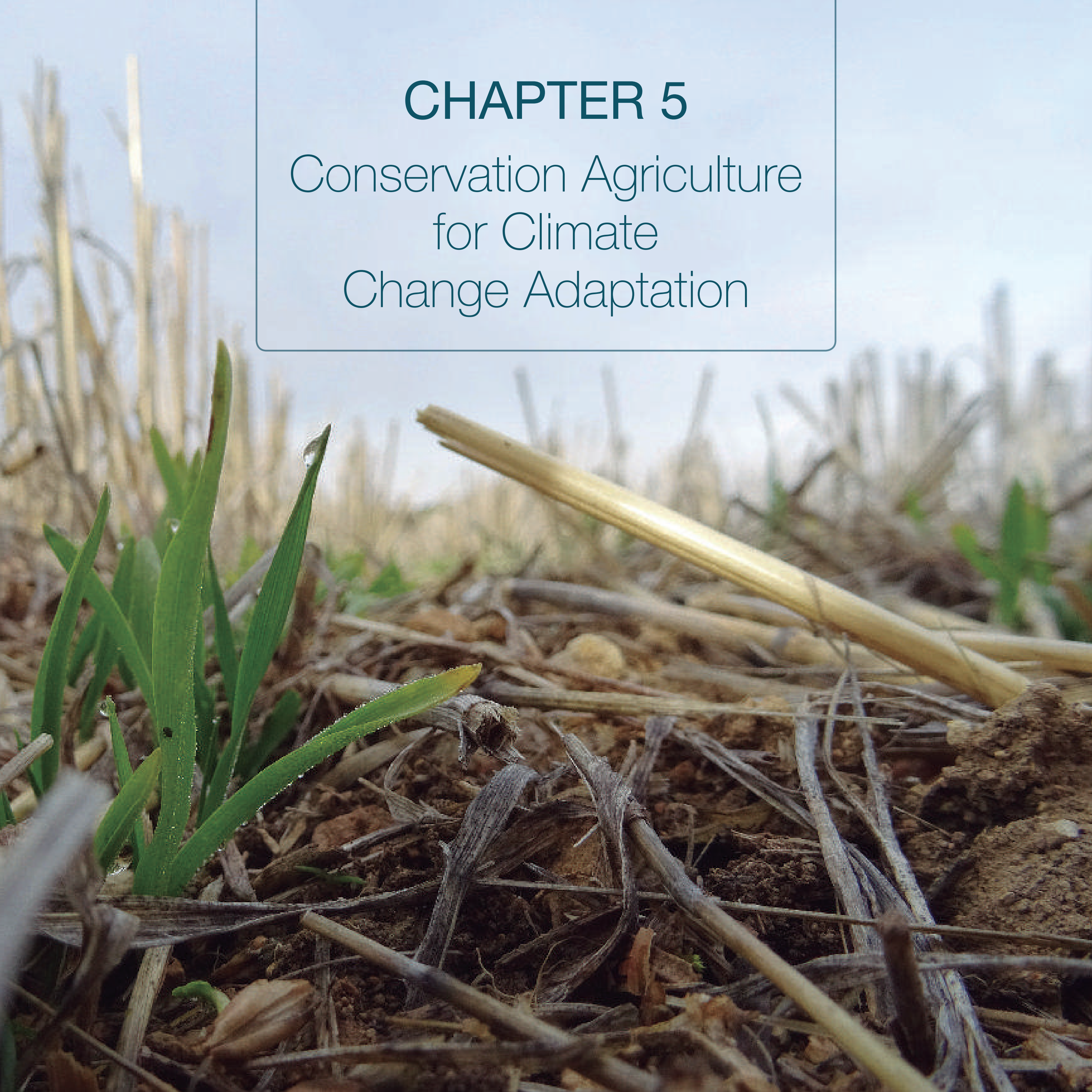
CHAPTER 5
Conservation Agriculture for Climate Change Adaptation



5.1. Introduction

As described in previous chapters, climate change impacts on all types of ecosystems, especially on the agricultural ones. In addition to the environmental consequences that this phenomenon generates, it has a great influence on the economic and social areas, taking into account the great interrelation they have with human activities.

Therefore, it is not only important to adopt strategies to mitigate phenomena which increase climate change, but it is also necessary to adopt practices which increase the resilience of agricultural ecosystems to reduce their vulnerability to the potential consequences of global warming, favouring the adaptation of crops to new climatic scenarios.

The term "adaptation" refers to all adjustments that need to be made in a system (in our case, in the agricultural system) to better respond to actual or anticipated changes resulting from climate change, and taking advantage of the opportunities given by the new climatic scenarios.

Farmers, in their daily work, have always had to make decisions to adapt their crops to the changing weather conditions that can occur in different seasons. So far, these decisions have been based on the *crop pattern alteration* or changes in crop management, but it seems that these measures will not be enough to face the expected short and medium term impacts, which are the consequences that climate change will have on agricultural ecosystems.

The adaptation strategies must be related to the expected changes according to the considered agroclimatic region, because the measures that can be adopted in a region of continental climate will be completely different from those adopted in a region with a subarctic climate. Adaptation means looking for strategies at the local level to respond to a global problem. The areas in which such strategies can be encompassed in the agricultural sector range from the means of agricultural and livestock production, market structure, risk assessment of climate change in the farm or the space related to the public support instruments.

Previous chapters have already cited the regional consequences of climate change in agro-climatic regions and the risks that this will have on agricultural ecosystems. In the present chapter, an analysis of these effects will be carried out taking into account the climate phenomenon and the solutions to some of these effects will be provided by Conservation Agriculture.

5.2. Key factors for adaptation of agricultural ecosystems to climate change: increased resilience

The options for adapting crops to the scenarios caused by climate change will increase the resilience of the ecosystems in which they are developing. The term "resilience" refers to the responsiveness of the medium to a disturbing agent or a harmful condition, minimizing the impact of such a situation and adapting to it.

In order to establish the premises for adaptation strategies based on increasing resilience of agricultural ecosystems, the effects of climate change on these ecosystems and the climate phenomenon that causes those effects must be identified first, because the measures which should be adopted have to respond effectively to those changes. The ways to respond could be, either mitigating them directly, or creating a response in the environment and natural resources on which it depends, counteracting the negative effects.

Table 5.1 summarizes the main expected effects on the agricultural ecosystems of the different phenomena of climate change, in each of the factors involved in agricultural production.

Table 5.1. Main effects of climate change on the factors involved in agricultural production. Source: *UNEP/Grid-Arendal and The Spanish Ministry of Agriculture, Food and Environment (MAGRAMA, 2009).*

CLIMATE PHENOMENON	CROPS	WATER RESOURCES	SOIL	AIR
TEMPERATURE CHANGE	Increased production in colder environments Decreased production in warmer environments Increased incidence of pests	Reduction of water supply	Increased soil temperature in warmer environments	Increased evapotranspiration demand in warmer environments
HEAT WAVES / HOT PERIODS	Reduction of production in hot regions Increased fire risk	Increased demand for water	Reduction in moisture content in the soil profile Release into the atmosphere of carbon stored in the soil	Increased evapotranspirative demand
EVENTS OF HEAVY PRECIPITATION	Damage to crops Cultivation difficulties because of waterlogging	Adverse effects on surface and ground water quality Pollution of water supplies	Increased erosion Reduction in organic matter content	
DROUGHT	Crop damage and loss Increased fire risk	More widespread water stress	Soil degradation Increased erosion Reduction in organic matter content Release into the atmosphere of carbon stored in the soil	Increased evapotranspirative demand
CYCLONES AND CYCLONIC SEASONS	Crop damage and loss		Soil degradation Increased erosion Reduction in organic matter content	

Taking into account the expected effects, it is possible to undertake various actions aimed at improving the quality of natural resources and biodiversity, which will result in an increase in the resilience of agricultural ecosystems, improving adaptation of crops to climate change (Table 5.2). In many cases, as will be seen a posteriori, many of these actions can be carried out implementing Conservation Agriculture practices, thus constituting not only a feasible tool to mitigate the effects of climate change, as described in the previous chapter, but also, as a measure of adaptation to its effects.

Table 5.2. Possible actions to increase resilience of agrarian ecosystems and agricultural techniques whose application involves adaptation of these actions. Source: Own elaboration.

Natural Resource	Actions to increase resilience	Agricultural techniques
WATER	Increased infiltration Reduced runoff Optimization of water use Improvement of soil water balance	Conservation Agriculture Deficit irrigation Precision farming Improvement of irrigation infrastructures and pipelines Use of irrigation monitoring systems Implantation of green filters, buffer strips, vegetation in the margins of the plot (multi-functional margins)
SOIL	Reduced runoff Increase in organic carbon (organic matter) Improvement of structure Increased soil fertility	Conservation Agriculture High flotation tires Soil health cards
BIODIVERSITY	Increase in the epigeal fauna Improvement of conditions for the habitability of steppe birds Increase in pollinating species	Conservation Agriculture Use of integrated fighting Implantation of green filters, buffer strips, vegetation in the margins of the plot (multi-functional margins)
CROPS	Increased resistance to drought Escape from water stress Reduction of weed invasion Reduced incidence of pests and diseases	Crop rotation Use of varieties resistant to drought Advancement of planting date Use of native varieties Crop cycle variation Use of integrated fighting

5.3. Conservation Agriculture: basis for crops adaptation to climate change

According to *Lal (2010),* Conservation Agriculture is a good strategy not only to mitigate climate change, but also to adapt agricultural ecosystems to their effects, by increasing crop resilience facing climatic variations. Thanks to its implantation, erosion is reduced, the quality and fertility of the soil is improved and the erosion is reduced, allowing the crop to have more water in dry periods. All this makes the responsiveness to climate changes greater and therefore crops under Conservation Agriculture systems have a better capacity of adaptation.

5.4. Conservation Agriculture and water resource improvement

As water is a scarce and in many cases a limiting resource, it is fundamental to manage the agricultural production system (Fig. 5.1) for the maximum harnessing of available water. So, in irrigated agricultural production systems, both agronomic and hydraulic strategies should aim to improve aspects such as the distribution and efficiency of irrigated water, while in the rainfed land, these strategies should be focused on maximizing the uptake of water and its use by plants.

The adoption and development of Conservation Agriculture practices lead to a number of benefits in the management of water used in the agricultural ecosystem, as well as increasing the availability of this resource for the crops and improving of its quality (Fig. 5.2).

Regarding advantages offered by Conservation Agriculture related to adaptation to climate change, this management system will be particularly interesting in ecosystems with a decrease in water resources availability or in those regions, in which, due to the increase of extreme precipitation events, the phenomena of runoff are increased.

On the basis of studies published by the European Environment Agency (EEA, 2012), it is expected, at European level, a reduction in precipitation in the Mediterranean and Continental regions. Therefore, there will be an increased demand for water resources in agriculture in the Mediterranean regions, which will make them especially vulnerable to the lack of water. On the other hand, an increase in extreme precipitation events in the Atlantic regions is expected, which will affect water quality and erosion.

Regarding water balance of the soil-cropping system, the existing studies determine that CA systems improve the uptake, conservation and use of available water in the soil by the crops, thanks to the fact that it favours

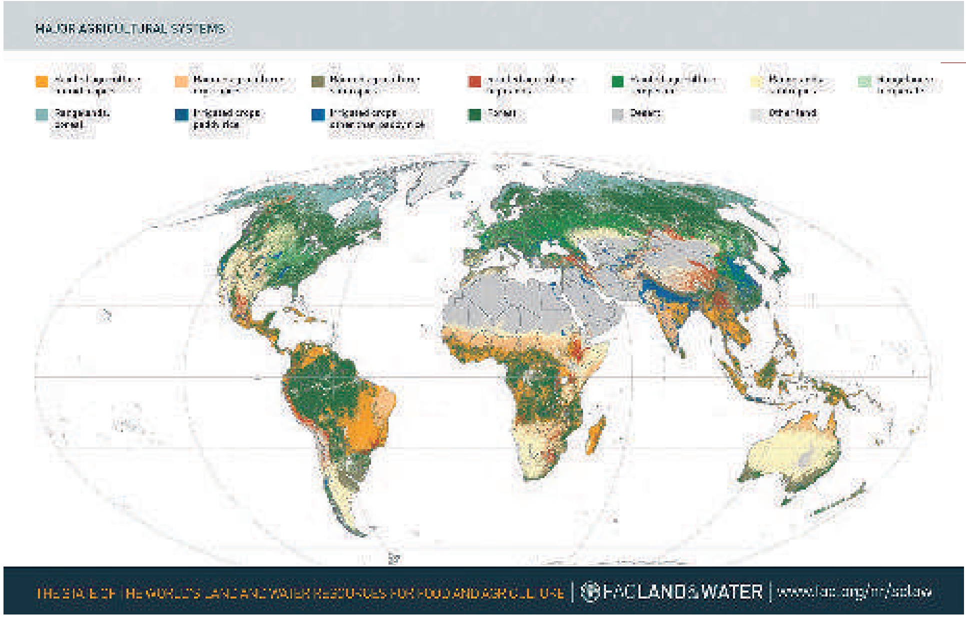


Fig. 5.1. Major agricultural systems. Source: *FAO, 2011.*

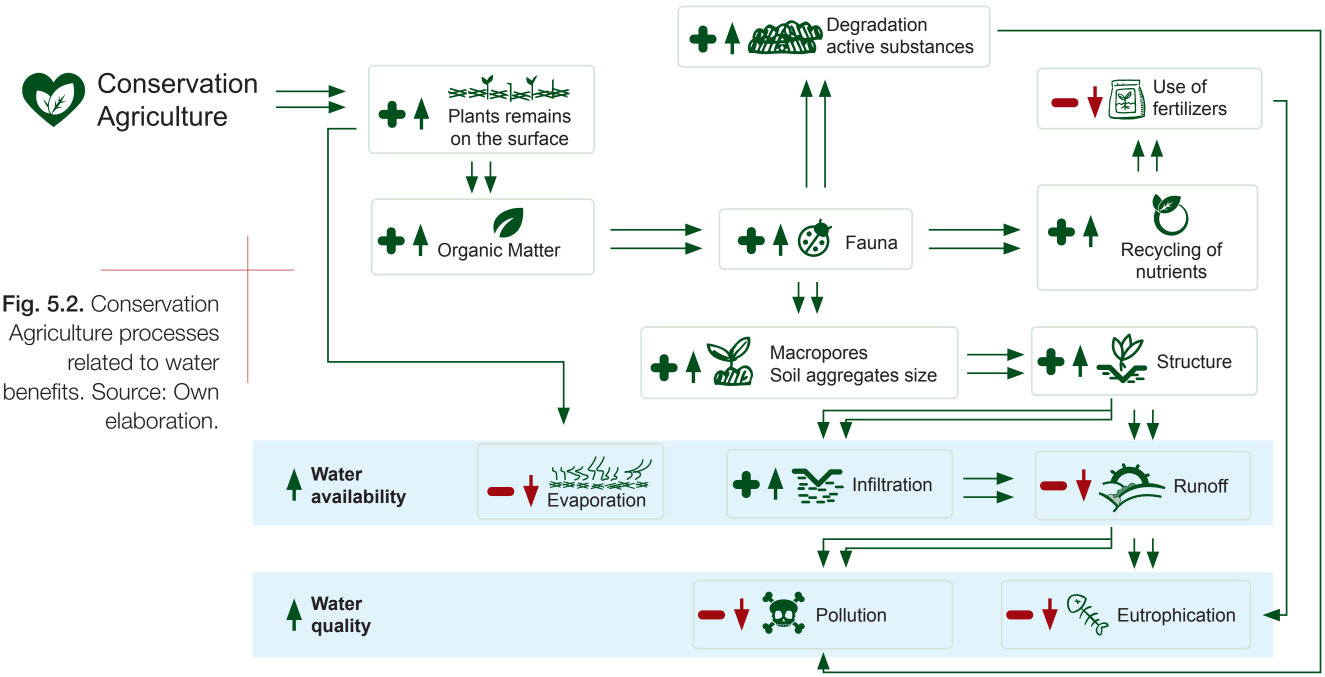


Fig. 5.2. Conservation Agriculture processes related to water benefits. Source: Own elaboration.

The carbon sequestration due to the adoption of CA across Europe would be equivalent to the emissions saving obtained by the installation of over **43,000** wind turbines.

infiltration, reduces runoff, increases water holding capacity and reduces evaporation. All this is achieved due to the maintenance of crop residues, which effects are described in Table 5.3.

Thus, thanks to the maintenance of crop residues on the soil, which could be either residues of the previous crop or living cover crops that maintain their root systems, the direct impact of raindrops is minimized, the infiltration is improved and the runoff is reduced. The greater the soil coverage the greater the reduction in water runoff.

5.4.1. Reduced runoff and increased infiltration and water-retention capacity

In Conservation Agriculture, runoff is reduced due to an increase in water infiltration because of the structural improvements stemed from Conservation Agriculture techniques along with the large amount of crop residues on the soil that slows the flow of water on the surface, preventing the formation of crusts which limit the infiltration of water.

Thus, due to the presence of soil covers, the speed of the water on soil surface decreases, reducing the runoff and increasing infiltration. In addition, having the soil covered protects it from the direct impact of raindrops, which are responsible for aggregates disintegration in bare soils, thereby producing a surface crusting, that limitis water infiltration and increases water runoff.

Several studies at the global level analyse the reduction of runoff occurring in Conservation Agriculture systems, with a decrease of 67% in no-till in annual crops (*Kertész et al., 2010*) and 43% using groundcovers in permanents crops (*Márquez et al., 2010*).

On the other hand, the increase in the infiltration rate that occurs in soils managed under Conservation Agriculture practices, improves water availability after rain periods, which is not the case in soils managed under a tillage-based system *(De Vita et al., 2007)*. Therefore, several studies have analysed the effects of soil management on dynamics and conservation of water.

According to *López-Garrido (2010),* in soils under Conservation Agriculture practices, the volumetric water

Table 5.3. Effects of permanent soil covers on edaphic moisture. Source: Own elaboration.

Effects	Direct causes	Indirect causes
Increase in infiltration-reduction of runoff	Greater retention of rainwater in permanent soil covers.	Through the increase of OM, soil struture is improved.
	Protection of the soil against the impact of raindrops.	Increased soil fauna (earthworms), which generate galleries and pores, favoring the circulation of water.
Reduction of evaporation	No direct incidence of radiation on wet soil.	
	Reduction of evaporation to the atmosphere.	

content of the first 20 cm is higher than in soils under CT practices. In addition, *Muriel et al. (2005)* concluded that CA techniques not only allow a greater retention of water in the soil profile, especially in the first 30 cm of depth, but also slow down the water discharge rate, which has a positive impact on the development of spring-summer crops, where the limiting factor of production is undoubtedly the lack of water. Fig. 5.3 shows the evolution of moisture contents for two soil management systems (NT: no-tillage and CT: conventional tillage). It not only shows higher water recharge given in NT

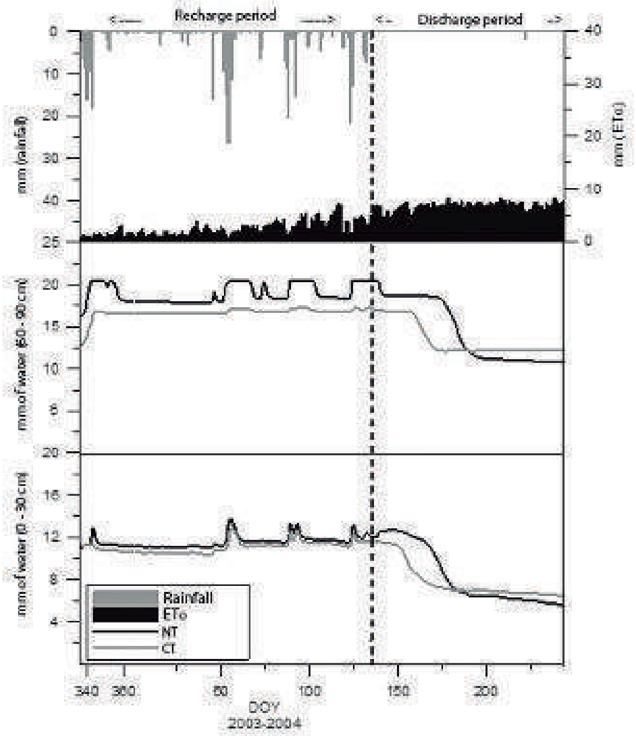


Fig. 5.3. Evolution of moisture content in two soil management systems. (NT: no-tillage and CT: conventional tillage). Source: *García-Tejero et al. (2010).*

system, but also greater soil discharge in the second part of the growing season, because in that case, and thanks to the greater availability of water, the crop is able to better satisfy the growing evapotranspiration demand which occurs in spring and summer.

Troccoli et al. (2009b) at CREA-CER carried out a field trial on a monoculture of durum wheat comparing conventional tillage and no-till systems. At the 14th year of experiment they assessed the soil moisture with gravimetric method during the 2009 growing season at four soil depths from April to June, and reported an average moisture content of the soil significantly higher in no-till (13% dry mass basis) than in conventional tillage (10%) management (Fig. 5.4), equivalent to about 22 mm of water savings.

5.4.2. Reduction of water evaporation

Conservation Agriculture systems prevent the direct incidence of radiation on moist soil and reduce water evaporation into the atmosphere. As a result, rainfed crops can better withstand stress conditions, as *Moreno et al. (1997)* and *Murillo et al. (1998)* found under conditions of Andalusian dryland, where spring and summer temperatures are high. This positive effect is especially noticeable in dry years.

Thus, Conservation Agriculture systems, by keeping the soil unaltered and covered by crop residues, cause a decrease in soil water evaporation during periods of high temperatures, and this means that the soil stays wetter during the spring and early summer (*Márquez et al., 2007*).

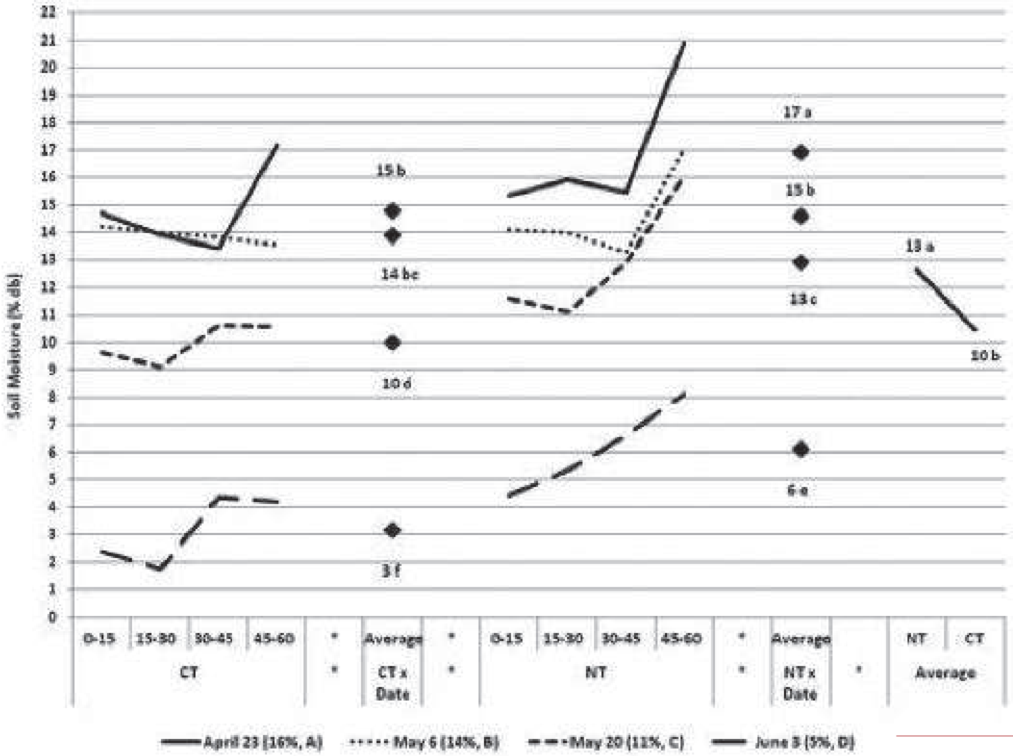


Fig. 5.4. Trend of soil moisture for a monoculture of durum wheat grown in no-tillage (NT) and conventional tillage (CT) systems. Source: *Trocoli et al. (2009a).*

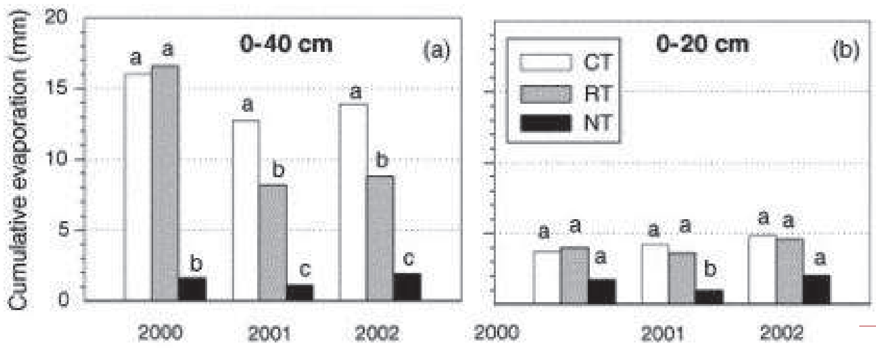


Fig. 5.5. Cumulative evaporation of soil water measured 24 hours after primary (a) and secondary (b) soil management practices. CT: conventional tillage, RT: reduced tillage, NT: no-tillage. Source:

Moret et al. (2006) observed, during three periods of long fallow (16-18 months), that soil, under an intensive tillage system with mouldboard plough, lost by evaporation 14 times more water than in NT system, in the 24 hours after the first tillage operations, (Fig. 5.5).

This improvement in water use efficiency is a key factor in adapting crops to future climatic scenarios with lower, more erratic precipitation and higher temperatures.

5.5. Conservation Agriculture and soil improvement

One of the keys to increase the resilience of the agricultural ecosystems that are possible thanks to adoption of Conservation Agriculture is the substantial improvement that occurs in the physical-chemical properties of the soils on which these agricultural practices are implemented. Soils with a better structure and less erosion, will respond better to events of intense rainfall. On the other hand, soils with a greater content of organic matter and greater natural fertility, are more and better prepared to respond to adverse climatic conditions that contribute to their degradation. Fig. 5.6 shows the processes through which Conservation Agriculture improves this resources.

5.5.1. Reduction of erosion

CA maintains permanent soil covers which minimize the direct impact of the raindrops on the soil, increase the infiltration and reduce soil erosion. The greater the coverage of the soil, the more effective reduction of erosion is. Therefore, soil management operations should leave as much crop residue as possible on the soil surface, in order to protect it and prevent erosion. Studies carried out by the Spanish Association for Conservation Agriculture Living Soils (AEAC.SV) shows that with 30% of soil covered, erosion decreases, and with 60% of soil covered, erosion almost completely disappears (Fig. 5.7).

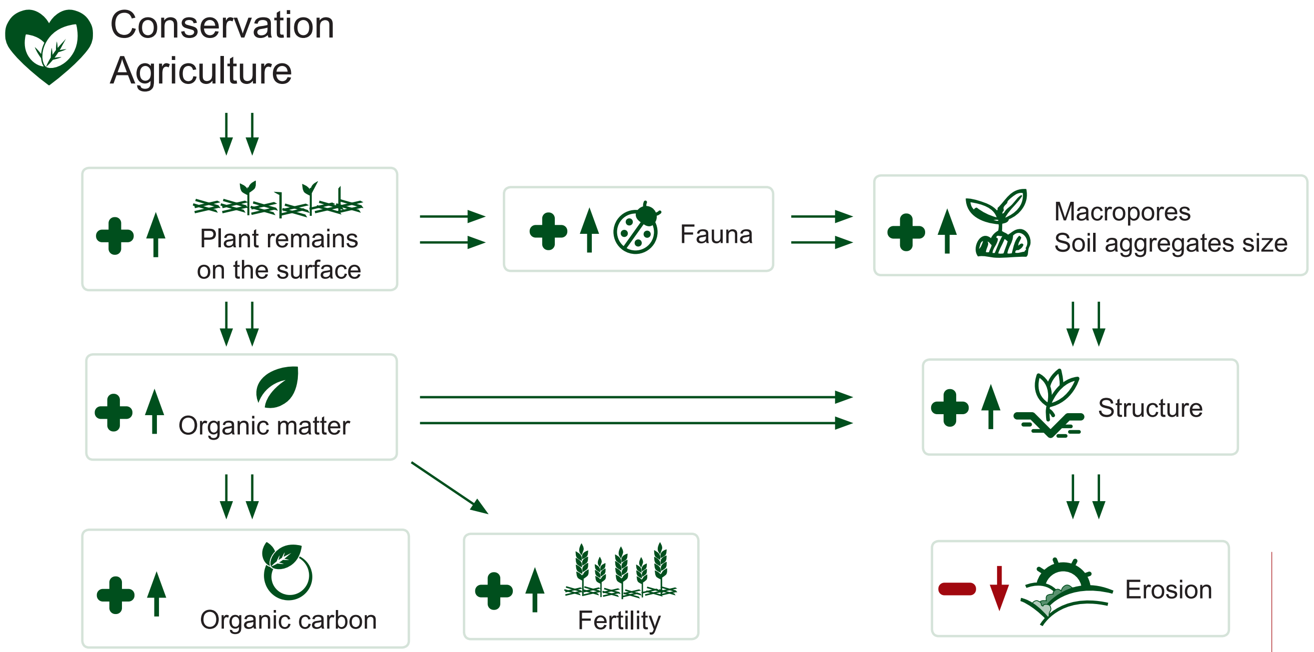


Fig. 5.6. Conservation Agriculture processes related to soil benefits. Source: Own elaboration.

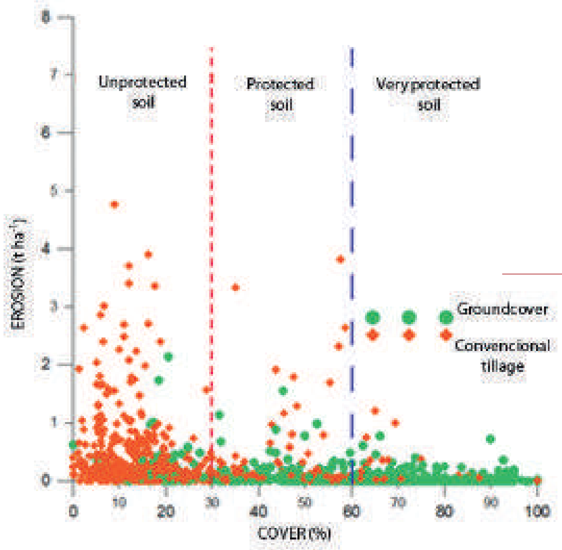


Fig. 5.7. Soil erosion related to the percentage of surface covered by crop residues. Source: AEAC.SV.

Based on this premise, investigations carried out in other countries certify erosion reductions of more than 90% in the case of no-tillage (NT) (*Towery, 1998*), and more than 60% in minimum tillage (*Brown et al., 1996*). More recent studies (*Kertész et al., 2010*) show erosion reductions in NT of up to 98.3%.

The maintenance of permanent soil covers also plays an important role in reduction of wind erosion. According to the results obtained by *Fryear (1985),* in a soil whose surface was covered by 20% of crop residues, the soil loss was reduced by 57%. In soils whose surface was covered by 50%, erosion was reduced by 95% (Fig. 5.8).

Regarding the influence of groundcovers on the reduction of erosion in permanent crops, there are many studies carried out in Spain, a country where CA practice is widely extended within the European context. In Spain there are several investigations in woody crops that study the influence of groundcovers in the reduction of erosion. Thus, *Márquez et al. (2013)* quantified average erosion reductions of up to 80.4% in olive groves, *France et al. (2000, 2006)* found soil losses three times lower in CA systems compared to the tillage plots and, finally, *Martínez Raya et al. (2010)* observed erosion rates almost 10 times higher in tillage systems compared to CA ones for almond tree orchards.

5.5.2. Increased soil organic matter and soil fertility

The reduction of erosion due to the implantation and development of Conservation Agriculture, leads to an increase in the organic matter content in the soil, which, in addition to being the basis of the C sink effect, improves soil quality, enhances the chemical and physical fertility of the soil, favours the development of the structure or aggregates, thus increasing soil resistance to erosion and favouring water infiltration. In addition, thanks to the ability of humus to retain cations and adsorb heavy and harmful elements, organic matter acts as a water filter, improving its quality.

Soil organic matter is an integrator of several soil functions and as such is a key component of soil quality and of the delivery of many ecosystem services (*Palm et al., 2014*). Conservation Agriculture practices of no-tillage and residue maintenance

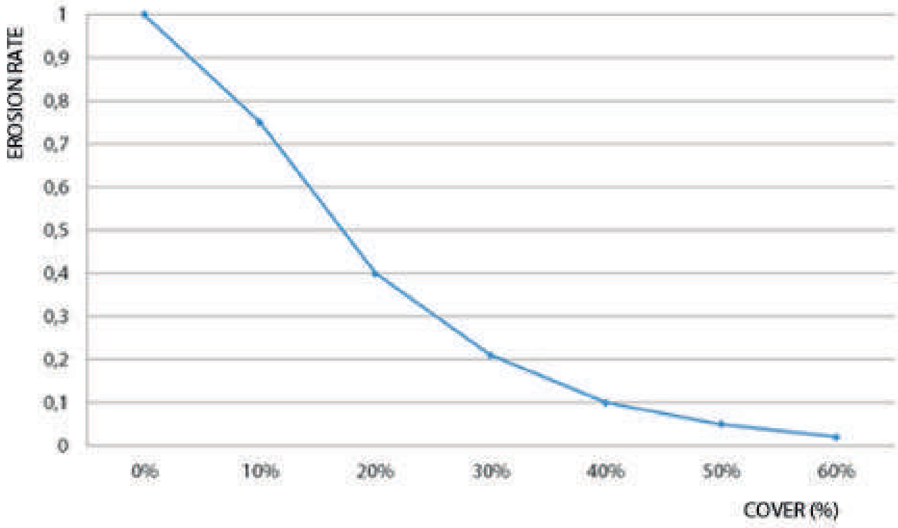


Fig. 5.8. Reduction of the rate of wind erosion according to the percentage of crop residues. Source: *Fryrear (1985).*

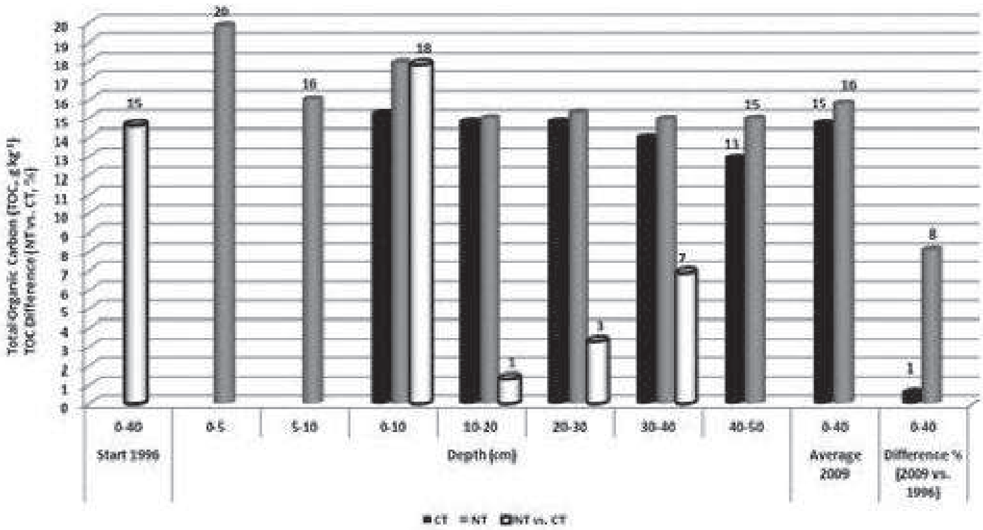


Fig. 5.9. Trend along soil profile of total organic carbon (TOC) values for no-tillage (NT) and conventional tillage (CT) systems. Source: *Troccoli et al., 2009a.*

are key-points to conserve or increase soil organic matter in the topsoil which in turn provides energy and substrate for soil biota activities and their contributions to soil structure and nutrient cycling, as well as many other soil processes and ecosystem services (*Brussaard, 2012*).

Scientific evidences show that due to the improvement in moisture regime over the growing season and soil storage of water and nutrients, as well as to the introductions of legume cover crops and build-up of soil organic matter, crops under CA require less fertilizer and pesticides to feed and protect the main crop (*Lafond et al., 2008; Crabtree, 2010; Lindwall and Sonntag, 2010*). Good mulch cover provides 'buffering' against extreme temperatures at the soil surface which otherwise are capable of harming plant tissue at the soil/atmosphere interface, thus minimizing a potential cause of yields limitation (*Kassam et al., 2012*).

5.6. Conservation Agriculture and the improvement of soil biodiversity

Soil biodiversity plays a key role in fertility, nutrient absorption by plants, biodegradation processes, the elimination of hazardous compounds and natural pest control. In other words, richer and more biologically diverse soils have greater capacity to respond to extreme phenomena resulting from climate change that can worsen their degradation, such as the incidence of heavy precipitation, temperature increase or the geographical displacement of pests and diseases, among others.

One of the environmental benefits of the adoption of Conservation Agriculture practices for agrarian ecosystems is the improvement of biodiversity in general, and in the soil in particular. In other words, under soil conservation practices, soil biota is enriched, allowing better recycling of nutrients and helping to control pests and diseases (*Holland, 2004*).

The implementation of CA benefits various groups of microorganisms (bacteria, fungi, protozoa, nematodes, etc.) which live in no-tilled soils. *Muñoz et al. (2007)* found significant differences in the number of microorganisms from the beginning to the end of the study about microorganisms in the soil under several management systems, which were always in favour of conservation systems. Thus, according to the mentioned study, the soil maintained using no-till practices had 50% more microorganisms than the soil under conventional tillage. Fig. 5.10 shows the number of microorganisms present in the soil in several soil management systems, including several no-till alternatives based on a larger amount of crop residues and a greater number of years of implantation (*Muñoz et al., 2009*). It should be noted that a direct consequence of the increase of microorganisms in the edaphic profile is the increase of the structural soil stability. Thus, large amounts of organic matter involved in the implementation of techniques such as no-tillage or groundcovers contribute to increasing microbial activity, which improves the stability of aggregates.

Another populations benefited by the implementation of Conservation Agriculture and whose activity supposes an improvement of the fertility of the soil and its structural stability, are earthworms. These living beings have great importance especially in productive ecosystems,

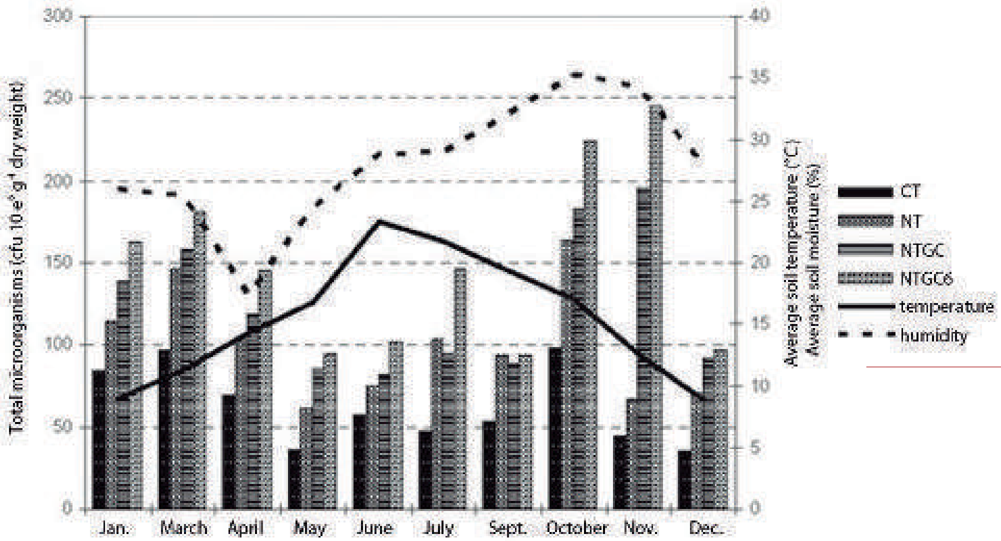


Fig. 5.10. Average soil temperature, average soil moisture content and average amount of microorganisms in each soil management system throughout the year. (CT: conventional tillage, NT: no-till, NTGC: no-till with winter groudcover, NTGC6: no-till with winter groundcovers during 6 years of implantation). Source: *Muñoz et al. (2009).*

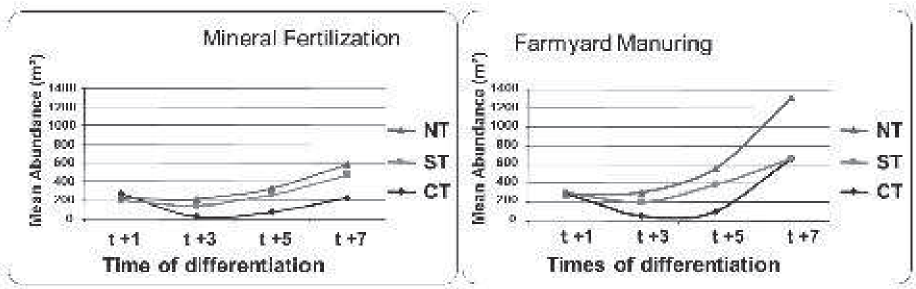


Fig. 5.11. Evolution of earthworm abundance under three treatments (CT: conventional tillage, ST: superficial tillage, NT: no tillage) according to mineral fertilization and farmyard manuring. Source: *Piron et al. (2010).*

due to their influence on the decomposition of organic matter, soil structure development and nutrient cycle. In addition, earthworms reduce bulk density and increase water infiltration, with the consequent advantages discussed previously related to the improvement of soil moisture content. It is verified that CA increases the activity of earthworms, because of lower soil disturbance and the increase in organic matter. Thus, studies by *Piron et al. (2010)* in France (Fig. 11), which made comparison between three management systems (no-tillage, superficial tillage and conventional tillage) with two fertilization strategies (mineral and organic fertilization), showed that in all cases, after 7 years of research, earthworm populations were superior in Conservation Agriculture than in conventional tillage.

5.7. Strategies in the agronomic management of crops: Conservation Agriculture and crop rotation

The increase in temperature during the critical periods of the crop, the changes in the monthly distribution of precipitation and the reduced soil water holding capacity because of climate change, could reduce productivity and crop quality. Therefore, one of the measures that can be taken to deal with these risks is the diversification of crops, praticing the crop rotations on the farm, which is one of the fundamental pillars of implementation and development of CA. In this way, pests and diseases are better controlled, breaking cycles that are maintained in monocultures, in addition to incorporating crops that can improve the natural fertility of the soil and biodiversity.

But crop rotation not only brings benefits for the optimized management of water and soil moisture, it also offers other advantages that help the agrarian ecosystem to be more and better prepared for the variety climatic scenarios caused by global warming, and, therefore, to be more sustainable. The following advantages can be highlighted:

- The establishement of crop rotations that explore different edaphic horizons and have different water needs, promotes synergies between them, improving the medium and long term productions in the global computation.
- Rotation is used to reduce pests and diseases in the cropping system and to control weeds.
- Rotations can also provide benefits, such as better soil quality (deeper roots, root exudates), better distribution of nutrients in the soil (deep root crops mobilize deeper nutrients), and increased biological activity.
- Through the rotations, the periods of high labour demand can be reduced and farming operations can be better distributed throughout the year, if, for example, sowing and harvesting dates for the different crops involved in the rotation do not coincide in time.

- Crop rotations can reduce the risk created by extreme weather events such as droughts or floods and their negative effects, since their incidence does not equally affect all crops. In this case, rotation represents a way to diversify risk.

- Crop rotations can balance the production of crop residues by alternating crops that produce few and/or easily degradable residues with crops that produce many and/or more long-lasting residues.

Therefore, the rotation of crops promoted by CA increases the resilience of the agricultural ecosystem, improving soil properties in general, while increasing the crop potential to obtain higher yields.

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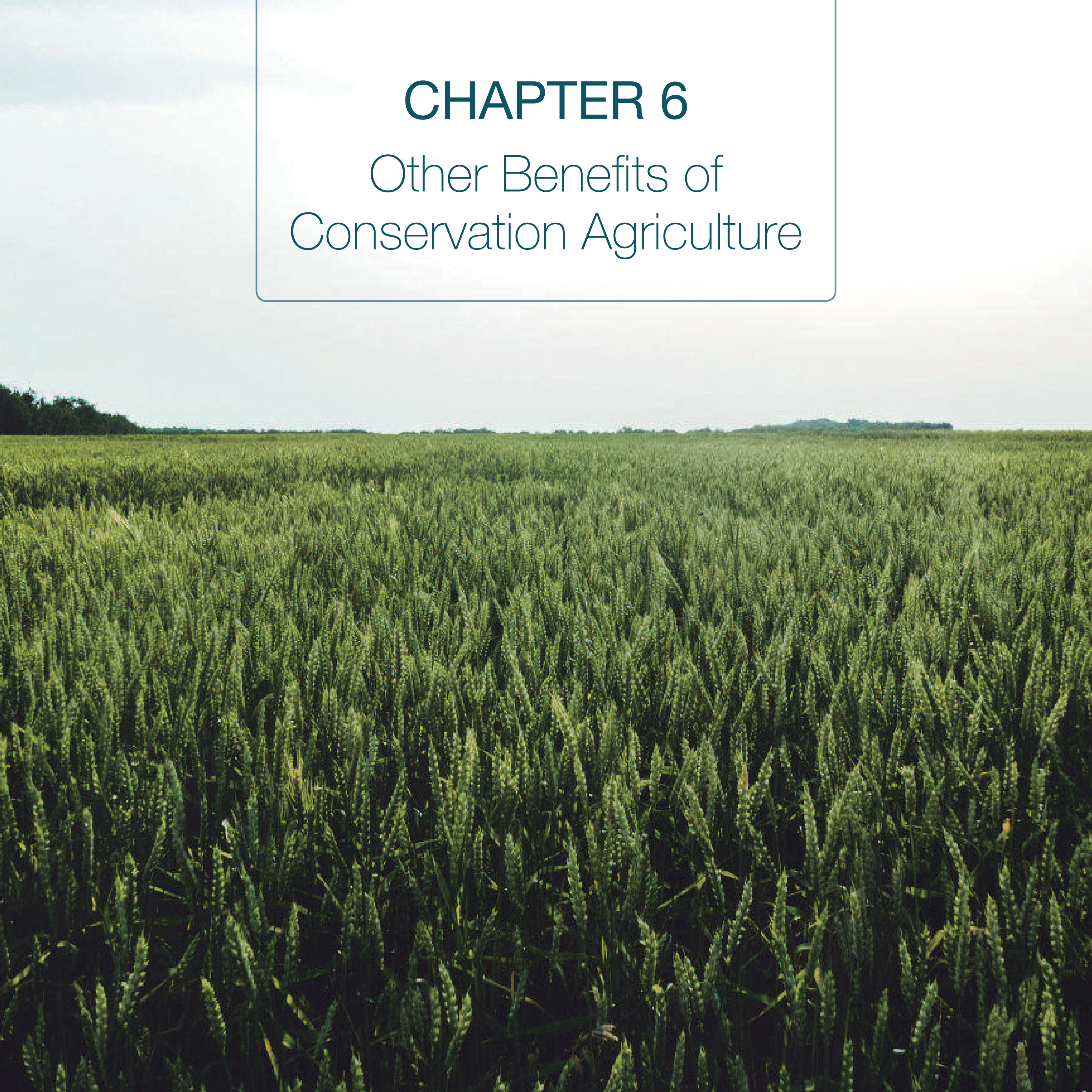
CHAPTER 6

Other Benefits of Conservation Agriculture



6.1. Introduction

The benefits of Conservation Agriculture (CA) related to improvement of atmospheric quality have been extensively developed in previous chapters. However, sustainability in agriculture includes other fields. A system can be sustainable if it is so for all the environment (not only at the atmospheric level), and if it has agronomic, economic and social benefits. All these facts make Conservation Agriculture the model of agriculture that best fits the definition of sustainable development provided by the United Nations World Commission on Environment and Development (WCED) in the Brundtland Report (1987): "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

This chapter will analyse agricultural sustainability, from different points of view:

- Environmental: Agriculture is an activity with a clear influence on the environment. The systems used must improve protection, conservation and, where possible, natural resources.

- Economic: It cannot be forgotten that agriculture is the farmer's sustenance. The economic benefits of farms are vital for their sustainability. Agricultural systems should aim to maximize these benefits through lower production costs and / or increased incomes (either through improved product quality, increased production or both).

- Social: The agrarian activity itself, and that of the agro-industries that are established in the surroundings of the farms producing raw materials, are the means to fix the rural population. Therefore, the social sustainability aspect of agriculture aims at the adoption of production systems that can improve the welfare of farmers and the population linked to agricultural activities. Another aspect that should be taken into account, from the social point of view, is the demand for food produced under certain quality and food safety standards. The model of agriculture that needs to be implemented should not neglect these social requests.

- Agronomic: Crops must be managed in order to maintain or improve the properties of the agrarian ecosystem in which they are growing, avoiding its degradation and improving its physicochemical properties, which can increase production. An agricultural model is sustainable from the agronomic point of view if it allows the implantation and the correct development of crops in the long term without degrading the environment in which they are developed.

Conservation Agriculture increases benefits and is sustainable in all the cases mentioned above. This chapter will discuss the benefits that CA provides to soil and water. It should be noted that these benefits, as will be shown below, do not reduce yields.

6.2. Soil benefits

6.2.1. Reduction of erosion

The main environmental problem caused by the current agricultural model based in tillage is the degradation of agricultural soils due to erosion and compaction processes. There are around 106 Mha (16% of Europe's area-excluding Russia) affected by water erosion, and 42 Mha affected by wind erosion all around Europe. According to *Jones et al. (2012a)* soil losses are higher than 10 t ha^{-1} yr^{-1} in almost 20% of Europe's surface area. There are also studies carried out by the Joint Research Center (*Bosco et al., 2015; Jones et al., 2012b*) that have estimated that mean soil losses from water erosion are of 2.76 t ha^{-1} yr^{-1} for the EU-27 (Fig. 6.1). In areas where soil loss is higher than 1 t ha^{-1} yr^{-1} these losses can be considered as irreversible over a period of between 50 and 100 years (*Huber et al., 2008)* due to the low soil formation rate.

Control of erosion can be improved by changing agricultural practices. When, for example, permanent soil cover is increased, soil loss rates are reduced exponentially *(Gyssels et al., 2005)*. This results from the fact that the maintenance of the crop residues on the ground acts as a protective layer that dissipates the energy of the rain drops and minimizes their direct impact on the soil thus avoiding its disintegration, reducing the runoff, and, consequently, greatly reducing soil loss. In addition, the decomposition of the roots of the cover crops in annual crops, or of the groundcovers in permanent crops, opens channels that favour a greater infiltration reducing the runoff, and therefore, the associated erosive processes. *(Martínez Raya, 2005)*. The effectiveness of soil protection against erosion is directly related to the coverage of the soil and, therefore, to the less burial of crop remains through tillage operations.

Although there are variations depending on soil type and local conditions, there is a general consensus in the scientific literature that Conservation Agriculture techniques (no-tillage, groundcovers) reduce soil erosion up to 90% in comparison with conventional tillage (CT) (*Towery, 1998*). Specifically, *Gómez et al., (2004)* found that CA implantation reduced 20% the probability of soil losses in a range of between 5 and 12 t ha^{-1} yr^{-1} in studies carried out in the Mediterranean area.

Other studies at European level have focused on how CA practices influence the C factor (crop management factor –groundcover–, dimensionless) of the soil loss equation (RUSLE), determining that the application of no-till techniques (NT) or groundcover (GC) can reduce its average value by 19.1% *(Panagos et al., 2015)*, which implies a decrease in the calculation of soil loss. Fig. 6.2 shows the reduction in C factor due to the presence of crop residues in the EU countries.

6.2.2. Increase in organic matter content

Tillage practices such as overturning increase CO_2 emissions, decreasing the amount of organic matter (OM) in the soil *(Schlsinger and Andrews, 2000; Lal, 2004; Álvaro-Fuentes et al., 2007; Cabrera, 2007; Lopez-Garrido et al., 2019)*. In cultivated soils OM can progressively decrease, with a large part being removed annually (harvest) and much of it being lost by mineralization if the tillage is very aggressive, such as the one that CT causes *(Wallace, 1994; Causarano et al., 2008)*.

OM has a great influence on soil physical, chemical and biological properties, necessary for the development of its functions *(Bauer and Black, 1994; Magfoffand Weil, 2004)*. The loss of OM from a soil, in addition to a negative effect on the balance between the different carbon pools, also affects the quality of the soil and its fertility can be seriously compromised.

Organic matter is fundamental for the physical fertility of a soil because it improves the formation and stability of aggregates *(Gajri et al., 2002)*. OM is considered as a source of energy for plants and soil organisms *(Brady and Weil, 2002)* with the amount, diversity and activity of the macro and mesofauna of the soil and microorganisms being directly related to the amount of OM *(González et al., 2004)*.

High contents of OM improve the cohesion between the different elements of the soil, which increases their adhesion properties and, for this reason, this parameter can be considered as an indicator of soil health status. In CA, crop residues are slowly degraded, resulting in an increase in soil OM content. Its increase in the first

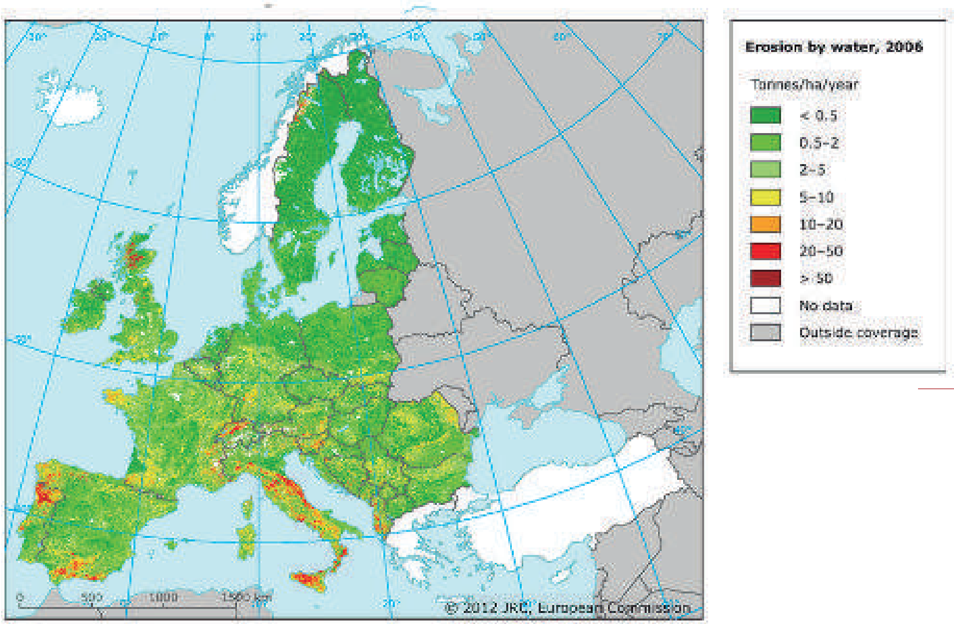


Fig. 6.1. Estimation of soil erosion by water in cultivated land. Source: *JRC/ Bosco et al. (2015).*

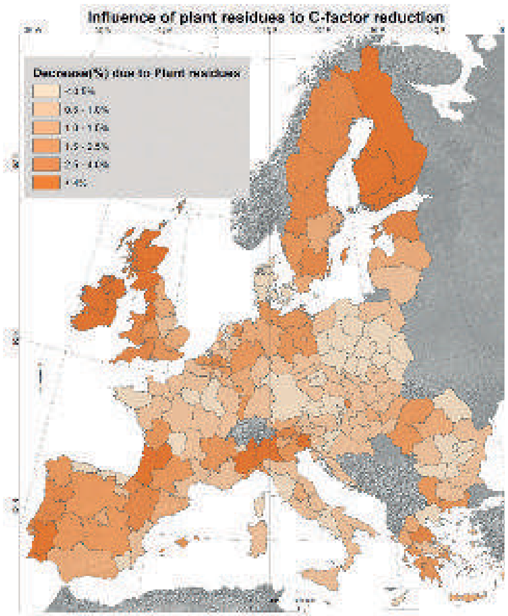
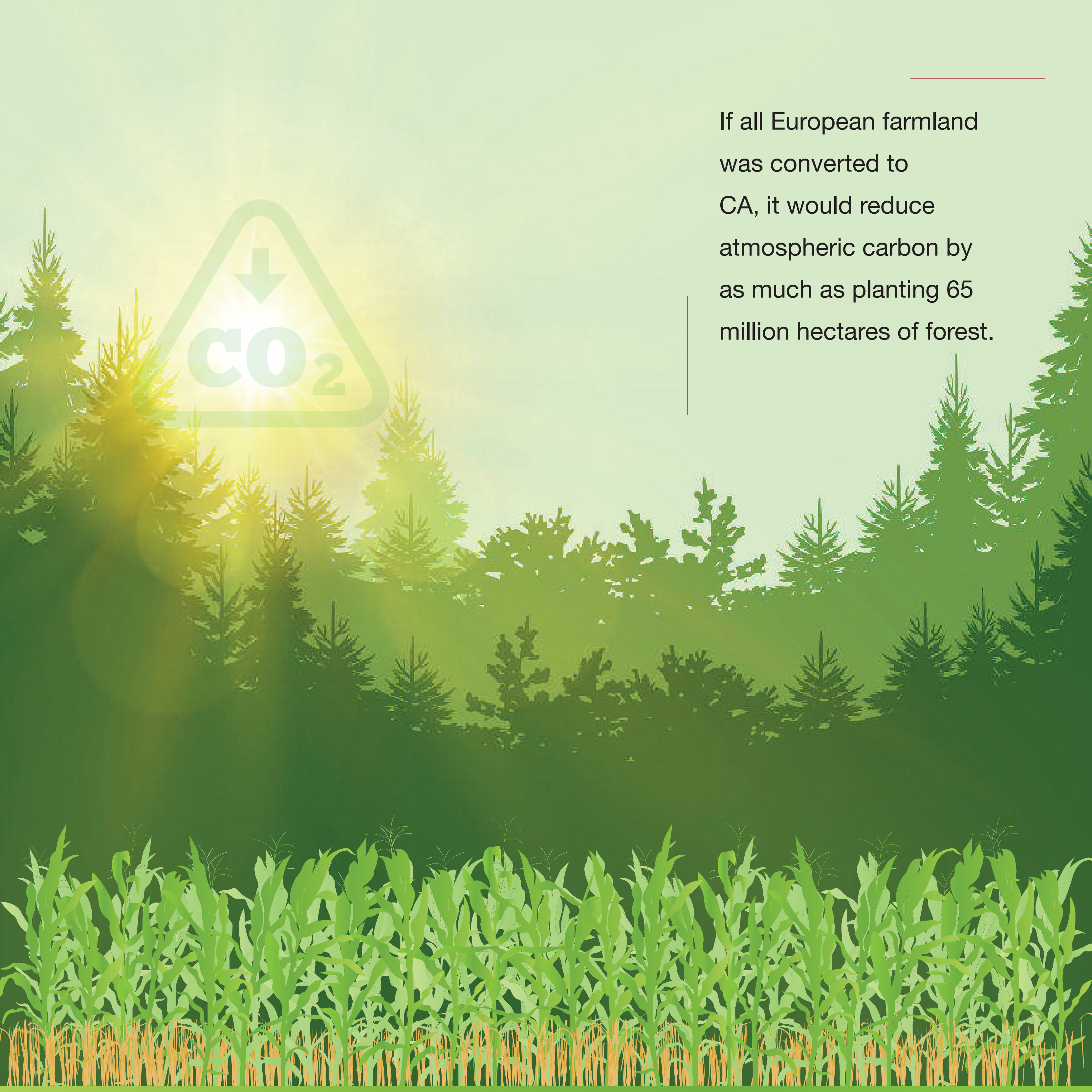


Fig. 6.2. Influence of crop residues in C factor of the RUSLE equation. Source: *Panagos et al., (2015).*



If all European farmland was converted to CA, it would reduce atmospheric carbon by as much as planting 65 million hectares of forest.

centimeters of the soil surface increases the nutrient reserves *(González, 1997; Rhoton, 2000)*, which can be released gradually and at a different rate than in tilled soils *(Fox and Bandel, 1987).*

In a study about CA where the influence of soil management on soil OM content was evaluated, *Giráldez et al. (2003)* verified that the OM content increased throughout the soil profile, compared to the CT system in which its percentage was reduced. In addition it was observed that the main causes that induce the different amount and distribution of OM in the soil profile are the type and amount of surface stubble and the climatology of the area.

6.2.3. Improvement of soil structure

The *Thematic Strategy for Soil Protection (COM (2012) 046)* identifies soil compaction as one of the main threats to soil. This is due to the fact that the overall deterioration of the edaphic structure happens because soil compaction limits root growth, storage capacity, fertility, biological activity and stability. In addition, if precipitation is strong, it is impossible for water to easily seep into the soil. Consequently, the high volume of runoff water increases the risk of erosion and, according to some experts, has been one of the triggers of some of the last floods in Europe (*EEA, 2001*). Soil compaction occurs when it is subjected to mechanical pressure, such as the use of heavy machinery and excessive grazing, especially if the soil is wet (*Huber et al., 2008*).

Another factor that affects the soil structure is the formation of superficial crusts, which are responsible for the loss of edaphic structural stability (*Micó et al., 2006*).

A series of benefits on the physical properties of the soil, which contributes to the improvement of soil structure are achieved through the implementation of CA. Thus, by keeping the soil unchanged by suppressing tillage operations, the generation of galleries resulting from root degradation, together with the higher amount of earthworms in a soil under CA, form so-called biopores. Water infiltrates in depth through these preferential channels.

In addition, the properties related to soil structure, such as aggregate size distribution, weighted average diameter and aggregation index, are improved thanks to CA *(López-Garrido et al., 2010)*. It also improves the stability of aggregates 1-2 mm in diameter in wet soils.

On the other hand, it is proven that OM is crucial in all the processes that occur in the soil and in particular for its quality, since it improves its structure, fertility and water storage capacity, being therefore widely accepted as an indicator of soil quality *(Podmanicky et al., 2011)*. The increase in soil OM content improves its structure and favors structural stability. Therefore, CA, due to the increase of OM that its practice implies, contributes to the structural improvement of the soil.

6.2.4. Greater biodiversity

Soil biodiversity tends to be higher in forests, prairies and undisturbed soils rather than in cultivated ones. The implementation of a field with natural vegetation involves a series of changes in the soil. The intensification of agrarian activity, derived from the tillage conducted in conventional agriculture, leads to a potentiation of these changes, decisively affecting the biodiversity of soil inhabitants, including epigeous fauna, which tends to disappear.

Regarding biodiversity, agricultural soils under CA can be considered intermediate between the two above mentioned extremes *(Kladivko, 2001)*. Thanks to the presence of a permanent soil cover, CA practices influence a series of parameters and characteristics of soil that improve the conditions to give food and shelter to many animal species during critical periods of their life cycle, thus, a large number of species of birds, small mammals, reptiles, earthworms, etc. Additionally, the interrelations between diverse parameters also improve the conditions for the development of aquatic life in water bodies close to CA plots (Fig. 6.3).

López-Fando (2010) carried out the analysis of both own and others research. This analysis shows the great importance of the characterization of microflora

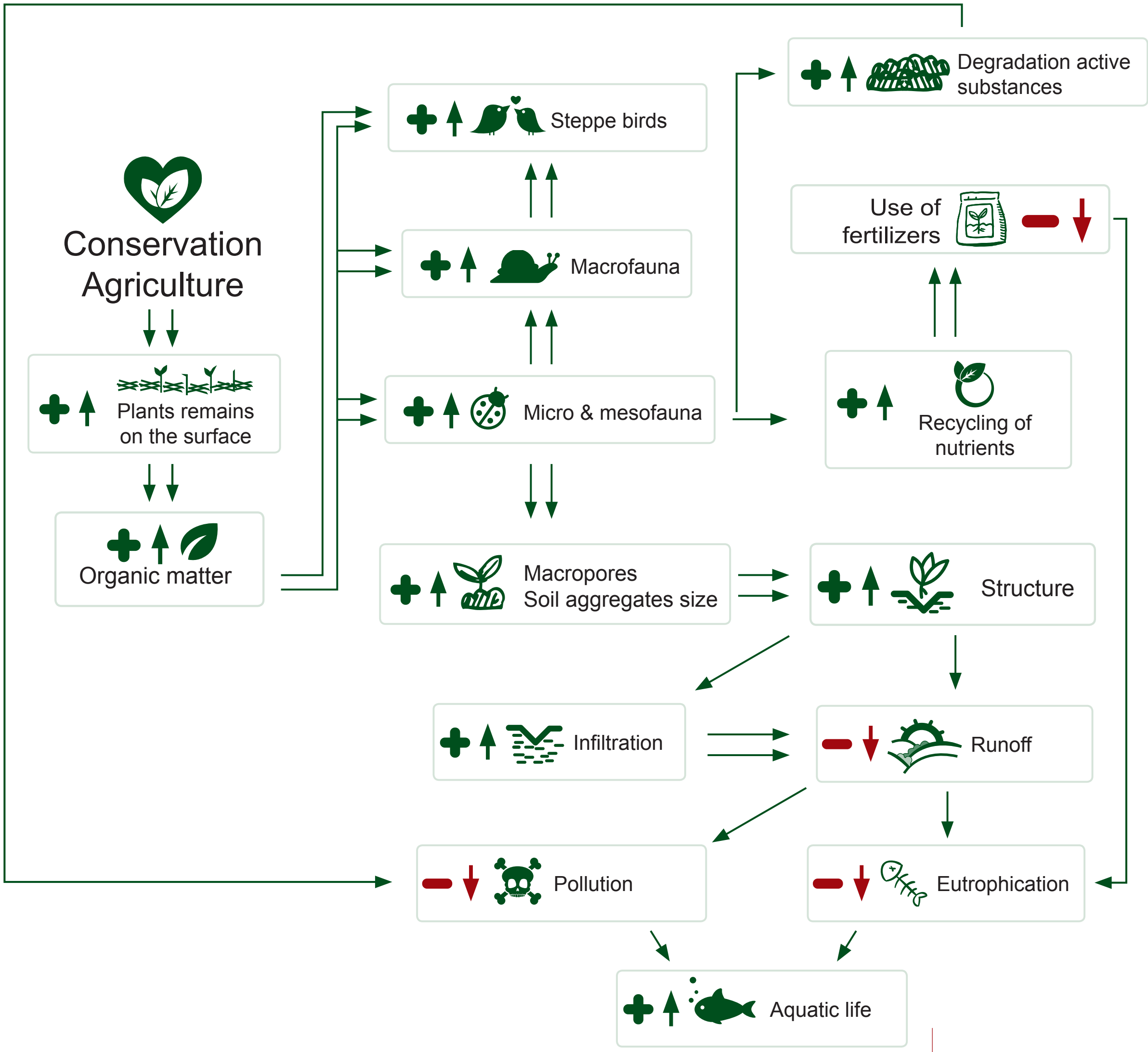


Fig. 6.3. Improvement of biodiversity due to changes promoted by the implementation of CA.

and edaphic fauna, with special reference to the study of their function in the different levels of organization in the trophic system. In particular, the seasonal dynamics and structure of soil organisms communities accuse changes in use. These studies have shown that CA can be an effective means of conserving and enhancing biodiversity.

There are research studying the influence of the application of CA on the micro, meso, macro and mega fauna, in addition to those mentioned in the chapter on the properties of CA to favor the adaptation of crops to the effects of climate change through the improvement of soil resilience. Table 6.1 shows the influence of the application of CA in the population of different types of living organisms.

6.2.5. Increase in natural fertility

There are various processes which occurrence lead to the degradation or loss of soil quality and quantity such as erosion, salinization, contamination, drainage, acidification, loss of structure, compaction or a combination of them. Inadequate human uses of soil can lead to one or several of these processes, which negatively affect soil quality and, therefore, its productive capacity or natural fertility. One of the examples of inadequate land use is agricultural practice based on intensive tillage because it contributes to degradation phenomena mentioned above. As a result, bad agricultural practices do not optimize the use of fertilizers because they adversely affect the OM content and do not return extracted nutrients.

In general, when the soil ceases to be tilled and the stubble is integrated into the productive management of the crops, soil parameters that have been traditionally used to evaluate soil fertility (OM, nitrogen-phosphorus-potassium availability) are favorably evolved. For all this, CA aims to improve soil fertility because the slow decomposition of crop residues produces a surface layer rich in compost, which, through its mineralization, provide crops with nutrients (*Roldán et al., 2003; Riley et al., 2005; Diekow et al., 2005*).

6.2.5.1. Conservation Agriculture and organic matter

The dynamics of OM play a very important role in the natural fertility of the soil. It mineralizes, providing nutrients to the plants and together with the clay, constitutes the colloidal fraction of the soil, responsible for its chemical fertility and the development of the structure or aggregates that increase the resistance of the soil against erosion *(Ordóñez Fernández, 2010).*

Particulate OM is a fraction of soil OM. It is closely related to the development of the soil structure and can be very easily destroyed by tillage (*Mrabet et al., 2001*). For this reason, dynamics of OM in CA, where ground cover is slowly degraded, are similar to that produced in natural ecosystems.

Increases in the OM content which is produced in the soil when implementing CA practices have been verified in several studies on this topic, already mentioned in the chapter 5. Percentage increases for these studies are shown in Table 6.2.

Table 6.1. Increase in the population of different types of living organisms thanks to the implementation of Conservation Agriculture.

Class / subclass / animal studied	Type of fauna	Conservation Agriculture Practice	Increase	Source
Arachnida	Macrofauna	Groundcovers	++	*Campos et al., (2002)*
Clitellata (earthworms)	Macrofauna	No-tillage	+++	*Cantero et al., (2004)*
Malacostraca (moisture cochineal)	Macrofauna	No-tillage	+++	*Alfaress (2002)*
Mites	Microfauna	No-tillage	+	*Perdue and Crossley (1989)*
Mollusks (snails and slugs)	Macrofauna	No-tillage	+	*Wolters and Ekschmitt (1997)*
Myriapods	Macrofauna	No-tillage	+	*Wolters and Ekschmitt (1997)*
Nematodes	Microfauna	No-tillage	++	*López-Fando and Bello (1995)*
Springtails	Macrofauna	No-tillage	++	*Shearin et al., (2007)*
Steppe birds (thistle)	Megafauna	No-tillage	++	*Cantero-Martínez et al., (2007)*

Table 6.2. Increase of organic matter content in the soil thanks to the implementation of Conservation Agriculture.

Conservation Agriculture Practice	Increased organic matter compared to conventional tillage (depth)	Years of study	Source
No-tillage	+15% (25 cm)	21 years	*Lacasta et al. (2005)*
No-tillage	+6.1 t ha^{-1} (30 cm)	16 years	*López Fando and Pardo (2011)*
No-tillage	+40% (30 cm)	19 years	*Ordóñez et al. (2007)*
Groundcovers	+45% (25 cm)	4 years	*Márquez et al. (2013)*

6.2.5.2. Conservation Agriculture and availability of nitrogen, phosphorus and potassium

Many long-term studies on the benefits of CA for soil nitrogen *(Lacasta Dutoit and Meco Murillo, 2005*; *Sombrero et al., 2006; Ordóñez-Fernández et al., 2007)* mark the increase of this nutrient in no tilled soils (Table 6.3). However, the intensity and extent of these differences in the soil profile depend on the climate, type of soil and crop rotation on the farm. In any case, there is some controversy about the influence of soil management on the nitrification, denitrification and volatilization processes that are, in the end, those that determine the availability of nitrogen in the soil for the plant. The rotation of crops with leguminous plants, a necessary practice in CA, significantly enriches the soil with organic nitrogen which, in the long run and due to the mineralization processes, is made available to crops. Therefore, this achievement, together with the other improvements provided by CA in relation to the rest of nutrients, make this practice one to be considered to enhance soil fertility.

Regarding phosphorus, the continuous management of soils in CA leads to a greater efficiency of phosphate fertilizer, increasing the concentration and availability of phosphorus, due to the stratification of OM in the surface horizon (*Phillips, 1985*). *Ordóñez et al., (2007), Bravo et al., (2007)* and *Saavedra et al., (2007)* noticed that, after more than 19 years of NT, the concentrations of phosphorus and potassium available for the crop were higher in the superficial horizon than those in CT.

6.3. Benefits for the water

Taking into account that a third of the water used in Europe goes to the agricultural sector, that agriculture affects both the quantity and the quality of water available for other uses and that in the EU there is an increasing demand by citizens and environmental organizations for cleaner rivers, lakes, groundwater and coastal beaches, it goes without saying that water management in agriculture is crucial.

Soils play a key role in the water balance of crops, due to their storage capacity according to their physical, chemical and biological characteristics. Thus, any management practice that increases soil quality, through the increase of OM, the improvement of its structure and of its biodiversity, will positively result in its capacity for water storage.

Table 6.3. Increased N content in the soil thanks to the implementation of Conservation Agriculture.

Conservation Agriculture Practice	Increase in N compared to conventional tillage	Years of study	Source
No-tillage	+26%	15 years	*Lacasta Dutoit and Meco Murillo (2005)*
No-tillage	+25%	10 years	*Sombrero et al. (2006)*

In general, CA systems contribute to a greater accumulation of water in the soil profile, motivated by the following reasons:

- Runoff is considerably reduced and infiltration is increased.
- It reduces the pollution of surface water, thereby improving its quality.
- There is an increase in the storage capacity of the soil due to the produced structural or biological changes.
- The evaporation of water from the soil is reduced.

As discussed in chapter 5, these processes have a direct impact in the adaptation of agricultural systems to climate change, but implementation of CA brings additional benefits to water.

6.3.1. Improvement of surface and groundwater quality

Tillage based conventional farming practices contribute to the deterioration of surface water quality (*Blevins et al., 1990; Sharpley et al., 1993; Douglas et al., 1998; Fleming and Cox, 1998*). In a study, *Christensen (1995)* classifies the following as potential pollutants that have the greatest impact on aquatic ecosystems, in descending order: sediments, nutrients, pathogens, OM, heavy metals and plant protection products. Thus, entrainment of soil particles, due to water erosion, contaminate riverbeds, worsening conditions for species survival in aquatic ecosystems. On the other hand, fertilizers and plant protection products are used on crops to increase their yield. When transported by runoff water, sediments become the main pollutant of surface waters.

CA techniques reduce runoff, and, therefore, reduce the risk of contamination by both suspended soil particles and plant protection products dissolved in the runoff water.

Comparison of no-tillage with conventional tillage has also shown that the transport of herbicides in surface waters is reduced by 70%, that of sediments by 93% and the runoff is also reduced by 69% (*ECAF, 1999*). As a result, studies on no-tillage in dry land crops, observed between 2% and 18% of soil water increases. All these data make us see that CA techniques prevent, to a large extent, water pollution, improving water quality.

6.3.2. Reduction of diffuse pollution

It would appear that increases in rainwater infiltration could increase nitrogen leaching. The studies carried out by *Kertész et al. (2010)* on no-tillage and by *Márquez et al. (2008)* in groundcovers show how the structural improvements, focused on a better relationship between the macro and micropores of the soil, increase the retention capacity of fertilizers in the shallow pores of the soil and facilitate the assimilation of this element by the plant, reducing losses of nutrients dissolved in runoff and adsorbed in the sediment.

According to the data collected in these investigations, no-tillage reduces nitrogen loss by almost 89%, phosphorus by 95.6% and potassium by almost 79%. In the case of groundcovers, the reductions are 38% in the case of nitrogen, 52% in the case of phosphorus (Fig. 6.4) and 57% in the case of potassium.

Regarding nitrogen, *Goss et al., (1993)* verified that in no-tilled plots, losses by leaching were 21% lower than those in tilled plots (Fig. 6.5). Approximately 95% of the nitrogen was present in the water infiltrated in the tilled plots, implying that most of this element was leached.

The implementation of CA, therefore, largely retains fertilizers and plant protection products in the area in which they are applied, until they are used by the crop or decomposed into other inactive components. Thus, conservation techniques not only greatly reduce runoff, but also lead to a sharp decrease in the amount of fertilizers, herbicides, etc. dissolved in the runoff water or adsorbed by the sediment.

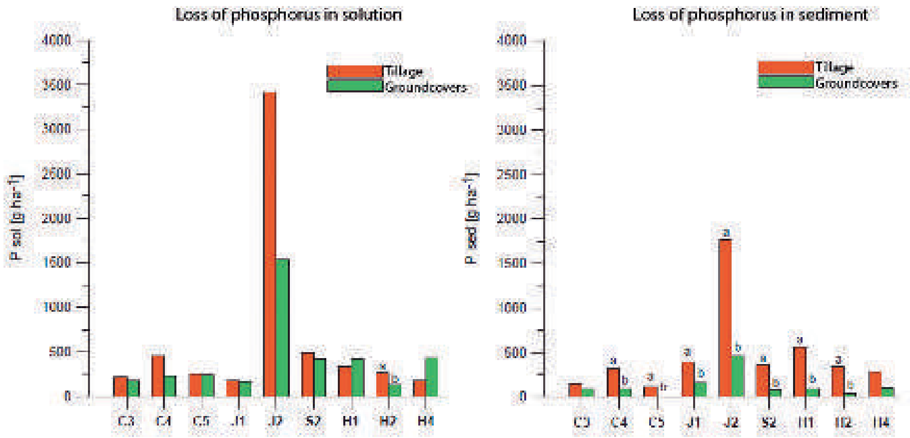


Fig. 6.4. Concentration of phosphorus in solution and associated to sediment in two management systems in olive grove. *Source: Márquez et al., (2008).*

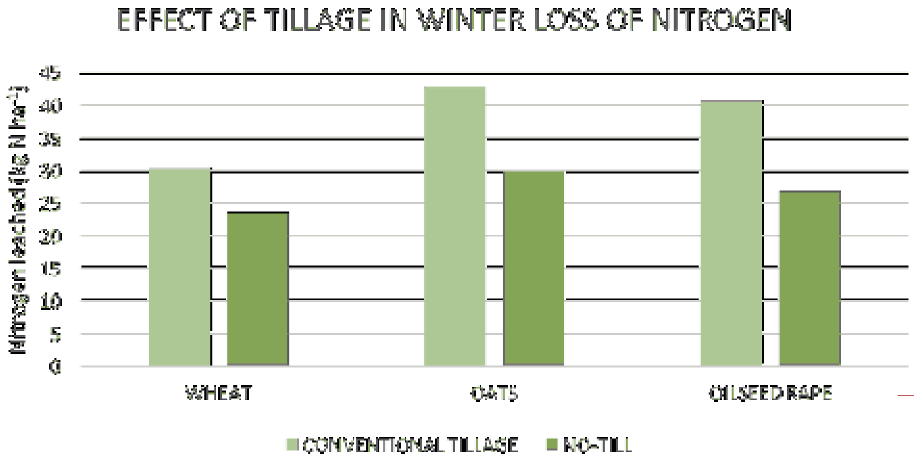


Fig. 6.5. Effects of soil management systems on the leaching of Nitrogen (kg ha^{-1}). Source: *Goss et al. (1993).*

6.4. Economic benefits

The implementation of CA systems entails several economic benefits, some of them are direct and easily quantifiable, such as the improvement of the accounting results of the operation. Some other, such as the cost for public administrations derived from the erosion, pollution, loss of biodiversity or the impact on CO_2 emissions are indirect but not less important.

The main direct economic benefit to the farmer comes from the reduction of production costs since the yield of the crops under CA is similar to conventional systems *(Domínguez Giménez, 1997)*. *Tebrügge and Böhrnsen (2001)* surveyed the opinions of 111 farmers in 7 European countries (Switzerland, Germany, Denmark, UK, Italy, Netherlands and Portugal) and found that reduced working time and lower costs were the dominant reasons for adopting no-till.

There are several studies in Spain in different agroclimatic situations that support the reduction of costs. *González-Sánchez (2010),* obtains that the variable costs of sunflower crop in NT are 250.50 € ha^{-1} compared to 323.50 € ha^{-1} of the crop managed by CT. Also, the cost of durum wheat in CT was 501.74 € ha^{-1} compared to the costs of 458 € ha^{-1} in NT farming system.

Within the framework of the LIFE + Agricarbon project, the CT and NT systems supported by precision agriculture (CA+PA) were analyzed. The profitability of the NT has been considerable, because, while maintaining yields, it showed cost saving compared to conventional management systems. In each campaign, the estimated cost savings were: 59.6 € ha^{-1} on wheat, 72.7 € ha^{-1} on sunflower and 62.0 € ha^{-1} on leguminous plants (Fig. 6.6). In percentages, the cost savings were 9.5% on wheat, 21.6% on sunflower and 15.4% on leguminous crops.

If we take into account that the hourly yield (h ha^{-1}) has decreased by an average of 60% in the CA+ PA systems compared to the CT systems, the benefit obtained per hectare increases even more. Other study that can serve as reference, and which underpin the figures obtained in LIFE + Agricarbon project, was carried out by *Crochet et al. (2008)*. This study compared labour, herbicide and mechanization costs for crop establishment by no-till and ploughing (Table 6.4) and showed the total of these costs for no-till was 50% of that for ploughing.

This cost reduction, while maintaining the income, in comparison with CT practices, implies a greater profitability for the farmer and therefore an improvement of their economy. Hence, there can be made great progress, considering the rate of implementation of CA techniques in Europe. According to data in chapter 3 of this report, the NT hectares of the main extensive arable crops represent only 3.48% of the total area of these crops, as opposed to the countries with higher implantation rate, such as Argentina, where its adoption is above 80%. External and intrinsic factors make farmer reluctant to change. Market uncertainty, strict regulation, future uncertainty - which creates immobility - investments with medium to long-term returns, etc. are some of the causes that explain this behavior.

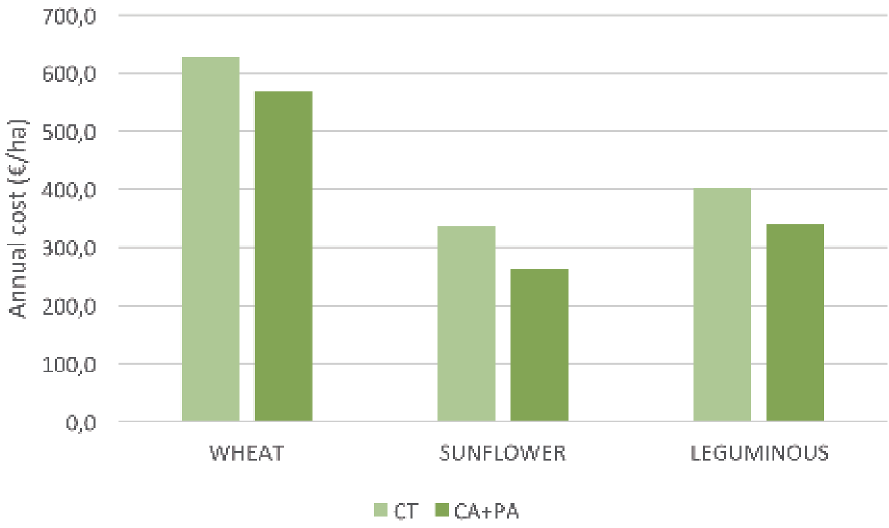


Fig. 6.6. Evaluation of costs (€ ha-1) obtained in the plots under conventional tillage (CT) and no-till+precision agriculture (CA+PA). Source: LIFE + Agricarbon.

Table 6.4. Cost of crop establishment for conventional and no-till treatments in France. Mechanisation cost includes equipment depreciation, maintenance and operating cost. Source: *Crochet et al., 2008.*

Tillage system	Labour cost (€ ha^{-1})	Herbicide (€ ha^{-1})	Mechanization[1] (€ ha^{-1})	TOTAL (€ ha^{-1})
Plough, cultivate, drill	31	2	134	167
Spray, direct drilling machine	10	7	67	84

Regarding permanent crops, *Gil Ribes et al. (2007)* have carried out economic profitability studies on olive groves in Spain, comparing four management systems: CT (harrow, cultivator, roller compactor), NT (suppression of labor and bare soil by herbicide treatments), spontaneous groundcover and sown GC, both mechanically mowed. The cost reduction in the spontaneous GC system with respect to the CT system was around 18 € ha^{-1}, while the sowing GC system, meant approximately 20 € ha^{-1} higher cost than in CT. It should be noted that, in all cases, the highest costs corresponded to the use of machinery, which were around 50%, resulting in the reduction of overall costs in CA systems, due to the reduction in working time. This decrease is greater if the mechanical control of the cover is replaced by a chemical control (which is also more economical).

The benefits of CA systems in permanent crops, mainly those obtained maintaining groundcovers, have been better perceived by the farmers, which has resulted in their greater implementation. According to data in chapter 3 of this report, groundcovers represent 15.6% (2,008,888 ha) of total amount of hectares (12,905,081 ha).

In the analysis of the cost-efficiency relationship, one also needs to take into account that the implementation of these practices by a farmer who previously carried out a conventional management system based on tillage, requires an initial investment in the case that he decides to purchase the necessary equipment. The higher cost the farmer would have to face is the no-till seeder, which can vary between € 18,000 and € 50,000 depending on the characteristics of the sowing train and the working width. Return on this investment will depend on the number of working hours per year, so it may be advisable for small producers to contract the services of an external company to carry out the sowing operation. An alternative for those farmers who do not want to make a significant initial investment is to subcontract the operations, and there are already companies in the market that can provide services that can respond to this type of demand. On the other hand, in the first years it is necessary for the farmer to be trained and informed appropriately in order to reduce the risks and problems that could arise when shifting the system. In any case, it is clear that the higher investment cost is returned by the increase in the profit margin obtained by changing the management system, which means that these practices not only bring environmental benefits, but also economic ones.

6.5. Social benefits

The reduction of costs and the improvement of the profitability increase the competitiveness of the farms and therefore their sustainability, fixing population in the rural environment and creating wealth. If an activity is not economically sustainable, it cannot be socially sustainable.

A study carried out by *Arnal Atares (2014)* shows the noticeable reduction of working time in crops. Adding all the working hours in the crop's agricultural operations (with the exception of the harvester which is rented), Arnal estimated that the average working time required for the analyzed crops (extensive herbaceous) was 7.50 h ha^{-1} in the case of conventional management, 5.75 h ha^{-1} in minimum tillage and 3.90 h ha^{-1} in NT management system, which means a decrease of 1.75 h ha^{-1} in minimum tillage and 3.6 h ha^{-1} in NT systems compared to CT (Fig. 6.7). This reduction implies that NT management uses 52% of the time required in conventional agriculture.

In 2013 there were 10,841,000 farms in EU-28 (*Eurostat, 2013*) and, as showed in Fig. 6.8, the majority of the employed labor is familiar, integrating the farmer and relatives, who often do not receive adequate remuneration from the performed work due to the low profitability of farms. The reduction of working hours per hectare thanks to CA in addition to the reduction of costs, allows more time for other activities both inside and outside the farm (family, training, leisure, activities for the community, etc.) improving the economic and welfare conditions of farmers and their families.

The decrease in the number of working hours per hectare should not lead to a decrease of employment in

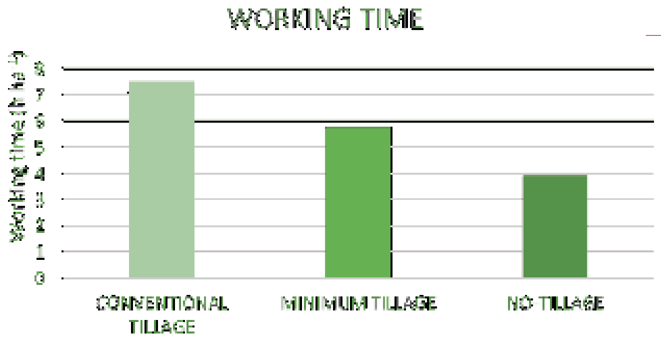


Fig. 6.7. Working time dedicated to agricultural operations in the analyzed systems, conventional tillage (CT), minimum tillage (MT) and no-tillage (NT). Source: *Arnal Atares, 2014.*

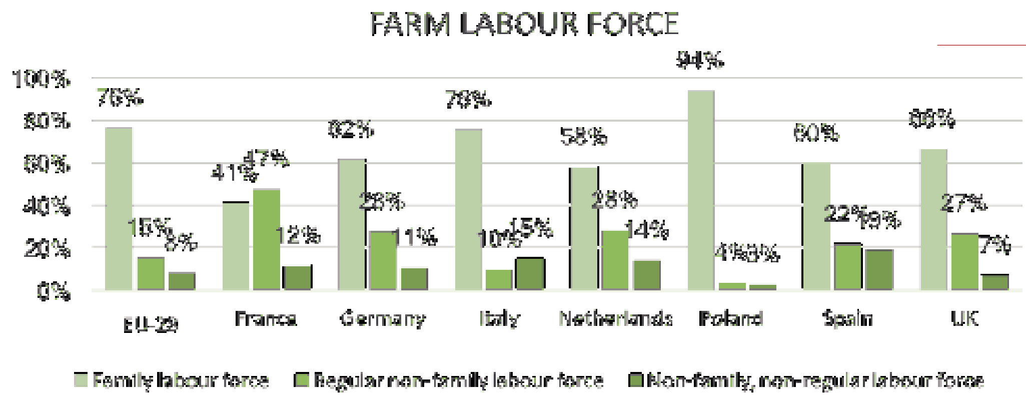


Fig. 6.8. Distribution of annual work units (AWU) according to the type of worker. Source: *Eurostat, 2013.*

rural areas where CA is implemented, since the greater use of technology induces indirect and more qualified work (machinery dealers, workshops, supplies, etc.), transferring employment from the agricultural sector to other sectors of higher added value.

Another important aspect related to society is that, due to the more complete training skills of CA farmers, their environmental awareness will be greater and they will have a deeper knowledge about the risks that agricultural activity entails and about the techniques to reduce them.

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CHAPTER 7
Conclusions

Conclusions

1. Conservation Agriculture is a sustainable farming approach based on three interlinked principles: (1) Continuous minimum mechanical soil disturbance; (2) Permanent organic soil cover; and (3) Diversification of crop species grown in sequences and/or associations. In practical terms, no-tillage is the term frequently used to refer to Conservation Agriculture in annual crops, whereas leaving groundcovers in-between tree rows is the case for permanent crops.

2. Conservation Agriculture has multiple environmental benefits, such as reducing soil erosion up to more than 90%, improving the quality of soil and water, increasing biodiversity, mitigating and adapting to climate change, among others. At the same time, Conservation Agriculture helps improve farmers' profits and competitiveness.

3. Climate change is a global threat, whose impact will adversely affect agricultural production also in Europe. The lower amount of precipitation, periods with excess rainfall and prolonged drought periods, together with the increase in temperature, will negatively impact the European countryside. Through Conservation Agriculture, these effects can be mitigated. Indeed, research confirms that Conservation Agriculture helps mitigate climate change by sequestering carbon in the soil and helps adapt through water saving as a consequence of less evaporation from the soil.

4. Carbon sequestration rates vary within the European continent. In the Mediterranean, the CO_2 stored in the soil through Conservation Agriculture can be up to 3 tons per hectare and year, whereas this rate is around 1.5 tons in the Continental region, 1 ton in the Atlantic, and only around 0.1 ton in the Boreal region. In

permanent crops, maintaining a groundcover in comparison with conventional agriculture, is capable to sequester more than 5 tons of CO_2 per hectare and year in the Mediterranean region, while in the Continental and Atlantic ones, this rate is approximately half.

5. International treaties, such as the Paris Agreement (COP21, 2015) and the Initiative 4 per 1000, identify the improvement of the management of agricultural soils as a key factor to mitigate climate change. In this context, around 100 of the 187 signatory countries have included land-related measures in their reduction plans. In the Paris Agreement, the European countries have committed themselves to reduce non - emissions trading system (non-ETS) emissions by 30% by 2030 which means over 856 M tons of CO_2. Therefore, non-ETS emissions in EU-28 by 2030 should not exceed 1,991 M tons.

6. Conservation Agriculture can contribute to reduce GHG emissions by storing CO_2 as organic carbon in the soil. The total figure would be around 190 M tons of CO_2. This means that carbon sequestration through the practice of Conservation Agriculture, at European level, could account for almost 10% of the EU non-ETS allowed emissions by 2030, and for over 22% of the commitments in non-ETS GHG reduction.

7. Conservation Agriculture is a holistic approach that promotes sustainable intensification of agricultural production, and therefore needs essential technologies and innovative solutions for its application on the field. The application of Conservation Agriculture implies a change in the management of the soils, since tillage is not used neither to eliminate adventitious vegetation nor to prepare the seedbed. Therefore, it is necessary to use seeding machines adapted to work on soils with a solid seedbed and groundcovers, and to control weeds with plant protection products instead of ploughing.

8. There are diverse types of no-till drills on the market adapted to the different European soil conditions, and to different cover crops and amount of residues that can occur in the rotations. In addition, broad-spectrum herbicides with a low ecotoxicological risk, such as glyphosate-based herbicides, are essential tools to control weeds, avoiding soil degradation caused by intensive tillage, commonly performed in conventional and organic agriculture.

9. Conservation Agriculture uses inputs in a more efficient way, which also leads to economic savings for farmers and environmental benefits through less off-site transport of nutrients and plant protection products. According to studies, through Conservation Agriculture, the farmer can save 24% of the total costs of cultivation in comparison with conventional tillage, and about 9% compared to minimum tillage. Conservation Agriculture is a win-win option for farmers, as yields are maintained or even increased, with lower production costs.