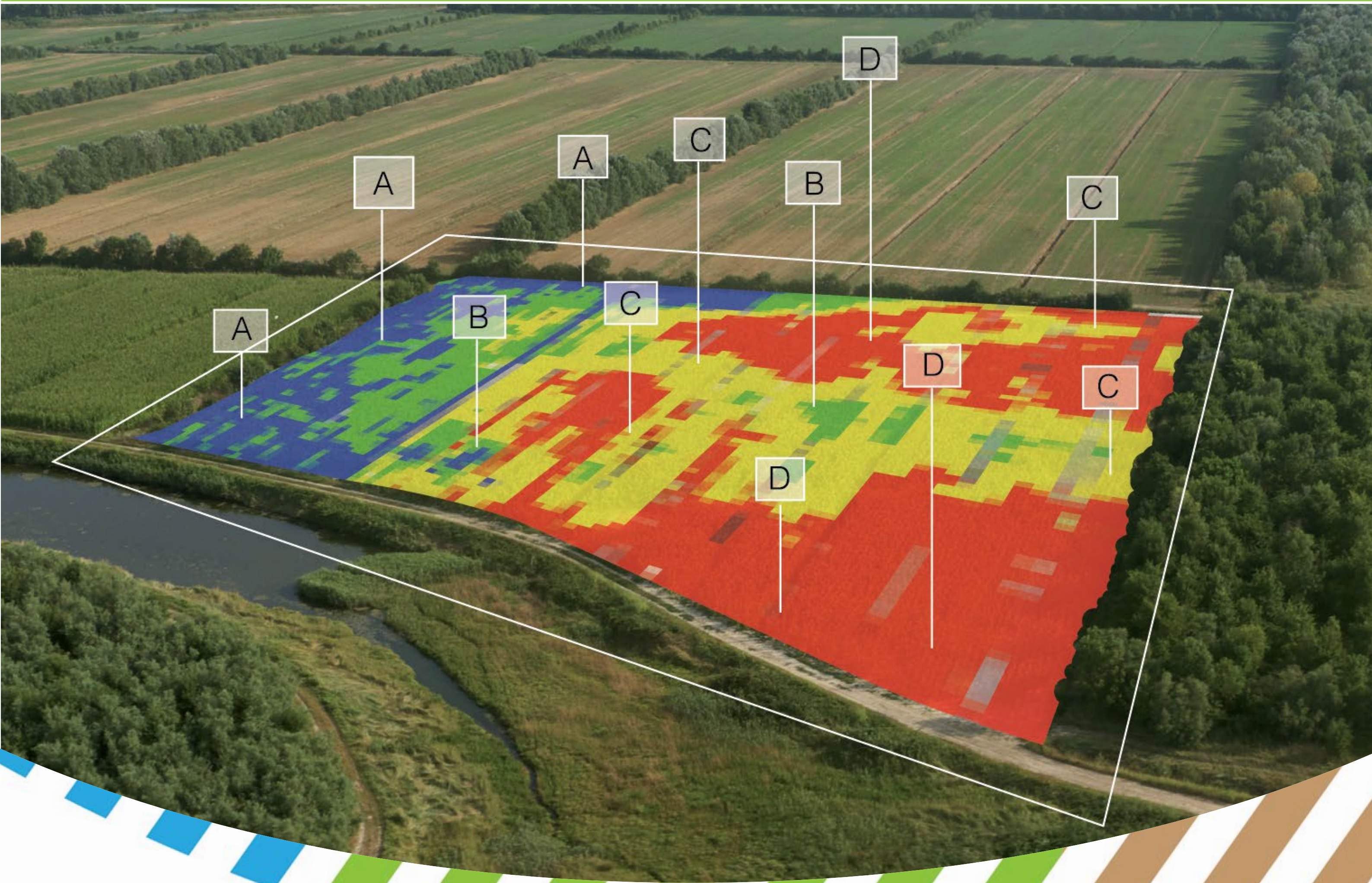
INNOVATIVE CROPPING SYSTEMS FOR A CLIMATE SMART AGRICULTURE



AGRICARE
Innovative Green Farming

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Cover: the pilot farm "Vallevecchia" and an example of a prescription map overlapped on the field.

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EXECUTIVE SUMMARY

In the coming years agriculture will have to face many fundamental global challenges: food security, economic development, environmental degradation, and climate change. The world population is expected to expand beyond nine billion by 2050 and increases in food demands associated with rising income levels is likely to require increases in total food production.

To achieve food security and agricultural development goals, adaptation to climate change and lower greenhouse gas emissions will be necessary.

The agricultural sector itself is a major contributor to GHG emissions and it is the world's largest driver of species loss and a major contributor to soil degradation.

To face the above mentioned challenges an overall approach can be provided by Climate Smart Agriculture (CSA), which integrates the three dimensions of sustainable development: economic, social and environmental by jointly addressing food security and climate challenges. In fact CSA could be described as an approach involving different elements rather than a set of practices that can be universally applied. In particular it requires tools to identify climate-smart sustainable agricultural growth pathways for given locations and situations. CSA aims at identifying technical and economic principles that can be applied in the development of climate-smart action options that are embedded in national and local institutional frameworks.

The agricultural sector can reduce its own emissions and those ones coming from other sectors (via the photosynthetic process), storing the carbon in soils, and reducing emissions in other sectors by displacing fossil fuels with biofuels. It offers several opportunities to mitigate the portion of global greenhouse gas emissions that are directly dependent upon land use, land-use change, and land-management techniques. In agriculture, mitigation is focused primarily on reducing GHG emissions and/or increasing carbon sequestration and storage (IPCC, 2007).

A decrease in greenhouse gas emissions can be obtained directly, by reducing energy consumption associated specifically with using machinery for the different cultivation operations (e.g. conservative agriculture techniques), but also indirectly, by changing soil and production of fertilizers.

In this framework a demonstration project, named AGRICARE, has been developed with the aim of comparing technologies and solution to reduce agricultural CO2 emissions, which can be considered an innovative approach for agricultural sector. The project, co-financed by LIFE+, the financial instrument for the environment of the European Commission, has demonstrated that it is possible to apply Conservation Agriculture techniques associated with Precision Agriculture techniques to deal with CO2 emission. The results reveal good development prospects and demonstrate how the economic and environmental benefits gained from the Conservation Agriculture will be amplified by applying the variability management techniques of Precision Agriculture.

The adoption of conservative and precision agricultural techniques are also strongly linked to those policies such as Rural Development Programmes and the development of carbon credit market, which give farmers incentives to implement them.

CHAPTER 1
AGRICULTURE AND CLIMATE CHANGE

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INTRODUCTION

Climate change was acknowledged as a primary topic in the international agenda with the ratification of the Kyoto Protocol. The Protocol fully commits to the valorisation of agricultural and forestry sectors in order to contribute to the reducing of greenhouse gases emission. Agriculture plays a double role: it is an net emitter of GHG due to fossil fuel consumption, nitrogen fertilization and enteric fermentation and on the other side it could play the role of carbon sink by enhancing its soil carbon sequestration potential.
At global level Agriculture sector accounts for approximately one-fifth of the annual increase in radiative forcing of climate change but estimates tell us that at the same time ecosystems remove carbon dioxide from the atmosphere by sequestering carbon in biomass, dead organic matter, and soils, and they are able to offset approximately 20% of emissions from this sector. The global soil carbon (C) pool is about 2500 gigatons and is 3.3 times the size of the atmospheric pool (760 Gt) and 4.5 times the size of the biotic pool (560Gt) (Lal, 2012).
The Soil organic carbon pool represents a dynamic equilibrium of gains and losses and agriculture could play a crucial role to keep it stable or increase carbon pool and avoiding soil C depletion by adopting appropriate soil management techniques.
Accounting GHG emission from agriculture it's a fairly complex issue and many efforts have been made in the last decades to better estimates the emission addressing the complex biological interactions of agricultural systems.
The estimates on the emissions are documented by each Member State on the National Inventory Report (NIR), which is the recognised instrument for emissions and carbon sink accounting. Those estimates are set according to the methodological guideline approved by UNFCCC (United Nations Framework Convention on Climate Change).

Climate change was acknowledged as a primary topic in the international agenda with the ratification of the Kyoto Protocol.

International steps for a climate policies
The Kyoto Protocol was adopted on 1997 and entered into force on February 2005. It commits the signing countries by setting internationally binding emission reduction targets. The detailed rules for the implementation of the Protocol were adopted in Marrakesh in 2001 and its first commitment period started in 2008 and ended in 2012. A further step was at the Paris climate conference (COP21) in December 2015 where 195 countries adopted the first-ever universal, legally binding global climate deal. The agreement recognised the priority of climate change challenges in the definition of development policies. Through more than a decade of continued policy, the EU has assumed world climate leadership putting strong efforts to reduce emission by introducing new legislation, target and incentives and we can observe that the EU has succeeded in decoupling its emissions from economic growth. Since 1990 GDP (Gross Domestic Product) increased by 45% (to 2013) while emissions decreased by 19%. At the same time the obligations under the Kyoto Protocol to 2012 were achieved and surpassed: a reduction of 8% was promised; a reduction of 18% was delivered. For the near future the European Commission is looking ways to make the EU economy more climate-friendly and less energy-consuming and set up a low-carbon economy roadmap with the goal, by 2050, to cut greenhouse gas emissions to 80%, below 1990 levels, with an intermediate milestones of 40% emissions cuts by 2030 and without any doubt to reach this goal all sectors need to contribute.

AGRICULTURAL SECTOR EMISSIONS

Agricultural sector emissions consider the following areas:

- emissions of N_2O (nitrous oxide) from soil, mainly driven by nitrogenous fertilisers use;
- emissions of CH_4 (methane) due to enteric fermentation and rice cultivation;
- emissions of CH_4 and N_2O due to liquid and solid manure management;
- emissions non-CO_2 (CH_4 and N_2O) related to stubbles and residues burning.

To the previous areas we must add those related to the LULUCF sector (Land Use, Land Use Change and Forestry) which considers, as a whole, all those aspects related to the different soil coverage and the feasible agricultural and forestry land management systems. The Kyoto Protocol regulated LULUCF sectors by identifying eligible binding activities (afforestation, reforestation and deforestation) for carbon accounting and voluntary commitments (forestry management, grassland management and revegetation). As an example the Italian government considered appropriate to take into account only those credits related to the forestry management, by excluding all the agricultural activities, at least for the period 2008-2012, due to the accounting procedures uncertainty. By the way starting from 2022, these estimates will be binding for each Member State and should be turned into official numbers inside the NIR despite the complexity and uncertainty of estimation.

The EC strategic guidelines for rural development set climate change mitigation as the priority areas of contribution of the Rural Development Programme . Agriculture, forestry and land management will play a key role in addressing climate change issues, thus contributing to achieve the European environmental objectives.

AGRICULTURAL SECTOR CONTRIBUTION TO GREENHOUSE GAS EMISSIONS

Agricultural sector contributes up to 10% of total greenhouse gases emissions in EU-28 (LULUCF excluded), equivalent to 464.3 million of tCO_{2eq}. Between 1990 and 2012 (Figure 1), non-CO_2 agriculture-related emissions decreased by 23.1%, mainly due to: the livestock fall, a better manure management, the progressive adoption of more effective farming practices, the reduction of the quantity of nitrogen delivered as well as the impact of economic crisis on input utilisation. These trends had been also influenced by the introduction of new regulatory framework and the implementation of policies focused on climate change mitigation, as already mentioned.

According to the National Inventory Report (NIR) in 2014 (ISPRA 2016) agricultural sector emissions in Italy are equal to 36.2 Mton of CO_{2eq}, the 6.4 % of total emissions.

The IPCC methodology applied for calculation attributes to agriculture only part of the items which are related to the primary sectors. There are not taken into consideration, for example, all those logistic costs for goods distribution which are counted in the transport sector, and also those energy-demand activities, such as tractor driving, irrigation, or packaging, which are attributed to the energy sector.

ITALIAN EMISSION TRENDS

In 2015 6.92% of the Italian GHG emissions, excluding emissions and removals from LULUCF, originated from the agriculture sector, was the third source of emissions, after the energy and industrial sector which account for 81.80% and 6.94%, respectively (NIR 2017). For the agriculture sector, the trend of GHGs from 1990 to 2015 shows a decrease of 15.9% due to the reduction of the number of animals and cultivated surface/crop production, the amount of synthetic nitrogen fertilisers applied and the recovery of biogas

(Figure 2). CH_4, N_2O and CO_2 emissions account for 61.6%, 37.0% and 1.5% respectively. In 2015, the agriculture sector has been the first source for CH_4 sharing 42.7% of national CH_4 levels and for N_2O accounting for 60.8% of national N_2O emissions. As for CO_2, the agriculture sector represents 0.12% of national CO_2 emissions.

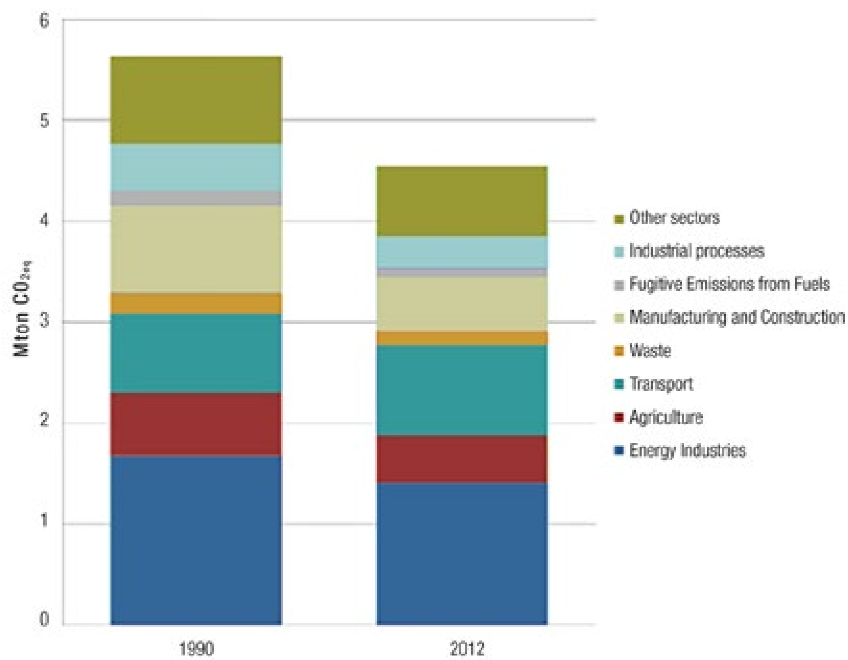


FIGURE 1

Changes in EU-28 greenhouse gas emissions by sector, 1990-2012 based on EEA (2014) and EEA Data viewer consulted 187372015

Source: EEA Technical Report n. 9/2014

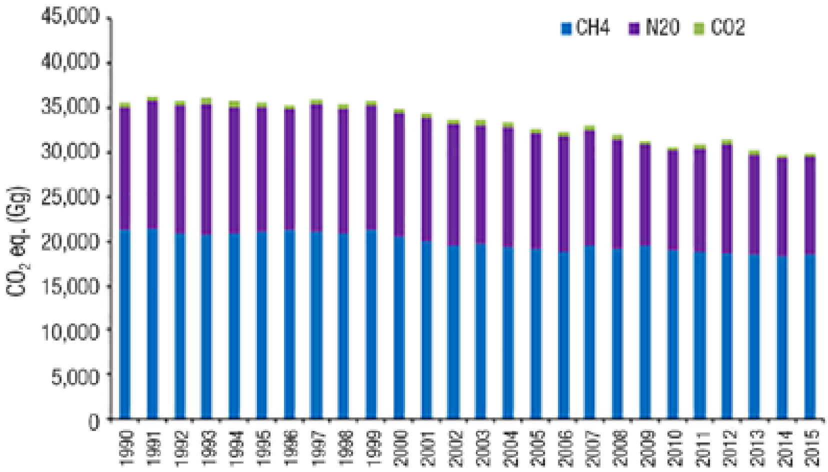


FIGURE 2

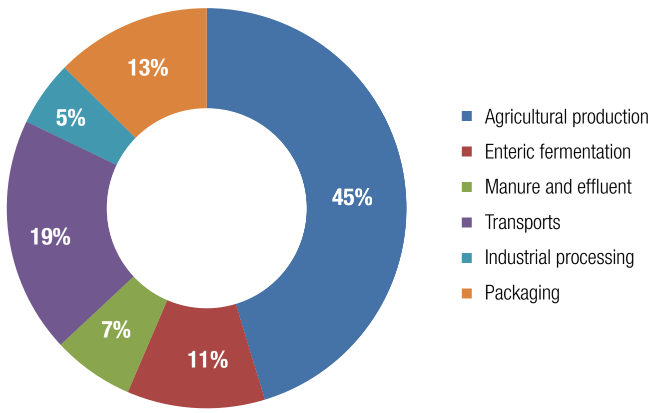
Trend of GHG emissions for the agriculture sector from 1990 to 2015 (Gg $CO_{2\,eq}$)

Source: Italian Greenhouse Gas Inventory 1990-2015 National Inventory Report 2017

However, by applying a Life Cycle Assessment approach to all those components of agriculture and agro-industry sector, such as production, processing, logistics and distribution of agri-food products (Figure 3), the emissions balance raises to 104 Mt CO_{2eq}, representing about the 20% of greenhouse gases emissions at national level (Report AGRICARBON ISMEA 2009); a value three times higher to that accounted by NIR. The in-depth sector analysis enables the estimation of the overall agri-food sector emission burden, providing a more comprehensive overview of weaknesses and opportunities in order to design a more responsive environmental sustainable policy (AA.VV., 2011). According to AGRICARBON research, emission reduction policies, based on good-farming practices, should cover up to 2.5 Mt CO_{2eq}.

FIGURE 3

Overall National emissions balance of agro-industry sector breakdown



Source: AGRICARBON project, Ismea 2009

EU Agriculture emission targets

The EU has taken up the challenge to limit climate change to 2°C and has based its policy on considerations related to cost effectiveness and relies on market based instruments. In 2011, EU took a further step forward and defined a roadmap for the transition to a low carbon emission economy setting the objective of reducing by 36-27% the GHG emission in agricultural sector by 2030, and a more ambitious target by 2050 (42-49%). Moreover, with the aim of assessing funding options to foster this transition, the EU Commission suggested the definition of a matching incentive scheme to achieve 2050 goals. Following the EU Decision n. 529/13 by 2021, within its National Inventory accounting framework, each Member State should provide preliminary estimates on GHG emissions and GHG carbon sink on soil and biomasses due to cropland management and grassland management. Starting from 2022, these estimates will be binding for each Member State and should be turned into carbon credits for those virtuous farms which absorbed more carbon than emitted. This could be recognized as a challenge due to the complexity and uncertainty of estimation.

LAND MANAGEMENT AND EMISSIONS

Agricultural soil is crucial to combat climate change, its contribution has not been already accounted by Italy in the Kyoto protocol framework although, as stated above, it should be included in calculation by 2022. Soils can absorb the organic carbon by the accumulation of organic substances that are produced from CO_2 organication due to photosynthesis (carbon sequestration). In natural soils, permanent grassland and agricultural lands managed with minimum or no working patterns, organic carbon (SOC), reaching the soil in the form of crop residues, can be higher than that lost during the decomposition and mineralisation of organic substance, so that its contribution on carbon sequestration from the atmosphere can be positive over time.

Conservation Agriculture techniques can increase carbon sequestration from the atmosphere and reduce GHG emissions of agro-ecosystems (Pisante, 2007).

The adoption of good farming practices contributes to increase soil organic matter and therefore organic carbon pool, impacting on soil-related biodiversity and on soil structure stability so as to enhance soil resistance to erosion.

Conventional practices, usually intensive in terms of depth and frequency, caused a substantial loss of carbon) and could increase soil erosion risk especially of the SOC rich top layer

Among those farming practices which influence the most soil carbon pool it is worth recalling: tillage practices, crop rotation and crops residual management (Lal, 2001).

Extending the analysis they are: appropriate soil management systems (avoiding soil layers' reversal), crop alternation (based on a large variety of crop species with an increasing role of fodder crops), cover crops and a conservative management of crop residuals.

Tillage operations determine more significant variation on soil in a shorter time with respect to other operations, generating effects (both positive and negative) on crops productivity and environment (Bonari e Mazzoncini, 1999)

Every modification in the soil use and management induces changes on carbon stock but we should be taken into consideration also the resulting fluxes of other greenhouse gas, such as nitrous oxide (N_2O) and methane (CH_4).

N_2O from the agricultural soil is a consequence of nitrogen fertilisers inputs and livestock waste for denitrification processes while CH_4 is mainly the result of soil organic matter degradation when anaerobic condition takes place, of manure distribution and combustion of crop residues.

Taking into account that N_2O and CH_4 shows a warming potential much higher than CO_2, (respectively 300 and 21 times higher), it is significant to control and decrease their emission.

Appropriate soil management has a key role to ensure an effective contribution of agriculture to mitigation of efforts. it is observed that soil layers are a dynamic and complex equilibrium of gains and losses. Innovation in soil and crop management techniques could be one of the greatest opportunities for agriculture sector to face with GHG emission reduction.

It is observed that soil layers are a dynamic and complex equilibrium of gains and losses. Innovation in soil and crop management techniques could be one of the greatest opportunities for agriculture sector to face with GHG emission reduction.

CHAPTER 2
CHALLENGES FOR CLIMATE SMART AGRICULTURE

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INTRODUCTION

In the coming years, agriculture will have to face many fundamental global challenges including food security, economic development, environmental degradation, and climate change.

The world population is expected to expand beyond nine billion by 2050 and increases in food demands associated with rising income levels is likely to require increases in total food production. FAO estimates that agricultural production will have to increase by 60 percent by 2050 to satisfy the expected demands for food and feed. Agriculture has to produce more food and fibre to feed a growing population with a smaller rural labour force and more feedstocks for a potentially huge bioenergy market.

In 2020, global food production is expected to have a gap between supply and demand of wheat, rice and corn by 14, 11 and 9% respectively, while only soybean production will be around 5% surplus, in addition, there will be a global deficit of major crops by 2020 (Hisas, 2011). Yield increases of major crops of 1.1–1.3% per year are required to feed the world in 2050 (Fischer et al., 2014). Global climate change will make it difficult to achieve these yield increases in some regions.

The agricultural sector is also a major contributor to GHG emissions and it is the world's largest driver of species loss and habitat conversion and a major contributor to toxic and nutrient pollution, soil degradation, and invasive species introductions. Therefore agriculture has to adopt more efficient and sustainable production methods and adapt to climate change, it has to become more resilient and adopt mitigation practices. These pressures on global resources will only continue to grow as world population and income levels rise. To ensure food security and adapt to climate change reducing emissions intensity, thus contributing to mitigate climate change, the agricultural sector and food system have to be more efficient in the use of resources.

A new agricultural paradigm is required, reducing dependence on high inputs and increasing crop diversity, yield stability and environmental resilience.

In the coming years, agriculture will have to face many fundamental global challenges including food security, economic development, environmental degradation, and climate change.

CLIMATE-SMART AGRICULTURE

Agriculture must therefore transform itself if it is to feed a growing world population and provide the basis for economic growth preserving natural resources at the same time. To achieve food security and agricultural development goals, adaptation to climate change and lower greenhouse gas emissions intensities per output will be necessary. According to these challenges, FAO at the Hague Conference on Agriculture, Food Security and Climate Change in 2010 (FAO, "Climate-Smart" Agriculture Policies, Practices and Financing for Food Security, Adaptation and Mitigation. 2010), defined and presented Climate-Smart Agriculture (CSA).

CSA could be described as an approach that involves different elements embedded in local contexts rather than a set of practices that can be universally applied. CSA relates to actions both on-farm and beyond the farm, and it has close links with technologies, policies, institutions and investment.

Different elements of climate-smart agricultural systems include:

- management of farms, crops, livestock, aquaculture and capture fisheries to balance near-term food security and livelihoods needs with priorities for adaptation and mitigation;

- ecosystem and landscape management to conserve ecosystem services that are important for food security, agricultural development, adaptation and mitigation;
- services for farmers and land managers to enable better management of climate risks/ impacts and mitigation actions.

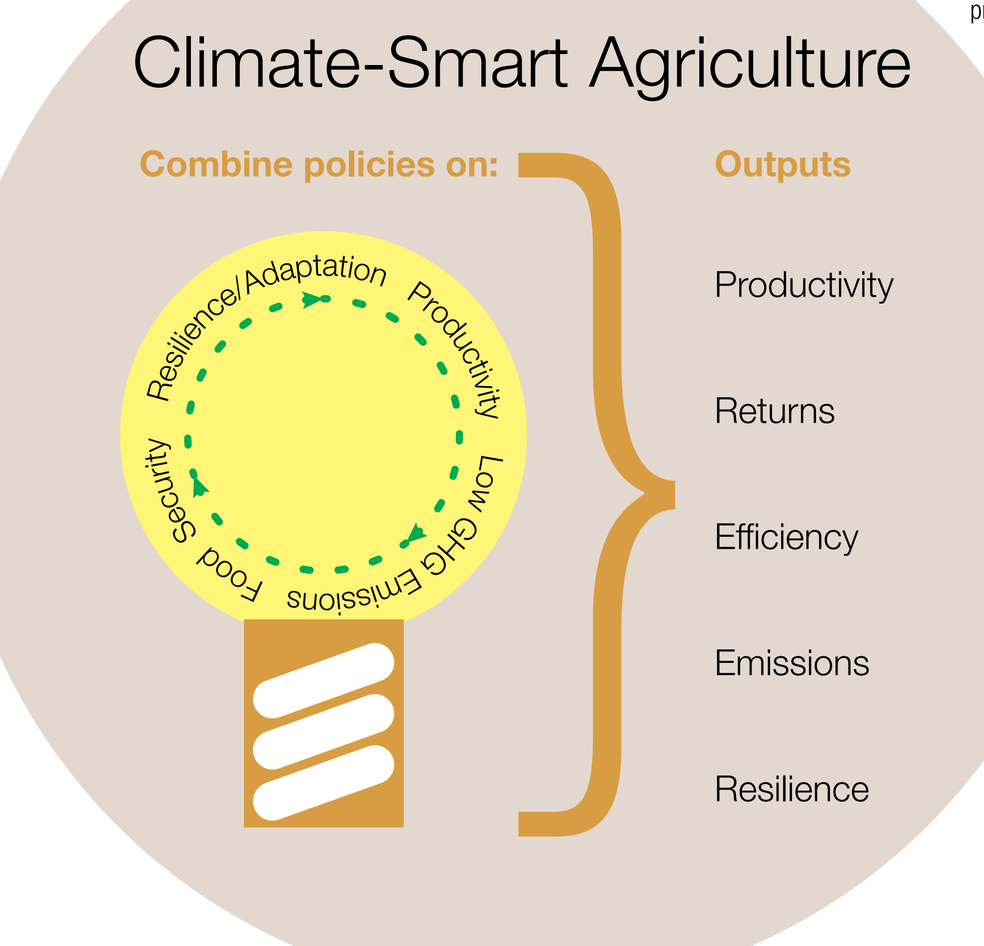
CSA integrates the three dimensions of sustainable development: economic, social and environmental by jointly addressing food security and climate challenges.

CSA contributes to the achievement of sustainable development goals. It brings toghether practices, polices and instituitions tha are not necessarily new but are used in the context of climatic changes. It integrates the three dimensions of sustainable development: economic, social and environmental by jointly addressing food security and climate challenges.
It is composed of three main objectives:

1. sustainably increasing agricultural productivity and incomes;
2. adapting and building resilience to climate change;
3. reducing and/or removing greenhouse gases emissions, where possible.

(Climate-Smart Agriculture sourcebook, FAO 2013)

The CSA approach involves tools to identify climate-smart sustainable agricultural growth pathways for given locations and situations. CSA aims to identify technical and economic principles that can be applied in the development of climate-smart action options that are embedded in national and local institutional frameworks.
CSA is one of the 11 Corporate Areas for Resource Mobilization under the FAO's Strategic Objectives. It is in line with FAO's vision for Sustainable Food and Agriculture and supports FAO's goal to make agriculture, forestry and fisheries more productive and more sustainable.
In order to achieve sustainable development goals, CSA should try to include not only few developing countries but also developed countries. In fact this approach will be able to mitigate the effect of climate change on agriculture and will make this sector sustainable.



CSA's OBJECTIVES

1. Sustainably increasing agricultural productivity and incomes
2. Adapting and building resilience to climate change
3. Reducing and/or removing greenhouse gases emissions, where possible

MITIGATION AND ADAPTATION ACTION

Climate change is affecting the productivity of the agricultural sector and the geographic distribution of crops. Major climate related disturbances include: increasing atmospheric carbon dioxide, rising temperature and a modified frequency of extreme events (heat/cold wave), possibly leading to more drought and floods, long dry spells. These changes will in turn alter the availability of water resources, productivity of grazing lands and livestock, and the distribution of agricultural pests and diseases.

Considering that, in the coming years, agricultural systems will face the future needs of an expanding global population, significant progress must be made in assisting the agricultural sector as a whole, particularly farmers, who are the main stakeholders to increase the resilience of agricultural systems to climate change, better preserving soil fertility and water resources, biodiversity and reducing greenhouse gas emissions and impacts on deforestation.

Although agriculture releases to the atmosphere significant amounts of CO_2, CH4 and N2O, in this work, consistent with what was done in the Agricare project, only the role of CO_2 was taken into account.

The agricultural sector can reduce its own emissions, offset emissions from other sectors (via the photosynthetic process), storing the carbon in soils and reducing emissions in other sectors by displacing fossil fuels with biofuels.

Concerning for the reduction of its emissions, it offers several opportunities to mitigate the portion of global greenhouse gas emissions that are directly dependent upon land use, land-use change, and land-management techniques .

The Intergovernmental Panel on Climate Change (IPCC) defined mitigation as “technological

The agricultural sector can reduce its own emissions, offset emissions from other sectors (via the photosynthetic process), storing the carbon in soils and reducing emissions in other sectors by displacing fossil fuels with biofuels.

change and substitution that reduce resource inputs and emissions per unit of output" (IPCC, 2007). In contrast to adaptation action, the potential benefits of mitigation action are uncertain, entail substantial lag time, and accrue globally rather than locally (Walthall et al., 2012). Adaptation has always been central to farming, and over millennia farmers have generally been adept at adapting agriculture to a changing environment (Organisation for Economic Co-operation and Development [OECD], 2012). Although farmers manage at multiple scales, their adaptation decisions are primarily driven by private benefits reaped in the here and now (Jackson et al., 2010). In the coming years, the effective issue will be the rate and nature of climate change compared to the adaptation capacity of farmers. If future climate change is relatively regular, farmers may successfully adapt to changing climates by applying a variety of agronomic techniques, such as adjusting the timing of planting and harvesting operations, substituting cultivars, and – where necessary – modifying or changing altogether their cropping systems.

In agriculture, mitigation is focused primarily on reducing GHG emissions and/or increasing carbon sequestration and storage (IPCC, 2007). Soil represents one of the most important carbon sinks on the planet.

AGRICULTURAL MITIGATION OPTIONS

In agriculture, mitigation is focused primarily on reducing GHG emissions and/or increasing carbon sequestration and storage (IPCC, 2007). Agricultural mitigation options can be mostly divided into two categories: a) strategies to maintain and increase stocks of organic C in soils (and biomass), and (b) reductions in fossil C consumption, including reduced emissions by the agricultural sector itself and through agricultural production of biofuels to substitute for fossil fuels.

STRATEGIES TO MAINTAIN AND INCREASE STOCKS OF ORGANIC C IN SOILS

Soil represents one of the most important carbon sinks on the planet and there are two main ways to maintain and increase carbon stocks in it:

1. to protect existing carbon in the system by slowing decomposition of organic matter and reducing erosion;
2. to increase the amount of carbon in the system.

A primary method for the first approach is to reduce the frequency with which the soils are tilled. It is important not only the frequency and the number of operations performed over time, but it is also critical the depth at which plowing is performed in the soil. To reduce field erosion and to preserve the amount of organic matter present in the soil, reduced tillage and reduced plowing can be carried out. Such techniques are one of the principles of conservation agriculture that will be addressed in the next chapter.

Soil carbon can also be maintain through practices that control erosion with covering soil permanent, using cover crops, stubble and crop residues, and managing natural flora.
The use of crop residues on the soil and the choice of a rational rotation are also the main principles of conservation agriculture, which at the same time protect the soil from erosion, increase its organic matter, reduce the presence of weeds, and increase the complexity of the cropfield system, its biodiversity and therefore its resilience, that is, the ability to face with adverse climatic conditions.

STRATEGIES TO REDUCE FOSSIL FUEL CONSUMPTION

A decrease in greenhouse gas emissions can be obtained directly, as mentioned above by reducing energy consumption associated specifically with using machinery for the different cultivation operations, but also indirectly, by changing soil management and production of fertilizers. The indirect emissions are connected with the system of extraction, transport, refining and distribution of fertilizer. The spreading of a fertilizer does not in and of itself result in direct CO_2 emissions. It is instead necessary to consider that a great aumont of fossil energy was used to produce it, which is “contained” in the fertilizer itself and virtually emitted when it is spread on the soil. In order to more efficiente use of inputs, farmers can adopt digital tools and precision agriculture techniques that ensure more precisely apply fertilizer.

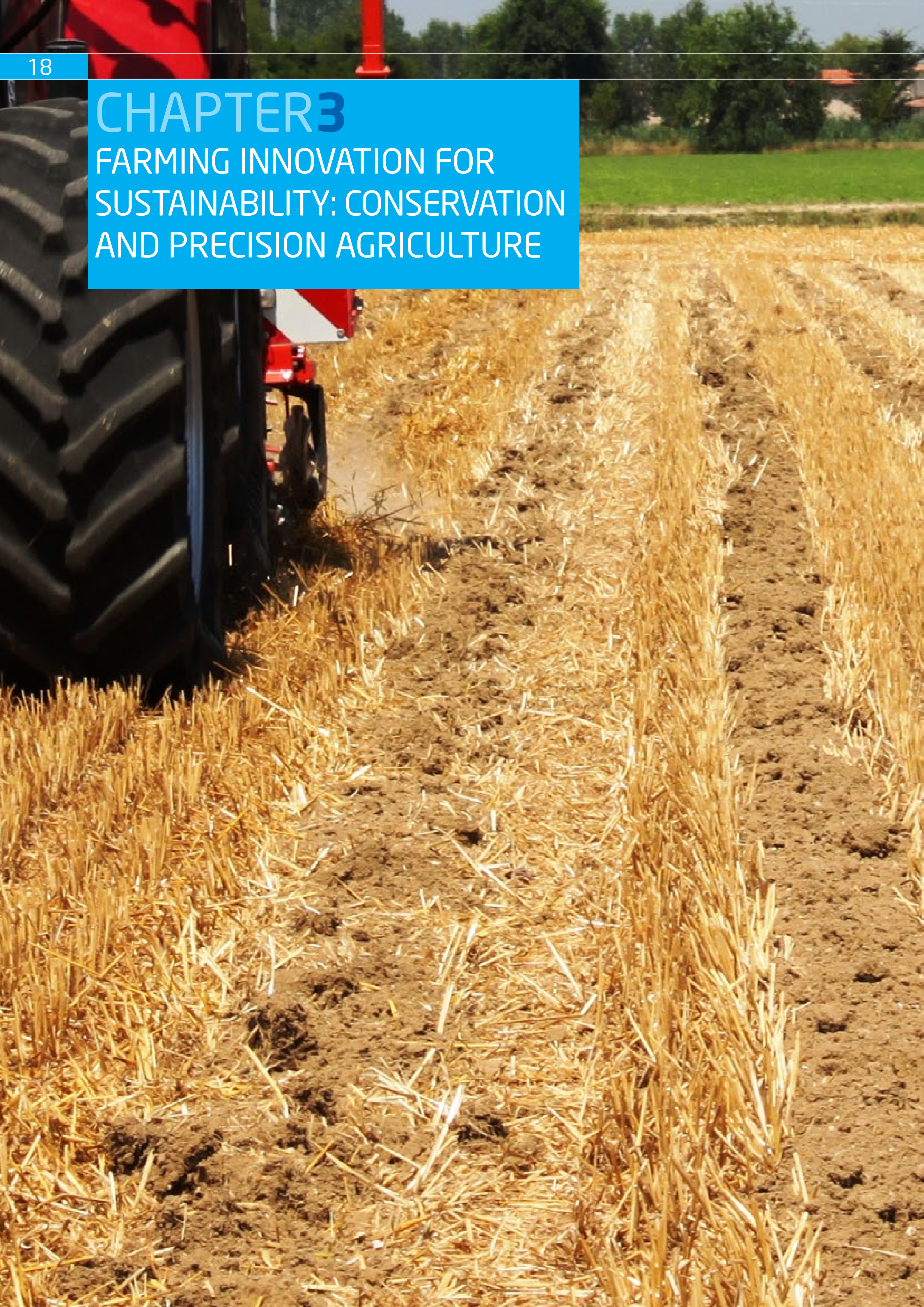
A decrease in greenhouse gas emissions can be obtained directly, by reducing energy consumption associated specifically with using machinery for the different cultivation operations, but also indirectly, by changing soil management and production of fertilizers.

CONCLUSIONS

The need to increase global food production and achieve social acceptance of farmers suggests that mitigation technologies should be in line with: reducing the impact of the agricultural sector on the environment and providing additional benefits to the farmer and society in general. The agricultural sector contribution to achieving GHG reduction goals will depend on economics as well as available technology and the biological and physical capacity of soils to sequester carbon. The level of reductions achieved will, consequently, strongly depend on the policies adopted. In particular, policies are needed to provide incentives that make it profitable for farmers to adopt GHG-mitigation practices and to support needed research. To achieve maximum results, however, policies must be put in place to promote, and make attractive to farmers, practices that reduce agricultural sector impact. Anotother contribution can be given by the development of CSA approach which involves the adoption of technical and economic principles. In the coming decades, such activities could be seen as new forms of environmental services to be provided to society by farmers, who in turn could additionally increase their income by selling carbon-emission credits to other carbon-emitting sectors.

CHAPTER3

FARMING INNOVATION FOR SUSTAINABILITY: CONSERVATION AND PRECISION AGRICULTURE



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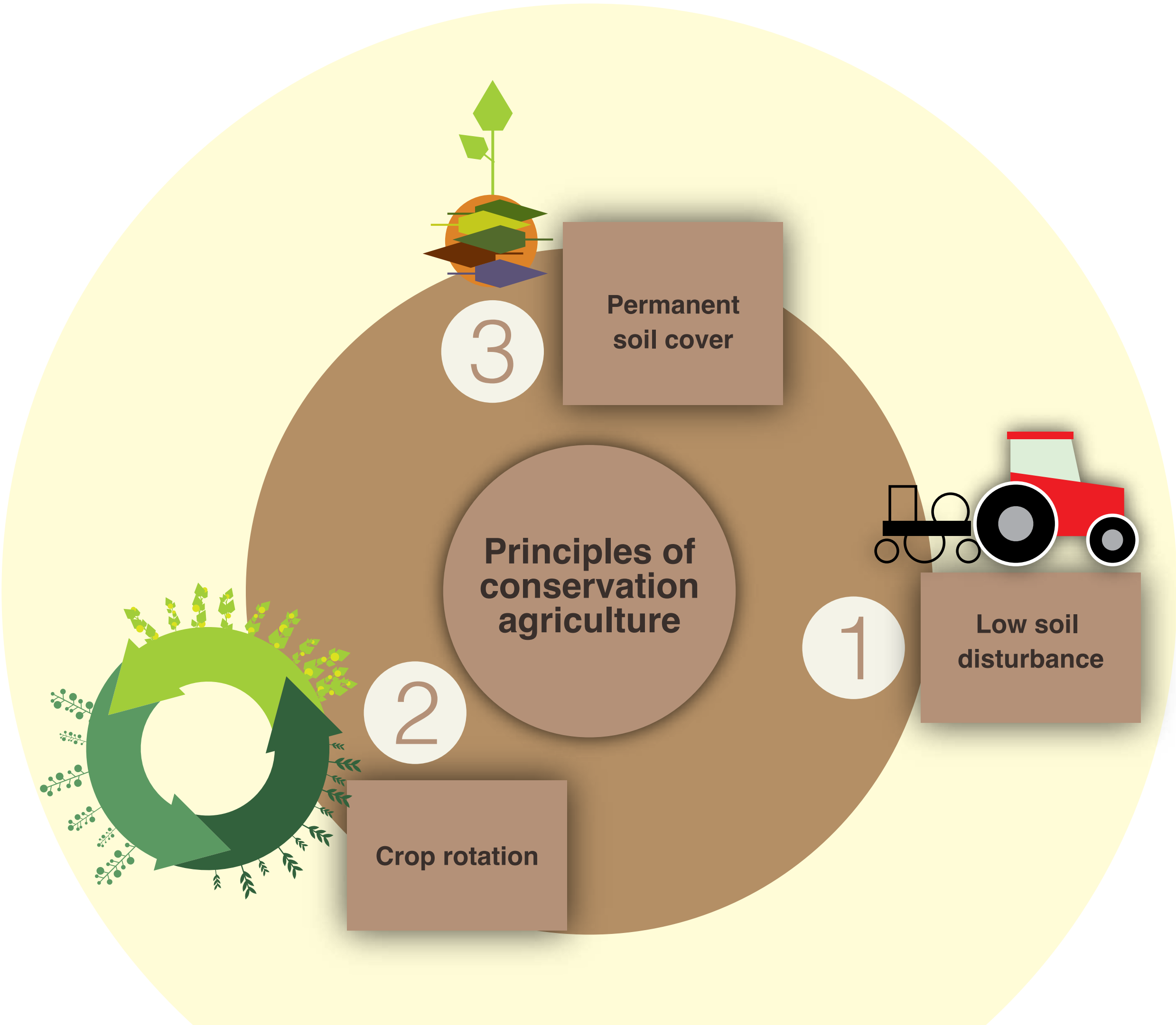
INTRODUCTION

Precision agriculture is closely linked to conservation agriculture both due to the environmental aims to be achieved and due to a degree of kinship originated in the past and projected in the future.
Conservation Agriculture is not just conservation tillage, but a series of land management practices that include crop residues retention, cover crops, appropriate cropping system rotation, integrated pest management able to minimize land degradation. Because of the complexity associated with natural and agricultural ecosystems, a land management practice found to be sustainable at one site might not be equally sustainable at another site. Agricultural production systems are inherently variable due to spatial variation in soil properties, topography, and climate. To achieve the ultimate goal of sustainable cropping systems, variability must be considered both in space and time because the factors influencing crop yield have different spatial and temporal behavior. Advances in technologies such as Precision Agriculture technologies have created the possibility to assess the spatial and temporal variability present in the field and manage it with appropriate site-specific practices.

Precision agriculture is closely linked to conservation agriculture both due to the environmental aims to be achieved and due to a degree of kinship originated in the past and projected in the future.



CONSERVATION AGRICULTURE

The adoption of Conservation Agriculture creates economies and preserves the environment, but is first of all a "strategic choice", which requires a "system approach" and a look projected over time. It is not at all a narrow view of agriculture, as it was a return to past agriculture. Conservation Agriculture needs more agronomy, more reflection and more observation than the conventional one, and it expresses an orientation towards new ways of producing that are constantly becoming and that, integrating with the use of water, farm management and plant protection, can lead to more powerful and sustainable farming systems.

Contemporaneous application of these three principles recreates the biological equilibrium necessary for the development of sustainable and fertile agricultural ecosystems, which are capable of generating environmental benefits as well.

THE THREE PRINCIPLES

Conservation agriculture is based on the simultaneous application of three principles:

1. **Low soil disturbance;**
2. **Crop rotation;**
3. **Permanent soil cover.**

Contemporaneous application of these three principles recreates the biological equilibrium necessary for the development of viable, fertile agricultural ecosystems and capable of generating environmental benefits.

LOW SOIL DISTURBANCE

Techniques that can be included in conservation farming have therefore the potential to have an affect as little as possible on the natural composition of the soil, its structure and biodiversity, increase the content of organic matter, increase water infiltration and maintain humidity, contrast erosion and contribute to improving water quality.
Such techniques are identified, in order to decrease intensity in tillage without inversion of the layers, minimum tillage, strip tillage and no-tillage

Tillage without inversion of the layers

Reduced tillage involves breaking only the most superficial layers of the soil (5-15 cm) to create conditions suitable for seed development, without inversion of the layers. This fact allows considerable energy and economic savings and at the same time it is also less "traumatic" for the soil, avoiding damage to the pedofauna and the microbial activities normally caused by plowing. Simple equipment is used, but combinations of tools (anchors, teeth, disks and rollers of various shapes and differently positioned) are currently very widespread as they can be adapted to most soils and types of residues.

Strip tillage

The strip-till allows to concentrate tillage only on "strips" of the soil within which the subsequent seed cultivation operation will take place while keeping the surface between the rows unaltered. The strips, generally tilled between 15 and 25 cm in depth, have a width of 15-20 cm and a spacing between 40 and 75 cm depending on the requirements of the next crop and the tilled soil is less than 50% of the entire surface.
The need for proper seed deposition at the center of the strip makes the use of semi-automatic GNSS[1] guidance systems in RTK[2] configuration particularly virtuous.

No tillage

The technique involves tillage only in the area affected by the sowing furrow. Since most of

[1] GNSS - Global Navigation Satellite System: any satellite-based navigational system that can locate points on the Earth's surface.
[2] RTK - Real time kinematic: a system that uses a fixed ground station to measure satellite drift accurately and send a correction signal by radio directly to GPS- equipped vehicles. Unlike satellite-based correction systems, RTK is not affected by atmospheric interference and as a result can give high and repeatable accuracy.

the soil mass is practically undisturbed, the residuals of the previous crop remain entirely on the surface.
Technique is one of the most effective tools to reduce production costs on the one hand and, to preserve the soil and improve the quality of its properties on the other hand.
Currently we are witnessing a progressive evolution of this particular kind of planters to versatile, economical and capable models that can handle any crop situation.

CROP ROTATION

To extend and diversify crop rotation and rotation, thus broadening the number of cultivated species and botanical families, avoiding the frequent repetition of the same crops on the fields, has multiple goals:

- cover the soil and protect it from climatic agents as effectively and as efficiently as possible;
- maintaining and improving the structure of the soil through the action of roots;
- stimulate biological activity in the soil, eliminating periods of crop breakdown;
- limiting environmental risks due to nitrate leaching, runoff and erosion, and loss of biodiversity.

Crop rotation alone allows for the preservation and enrichment of soil fertility, to ensure and sometimes also improve yield and reduce the use of fertilizers and agrochemicals and favor the use of more environmentally friendly chemical products.

The positive effect of conservation agricultural techniques can therefore be twofold: reducing C emissions (as CO_2) as a result of lower use of fossil fuel and greater sequestration of C in the soil as a result of lower mineralization of organic matter.

PERMANENT SOIL COVER

The placement of crop residues in the soil surface and the use of cover crops have the role of keeping the soil covered between two cash crops.
Cover crops are herbaceous species that are inserted into rotation as intercalary crops without a productive purpose, but in order to preserve and increase the physical, chemical, and microbiological fertility of the soil. They are one of the best practices to increase soil fertility because they:

- have a preventative action against erosion;
- accumulate the nutrients deriving from the mineralization of the organic matter, which would otherwise be lost for leaching or runoff;
- reduce nitrate pollution in deep waters;
- adsorb nutrients, especially atmospheric nitrogen, in the case of legumes;
- increase the infiltration of water and limit the water surface runoff ;
- facilitate the management of weeds by controlling their spread and development;
- increase biodiversity within agro-ecosystems;
- moderate the soil temperature;
- mitigate the negative effects of no-tillage because they favor the degradation of crop residues and reduce soil compaction.

BENEFITS OF CONSERVATION AGRICULTURE

Reduction of erosion

Conservation tillage are the most effective tools for controlling erosion and maintaining the quality of water runoff out of the fields.

Maintenance of soil organic matter

Strong tillage reduces organic matter by shifting the process of transformation to mineralization rather than humification; furthermore deep plowing buries crop residues in such deep and asphyxiating horizons that penalize humification.

Better transitability and reduced compaction

The beneficial effect of soil organic matter has an impact on the stability of structural soil aggregates and on the best transitability and workability of the soils: in other words, the useful period and the timeliness for the mechanized operation and in general for the entry into the field of the machines is increased with less damage to the soil.

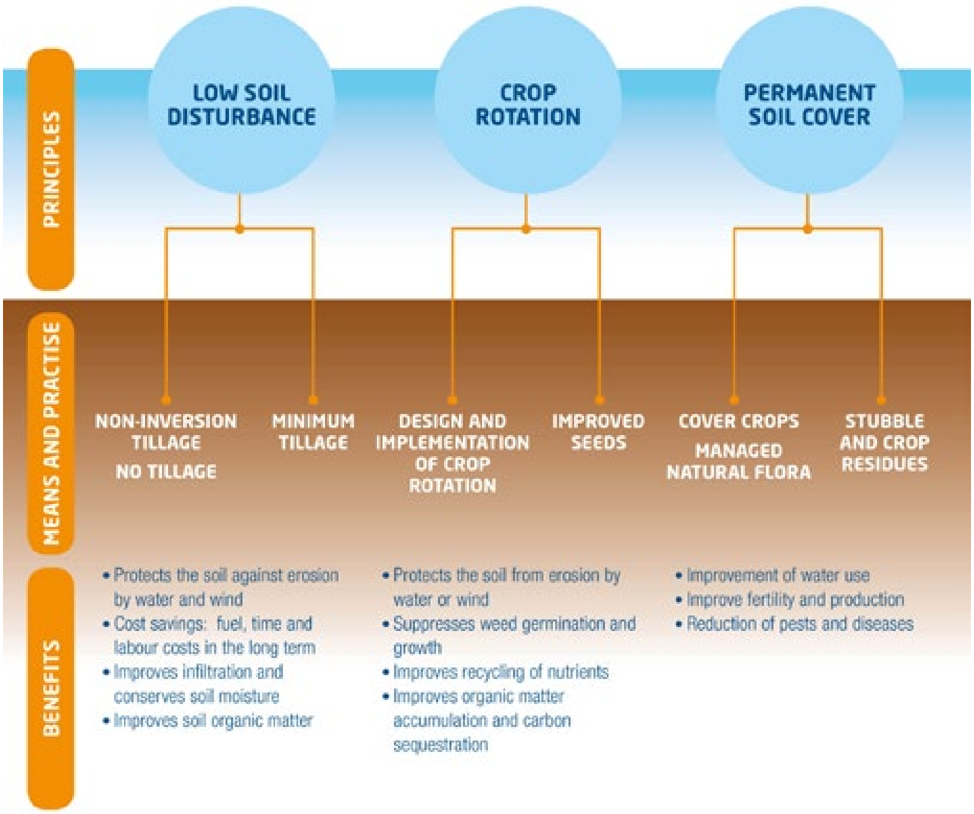
Lower greenhouse gas emissions

The positive effect of conservation agricultural techniques can therefore be twofold: reducing C emissions (as CO_2) as a result of lower use of fossil fuel and greater sequestration of C in the soil as a result of lower mineralization of organic matter.

Cost reduction

Reduced tillage reduces the required mechanical and agricultural machinery, tractor power, fuel consumption, and working hours.

CONSERVATION AGRICULTURE



PRECISION AGRICULTURE

Agricultural ecosystems are inherently variable entities. To manage spatial variability it is necessary to adopt management practices that allow for the precise management of soils, crops, pests according to localized within a field. Innovative agricultural techniques, known as Precision Agriculture, are techniques to improve production and reduce environmental pollution. Precision Agriculture could be defined as the application of technologies and principles to manage spatial and temporal variability associated with all aspects of agricultural production for the purpose of improving crop performance and environmental quality (Pierce & Nowak, 1999). The site specificity of precision agriculture is intuitively appealing and represents a means of improving the economic and environmental performance of cropping system.
The assumption of uniform conditions across the field is not realistic. If fields were uniform, there would be no need for precision farming. Without variability, the concept of Precision Agriculture has little meaning and would never have evolved. Fields usually contain a

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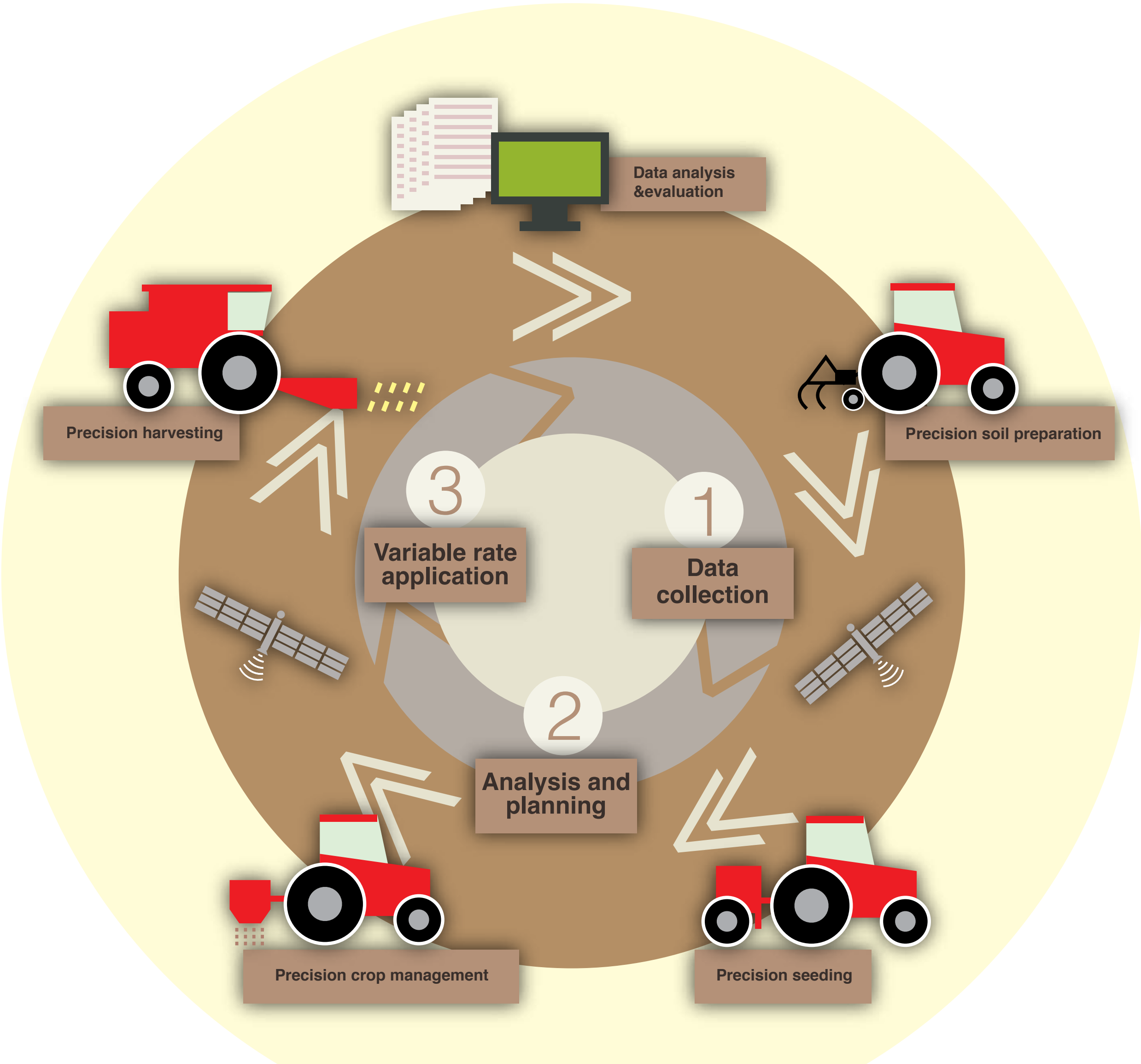

complex arrangement of soils and landscapes thus extensive and spatial variability in soil properties and crop productivity is the norm rather than the exception. Precision Agriculture encompass a broad array of topics ranging from variability of the soil resource base, weather, plant genetics, crop diversity, machinery performance, most physical, chemical, biological inputs used in crop production, and socio-economic aspects.

A successful precision agriculture system depends on how well it can be applied to manage spatial and temporal variability in crop production and what benefits could bring.

Precision agriculture has three components: capture of data at an appropriate scale and frequency, interpretation and analysis of that data, and implementation of a management response at an appropriate scale and time. The most significant impact of precision agriculture is likely to be on how management decisions address spatial and temporal variability in crop production systems. Direct field measurement and remote sensing are the two most common forms of data collection.

Precision agriculture has three components: capture of data at an appropriate scale and frequency, interpretation and analysis of that data, and implementation of a management response at an appropriate scale and time.

The development of continuous yield-sensor and DGNSS has been perhaps the most important and influential development in precision agriculture data collection. Yield rates vary spatially and maps produced by the yield monitors systems are evidence of the degree of within-field variability.

A key difference between conventional management and precision agriculture is the application of modern information technologies to provide, process, and analyze multisource data of high spatial and temporal resolution for decision making and operations in the management of crop production. Advances in the technologies will be an evolutionary process and they will continue to be adapted for agricultural decision making. Precision agriculture is best considered a suite of technologies rather than a single technology. Many of the technologies at the core of precision agriculture today—satellites, sensors, and geographic information systems (GIS)—are unusual for agriculture in that they were developed outside the traditional agricultural research, development, and dissemination system and were imported from industries not traditionally associated with agriculture.

VARIABLE RATE TECHNOLOGY AND YIELD MAPPING

Prescription of variable rate input can only be performed once the factors responsible of yield variability have been assessed. Variable rate application should always follow and economic and environmental analysis carried out with the goal of determine the realistic benefits of such variation in input application.

The agronomic practices that could be varied over space range from variable depth tillage, seeding spacing and cultivars, irrigation, fertilization, pesticide and herbicide applications.

Spatially variable input applications can be created following two approaches. One based on previously created prescription maps and the other driven by real-time on the go sensors mounted on the tractor. The first approach has the advantage of being more robust because it is a results of a more complex analysis carried out with the use of various layers of information (remotely sensed vegetation maps, maps of simulation scenarios, sampling, scouting etc) from the decision maker, the VRA based on on-the-go sensors is simpler but it may not be the proper variable responsible for the ultimate yield variation over space.

BENEFITS OF PRECISION AGRICULTURE

The Precision Agriculture may have an impact on world agriculture at various levels and in different ways depending on the different level of economic development in which it is introduced. Most of the experiences so far agreed to highlight the economic viability for farms, environmental sustainability for civil society, quality and product safety and traceability for consumers.

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Dignity of agricultural work

This farming system, requiring skills in the use of technologies, but a
lso organizational and decision-making skills, enhances the knowledge, qualifies the skills and the intelligence of the farmer, gratifying it in his profession, which will be considered to the same degree of dignity as others. It can also be a good system for young generations to continue farming.

Semi-automatic navigation systems reduce fatigue and stress at the end of the day, slowing down the boredom of the bores, and therefore the attention phase is longer. More attention will limit accidents.

Greater chemical efficiency

Environmental benefits derive from a more rational use of chemical products, an improved efficiency or, in the case of pesticides, from a reduction of the resistance to various active ingredients.

Chemical reduction has effects on the water quality and its consumption, on the soil and air quality, on mitigation of climate changes and on the energetic aspects.

Many studies have been done on nitrate and these emphasize a reduction of nitrate leaching up to 75% in comparison to a uniform distribution (from 7 to 15% in trials in Italy).

The reduction of consumptions of herbicides and pesticides (24% and 19% respectively) favor less pollution of water and air. The precision irrigation can rationalize the consumption of irrigated water (20% reductions) and greatly increase its efficiency.

Economic benefit

Economic benefits are difficult to quantify and come from a better management of inputs and crop operations, rather than from a substantial reduction of the single factor.

Economic aspects and the entity of the cost that the farmer must sustain to start a different rate application system are hard to evaluate.

What makes univocal the results are the intensity of the field variability and the propensity of the farmer to the risk.

The economic benefit is destined to increase with the increase of the costs of the production factors, with the continuous reduction of the required investments in technology and thanks to the local policies that support much more the sustainable agriculture rather than the conventional one

Improvement of products quality

The quality approach becomes concrete with two benefits. The first one regards the possibility to test quality during harvesting or through remote sensing. The aim is to divide the product into classes that might be paid differently. Precise and reliable sensors are installed on the mechanical grape harvesters to evaluate the quality characteristics of the grapes and on the combines to evaluate the protein, the starch and the fat content of the grain. The second aspect regards the possibility to map the quality to create different cultivation techniques to optimize the wanted qualitative characteristics.

The production of a sustainable and good quality foodstuffs would not be of much need if all the process was not properly documented for the buyer that wants always more information on the products.

Traceability

Precision agriculture offers the possibility to track the product through a system. The ultimate aim would be a label capable of being read by a consumer's handheld computer/phone/

organizer that describes the operations that have been undertaken to produce the product in that region as well as the precise area of the field.
Product tracking and traceability should be the major new focus of precision agriculture research, particularly to provide the tools on-farm to initiate the process.
Only with precision agriculture application, the "*farm-to-fork*" chain is completely guaranteed and potentially certified.

In the face of the wide offer on the market and in view of the fact that this technology has been introduced in Italy for some decades now, the situation in the country remains in the first phase of development, unlike other European and extra European countries.

THE REAL SITUATION OF THE PRECISION AGRICULTURE IN ITALY

Although these potential are acclaimed, the spread of Precision Agriculture in Italy remains very limited. The reasons for this slow transfer are not due to the lack of supply and not even the scarcity of research and experimentation undertaken in our territory. The technology offering in Italy has nothing to envy to other European markets because are available:

- GNSS (Global Navigation Satellite Systems) reliable, accurate, with more accurate corrections
- Semiautomatic / automatic GUIDE SYSTEMS with large monitor (> 7 ")
- YIELD MONITORS on extensive crops, industrial, vines
- SENSORS for cultivation, soil and machines. Non-invasive, often remote and mounted on drones
- ISOBUS for tractors and implements
- VARIABLE OPERATING SYSTEMS for fertilization, spraying, irrigation, harvesting
- TELEMETRICS AND TRACCIABILITY SYSTEMS

In the face of the wide offer on the market and in view of the fact that this technology has been introduced in Italy for some decades now, the situation in the country remains in the first phase of development, unlike other European and extra European countries. Especially in Italy and with reference to tractors sold annually, light bar guidance systems account for 7-8%, while semi-automatic driving systems are about 1%. Harvesters with a yield mapping system cover 10% of the area for cereals and the services for the provision of prescription maps (soil or vegetation) covered only 12,000 ha.
With regard to machine technology, ISOBUS tractors are about 10% of those sold annually, and a lower percentage is found for implements. Sprayers, spreaders and seeders with unit control or distribution width are about 4-10% on new machines.
Variable rate distribution with precision farming principles is actually applied by no more than 200 farms across Italy and only with regard to fertilizer control.

BARRIERS TO THE DIFFUSION OF PRECISION AGRICULTURE IN ITALY

In the face of this situation which is not comparable to that of most advanced agricultural countries, it is first necessary to consider which are the barriers to the diffusion of these technologies that are linked to the structural situation of Italian farms and also to more technical aspects.

BARRIERS	CAUSES	REMEDIES
Structural barriers	High and obsolete mechanization	• Aid for modernization of machines
	low farms surface area	• Involvement of contractors with some form of support for this category
	Few computerized and web-based farms	• Promote generational replacement • Computer Literacy and Upgrade Courses
	High agricultural entrepreneurs age	• Promote generational replacement and increase the attractiveness of agriculture with new technologies. • Upgrading courses for agrarian students
Technical barriers	There is little compatibility between systems used by manufacturers	• Adopting systems compatible with all brands of machines
	Complexity and difficulty in operating with frequent breaks or malfunctions	• Promote individual courses for operators
	Difficulty of updating new technologies by vendors or extensions service	• Encourage training and training programs
	Time required to process data and high initial investment	• Disclose the results and benefits of experimentation • Make the right choice of technology and equipment
	The economic benefits are unclear	• Disclose the results of experimentation • Ensure fast transfer of technology information through cooperation between farmers and user networks • Creation of a regional observatory on the AP

CONCLUSIONS

The Agricare project has demonstrated that it is possible to apply Conservation Agriculture techniques together with Precision Agriculture techniques. The results reveal good development prospects and demonstrate how the economic and environmental benefits gained from the Conservation Agriculture will be amplified by applying the variability management techniques of Precision Agriculture.

If Conservation Agriculture alone has allowed cost reductions, organic matter conservation and lower CO_2 emissions, it also, coupled with Precision Agriculture techniques, allows higher incomes and lower environmental impacts thanks to the best efficiency of fertilizer and seeds use.

CHAPTER4
AGRICARE: A DEMONSTRATION PROJECT FOR CLIMATE MITIGATION

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Veneto Agricoltura – Agency of the Veneto Region for the innovation in the Primary Sector
Luigi Sartori, *University of Padua*
Nicola Colonna, *ENEA*
Christian M. Centis, *Maschio Gaspardo*

INTRODUCTION

The AGRICARE project[1] has been developed to compare technologies and techniques to reduce agricultural CO_2 emissions, which can change farming methods.
The AGRICARE objective is to demonstrate how the application of advanced techniques in precision agriculture, combined with different types of conservation agriculture practices, can have an important effect in terms of reducing greenhouse gases and increasing soil protection.
The project regards 4 different rotated crops (winter-wheat, canola, maize, soybean) and 4 different soil management techniques (conventional, minimum tillage, strip tillage and no tillage), at the pilot farm ValleVecchia (Venice, IT) managed by Veneto Agricoltura – Agency of the Veneto Region for the innovation in the Primary Sector.

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AGRICARE OBJECTIVES

The specicif objectives of the project have been:

- verify and demonstrate the effective potential of the precision agriculture techniques in terms of energy saving and greenhouse gas reduction;
- analyze the efficiency of the machines used, enhanced by electronic precision agriculture devices which reduce CO_2 emissions;
- examine the suitable scenarios for the diffusion of such techniques in different Italian agricultural contexts;
- assess the threshold of economic convenience and environmental benefits;
- assess through analytical models based on “ground, machine, climate” data and Life Cycle analysis (LCA) the long term effects of the experimented technologies newly introduced;
- replicate what examined and proven by tests outside of the pilot farm to encourage dissemination of such technologies and techniques.

PRECISION AGRICULTURE TECHNOLOGIES

Precision Agriculture (PA) technologies, adopted in the project, can be subdivided into two large categories:

1) Assisted steering and uniform application (UA)

This technology enables the machinery to precisely identify already travelled paths and those to be followed, thereby avoiding overlaps and ensuring greater working efficiency regardless of the operator. This is achieved via the GNSS steering system assisted by an RTK antenna to adjust for satellite errors and achieve accuracy of about 2.5 cm. The use of the technology increases the working capacities of the machines, reduces operator fatigue, and drastically cuts fuel consumption and, more generally, machine operating costs. In addition, overlaps are sharply reduced, and, as a result, so are waste of inputs (seeds, fertilizers, pesticides, water) and the negative effects of over-application.

2) Assisted steering and variable application (VA)

This technology allows to vary quantity and application of inputs depending on crop needs and soil properties. This variability can be defined beforehand based on measurements and data analysis used to “design” a georeferenced “prescription map” for each plot that shows how much product to apply on a point-by-point basis. The map is up- loaded to the tractor computer with a plain SD card. A tractor equipped with the technologies described above (GNSS steering and RTK antenna) sends the map prescriptions to the implements (seed drill, fertilizer spreader, etc.) via ISOBUS system. Therefore, the inputs (seeds, fertilizer, etc.) are

[1] LIFE – AGRICARE Introducing innovative precision farming techniques in AGRIculture to decrease CARbon Emission is co-financed by LIFE+, the financial instrument for the environment of the European Commission (LIFE13 ENV/IT/000583) Coordinated by Veneto Agricoltura – Agency of the Veneto Region for the innovation in the Primary Sector
in collaboration with Maschio Gaspardo, University of Padua and ENEA.

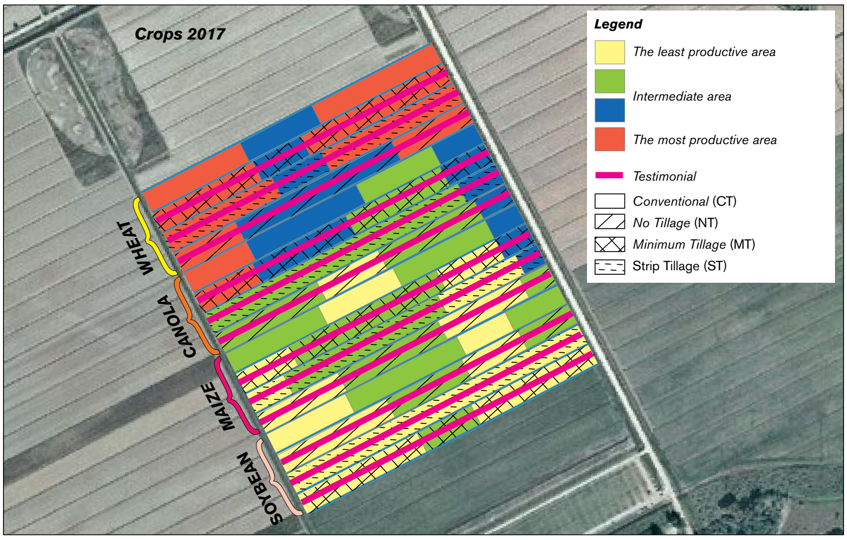
applied within a specific area of the plot and in the proper quantities to achieve the farmer's speci c objectives. The application rate of inputs depending on position can also be varied in real time (without prescription map), such as, for example, on the basis of data gathered from cameras or properly calibrated sensors.

FOUR COMPARING THESES

The research involved 16 plots for a total of 23.6 hectares[2] under wheat/canola/ maize/ soybean rotation (Figure 1). Conventional tillage techniques (CT) were compared against conservation techniques: minimum tillage (MT); strip tillage (ST); no-till (NT).

FIGURE 1

Experimental Plan adopted during the two-year trial.



Precision Agriculture tools were adopted in the plots under the three conservation agriculture techniques. In each plot, Precision Agriculture was applied with assisted steering and uniform application (UA) strategy and with assisted steering and variable application (VA) strategy.

The study began by analysing the variability of the soils through the use of historical yield maps, aerial photographs, and geo-resistivity meters[3]. Analysed with specific software, the data allowed to pinpoint four homogeneous zones with different yield potential (two with sandy-loam soil, one with loam soil, and one with clay loam soil). With specific software, the data was used to simulate yield responses for each soil management technique and for each crop to changes in seed density and nitrogen application (with the exception of soybean). "Prescription maps" were prepared based on these simulations to indicate how to vary the delivery rate of these inputs in the various areas. In the areas managed with variable application technology, the choice made was to increase, in relation to the homogeneous application rates of the conventional technique, seed density and nitrogen levels in the more fertile areas, and to maintain or reduce these levels in the areas with a lower potential.

Integrated Pest Management in accordance with the prescriptions of the Arable Crops Report[4] was applied for all the crops used in the project.

Harvesters equipped with yield mapping systems were used in all the plots.

[2] For location of the plots, refer to the crop map in the publication "LIFE+ AGRICARE project – 2017 Experiments for Sustainable Agriculture - ValleVecchia Farm" which can be downloaded from the Project website http://www.lifeagricare.eu/it/approfondimenti.

[3] A geo-resistivity meter is a device that measures the apparent electrical resistivity of the soil (as opposed to conductivity). The analysis of this data makes it possible to define the variability of the soil's chemical and physical characteristics.

[4] The "Bollettino colture erbacee" (Arable Crops Report) is an initiative of Veneto Agricoltura with the collaboration of the Plant Health Service of the Veneto Region, the ARPAV, the University of Padova and the Horta. Info: http://www.venetoagricoltura.org/subindex.php?IDSX=120.

Conventional tillage (CT)
In this thesis, tillage is done including plowing that implies the inversion of soil layers. Precision techniques such as variable density of seeds and fertilizers are not applied. The plowed soil is left to rest until the sowing of the next crop. The main implements involved are plow, cultivator, rotary harrow, seed drill, self-propelled sprayer.

Minimum tillage (MT)
In this thesis, tillage is performed at a depth less than 20 cm without inversion of soil layers. All machines are equipped with automatic guidance systems and variable seed and fer-tilizer distribution according to georeferred prescription maps. Continuous coverage of the soil with cover crops is contemplated when no main crop is present. The main equipments involved are: cultivator, combined seed drill, self-propelled sprayer.

Strip tillage (ST)
The strip-till allows to concentrate the tilled area exclusively on "strips" of the soil where the next sowing operation will take place. Continuous coverage of the soil with cover crops is contemplated when no main crop is present. The main implements involved are: strip-tiller, sowing machines, self-propelled sprayers.

No tillage (NT)
In this thesis there is no inversion of soil layers or no tillage such as weeding. The main operation is the sowing matched with the distribution of fertilizer. A special seed drill able to drill seeds and fertilizer in untilled soil is used, equipped with Precision Agriculture technologies. In this case, too, the soil is continuously cropped.

GRAIN YIELD

The analysis was based on the yield data measured and georeferenced by the yield monitoring system installed on the harvester. The timely yield data was thus used to calculate the yield of each single homogeneous zone and obtain weighted averages for the different experimental scenarios (CT, MT, ST, NT, Figure 2).

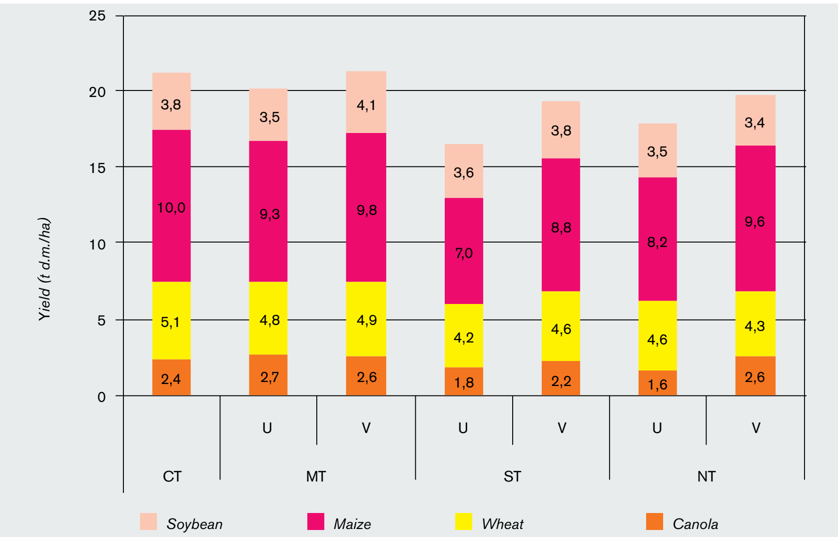


FIGURE 2
The average crop yields obtained during two years of ex-perimental trials for 4 crops by adopting different soil management techniques with the support of precision farming or not.

Crop management efficiency was increased both as a result of the use of Precision Agriculture with variable application (VA) and the agronomic choices adopted, whereby more inputs were applied in the areas of the plot where productivity was potentially greater while, at the same time, yield levels were maintained in the areas of the plot with a lower yield potential. Over-application of inputs was thus avoided and their use was actually even lower than the farm's usual standards.
Generally speaking, CT soil management technique provided the trend for the highest yield records. Nevertheless MT is also competitive. The most simplified techniques (ST, NT) showed a tendency to give lower yield; this concerned all the crops for ST while NT technique has led to a yield reduction mainly for maize and canola crops. NT performance appeared more susceptible to weather conditions that may cause an higher risk of inad-equate plant density.

Crop management efficiency was increased both as a result of the use of Precision Agriculture with variable application (VA).

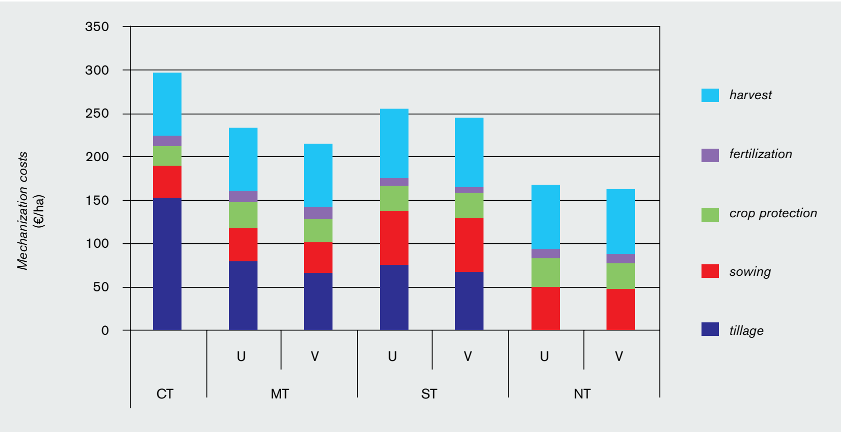
In contrast to the higher investment cost associated with the purchase of the various equipment, there is a lower cost of operating the machines related to the use of satellite navigation systems, which actually increase the speed of advancement and the effective working width.

ECONOMIC RESULTS

THE COSTS OF MECHANIZATION AND PRECISION

It can be said that conservative tillage requires on average less mechanical necessity and this results in a lower cost. It should also be expected that, as a reduction in processing intensity, there will also be a reduction in costs, at least for machines. This happens in the case of MT, where there is a 24% reduction in costs compared to CT, and also for NT where reductions are 45%. Cost reduction is almost exclusively due to land machining, which is halved compared to conventional machining for MT and ST, and negligible in the NT case.
In the case of ST, cost reduction was not as expected because of the high cost of seeding and harvesting. In fact, the machines used for processing and seeding on ST are characterized by reduced width and low feed rate and therefore low work ability. Therefore, it is clear an increase in the cost of these equipment which could be greatly reduced with the tuning of more powerful versions. ST harvesting costs were higher due to the lower advancement speeds of maize and soybean harvester which were sown with inter-rows that were incompatible with commercial harvesting heads.
Concerning the application of precision agriculture, this has led to a general reduction in the costs of mechanization, which can be quantified on average by 6%. In contrast to the higher investment cost associated with the purchase of the various equipment, there is a lower cost of operating the machines related to the use of satellite navigation systems, which actually increase the speed of advancement and the effective working width.

FIGURE 3
Unit costs (€/ha) of the machine used for the different soil management techniques (CT, MT, ST, NT).



TOTAL COSTS

In the project, the crop rotation adopted is characterized by crops having different characteristics and needs. Spring crops, like maize and soybean, are different from autumn-winter crops in that they require irrigation if there are drought conditions in the summer months. Soybean, nitrogen- fixing crops, does not need any further nitrogen inputs.
Wheat demanded lower production costs, followed by canola and spring summer crops, which, unlike previous ones, were irrigated and need drying. In fact, for these crops the irrigation was the biggest cost cause. For wheat and maize is evident the contribution of fertilizers and sowing.
The average costs of conservative management are, on average, lower than conventional management, due to the simplification soil tillage. Concerning conservative tillage operations, variable application seems to have achieved a small reduction in costs. This is noted in the result, but some individual costs present some differences. The most affected operations are: seeding with an increase in costs for the largest quantity of seed used, and fertilization for the lower use of fertilizers.

GROSS INCOME

Average gross earnings achieved with traditional techniques are superior to conservative techniques, regardless of the uniform or variable application type. However, it is clear (Figure 4) that in the latter the variable application is more profitable than the uniform one and in some cases superior to the conventional management, especially in the MT and NT theses. Reducing the intensity of machining, while reducing costs, does not always allow comparable CT incomes because of lower production, especially with the most simplified techniques.
The introduction of variability application techniques leads to an increase in production and in any case to a greater efficiency of the inputs provided, so that the best incomes are those obtained with variable MT and NT distribution.
About ST, this technique has yet to be developed for both the mechanical and agronomic part. However, despite this, the precision agriculture has demonstrated its validity by attenuating the losses that have occurred in maize and canola. Within each soil management tecniques, the introduction of precision agriculture variability application technologies has proven to be decisive. With MT, in fact, a higher income was achieved from spring crops in the areas managed with variable application precision agriculture than in those under uniform rate application.
This was possible because an increased production was achieved as a result of an increase in the efficiency of the use of inputs used which allowed for a higher gross sales output. Soybean showed to be less susceptible to the change in soil tillage technique and the most susceptible to PA techniques, especially MT and ST. Also for maize where the only thesis comparable to the standard (CT) were the technique of MT, NT supported by variable application. Wheat yields comparable to CT can be obtained with MT and NT, while ST does not seem economically feasible. With regard to canola, MT seemed to be the most profitable technique, while NT and ST do not seem convenient (NT mainly due to the difficulty of getting good investments).

Within each soil management tecniques, the introduction of precision agriculture variability application technologies has proven to be decisive.

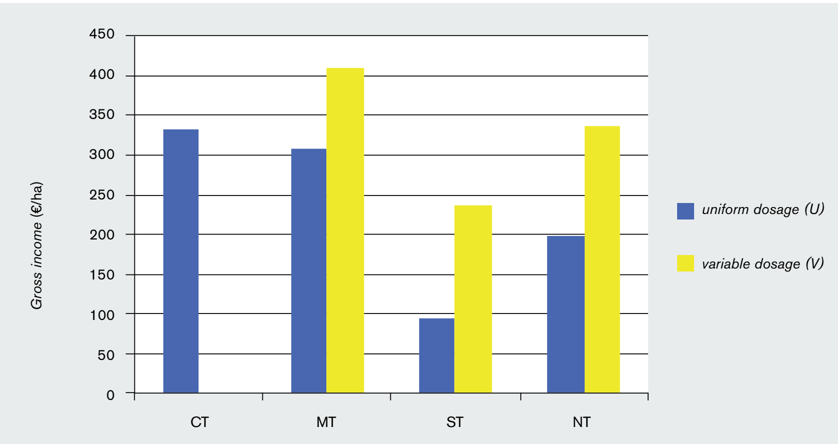


FIGURE 4

Gross income for the 4 soil management techniques accord- ing to the cultivated crops and the different input management modes (uniform and variable) mediating crop data for each soil management technique.

CONCLUSIONS

By focusing on fuel consumption analysis, which is the most important factor for farmers, it should be noted that conservative tillage techniques show a significant fuel economy as expected. Fuel consumption for each crop, without considering cover crops, decreases both for MT and for ST and NT. In addition to the effect of the conservative tillage techniques, the application of the assisted steering with respect to its absence involves a fuel savings ranging between 8 and 15% as a two-year average, for different crops. The optimization of field paths, which can be achieved thanks to the satellite guide, explain these differences. The results, though limited to only two years of testing, clearly show the direct benefits to the farmer since the introduction of these techniques.

CHAPTER 5
MITIGATING IMPACTS THROUGHOUT PF AND CA

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CARBON EMISSIONS EVALUATION

The Agricare project was designed to demonstrate how the application of advanced precision agriculture techniques, paired with different conservation agriculture practices, can reduce greenhouse gases and protect the soil. A decrease in greenhouse gas emissions can be obtained directly, by reducing energy consumption associated specifically with using tractors for the different cultivation operations, and indirectly, by changing soil management and fertilizer use and spreading. The use of each tractor entails diesel and oil consumption, both of which are fossil fuels, producing the emission of CO_2 into the air. The calculated emissions are the sum of direct emissions, produced by the combustion of diesel in the motor, and indirect emissions connected with the system of extraction, transport, refining and distribution. The spreading of a fertilizer does not in and of itself result in direct CO_2 emissions. It is instead necessary to consider that a great deal of fossil energy was used to produce it, which is "contained" (embodied) in the fertilizer itself and virtually emitted when it is spread on the soil. It is therefore the "hidden" energy in the fertilizer production process that is counted. Adding direct and indirect emission we can obtain the total CO_2 emission for each hectare.

The calculated emissions are the sum of direct and indirect emissions.

CO_2 calculation showed that, as an average, by applying CA and PA techniques to our crop rotation we can have about 0,5 tons of CO_{2equiv} savings per hectare while by MT techniques application we can reach a 0,25 CO_{2equiv} reduction. In addition to the calculation of CO_2 emissions associated with energy and input consumption, it is also necessary to consider the amount of this gas that is emitted or retained by the soil as a result of the variation in the organic carbon content in the soil caused by the change in the soil management system. Through the use of the "Salus" model, it was possible to simulate and estimate this phenomenon over a period of 17 years.

The estimate of CO_2 potentially not emitted from the soil due to the adoption of conservative treatments compared to CT results to be around 630 kg/ha year in the case of MT adoption and 2,500 kg/ha year in case of NT adoption, with few variations depending on the type of soil. Conservation agriculture (CA), through the utilization of alternatives to the traditional plough, conserves the organic matter in soil, reduces emissions and saves energy. Precision agriculture (PA) enables the optimal distribution of means of production (fertilizers, pesticides, water) and thereby reduces consumption, leading to decreased indirect emissions of CO_2.

The tests in the project were planned to show the benefits and demonstrate the real possibility of applying these techniques and their advantages. The results of the project, albeit after only two years of field tests, demonstrate that the application of CA and PA techniques, in comparison to conventional methods, leads to energy savings and a reduction in greenhouse gas emissions when compared to traditional techniques to cultivate crops like maize, canola, soy-beans and wheat. Nevertheless more trials in different pedoclimatic context and on different crops rotation is needed to understand how our results could be extended.

The application of CA and PA techniques, in comparison to conventional methods, leads to energy savings and a reduction in greenhouse gas emissions.

ENERGY CONSUMPTION ANALYSIS

To make precise evaluations, each cultivation step was thoroughly monitored. All consumptions and each factor distributed on the soil were recorded, drawing up a true accounting of the energy. An energy balance was therefore produced by converting each resource used to a single energy measurement unit, the MegaJoule.

The total energy employed to produce each individual crop was then evaluated. It emerged

Significant fuel savings are noted in cropping techniques that apply the principles of conservation agriculture.

that the different experimental crops in the project had very different energy burdens. Maize is the most energy-intensive crop, followed by wheat and canola, and finally soybean, which require about half the energy needed to produce a hectare of maize. Soybean cultivation requires a limited use of fertilizers because, as a legume, it is naturally capable of producing nitrogen through symbiosis with soil bacteria.
The energy analysis was made per cultivated hectare and per unit of product. Since yields can vary widely depending on the technique used, the trend of the results is more complex in this case. Significant fuel savings are noted in cropping techniques that apply the principles of conservation agriculture. This means that the quantity of direct energy needed to produce a hectare of crop decreases by as much as 50-60% with the NT technique. Other benefits are observed when conservation agriculture is combined with assisted driving of tractors, thanks to satellite technology. The greater precision in each operation and optimization of the maneuvers of the tractors leads to additional savings. The conservation techniques, when combined with the PA (assisted driving and variable distribution of fertilizers) enable a significant quantity of diesel to be saved and a reduction in CO_2 equivalent emissions to average values that range between 5 and 20% for minimum tillage (MT) and no till (NT), compared to traditional methods.
NT, also known as zero tillage or direct drilling, is the technique that saves the most energy, primarily due to not working the soil deeply and the ability to perform several operations in a single passage. The balance to evaluate the effective advantage of innovative technologies must take into account the grain yields that can effectively be obtained by the systems being studied. The lower the ratio between the sum of all the inputs used and the outputs obtained (production) are higher energy efficiency.
A more detailed approach to evaluate environmental impacts is the Life Cycle assessment a tool that is widely used today to compare solution and evaluate innovation.

The LCA is a standardized analytical calculation method that takes into consideration all the steps in a process, taking into account all the direct and indirect impacts, from the cradle to the grave, or in our case from the seed to the farm gate. In practice, conducting an LCA means listing each action/stage/process and, for each one, linking the associated consumptions of water and energy, emissions of greenhouse gases and acidifying gases and production of ozone. As an example, sowing the grain entails calculation for the use of machinery and therefore diesel consumption to power the machinery, but also for the energy necessary to produce the seeds used. Similarly, the energy utilized to produce the tractor itself (iron, plastic, tires and all other parts) is also taken into consideration. It is a complex method that is useful for comparing processes that are similar but have several variations. The LCA has been standardized and corresponds to ISO 14040.

LIFE-CYCLE ASSESSMENT

The Life Cycle Thinking (LCT) is recognised as a fundamental approach for addressing current challenges and complex problems, such as those related to the sustainability of food production and consumption.

Adopting LCT means going beyond the focus on the manufacturing process to include environmental impacts of a product over its entire life cycle, and may also include social and economic impacts.

To include environmental impacts of a product over its entire life cycle.

Life cycle approaches and tools have been developed in the last decades, and are more and more integrated into the organizations' strategies and decision-making processes. Among the LCT approaches and methodologies, the Life Cycle Assessment (LCA) stands out, and its role has been further strengthen by several initiatives at EU level. In particular, the European Commission, with the EU Communication (COM 2013 196) on Building the Single Market for Green Products, has developed a methodology, namely the Product Environmental Footprint (PEF) for the harmonized calculation and communication of the environmental footprint of products. The methodology is based on the life-cycle assessment technique and other existing standards and guidance documents; in addition, rules have been developed for individual product categories to account for specific details at the product level. The approach has been tested between 2013 and 2017, with more than 280 volunteering companies and organisations, with the ultimate goal to understand the potential of the methods and its use in the policy arena.

The test in Europe has involved different sectors, including the agricultural one (indirectly) through the product groups of wine, pasta, olive oil and feed, just to mention some, and other will come in the next years: in fact, from 2018 to 2020, a new phase of the PEF development will start, called transition phase, during which the methodology will be applied to an increased number of products while its policy adoption is discussed.

This methodology has been applied within the AGRICARE project to quantify the potential environmental impacts of the precision farming techniques compared to the conventional ones, also as a contribution to the forthcoming PEF transition phase.

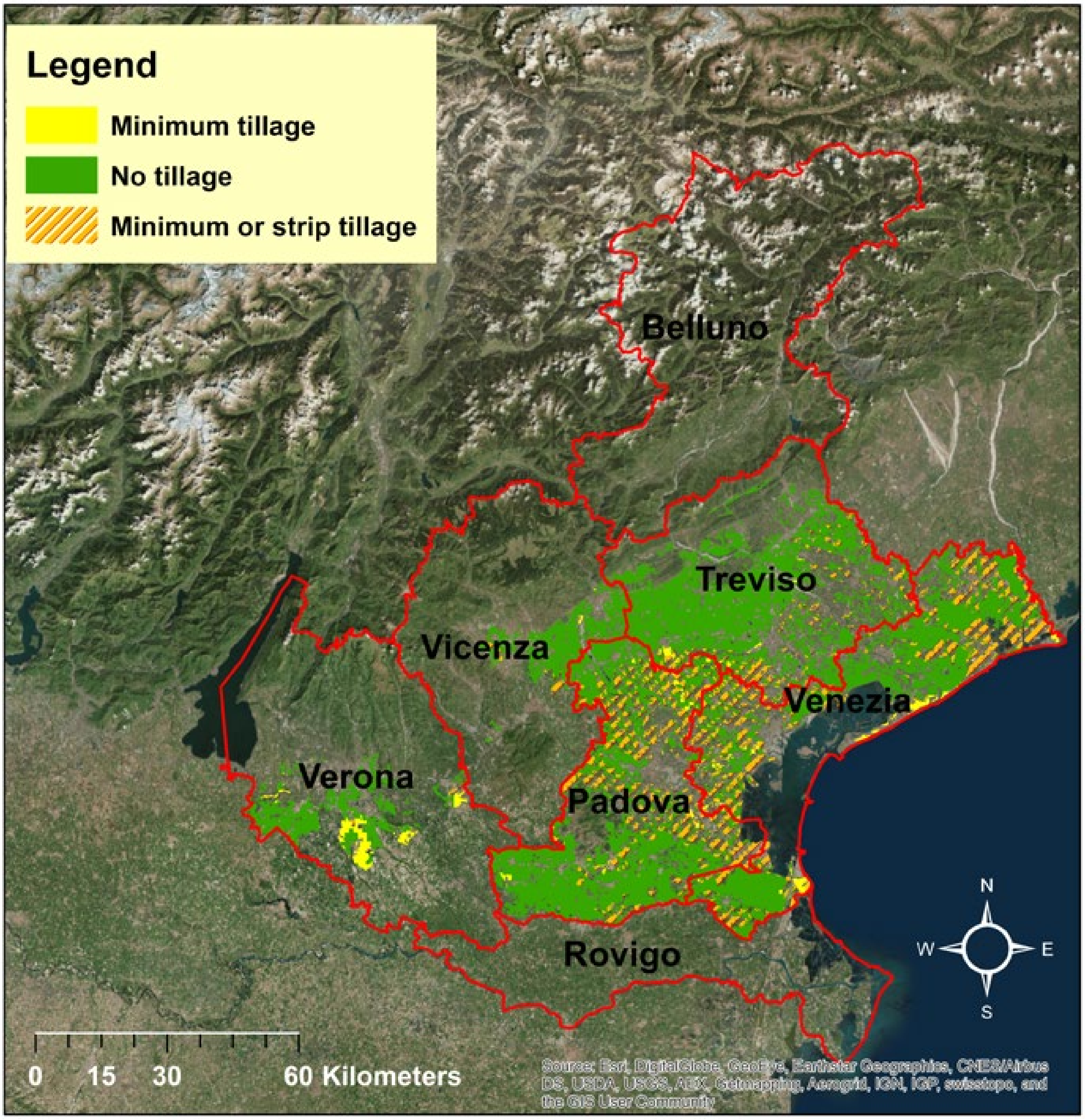
The analysis of the environmental impacts related to the precision farming and the traditional techniques, highlighted that chemicals such as fertilizers and pesticides, and the fuel consumptions to run the machinery, are the most relevant sources of impact to both climate change and the other environmental media considered.

Thanks to the AGRICARE project, an average reduction on the fuel and chemicals use can be achieved (up to 10%), compared to the traditional farming techniques. Such optimization in the input side, is directly reflected in the results with a lower environmental burden, which may become more relevant if precision farming would be applied at a larger scale, i.e. at a national level. Moreover, one of the key parameters in the comparison between traditional and precision farming techniques is the yield. It resulted that when the yield is similar or equal, the environmental benefits generated from the precision farming can be easily appreciated, whereas when it is higher for the conventional, the impact in the two scenarios are very similar (±5%).

No Tillage emerged as the most promising case, thanks to the highest reduction in the inputs needed.

Among all the scenarios analysed, No Tillage (NT) emerged as the most promising case, thanks to the highest reduction in the inputs needed, without compromising too much, in most of the cases, the yield.

The results of the study performed on the energetic and environmental impact generated from the precision farming techniques, pointed out their potential benefits for the


Legend
Minimum tillage
No tillage
Minimum or strip tillage
Belluno
Treviso
Vicenza
Venezia
Verona
Padova
Rovigo
N
W
E
S
0 15 30 60 Kilometers
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

environment. With equal yield, precision farming scenarios show better results from an environmental perspective, for all the impact categories considered in the study, reaching peaks of improvements of over 20%.

How much can we expand CA approaches in the Italian rural surfaces?

LARGE SCALE INTRODUCTION OF NEW SOIL MANAGEMENT TECHNIQUES

The potential advantages generated from the innovative cropping systems described above are linked to their application at a larger scale, which may be a considerable share of the national agricultural areas. The open question is how much can we expand CA approaches in the Italian rural surfaces according to their suitability? We know from FAO statistics(FAO, 2013) that around 380.000 hectares of arable lands use some kind of CA methods, but the total arable land in Italy is about 6 million hectares and there is a large potential to expand it. Thanks to the use of GIS, different suitable areas have been identified in 3 different Italian regions, where the techniques experimented in AGRICARE might be implemented.
A GIS-based analysis was carried out in order to evaluate the amount (hectares) and location of agricultural areas wherein to apply those conservation practices tested within the project (i.e. no or minimum).
On the basis of the available data and adapting the approach proposed by Stengel (Stengel et al., 1984) three Italian regions were investigated: Veneto, Emilia Romagna and Tuscany.
In all the three regions results show that a significant portion of agricultural area may potentially adopt these conservation practices. In the following picture you can see the maps results for the Veneto Region.
However it is worth highlighting that the rather simple method utilised which take into account few soil parameters, necessarily represents only a first estimate of the potentially suitable territories. By the way those results shows that over an investigated area of about area 450.000 hectares around 70% results suitable to No tillage and 25% to Minimum tillage application.

A significant portion of agricultural area may potentially adopt these conservation practices.

	HECTARES
Regional surface	1.840.700,0
Investigated area	453.935,9
No tillage	325.599,3
Minimum tillage	115.868,7

In those areas a further, focused assessment integrating a more detailed dataset in terms of spatial scale and soil/environmental characteristics possibly supported by an economic evaluation, would certainly give a more truthful picture of candidate areas. where these kind of agricultural conservation techniques may be effectively promoted.
In order to enhance a wider application od CA tehcniques, financial incentives can be introduced, such as those called contributions to mitigations as described and analysed in the following chapter.

CHAPTER 6
INCENTIVES AND CREDITS TO SUPPORT INNOVATION DIFFUSION

Source: Pixabay

Matteo De Sanctis, Leonardo Ambrosi e
Stefano Lo Presti
Centrale Valutativa

THE EXISTING INCENTIVE SCHEMES

Carbon reduction incentives can be of direct type, disbursed on the basis of CO_2 actually saved, and of indirect type, connected to other instruments under the first and second pillar of the Common Agricultural Policy (Figure 1).
As regards direct incentives, the reduction of greenhouse gas emissions is traded under the form of "carbon credits[1]" generally expressed in tonnes of CO_2. There are two types of carbon markets: regulated markets and voluntary markets.
Indirect incentives are payments and contributions to farmers who adopt and maintain agricultural activities that have positive effects on the environment, especially on the reduction of GHG emissions. One of the most important changes in EU programming period 2014-2020 is exactly a stronger attention to the environmental aspect.

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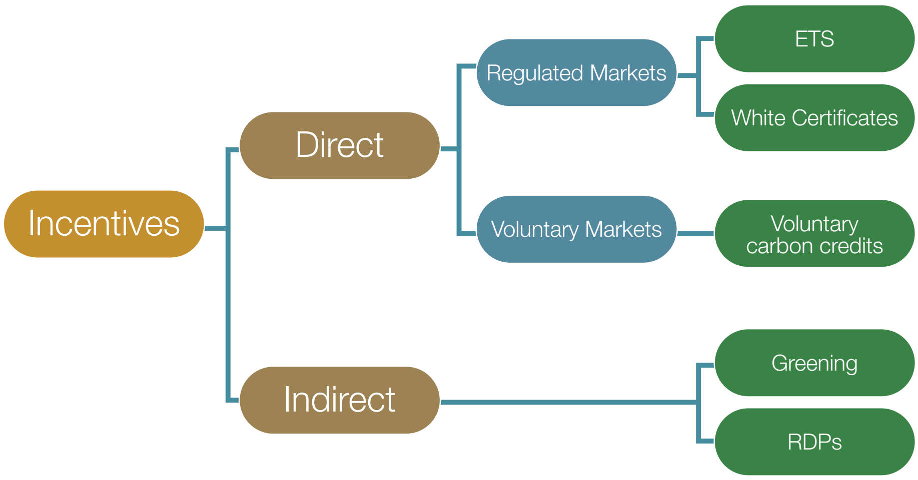

FIGURE 1
The incentives schemes

DIRECT INCENTIVES: ETS

The most important carbon credit market is the Emission Trading System[2] (ETS), one of the instruments developed in the Kyoto Protocol to reduce greenhouse gas emissions and came into force since January 2005. The ETS is based on the Cap and Trade system, where each State sets individually the cap for emission limits for all major emitters that are included in the ETS market. Within this market, companies receive a maximum number of permits.
At the end of each year, if industry has emitted more than assigned, it can buy market credits from volunteers. If industry, on the other hand, has managed to reduce emissions more than the cap granted, it acquires the right to sell the credits. The number of permits granted is reduced annually and in 2020 overall emissions will be 21% lower than those measured in 2005, year of the launch.
At the present, farming is excluded from the ETS but in the future this approach may be subject to variation.
White Certificates are the most important incentives for energy efficiency in terms of national and European targets. The main electric power and gas distributors (over 50,000 customers) are required to achieve annual energy savings determined by the Ministry of Economic Development, in agreement with the Ministry of the Environment and the Protection of the Territory and the Sea. The savings are attested by special certificates, each one corresponding to 1 tonne of oil equivalent savings (TOE), called "energy efficiency certificates" or "white certificates" (EECs).

[1] A carbon credit is an "intangible" entity created by an activity that absorbs carbon dioxide or avoids greenhouse gas emissions. The carbon offsetting is a mechanism whereby, alongside the reduction of greenhouse gas emissions at source, an emitter purchases from a more virtuous emitter a quantity of carbon credits equivalent to the emissions to be reduced. The basic principle of carbon offsetting is that a certain amount of greenhouse gas produced at a site can be offset by reducing or sequestering carbon for the same amount elsewhere.
[2] In Europe, ETS involves over 11,000 operators: thermoelectric and industrial plants operating in energy production and manufacturing (energetic activities, production and transformation of metals, cement, ceramic and bricks, glass and paper). Starting from 2012, aircraft operators are included too and from 2013 ETS concerns also plants for the production of aluminium, lime, nitric acid, adipic acid, hydrogen, sodium carbonate and bicarbonate and plants for the capture, transportation and storage of CO_2. Nowadays, over 1,300 Italian plants, of whom 71% operates in manufacturing, are included in the system.

Obligated distributors can collect white certificates directly, by carrying out an energy saving investment or by making an agreement with any end customer, or indirectly, by buying the certificates from the voluntary actors on a dedicated stock exchange.
The most interesting investments for agricultural sector are: thermal systems using biomass or biogas, heat pumps, solar thermal panels, energy-saving systems for greenhouses, pumping, lighting. A single farm can benefit from the operating of the system by striking an agreement with a company providing energetic services or with a distributor or by submitting a project directly.
The EECs system is still little used by the agricultural sector because of the need to aggregate projects realised in different farms in order to reach the minimum saving threshold, the high complexity of the project planning in the case of direct submission and the non-combinability with other incentives.
The voluntary carbon credit market (VCCM) is dedicated to companies not included in the category of large greenhouse gas emitters. These companies, in order to achieve the reduction of greenhouse gas emissions, can present innovative projects that, once certified by an independent entity, entitle to generate Carbon Credits denominated Verified Emissions Reductions or VER (1 VER = 1 ton CO2 eq).

Although the VCCM represents less than 1% of the global carbon credit market, it introduces interesting opportunities for the primary sector, especially for forestry, according to the “polluter pays” principle.

Although the VCCM represents less than 1% of the global carbon credit market, it introduces interesting opportunities for the primary sector, especially for forestry, according to the “polluter pays” principle. A farmer and/or a forestry entrepreneur could get an income from the sale of carbon credits obtainable through specific interventions aimed at increasing the carbon stock in the above and below ground biomass, litter, necromass and soil (through forest plantations or adopting particular agronomic and forestry techniques, etc.).
A further development of the VCCM should come from the recent approval (September 8, 2016) of Uni 11646: 2016 on “ Greenhouse gas - System For The Carbon Credit Voluntary Market Management Arising From Projects Of Greenhouse Gas Emission or improve of GHG removal”, a basic technical and methodological reference for agroforestry companies that intend to “monetize” the carbon absorption produced in voluntary markets.

INDIRECT INCENTIVES: GREENING

One of the major innovation brought in under the 2013 Common Agricultural Policy (CAP) reform is “greening”, envisaged by Regulation (EU) 1307/2013. It is a specific part of the direct payments that is additional to the basic decoupled-from-production payment, supporting mandatory agricultural practises beneficial for the climate and the environment. Greening is a relevant part of direct payments as it accounts for 30% of EU countries’ direct payment budgets. Italian green direct payments budget amounts to 1.1 billion euros per year, approximately 90 euros per supported hectare.
Farmers receiving a green payment, that in Italy is defined as a fixed share (about 60%) of the basic payment, have to follow up, on the entire farmland, to three specific commitments:

- Crop diversification (art. 44): when arable land exceeds 10 hectares, farmers shall cultivate, with some specific exception, at least 2 different crops on that arable land,
- Permanent grassland (art. 45): farmers shall not convert or plough permanent grassland situated in Natura 2000 areas or in other similar areas,
- EFA - Ecological Focus Area (art. 46): when arable land exceeds 15 hectares, farmers shall dedicate, with some specific exception, at least 5% of that arable land to “ecologically beneficial elements”, such as land lying fallow, terraces, buffer strips, etc.

Greening commitments are applied to the arable land only; organic farms receive green payments but they don’t have to follow up to greening commitments.

THE ROLE OF RURAL DEVELOPMENT PROGRAMMES

The Rural Development Programmes (RDP), the second pillar of the CAP, subsidizes several lines of action that determine a positive impact on reduction of carbon emissions in the agricultural sector (Figure 2). Various measures in combination contribute to the pursuit of EU strategic priorities of climate-environmental "Promoting resource efficiency and supporting the shift towards a low-carbon and climate resilient economy in agriculture, food and forestry sector "(Priority 5: EU Regulation no. 1305 of 2013).

Several intervention measures may produce significant savings in terms of CO2 emissions, by increasing forest areas and wooded land and by protecting the existing situation (M08) and by promoting sustainable agricultural practices (M10 and M11).
Furthermore, the production of energy from renewable sources is being stimulated by subsidizing investments made by farms (M04 and M06) and by associations and/or public bodies (M07).

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THE RURAL DEVELOPMENT PROGRAMMES IN ITALY

In the Italian context, 21 RDPs allocate to interventions aimed at reducing GHG emissions a total of 808 mn € of public expenditure, of which 148.4 mn € for the 5D Focus Area "Reducing greenhouse gas and ammonia emissions from agriculture" and 659.5 mn € for

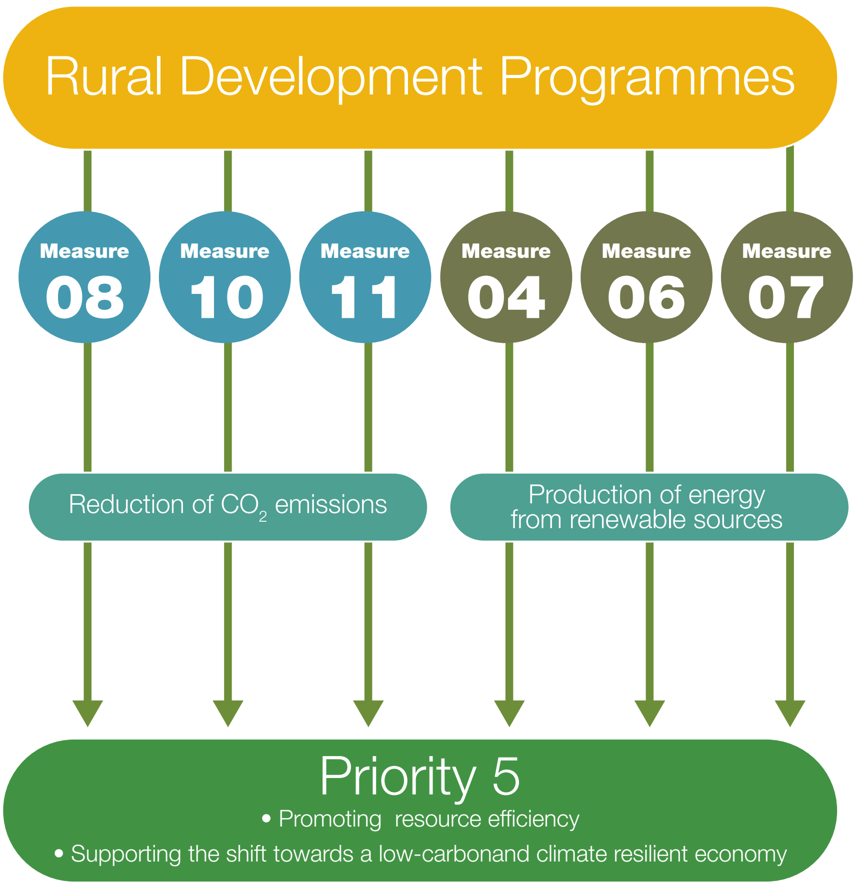

FIGURE 2
Rural Development Programmes

Only 7 Regions envisage specific actions to support the conversion to and the maintenance of conservation agriculture, for a total budget of 92.2 mn €, only 0.5% of the total national budget for 2014-2020 programming period.

the Focus Area 5E "Fostering carbon conservation and sequestration in agriculture and forestry". These measures concentrate about 10% of national public planned expenditure for the purpose Climate Change and more than 4% of the total planned for the period 2014-2020.
Only 7 Regions envisage specific actions to support the conversion to and the maintenance of conservation agriculture, for a total budget of 92.2 mn €, only 0.5% of the total national budget for 2014-2020 programming period. It is expected to convert/maintain about 90.000 ha of agricultural area, only 1.2% of the total national arable land. Considering that in Italy conservation agriculture involves about 380,000 hectares, the CA-dedicated financial resources are enough to cover only 23.6% of the total land already cultivated with these farming techniques (Table 1).
Just three of the seven Regions support both no tillage and minimum tillage; three Regions allow cover crops or green manure as an optional additional commitment. Premiums are very different from Region to Region.

Table 1: Planned public expenditure, target surface and premiums awarded for conservative farming in Regions that have provided for the activation of the specific line of intervention

REGION	MEASURE	ACTION	PUBLIC EXPENDITURE (EUROS)	TARGET AREA (HA)	NO TILLAGE PREMIUM	COVER CROPS PREMIUM	MINIMUM TILLAGE PREMIUM
Emilia-Romagna	10.1.4	Conservative agriculture and soil organic matter enhancement	4.851.410	3.732	250	30	
Sicily	10.1.f	Use of conservative farming techniques	4.000.000	2.240	253		
Friuli Venezia Giulia	10.1.1	Conservative management of soils	2.000.000	800	600		534
Lombardia	10.1.4	Conservative farming	38.000.000	51.000	55-240	180	
Piedmont	10.1.3	Conservative farming techniques	22.000.000	19.000	280	230	180
Veneto	10.1.1	Low environmental impact agronomical techniques	9.740.260	4.441	530-600		325
Lazio	10.1.5	Conservative farming techniques	11.600.000	9.700	130-300		
		TOTAL	92.191.670	90.913			

Source: Rural Development Programmes

Other RDP operations that aim mainly to objectives of competitiveness (particularly Measure 4), still have some positive effects on the reduction of GHG emissions through the support to the diffusion of conservative and precision agriculture practices.
The Sub-measure 4.1 - "Support for investment in agricultural holdings" supports the purchase of technical equipment for conservative and precision agriculture. Table 3.2 shows an analysis of selection criteria in tenders emanated from the regions of the Po Valley (Table 2).
Given that none of the considered regions has provided for the construction of an operation dedicated to the development of precision or conservative agriculture, most of them have granted proper selection criteria for the purchase of specific machines and equipment aimed at developing precision and conservative farming.

Table 2 – Premium provided for Measure 4.1 in favour of precision farming and conservation agriculture

REGION	PRECISION AGRICULTURE PREMIUM	CONSERVATIVE AGRICULTURE PREMIUM
Lombardia	X	X
Veneto	X	X
Piedmont		
Emilia Romagna	X	X
Friuli Venezia Giulia		X

Source: RDP Measure 4.1 tenders

The analysis shows that, although the Rural Development Policy provides for priority actions specifically aimed at mitigating climate change, the resources devoted to the promotion of conservative agriculture techniques, especially through Measure 10 Agri-Environment-Climate payments (AEC), represent a small part of the total budget of the RDPs (0.5%); such resources potentially affect just 1.2% of total national area which is down to arable crops. It is also noted that, in the most suitable regions (Po Valley), no RDP provides lines of action aimed to purchase machinery or equipment to develop conservation and precision agriculture techniques. Most of them however, excluded Piedmont Region, have defined specific priority criteria.

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THE CARBON-CREDIT SYSTEM IN THE FARMING SECTOR

Following the Paris Agreement, EU members have set the 2030 targets for the reduction of GHG emissions in the different production sectors.
As regards agriculture:

- in non-EU ETS sectors[3], is expected a 30% reduction of current emissions compared to those of 2005;
- in LULUCF sector[4], is set the “no debit” rule, as the commitment of a zero-carbon balance.

The reduction of non-CO_2 emissions from the farming sector in the non-EU ETS system, one of the objectives of the Paris Agreement, could encourage the adoption of precision farming techniques for a more efficient use of nitrogen fertilisers, resulting in a reduction of NO_2 emissions (Figure 3).
In the LULUCF system, the “no debit” rule and the possibility of generating carbon credits that can be used to achieve the objectives in the non-EU ETS system, could promote actions aimed at sequestering carbon in soil and reduce fuel consumption following the application of conservative farming techniques.
The methodology for the accounting of the farming emissions in non-EU ETS sector is by now consolidated, as it has been included in the Kyoto Protocol. The estimation of the farming emissions in LULUCF is far more complicated and it is now under study. It has to calculate the agriculture’ CO_2 emission and/or absorption, considering the different farming

[3] Non-EU ETS (Emission Trading System): building heating emissions, transports, farming non-CO_2 emissions, waste, small industries, etc.
[4] LULUCF (Land Use, Land Use Change and Forestry) includes the CO_2 emissions and absorptions in cropland, forestry land and grazing management and land use changes (excluding the CH4 and N2O farming emissions already included in non-EU ETS sectors)

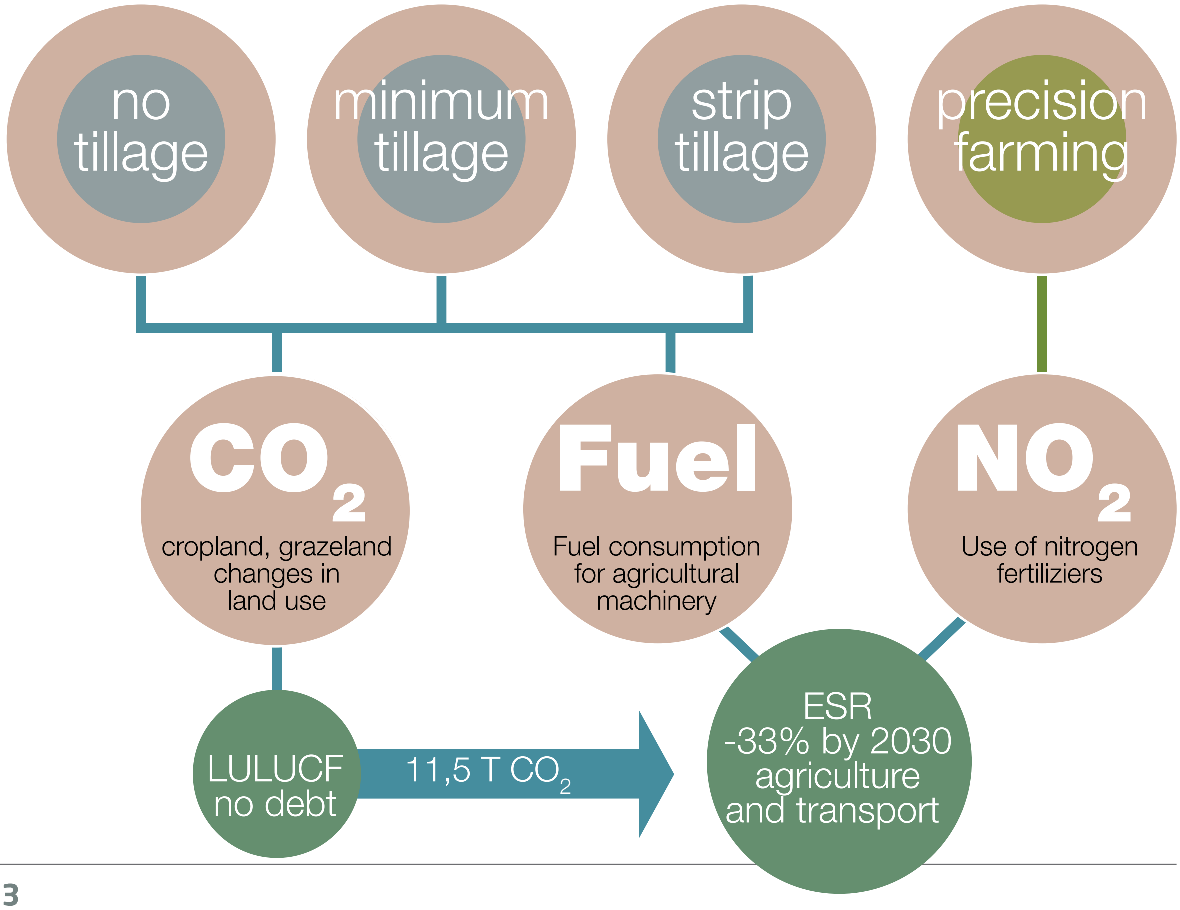

FIGURE 3

Contribution of the cultivation techniques envisaged by AGRICULTURE on the accounting of emissions as proposed in COM (2016) 482 final on the non-EU ETS sectors and LULUCF

techniques that have been adopted by the farmers.

The creation and the proper functioning of a specific market for carbon-credits need:

1. a new system for the accounting of carbon-sink in cropland and grassland soils of LULUCF sector, no more based only on land use changes, but considering also the cropland and grassland management, may lead to a balance with emissions exceeding absorptions; that should stimulate, in order to be compliant with the "no debit" rule, the adoption of "virtuous" farming techniques, as precision farming and conservative farming;
2. broader compensation possibilities between LULUCF sector and non-ETS sector.

The implementation of a carbon-credit market has to be based necessarily on an accounting mechanism that differentiate the CO_2 emissions and absorptions basing on:

- the farming techniques (no tillage, minimum tillage, strip tillage, organic farming, cover crops, etc.);
- the different pedoclimatic conditions;
- the different crops.

Then political decision-makers have to adopt:

- a market-ruled compensation mechanism, based on the "polluter pays" principle: net emitter farms pay for the tonnes of CO2 they have emitted and net absorber farms receive a contribution basing on the tonnes of CO2 they have absorbed;
- or a system in which only the net absorbers receive a contribution, financed with a specific tax (e.g. carbon tax).

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