HELPING ENHANCED SOIL FUNCTIONS AND ADAPTATION TO CLIMATE CHIANGE BY SUSTEINABLE CONSERVATION AGRICULTURTE TECHNIQUES

Guidelines

for Conservation Agriculture application and dissemination

The Life project "HelpSoil - Helping enhanced soil functions and adaptation to climate change by sustainable conservation agriculture techniques" had the objective of evaluating and demonstrating "on the ground" innovative agricultural land management techniques, which, by improving the functionality of soils, could contribute to resilience and adaptation to climate change.
The project actions took place between 2013 and 2017 and involved the Po Valley and Veneto-Friuli area and the surrounding hill areas of the Apennine and Alpine borders.
During the project, conservation practices and conventional land management practices were compared by monitoring agronomic and environmental indicators for three consecutive agricultural years in 20 demonstrative farms.
The details of: cultivation techniques descriptions, data collected and the test results carried out in demonstrative farms are reported on the project website www.lifehelpsoil.eu.

The hereafter "Guidelines" provides indications for the Conservation Agriculture application and dissemination, highlighting opportunities and limitations, the positive effects and details that still require agronomic development. The document has the aim to define a framework of shared technical references, appropriate for the Po Valley and Veneto basin, but open and transferable also in other Italian and European agricultural contexts.
The "Guidelines" are addressed to farmers, agricultural technicians, institutions, students, high school teachers, citizens, etc., that are interested in knowledge of the rules and agro-environmental aspects of Conservation Agriculture, finding the necessary information to approach it in a proper way.
The definitions of Conventional Agriculture and Conservation Agriculture reported in this "Guidelines" are:

Conventional Agriculture (based on plowing)

Traditional approach of preparing the soil for seeding, which includes plowing and a series of subsequent refinement operations, carried out with harrows and/or similar operating machines. Plowing involves turning the soil, normally at 30-40 cm depth (at greater depths in clayey soils); it modifies and strongly disturbs the soil biological activity. This practice is also expensive, both from economic and energetic point of view, due to the high number and cost of the machines needed to perform. The high consumption of fuel is also source of significant emissions of greenhouse gases.

THE KEY PRINCIPLES OF CONSERVATION AGRICULTURE

Conservation Agriculture

Set of techniques based on the concurrent application of three basic principles:

1) crop rotation;
2) minimum mechanical soil disturbance;
3) permanent organic soil cover.

Regarding the second point, in these Guidelines fall within the definition of Conservation Agriculture both “No-Tillage” and “Minimum Tillage” techniques. In the following text, when the contents are related to the whole conservative practices, it is generally referred to “Conservation Agriculture”. Otherwise it is specified when is referring to the individual techniques of "No Tillage" and "Minimum Tillage".

Crop rotation

Expanding the number of cultivated species, avoiding the frequent repetition of the same crops on soil and reducing the periods of crop interruption, has multiple objectives:
a) cover the soil and protect it from the elements in a continuous and more effective way;
b) improve the soil structure through the action of the root systems of different plants; stimulate biological activity in the soil;
c) restrict environmental risks due to nitrate leaching, surface runoff and erosion, loss of biodiversity.
Crops diversification allows to preserve and enhance soil fertility, to ensure and sometimes even improve yields and to reduce both the use and the impact of fertilizers and agrochemicals.

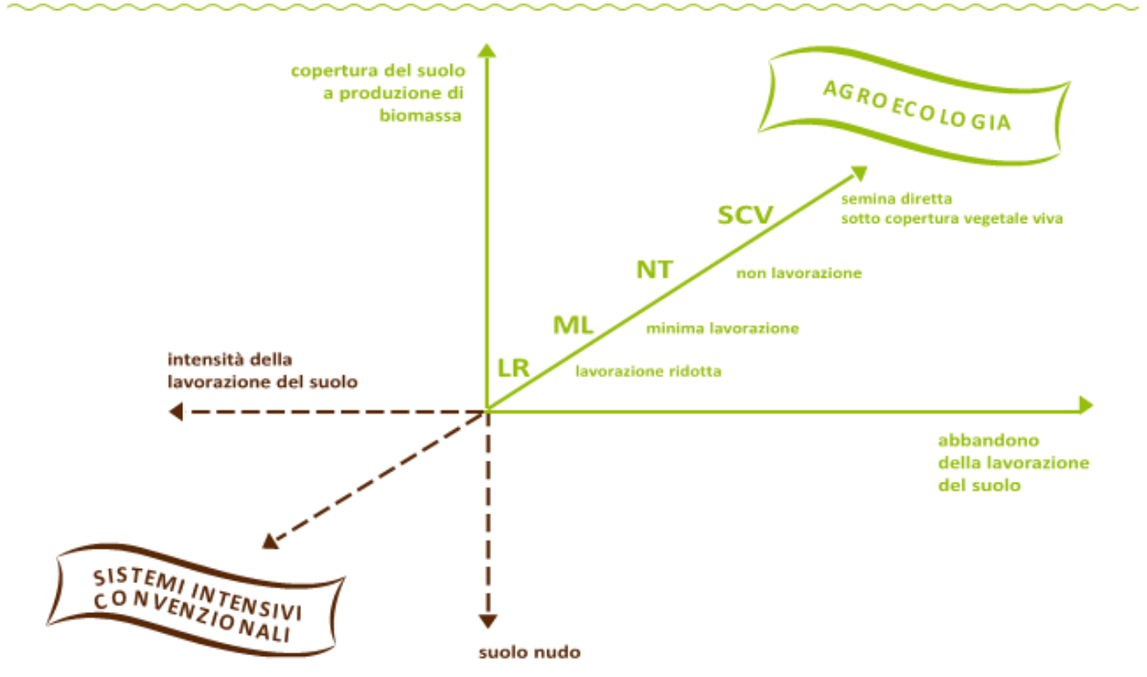
Reduction of soil disturbance

The aim of the reduction of soil machinery workings is to limit as much as possible the soil disturbance, without reversing the soil layers, and to support the organic carbon incorporation, improving its quality, quantity and distribution along the soil profile. Decreasing the intensity and depth of soil workings influence a greater physical protection of soil organic carbon inside the micro-aggregates reducing its oxidation. The undisturbed biological activity, even from the earthworms activity, contribute to the evolution of the organic compounds and settled the structuring action ensured by roots. The absence of soil mechanical disturbance, associated with fewer transits, allows to increase soil fertility, which develops its natural porosity and increase the ability to infiltrate water. The reduction of soil working decreases the machinery needed, the traction power, the fuel consumption (with consequent emissions reduction of greenhouse gases) and the hours of work required.

Soil cover

Preserve the physical fertility and increase the soil organic carbon especially in the first soil layers are both essential key of Conservation Agriculture. Return the crop residues on the soil surface, or buried in the first centimeters, and introduce a cover crop rotations in order to ensure the permanent coverage of the soil, protect it from climatic agents and allow the continuous feeding of the soil biological activity. Improvements generally start to occur when at least 30% of the soil surface is covered, but with greater residuals cover we achieve faster and more significant positive effects.
The concurrent and continuous application of these three principles lead to the biological equilibrium necessary for the development of vital agricultural ecosystems, capable of generating environmental benefits. The knowledge of the local conditions and the characteristics of the farms are however essential to allow a correct selection and management of conservation practices. Technical assistance therefore plays an important role in directing the "conservative farmer" into the choices to be taken. Switching to Conservation Agriculture allows savings and preservation of the environment, but it is a "strategic choice", which requires a "system approach" and a look over time, as well as an appropriate technological investment to insert a good level of innovation at farm level. Conservation Agriculture aims to enhance the potential fertility of soils and needs more agronomy, more reflection, more technical expertise, more innovation and more observation than conventional agriculture. It expresses an orientation towards new ways of producing that are continuously evolving and integrating with the rational use of water, the management of breeding and the phytosanitary defense, to lead toward more efficient and sustainable agricultural systems.

RIPRODUCE THE NATURE TO DELIVER FOOD AND AGRO-ECOSYSTEM SERVICES



Fonte: adattamento da MATHIEU PORTIER, 2008, ENESAD

«MINIMUM TILLAGE» IS PERCEIVED IN SOME CASES AS A FIRST APPROACH TO CONSERVATION PRACTICES IN ORDER TO A TRANSITION TO «NO TILLAGE»

WHERE THE CROPS NEED IRRIGATIONE AND RAPIDY DRAINED SOILS, «MINIMUN TILLAGE» MAY AT THE MOMENT BE THE ONLY VIABLE SOLUTION

CONSERVATION SOIL PRATICES

It includes all the soil preparation techniques that no longer require plowing and therefore allow to reduce the number and/or the soil working intensity compared to the conventional practice: in particular, it eliminates the deep soil layers turning. Only when the reduction in soil disturbance becomes more marked, this type of management can be identified as Minimum Conservative soil working.

Minimum Tillage

Is a soil working technique at a very thin depth to create a satisfactory sowing bed obtained with one or two passages of the machine. Generally, only the operations carried out at a maximum depth of 20 cm with working tools not moved by power and determined a relatively reduced soil disturbance are considered compatible with the definition of "Minimum Tillage". This technique must also be carried out in a way that crop residues remain partially visible on the ground, covering at least 30% of the surface.
Although there is some lack of certainty about which mechanical operations can be included in the concept of "Minimum Tillage", the essential elements are in any case to be identified in: limitation of the depth of works, non-mixing different soil layers and use equipments that don’t mush the soil and do not demolish their structure too much.
These principles remain valid also for farms, due to the soil characteristics or the cultivation practices adopted (in particular in the spring and summer cultivations), secondary work on soil is implemented like weeding or ridding.
The "Minimum Tillage" represents a step towards a more sustainable agriculture, since it reduces costs and energy consumption. However, the simple replacement of plowing restrict the environmental benefits that are potentially achieved by adopting the whole practices of Conservation Agriculture. The positive externalities and the ecosystem services generated by the "Minimum Tillage" can become more significant if it is also followed by: the practice of cover crop; the development of mechanical equipment for the reduction of herbicides doses and the fertilizers efficiency. However, is helpful to warn against the risk of repetition over time of the "Minimum Tillage" technique: if incorrectly performed or under unsuitable soil moisture conditions could also lead to a plow pan formation, harmful because very superficial.

Vertical Tillage

It is a technique that consist of treating the soil in its superficial layer (around 3-5 centimeters) with tools provided of vertical disks that don't have any inclination with the proceeding direction.
Because of that particular shape and position of the disks, the tools doesn't move or mix the soil.
The shallowness of the intervention is justified to minimize the alteration of the biochannels formed in the "No Tillage" regimes and do not represent a penalization of the water infiltration capacity. Thanks to the high speed and limited working depth, crop residues remain almost entirely on the surface. The technique, recently introduced, has the following objectives: to cut off crop residues, to remove them from the sowing line, which will heat up more, and to don’t allow any superficial soil crust formation. The "Vertical Tillage" can contribute to the weeds control at the early stage but also facilitate the germination of other weeds thanks to the superficial layer displacement.
Another achievable result is to obtain a good seed placement even with seeders not specifically designed for sod seeding. This operation could be useful occasionally, especially during the transition years from the conventional system to the "No Tillage" or when corrective measures are needed, in particular on cold soils, to avoid crusts and when the organic matter has not yet adequately accumulated in the first layers.

CHARACTERISTICS OF A SOD SEEDER FOR PRECISION SOWING. IT IS GENERALLY CONPOSED OF:

1) **RESIDUE SPACERS**
2) **FRONT CUTTING DISC**
3) **DOUBLE DISC CUTTER**
4) **DEPTH WHEELS**
5) **CLOSING WHEELS**
6) **TOOLS FOR CUTTING PRESSURE AND SEEDING DEPTH CONTROL**

A «NO TILLAGE» SOWING MACHINE MUST ENSURE THE CUTTING OF RESIDUES AND SOIL, THE DEPOSITION OF THE SEED INTO THE SOWING ROW, THE CLOSURE OF THE ROW, THE POSSIBLE DISTRIBUTION OF STARTERS, FERTILIZERS AND/OR SNAIL AND PEST CONTROL PRODUCTS

Strip Tillage

Technique used to work the soil in "stripes" where the sowing must subsequently take place. The width of the stripes should not exceed 15-20 cm and a depth of 15 cm. Usually, stripes should affect around 25-33% of the soil surface, so that on the remaining area be left all crop residues. Typically it is done for crops as corn, with working widths of 15 cm and inter-row of 70-75 cm, or soy and sorghum, with working widths of 10 cm and inter-row of 40-45 cm.

The "Strip Tillage" is born in harsh climate to preserve the advantages of "No Tillage", even with the compromise of working a small strip, mainly to encourage the soil heating in the seed deposition area and allow a quick birth of the plant. The technique is also well adapted to the simultaneous distribution of fertilizers, burial of zootechnical effluents and pre-seeding weed control.

Commonly the "Strip Tillage" machines consist of (in sequence): a cut-residues vertical disc; two star wheels for the residue removal from the strip; an anchor with vertical soil processing inserted between two disks (which delimit the width of the strip); finally, a sod cutter.

Depending on the area and the soil types, the "Strip Tillage" may require one or two steps, one in autumn and one in spring (generally lighter). Moreover, to reduce the soil disturbance the position of the strip should remain the same through the different crops: the use of satellite-guided driving and controlled traffic becomes essential.

The "Strip Tillage" adoption can find economic (increase in operating efficiency and reduction of energy inputs) and environmental (soil erosion reduction and soil water conservation potential increase) justifications.

No Tillage

Crops sowing technique on "sod" soil in presence of residues from the previous crop, which are left entirely on the ground. With this technique no tillage work at all is carried out, apart from the minimum disturbance caused by the seeding tools.

The properly said "No Tillage" is based on its continuous adoption and on the establishment of a new balance between physical, chemical and biological elements of the soil. Thanks to "No Tillage", into the soil we can observe a structure stabilization and a durable, more continuous and interconnected porosity, which replaces the transitory and precarious one obtained mechanically with the plowing and other land preparation operations. This creates a better functional balance between infiltration, drainage and aeration. With "No Tillage" the temporary curative effect of the soil work is missing, so it becomes very important to keep under control the physical soil state avoiding compaction. Negative physical conditions of the agricultural soils may derive from: a low organic matter content; an irregular soil levelling and land arrangement; an irregular distribution of crop residues; an excessive compaction from the harvesting operations. Under these conditions it is more likely that there will be a lack of uniformity in the depth of sowing and more parasitic and fungal attacks.

Transition from plowing to no tillage

It is the most difficult period because: the initial results may seem unsatisfactory, there is often inexperience, lack of information and, frequently, it is not easy to find suitable machines for different soils. However, usually those who have adopted "No Tillage" say that constancy and perseverance generally pay.

With that transition a soil step in a transitional period with a variable duration depending from: the soil type, the previous agronomic management, the skills acquired from the farmer and the adopted techniques. During this period the yields suffer a certain decline, before return comparable with those at the beginning. In most soils and crops the transition period normally has a duration within 5 years, and, at the end, yields can also reach higher levels than the starting ones. However, there are situations in which a lower natural fertility of the agricultural ecosystem or, more often, others unfavorable conditions (degraded soils, very low organic matter content, presence of salinity, management errors like strong compaction or irregular sowing, etc.) make the transition more difficult and slower than expected.

In the "No Tillage" schemes, in any case, some corrective measures may be necessary over the years in order to avoid negative drifts. The adaptation to the local conditions and to the characteristics of the farmers is always essential and technical assistance plays an important role in guiding the "conservative farmer" in the correct technical choices to be adopted.

No-Till seeder (Direct seeder)
Although the availability of adapted seeder has increased in recent years, both from abroad and on internal market, it may still be difficult to find the most suitable seeder for particular soils and operating conditions. For a successful "No Tillage" seeding it is essential that the seeder is able to "cut the soil" and crop residue, deposit the seed and "close the line" without reopening later. No-Till seeder are generally tow, heavier and more expensive than those used in conventional agriculture.

Decompacting
It is a technique that, without turning or remixing the superficial layers, cuts horizontally and raises the soil at a specific depth, ventilating it and restoring it, when it becomes compromised the proper porosity, water conductivity and roots area. Requires the use of tools (specially called "decompatters" to distinguish them from the more energetic "subsoiler", not suitable for this purpose) equipped with thin anchors able to work at a maximum depth of 35 cm, without producing a clear plowing of the soil. The technique involves a high energy absorption and must be understood as a "rescue operation", to be carried out only occasionally and in case of real need in the soils that present a sub-superficial compaction that cannot be solved in a short time by other agronomic means. It is not in any case similar to decompaction as usually known with rippers, which have other purposes and which cause a disturbance of the soil much more intense.

COVER CROP

Function of cover crops

The cover crops are inserted in agricultural rotations between two main crops in order to provide adequate soil cover, even in the intercultural period, and to bring biomass residues to the soil stimulating biological activity. The functions of the cover crop are therefore multiple: they protect the soil against erosion and compaction, improve its structure and porosity, promote the nutrients recycling by limiting losses, ease the pests control, provide nitrogen to crops and allow to increase soil organic matter.

The choice of cover crops

According to the crop cycle, cover crops are divided in summer and winter-spring cover. In general, they are not collected but left entirely in the field. Many plant species can be used alone or in a mixture as a good cover crop. The choice must be made considering the farm crop rotation and the soil rehabilitation type and intensity that must be achieved. If the goal is to enrich the amount of soil organic matter the choice will be over species that produce a lot of biomass; but if the need is to improve the physical soil fertility, we can move towards the use of fasciculated root species, such graminaceous plants, or species that have a strong decompacting activity, such as Brassicaceae (horseradish, mustard and rape). The use of nitrogen fixator cover crop (crimson clover, berseem clover, hairy vetch or common vetch) leads instead to an nitrogen enrichment of the soil and to a possible saving of synthetic fertilizers. In many cases it may finally be useful to choose mixtures, rather than single species, able to combine multiple effects: especially in poor soils, with no or weak structure, mixtures of grasses (such as rye, italic ryegrass, oats), legumes (vetch, crimson clover), brassicaceae (horseradish, mustard) and/or others (phacelia, buckwheat) can give interesting results.
The agronomic evaluations must be accompanied by others about farm arrangement and economic issues. In Italian environments, for example, the insertion of a cover between two crops is usually easier during the autumn-spring period. In summertime, the environmental conditions (high temperatures, lower water availability) are less favorable to the cover crop success; in addition, the range of available species is lower.

COVER CROPS RECYCLE NUTRIENTS, LIMIT NITRATES AND PHOSPHORUS LOSSES, PROVIDE SUPPORT TO THE SOIL-BASED BIOLOGICAL COMMUNITY, INCREASE BIODIVERSITY AND RESTRICT THE SPREAD OF WEEDS

AUTUMN-WINTER COVER CROPSSHOULD BE SOWN BY THE END OF SEPTEMBER

THE «ROLLER CLIMPER» IS A SHAPED ROLLER WITH FIXED BLADES THAT ALLOW THE COVER CROPS DEVITALIZATION

MUSTARD IS A WINTER COVER CROP. THAT DIES WITH COLD AND FROST, LEAVING A RESIDUE THAT ALSO ALLOWS DIRECT SOWING WITHOUT TERMINATION INTERVENTION.

SOME COVER CROPS RELEASE ALLOPATHIC SUBSTANCE IN THE SOIL THAT INHIBIT GERMINATION AND DEVELOPMENT OF WEEDS

From an economic point of view these crops are not given an immediate income: it is convenient to make choices aimed at minimizing planting and cultivation costs, including the possible use of seeds coming from the farm. Finally, in some cases, it may be appropriate to leave the independence to choose during the year if partly allocate cover crops to different destinations.

Measures to be used in the cover crop cultivation

The seeding of the crop cover must be carried out early after harvesting the main crop, so that it can exploit the residual moisture to germinate and reaching an adequate development before the cold season or the termination. Furthermore, the crop residue (straw, chaff, stalks, etc.) should be appropriately managed to reduce interference with seeding and emergence of the cover. In the case of the threshing of cereals, for example, it is necessary to avoid accumulation of straw and especially chaff, equipping the combine harvester with chaff and straw spreader.
The termination of the cover crop must also be carefully schedule to allow the sowing of the next main crop on time. Covers can be chemically dried, or mechanically finished by mowing or chopping. A new way is the use of a devitalizing roller (roller crimper) provided with perpendicular blades which provide to cut the plant in several parts till its death. However, this technique requires further development, in particular for the devitalization of the plants that are able to put new stems (rye, italian ryegrass, common vetch), becoming weeds of the next main crop.
The cover termination can be facilitated choosing species or cultivars that do not tolerate winter and are devitalized after an adequate period of frost. In addition, a passage of a roller during frost maximizes the devitalizing effect.
In the "No Tillage" management, where the termination is due to chemical drying, it is generally not advisable to shred the residue of the cover, even if the vegetative development has been remarkable; in fact, keeping them still anchored to the ground facilitates the sowing operations, preventing the occlusion of the seed distributing organs and the superficial biomass dragging, factors that can interfere with the seed burial and the birth of the plant.
In "Minimum Tillage" management, the termination can be done with a disc harrow, at the same time making a partial burial. In case of species with high capacity to put new stems, this operation cannot guarantee complete devitalization.
Finally, it should be noted that, following cultivation methods experimented in France and Switzerland, they are spreading new techniques that involve: the distribution of other seeds on the cover, taking care that they take root, or the contextual sowing while harvesting the previous main crop.

Effects on pest control

Cover crops must be competitive against weeds, to avoid their increasing. A fast total land cover and development of the cover is therefore very important: with the same hectare dose, especially for species who die in winter (horseradish, mustard), we can observe a strong difference in terms of competition capacity even with few days of sowing time gap.

Some species used as cover crop have also allelopathic effects, due to the release of toxic substances, especially active towards small seed weeds. The use of these plants, alone or in mixture, can therefore give, together with the rotation, a useful contribution to a more easy control of the weeds. The most promising results seem to come from rye and villous vetch. The correct technics is still under study: however, it has been observed that when these species are buried allelopathic action is considerably reduced.
Finally, other crops, in particular belonging to the family of brassicas (horseradish, mustard, rape), release glucosinolates with anti-nematode effect in the soil.

THE AGRI-ENVIRONMENTAL EFFECTS OF CONSERVATION AGRICULTURE

Improvement of soil fertility

The concept of soil fertility is very broad and includes many aspects: physical, chemical and biological. Together they contribute the soil functionality with the ability to sustain over time agricultural production and provide "ecosystem services" essential for environmental balances. Conservation Agriculture aims to increase the "natural fertility" of soils. In fact, it usually increase: the soil organic matter, the biological activity and roots symbioses, the regulation and the circulation of water in and on soils, ensure the bioavailability of nutrients. Often, together with tillage reduction, rotations and crop covers play a fundamental role in protecting soils from hazardous atmospheric agents and containing the pest charge and the spread of weeds.

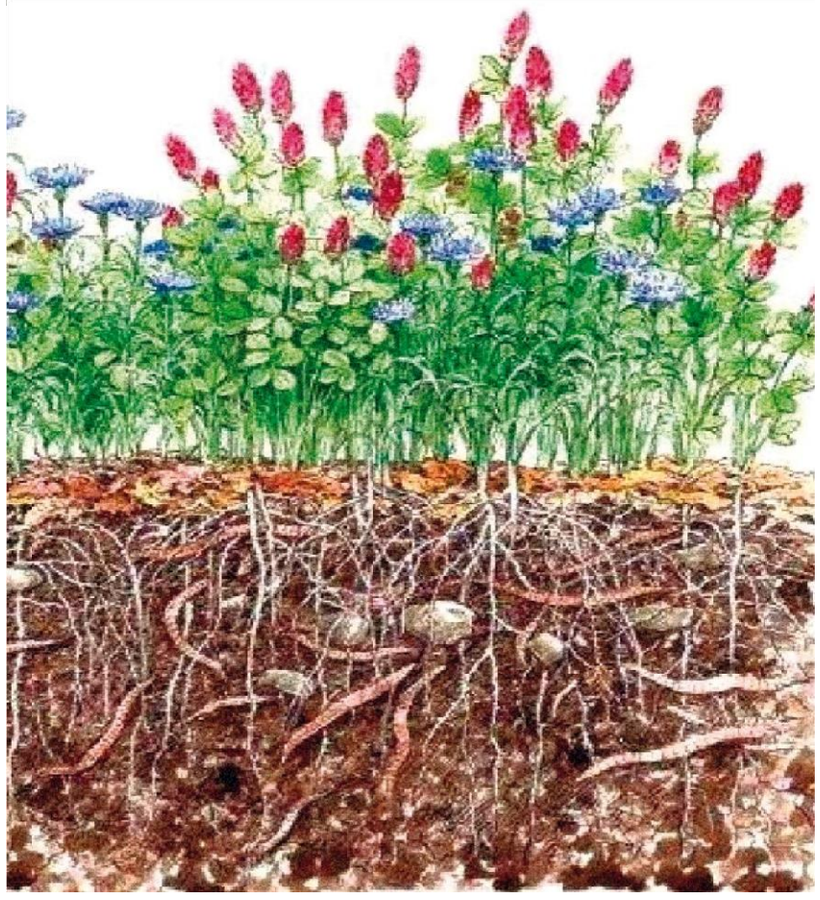
Soil carbon sequestration

In Conservation Agriculture everything should be done to facilitate the maintenance and the increase of soil organic matter, since it represents a very important factor of soil health. When this happens, the soil is also able to act as a carbon "sink" and the increases in organic matter obtained correspond to CO_2 subtracted from the atmosphere. However, the increase in soil carbon that can be achieved is extremely variable and depends on: soil type, environmental and climatic conditions, soil management techniques and the interaction between them. At the state of the studies, with conservative practices, "No Tillage" and favorable conditions, we can reach an increase up to 0.2-0.5 t ha-1 year-1 of carbon. In general, the carbon storage potential is greater in the most degraded and exhausted soils. The rate of increase in carbon is, however, constrained to decrease over time until its zero to achieve a new and stable balance in the soil. Moreover, in comparison with conventional agriculture, there is a different distribution of the carbon with the depth, with increases in the most superficial layers and reductions in the deeper ones due to the lack of organic matter burial usual with the plowing. With the "Minimum Tillage", the differences in organic carbon content between plowed soils are normally less significant.
Overall, the still largely incomplete knowledge of the carbon transformation dynamics and processes into soils induced by the shift of plowing techniques suggest the need for further studies on different soils types, cultivation systems and climates before reach definitive conclusions. However, others environmental benefits due to the improvement of the soil functional qualities which are induced by the increase of the organic matter in soil surface layers are:
- filter and buffer against pollutants, reduction of nutrient losses in the environment;
- regulation of matter (carbon, water) and energy flows between lithosphere and atmosphere;
- water storage, fertility and agricultural productivity, biodiversity development;
- less fertilizer requirements to reach the optimal level of crop yield.

Nitrous oxide and methane emissions

The role of "No Tillage" in the nitrous oxide (N_2O) emissions control is not yet sufficiently clarified, as experimental data are still few and often discordant. Nitrous oxide is formed both by aerobic nitrification processes and by denitrification in anaerobic environment. In agroecosystems, the degree of water saturation and soil temperature, compaction, nitrogen fertilization and soil tillage have an influence on the N_2O production. Between these, the most important factor seems to be soil moisture. Studies that report higher N_2O emissions under "No Tillage" compared to conventional agriculture show a correlation with a higher soil water, carbon and nitrogen content. In other studies "No Tillage" emissions were found to be lower than those recorded from plowed soils, especially in well drained soils. Finally, in a last study, after an initial increase, a long-term decrease in N_2O flows in "No Tillage" soils was observed, due to the slow process of reorganization of the structure and internal drainage of the soil.
With regard to methane flows (CH_4), which may be important in rice fields due to the prolonged submersion of soils, soil tillage techniques do not seem to significantly affect.

PLANTS PROVIDE THE ENERGY FOR LIFE ON EARTH. COUPLINS THE INCREASE OF AERIAL AND RADICAL BIOMASS INTENSIFICATION OF GROPPING SYSTEMS AND INTERGROPPING WITH THE REDUCTION OF TILLAGE DISTURBANCE, ENRICH SOILS IN ORGANIC MATTER, MAKES THEM LIVELY AND FERTILE, PRODUCTIVE AND CAPABLE TO DELIVER ECOLOGICAL SERVICES



Saving of fossil fuels

The fewer workings and cropping operations and the lower traction force required in the "No Tillage" allow to reduce the consumption of diesel oil. It is estimated that the fuel saving for the operations of soil preparation and sowing, even within a wide variability due to the soil type and depth of plowing, can reach 60-70% and the CO_2 and other greenhouse gases emissions are reduced. On the basis of various studies, with the adoption of "No Tillage" practices, it has been estimated an average saving of 40 l/ha of fuel and 150 kg/ha of CO_2 in emissions reduction. In "Minimum Tillage", instead, the fuel saving is around 30% depending on how much the cultivation operations are reduced, with a proportional emissions reduction.

Erosion control

The permanent cover and the reduction/absence of tillage protect the soil from water and wind erosion. The role of cover crops and crop residues is crucial in mitigating the impact of atmospheric agents (rain and wind) on soil particles; moreover, their presence slow down the water flow that does not infiltrate into the soil, reducing the removal possibility of soil particles. Furthermore, surface water quality improves due to the reduction of transported sediment. In the "No Tillage" managed soil an almost total protective action can be achieved, comparable to that offered by a permanent plant cover: thanks to the root systems action, the development of massive subsurface layers is avoided, which often become "sliding surfaces" on which usually soil erosion and landslides start.

The "Minimum Tillage" is placed in an intermediate position with respect to what happens in the plowed land, in function of plant residue quantity left on the surface after soil works. Regardless of the adopted practices, protection against erosion assumes importance especially in hilly environments: nevertheless it must be kept in mind that, in susceptible soils, erosive processes can occur even in the presence of very weak slopes and/or at ditches outlet points.

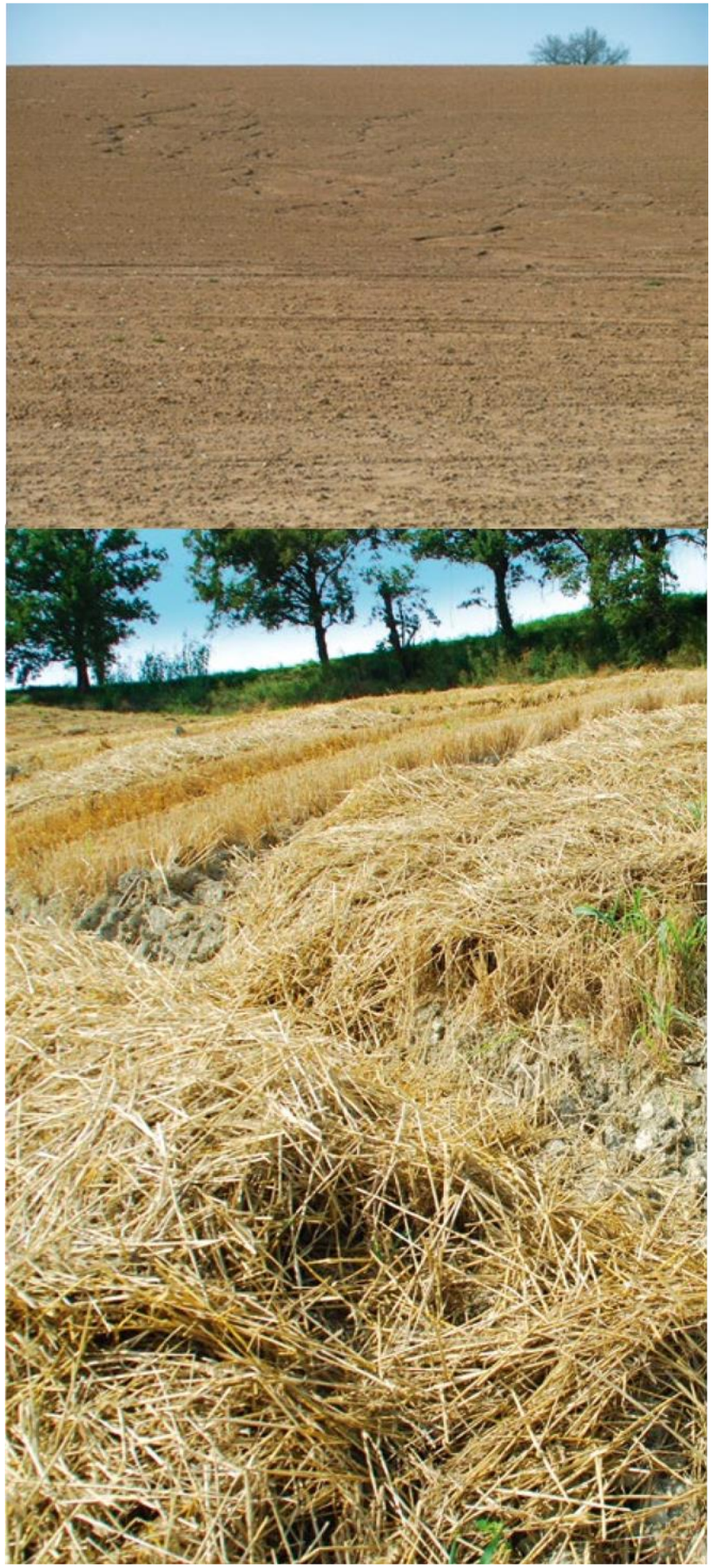
Increase of soil biodiversity

The lower soil disturbance due to conservative practices and the organic matter accumulation into soils promote biological, microbial and enzymatic activity: organisms (meso and microflora) living in soil increase in number and population density. In soils subjected to "No Tillage" the earthworms can be up to 10 times more than in conventional worked soils; in "Minimum Tillage" soils the density of earthworms and the increase in overall agrobiodiversity depends on the intensity of the disturbance. In any case, with Conservation Agriculture, the cultural rotations and cover crops bring to soil different plant species that are the habitat of a wide and diversified spectrum of living organisms (especially in the subsoil).

Regulation of hydrological and nutrients cycles

"No Tillage" improves the water infiltration and the soil water retention capacity, thanks to the reconstruction and maintenance of an interconnected bio-porosity, come from the bio-channels digged by living organisms and decay of radical apparatus not destroyed by tillage. At the same time, the best soil structure and the highest organic matter content can increase the water retention capacity. From a physical and structural point of view, the soil achieves a better hydrological equilibrium and closer to the natural conditions, which translates into more available water and a decrease in surface runoff and evaporation. In the literature there isn't a total consensus regarding the risks of nutrients loss: in most cases, however, less total nitrogen and phosphorus losses were observed in "No Tillage" soils compared to plowed ones. In particular, in order to minimize runoff losses, is recommended to maintain a good infiltration rate and to favor the soil internal drainage.

In the "Minimum Tillage" it can be assumed that, thanks to the lower disturbance of the subsurface layers, the effects that can be found on the regulation of hydrological cycles are intermediate, always depending on the extent of the reduction of mechanical works



PLOWING AND PASSAGE OF AGRICULTURAL MACHINERES ON BARE SOILS MAY CAUSE THE FORMATION OF UNCONTROLLED PATHS OF WATER LINES, STRONGLY INCREASING THE EROSION RISK, MOSTLY ON SLOPES

THE MOST BRIGHT ADVANTAGES OF COVER CROPS IN PUDDY FIELDS ARE: THE SOIL FERTILITY IMPROVEMENT, THE WINTER SOIL EROSION REDUCTION AND THE MITIGATION OF SURFACE CRUST FORMATION, WICH IS PARTICULARY HARMFUL FOR UNDERGROUND ROW SOWING

AGRONOMIC IMPLICATION

Ecosystem services

The environmental benefits of Conservation Agriculture are displayed at the farm level, first of all. However, when the effects are spread in a larger area with implementation by many farms, the "eco-system services" and the "public value" generated grow further. The whole society therefore benefits from this, in terms of: water and air pollution abatement, water outflows regularization and flooding risk reduction, slope stability and hillside erosion decline, landscapes richness in terms of colors, shapes and aesthetic appearance, water treatment costs reduction, hydrogeological instability damage decrease and greater climate change adaptation capacity.

Soil Suitability to Conservation Agriculture

The success of "No Tillage" and the speed of soil response in achieving a production equilibrium similar to conventional agriculture are variable and may depend on environmental and farmer expertise factors. To obtain good results in reasonable time is necessary to "start with the right foot". Important and often crucial aspects are: the soil homogeneity in the plot, its correct hydraulic arrangement and surface regularity, a good drainage, no soil compaction and water stagnations. Moreover, in soils with little organic matter it is essential to increase it, possibly by meadow or by huge amounts of organic matter (manure, digestate, compost). About textural classes, sandy, mixed and clayey soils are generally well suited to the "No Tillage" regime; the most frequent problems occur in silty soils (over 60-70% of silt or if associated with high content in very fine sand), especially if not calcareous and lacking in organic matter, due to the very low capacity to self-structuring.

The "Minimum Tillage" offers a wider range of technical solutions, so, except for specific local conditions, it adapts to all types of soils: it should however be kept in mind that the "Minimum Tillage" techniques are not "self-conservative" of the soil structure and may periodically require the breakage of subsurface hard layer caused by the tillage.

Conservation agriculture in rice field

Italian rice cultivation is usually carried out in a succession regime (rice after rice) as a consequence of the high specialization level of the rice farms and the land hydraulic and hydrological conditions. The soils nature in the rice area and the almost total absence of any zootechnical activity are limiting factors to a good soil fertility, with negative effects on the organic matter turnover and nitrogen availability. In this context, very often there are production losses due to the high soils compaction caused by conventional tillage, intensified with the introduction of the laser leveling. The "No Tillage", with sowing in rows and delayed submersion, has some critical points for its diffusion in rice cultivation: the formation of wheel lanes caused by harvesting operations; the presence of huge amount of crop residue that could obstruct seeds germination; the "crodo rice" control with herbicides, applied after the false sowing, is made more difficult by the shielding action of the straws towards the herbicidal solution. Recent experiences seem to highlight a significant reduction of the cockspur infestation after several years of "No-tillage" management of rice fields.

"Minimum Tillage" techniques have some advantages like reduced production costs and good production potential. The choice of the most correct equipment is crucial in order to avoid the formation of tillage "sole", and to allow an adequate growth of the root systems.

The cover crops use offers a diversification in a mono succession regime. The species from to the legume family are well suited to the rice field (Vicia villosa, for example) and allow a soil organic nitrogen enrichment, very useful to compensate the limitations highlighted for the rice area. The grasses, in addition to the function as catch crop ("capture" of residual nitrogen which is subtracted from leaching), develop a soil structuring action with its fasciculated root apparatus. It benefits from that the sowing bed preparation, particularly in case of buried rows sowing. The main limitation for the development of a good cover crop in the rice field is to avoid water stagnation and to sow no later than mid-October.

Conservation agriculture and irrigation

All irrigation techniques (flow, sprinkling, drip) are compatible with Conservation Agriculture. Some mechanical soil interventions on spring-summer crops (corn, in particular), to encourage the channeling of water along the lanes during sliding irrigations, are compatible only with "Minimum Tillage". On the other side, irrigation with underground ("subirrigation") or superficial dripping wings is well suited to "No Tillage" lands, where no work is carried out and the synergy between the two techniques amplifies the environmental and agronomic benefits.

In any case, Conservation Agriculture can contribute to: increasing the water efficiency; reducing evaporative losses (according to FAO, there is a 5% reduction every 10% of land cover with crop residues) and percolation; increasing the soil water retention and the storage, over time, of rainwater.

Conservation agriculture and livestock manure management

The "No Till" experience in livestock farms is more limited and specific equipment is still not widespread. First of all, the need for reduced trampling must be respected, adopting distribution suitable equipment, such as carts equipped with multiple axes and low pressure tires. Secondly, it is necessary to adopt distribution methods to minimize the atmospheric emissions of nitrogen compounds. To bring sewage to soils (and in general all liquids effluents) the techniques that can be used are: the low-level distribution, the direct injection into the ground with sub-surface tools (maximum 10 cm depth) or fertigation. In "No Tillage" technique the manure distribution can instead take place only on living grass or in presence of crop residues, with natural or mechanical mixing. The presence of residue, which has a high adsorption capacity, and the high soil biological vitality stimulate the manure management by the pedofauna and the microflora with a quick incorporation into the soil.

With "Minimum Tillage" the use of zootechnical wastewater presents less troubles: surface tools can be used bringing the effluents without upset soils and turning upside down layers or, for the liquid fractions, ground distribution and fertigation. In case of "Strip Tillage", the sewage can be buried at the time of processing.

Conservation agriculture and weed control

The changeover to "No Tillage" management involves changes to the weed populations and therefore requires different strategies than those previously used.

The following aspects must be taken into consideration:

- before and during the transition phase from conventional to conservative regime is necessary to spend particular care to the "seed bank" reduction and weeds control; afterwards it becomes generally possible to reduce the treatments, avoiding and/or limiting both those in pre and post-emergency.
- in case of cover crops, unless their termination is mechanical, the herbicide generally becomes the main chemical treatment to be foreseen that also exercise a control action on weeds; without cover crops the treatment plans do not differ so much from those used in conventional agriculture.
- natural predation (granivorous, slugs, etc.) against weeds increases.
- crop rotations and covers are essential for controlling weeds and reducing herbicide dependency.

In "Minimum Tillage" no particular differences are observed with conventional agriculture, even if the crop rotation adoption tends to reduce the pressure of the weeds. However, certain types of weeds, especially stoloniferous and rhizomatous which are very competitive and harmful to ensure a normal and regular seeding density, may be more difficult to control.

THE MANURE DISTRIBUTION ON SOILS WITH VEGETATION (LAWNS, GRASSES, COVER CROP, NEST CROPS) REDUCES NITROGEN LOSSES TO THE ATMOSPHERE AND LEACHING FARM THE SOIL

SLATES IN «NO TILLAGE» REPRESENT IN SOME YEARS A KEY PROBLEM, WICH REQUIRES CAREFUL MONITORING AND PROMPT INTERVENTION

THE BRASSICAS (MUSTARD, RAPE, HORSERADISH) RELEASE GLYCOSIDE IN SOIL THAT HAVE A NEMATICIDE EFFECT

Conservation agriculture and pest management

Conservation Agriculture does not involve substantial changes in phytosanitary defense approach, which can be carried out using the integrated pest management methods and the normally used equipment.

In "No Tillage" a specific additional attention must be reserved to the slugs control: in particular humid periods, and huge amount of crop residue still fresh, can occur in high numbers and seriously damage young plants during germination and emersion, until cause complete failure of the crop.

Corn, sunflower, soy and rape are particularly at risk, but the attacks are not easily predictable and have a very irregular spatial distribution, often coming from ditches and heads of the fields. The slugs population must be monitored carefully and, in the event of heavy infestations, it is possible to set in a treatment with ferric phosphate-based baits, to be distributed as soon as sowing or in the early development stages of plants, particularly at the edges of the cultivated fields.

Conservation agriculture and mycotoxins development

The mycotoxins values in wheat and corn grains are mainly influenced by meteorological trends and stress factors that help their formation (high humidity, thermal excursions, water stress, insect attack), as well as the presence of inoculation in the environment. Moreover, the succession of grasses (ex: corn/wheat) and also the tight rotations do not offer protection against mycotoxins (fumonisins, aflatoxins, trichothecenes). Finally, crop residues that remain on the field may represent a potential inoculum for fungal infections, in particular fusariosis, with consequent greater risks of mycotoxin formation in cereals.

In conservative agriculture, however, crop rotation is a basic pillar of the technique, so that the temporal trailing of the fungal inoculum is minimized. Furthermore, crop diversification and the greater biological activity of conservative systems can represent an effective factor of "natural control" of pests.

The available data indicate that, for mycotoxins control, the recommendations of monitoring their presence and apply strategies suitable to contain their development, including the application of antagonist fungi like Trichoderma spp., are valid both for conventional schemes and also to Conservation Agriculture.

Conservation agriculture and soil work management

In "No Tillage" regimes, the only work consists in sowing. In a survey carried out in some European farms that from long time used this technique, it has been estimated that mechanization investments for conventional systems based on plowing exceed "No Tillage" systems by a factor of 1.63, while the maintenance costs are 4 times higher, fuel costs up to 6.5 times higher and the required work time per unit of surface is 5 times greater.

In "Minimum Tillage" the mechanical interventions number is higher, but they decrease the power used, the energy consumption and the time required for the operations, compared to conventional practices. Conservation Agriculture makes it easier to respect the ideal windows for sowing crops, lowering the risks due to unfavorable climatic trends, leave soils with better load capacity and ensure greater flexibility in operational calendars.

Finally, the "traffic control" technique (satellite assisted driving) allows to reduce, even in Conservation Agriculture, the risks of too many crossings of agricultural machinery on soils. This technique makes it possible to concentrate all the operations in few and (always) the same lanes, thus avoiding the compaction of the remaining surface.

Management errors

Management errors, more easily recoverable in conventional agriculture, can have particularly heavy impacts in Conservative Agriculture and require longer times to be solved. Soil compaction is the most common and frequent problem. A first choice is try to prevent it, avoiding and limiting as much as possible the operations number, the agricultural vehicles transit with excessive soil moisture, the use of heavy working machines, the formation of "lanes" and areas of stagnant water on soil. The cover crop also has a role in increasing the lift, resistance and resilience of the soil to these impacts. Finally, to aerate the soil more in depth, and improve the water circulation where the subsurface compaction can not be resolved in any other way, it is possible to proceed at decompaction with special tools (decompacters).

PRECISION FARMING ALLOWS AN OPTIMAL MANGEMENT OF THE SOIL VARIABILITY THAT CONSERVATION AGRICULTURE CAN ALSO BENEFIT

IN CONSERVATION AGRICULTURE, SOIL COMPACTION IS THE MAIN RISK TO PREVENT, AVOIDING THE FORMATION OF «ROADWAYS» AND WATER PONDING

CONSERVATION AGRICULTURE PROMOTION

Conservation agriculture as sustainable agriculture model

Support for Conservative Agriculture is part of a broader view of sustainable agriculture models development where economic and environmental objectives can be met. An agriculture capable to "produce more with less" and/or address, as claimed by FAO, a "sustainable intensification of agricultural production". In many cases, such as the northern Italian one, it is not a question of continuously increasing yields, but to create awareness that through a more careful and less impacting use of resources, especially of "soil resource", it is possible to achieve a more effective defense of agricultural income. On the other hand, doing Conservation Agriculture is a challenging choice, which requires attention, perseverance, adequate support, training, technical assistance and the establishment of service networks play a central role in its diffusion.

Approach to Conservation Agriculture

In all situations, the transition to Conservation Agriculture involves a rethinking of the management methods, both for crops and farm organization, which concerns investments, work distribution and development entrepreneurial choices.

In approaching conservative practices, it may often be appropriate to maintain some flexibility. In fact, while respecting the fundamental principles, conservative techniques require adaptations at the agricultural practices or cultivation plans already set by farmers, including possible "in progress" adjustments.

Economic supports (such as those provided by the Rural Development Programs) are a way to bring farmers closer to Conservation Agriculture. However, in these cases it becomes necessary a greater inflexibility in the commitments definition to be undertaken and in their maintenance, due to the need for practices implemented control into the farms.

Farms interested in Conservation Agriculture

Conservation Agriculture is a land management type designed to the agro-food productions still relatively little spread in Italy and in Europe, but receiving now an increasing attention with the expectation that it can contribute to the production costs reduction.

Like any innovation, it must however be decoded and placed in the geographical reference and socio-economic context. Not all farms have suitable cultivation, sizes and business models to be able to easily switch from conventional to conservative. For bigger farms it is easier to adopt scale economies, while for smaller companies aggregation forms and sub-contracting can become decisive. At present the Conservation Agriculture techniques are consolidated for arable crops, in particular for cereals, soybean, sunflower, and forage, grown both in plains and hills. In the future, however, even the horticultural crops could benefit from this innovative technique: first experiences (tomato from industry, potatoes, legumes) begin to appear. Finally, in the hill areas, protocols defined for the grassing of vineyards and orchards, associated with conservation techniques adoption in arable land, should in future become part of a sustainable land management strategy with the aim of landscape redevelopment and hydrogeological fragility prevention.

The socio-economic context also has its importance. The dissemination and promotion activity of conservative practices should be concentrated in farms that have an innovative spirit, inclined to invest and modify their techniques and equipments.

WITH CONSERVATIION AGRICUTTURE, TIME IS SAVED AND COULD BE DEDICATED TO OTHER BUSINESS ACTIVITIES, PERMANENT TRAINIG OR MAINTENANCE (I.E. DITCHES, HEDGES, ROWS)

Farms service networks

Essential services to farms for the spread of Conservation Agriculture techniques are:

- education and training for:
  - farm owners and their employees, so that they can "learn before starting" and continue to update themselves;
  - contractors, to acquire a "conservative" understanding in the equipments purchase, in their use and interaction with farmers;
  - technicians in charge of business advice, so that farmers are "assisted", especially in the transition phase from conventional to conservative;
- promotion of joint initiatives to encourage the use of collective collaboration agreements, collective equipments purchase or to take advantage of mechanization cooperatives;
- support for sub-contracting services development;
- media dissemination addressed to farms (i.e. technical monographs, budgets, etc.), which should not be occasional and must be supported by technicians who provide assistance, also to analyse and support failures occurring in the field;
- field demonstrations to be carried out primarily at farms;
- application testing in different pedoclimatic and business conditions, creating a functional link with consultancy, training and support services;
- the commercial networks development and environmental certification schemes (carbon and water footprint, LCA) appropriate for agricultural production in order to guarantee and communicate at consumers the farms ecological performance and promote the environmental added value of conservative practices;

Main strengths and concerns

The farmers inclination to adopt conservative practices, and "No Tillage" in particular, is generally restrained by the fear for a greater soil compaction, less water retention capacity, greater risk of stagnation, wider spread of weeds and pests and ultimately lower yields. The inexperience, the propension to conserve their habits, the possible operative errors and the concern that the yield reductions can continue and lead to a unsustainability situation, frequently discourage those approaching for the first time these practices. In reality, converting the cultivation system from conventional to conservative should be seen as an investment, capable of giving benefits especially in the medium-long term. In fact, once the "soil-crop system" has reached the new equilibrium, it can offer greater profit margins, reducing production costs but it also saves time that can be dedicated to diversifying entrepreneurial activities or developing farms innovation.

Education and technical training responsibility

For the Conservation Agriculture dissemination, it is opportune that its concepts are included in a more systematic way in agronomy courses, both in high school and university.

Equally important are the "continuous training" opportunity for farmers and technicians: exchanging experiences, study visits, demonstration activities, use of social media and any other tool and initiative to share more easily the experiences of those who try Conservation Agriculture. Finally, a more systematic interaction with the agricultural machinery manufacturers can facilitate the production of equipments more and more suited to the pedoclimatic and business conditions.

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WEB SITE

www.lifehelpsoil.eu – Life HelpSoil Project
www.asso-base.fr –BASE Biodiversitè, Agriculture, Sol & Environnement
www.fao.org – Food and Agriculture Organization of the United Nations - FAO
www.sare.org – Sustainable Agriculture Research and Education
www.ctic.org – Conservation Tecnology Informatione Center
www.aei.asso.org – Asssociation Internationale pour une agriculture ecologiquement intensive
www.agriculture-de-conservation.com – Le portail des agriculture ecologiquement intensive
www.apad.asso.fr - Association pour la Promotion d'une Agriculture Durable
www.ecaf.org – European Conservation Agriculture Federation
www.aigacos.it – Italian Association for Agronomic and Conservative Management of Soil
www.novagricoltura.com – Nova Agricoltura – cultivate innovating
www.lifeagricare.eu – Life Agricare Project on precision agriculture
www.uworganic.wisc.edu – Organic Agriculture – University of Wisconsin – Madison
http://rodaleinstitute.org/- Rodale Istitute
www.aipas.eu – AIPAS Notill Italian Association
www.reterurale.it – Italian National Rural Network

MEASURE AND COMPARE THE FARM RESULTS TO IMPROVE THE AGROSYSTEM MANAGEMENT AND THE SOIL HEALTH

AGRI-ENVIROMENTAL INDICATORS

Ecosystem service	Conservation Agriculture Effect	Note
Agricultural production		
Total biomass production	+	Overall higher, if rotations and continuous land cover are adopted (cover crop)
Productive yields	≃ –	Production comparable to conventional management once the transition period is over Possible negative effect during the transition period or with problems in: compaction, surface crusts, surface residues management and weed control
Production stability	++	Yields are less influenced by climate trends (dry, very rainy years) thanks to rotations, resilience, water retention
Cover crop	+++	Strong influence for: biomass contribution, organic matter increase, biodiversity conservation, biological activity, erosion control, nutrient losses reduction, weed control
Greenhouse gases regulation		
Energy consumption	+++	Lower CO_2 emissions due to the strong reduction in fossil fuels consumption, especially for No Tillage, and reduced mechanization
Soil carbon	++	Positive effect in the first 20-30 cm, especially if the reduction/abandonment of the soil works is matched by permanent cover (cover crops) and crop diversification. There are no substantial variations in the deeper layers
Nitrous oxide and methane	–/+	At the moment not consistent data, still insufficient to reach good conclusions. Increased emissions of nitrous oxide in very humid soils and reduction in well-drained soils are possible. Not significant differences for methane emissions
Water cycle regulation		
Evaporation	+	Reduced water losses due to the crop residues mulching effect
Infiltration	+	Positive effect on water infiltration capacity (if soil compaction is avoided)
Available water	++	Linked to increased infiltration, lower evaporation and greater retention capacity due to the soil organic matter enhancement
Water consumption	≃/+	Mainly depending on the irrigation system, but the water requirements are lower and it is easier to obtain good yields in non-irrigated conditions or water scarcity.
Soil temperature	–	The lower direct exposure of soil surface to solar radiation and the reduced evaporation make the soils colder; the spring sowing must be delayed and the autumn sowing anticipated compared to the conventional management
Soil erosion	+++	Clear and immediate effects, amplified if the soil cover is continuous and permanent
Nutrient cycle		
Nitrogen and Phosphorus requirements	≃/+ ≃/–	The need for fertilizers may decrease as the total nitrogen present in the soil (in particular with legume cover) increase; in calcareous soils, the phosphorus bioavailability is higher During the transition period, a small nitrogen apply may be necessary until a suitable microflora is selected for the conservative regime
Nitrate leaching	++ ≃	With autumn-winter cover crops, which act as "catch crop", a very positive effect Without cover crops differences are not significant, due to the remarkable pedo-climatic variability
Runoff	++	The erosion reduction considerably limits nutrient losses due to surface runoff
Ammonia and dust emissions	++	The ammonia release into the atmosphere and the powders raise are reduced in presence of live grass coppices, crop residues and crop cover
Crop pests		
Weed control	+ ≃/– ++	Once the transition period is over, the need for herbicides is generally lower During the transition period the herbicides use may not differ from conventional management, as it is necessary to reduce the soil "seed bank" When Conservation Agriculture is applied in organic farms and/or mechanical/agronomic means are used for weed control and crop cover termination
Slugs and birds damages	–	In No Tillage slugs attacks can be greater; properly sown (seed buried, furrow closed and not reopened) limit the damage from granivorous birds
Fungal attacks, mycotoxins	≃	Depends on the weather pattern and crops stress factors. Rotations have a decisive role to reduce their incidence
Agro-Biodiversity		
Biodiversity, land cover	+++	The number of cultivated species and botanical families increases; the soil cover index with "live crops" (main and cover) may exceed 90%
Biomass and microbial activity	+	Increases in general
Earthworms	+++	The number and species in soils is consistently superior
Arthropods	++	The number and the species of microartropodi in soils is generally much higher
Resilience	+++	The most complex agricultural systems with greater biodiversity are more stable in their properties and able to better face adversity

Ecosystem service	Conservation Agriculture Effect	Note
Economic return		
Revenue / Costs	**≃/+** **–**	After the transition period, profitability is generally higher than conventional management In the transition phase, revenues may be lower and/or production costs could be higher
Labor	**++** **+**	In No Tillage the need for work is considerably reduced, but more investment is required in the training and technical skills development In Minimum Tillage the work requirement is reduced and improves the company organization

LEGEND: + Positive effect (+++ strongly positive, ++ very positive, + quite/normally positive); - Negative effect (generally/frequently); ≃ No significant differences with conventional agriculture

Project info

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Partners:
Piemonte region – Direzione Agricoltura
Veneto region – Direzione Agroambiente
Emilia Romagna region – DG Agriculture, Economy, Ittica, Attività Faunistico Venatorie
Regione Autonoma Friuli Venezia Giulia – Direzione Centrale risorse rurali, agroalimentari e forestali
ERSAF – Ente Regionale per i Servizi all'Agricoltura e alle Foreste
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Guidelines for Conservation Agriculture application and dissemination

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