Sustainable Agriculture And Life Project

T.C. KONYA VALİLİĞİ İL TARIM VE ORMAN MÜDÜRLÜĞÜ

TÜRKİYE ULUSAL AJANSI
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CONSERVATION AND SUSTAINABLE

AGRICULTURAL PRINCIPLES BOOK

CONSERVATION AND SUSTAINABLE AGRICULTURAL PRINCIPLES BOOK

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Konya Provincial Directorate of Agriculture and Forestry
Preface

Population of the world meets its basic nutritional needs from the soil. Agriculture is the main food source for the growing world population over the years. Agriculture is all of the work done on the soil in order to obtain plant products. Agriculture does not only meet our food needs. Agriculture also encompasses the whole of social, economic and ecological systems, such as the activities of ensuring the well-being of farmers and society, and the management of the physical and biological environments. Hence, the sustainability of agriculture is of great importance and essential.

In recent years, as a result of intensive agricultural production, serious deterioration in the soil structure has begun in agricultural lands. In addition, climate change and its effects are an important global problem that has started to be observed more frequently today. Agriculture is the sector most affected by climate change. Climate change is no longer an environmental problem, but directly a problem of ensuring the sustainability of human life. In order to ensure the living standards of future generations, it is now inevitable to take the necessary measures against climate change in our agricultural production in national and international cooperation.

Because of the mentioned reasons; Under the coordination of our Konya Provincial Directorate of Agriculture and Forestry, our project named 'Sustainable Agriculture and Life & Living Soils', in short, 'Living Soils' has been prepared. In the project, there are 8 institutions and organizations from 5 countries, including Turkey - Konya Provincial Directorate of Agriculture and Forestry, Selçuk University Faculty of Agriculture, KOP (Konya Plain Project) Regional Development Administration, Konya Karaman Agricultural Cooperatives Regional Union, the European Conservation Agriculture Federation (ECAF) from Belgium, Cordoba University from Spain, Lega Cooperative from Italy, DEULA-Nienburg GmbH from Germany.

By the Living Soils Project; it is aimed to create a cooperation network between countries that have successful studies on sustainable agriculture, to exchange and disseminate good practices by sharing new ideas and methods, to

develop the institutional capacities of all partners by operating at a transnational level, to contribute to the professional development of technical personnel and farmers in the sector.

Agricultural production with sustainable protective agriculture techniques, protection of natural resources such as soil, water, air and environment, reducing the effects of the causes and consequences of climate change, creating environmental awareness, increasing profitability and productivity in agricultural production, ensuring food safety are the expected results of the present project in the short and long term.

By the end of the present project activities, this book called as CONSERVATION AND SUSTAINABLE AGRICULTURAL PRINCIPLES, which contains 3 good practices and results of each country in this regard, has been prepared. The book contains a total of 15 good practices under 3 main sections, namely as: "Soil Management", "Crop Management" and "Input Optimization" respectively. This book will be prepared in German, Italian, Spanish, English and Turkish and shared with industry actors by all the project partners.

The Project Coordinator - Konya Provincial Directorate of Agriculture and Forestry, will continue to work towards the adaptation of our region's agriculture to climate change and protective and sustainable agriculture concepts.

We would like to thank the project partners, project participants, project management team and Turkish National Agency for their support for the Living Soils project.

Project Coordinator Institution

KONYA PROVINCIAL AGRICULTURE AND FORESTRY DIRECTORATE

European Conservation Agriculture Federation (ECAF) Preface

Nowadays, one of the great challenges that society should face is soil protection. The importance to minimize the soil threats that decline soil health and the urgent need to mitigate climate change make essential the transfer of knowledge between the different actors involved in order to achieve more sustainable agriculture based on soil care.

The European Conservation Agriculture Federation (ECAF), which is formed by 19 National Associations, has among its goals to disseminate information to farmers, advisors, policy-makers and all stakeholders related to the agricultural sector about the techniques that make possible the improvement of soil health through a sustainable agricultural management based on the tree principles of Conservation Agriculture. To achieve this objective, ECAF develops and promotes training and dissemination actions and also works to facilitate research in any aspect related to Conservation Agriculture and soil health improvement.

After more than 20 years of continuous activity towards the improvement of soil health, for ECAF, the participation in the Erasmus+ project **2019-1-TR01-KA202-076825 "SUSTAINABLE AGRICULTURE AND LIFE & LIVING SOILS PROJECT"**, has been an incentive to continue with the actions we carry out. Thanks to the activities developed by the participants in the project at the Transnational Project Meetings (TPM) and in the Training, Teaching and Learning Activities (LTTA), ECAF has been able to know in deep different ongoing actions to enhance sustainability in some regions at the European countries that participate in this amazing project. The active joint in the Project has provided a great experience to ECAF and raised knowledge to spread among its partners for the conservation and improvement of agricultural resources. The close collaboration among all the project participants to show useful management techniques for environmentally friendly and Profitable agriculture for farmers has resulted in the publication of this book of good agricultural practices in which part of the knowledge and experiences shared during the development of the project is shown. This publication should be a useful tool for achieving the objectives of improving sustainability in agriculture.

Finally, ECAF would like to thank the Erasmus + programme for the opportunity that provides to know the different cultures that exist in Europe, and all the people involved, directly or indirectly, to ensure the proper development of the project.

DEULA Nienburg GmbH
Preface

Sustainable agriculture offers unprecedented opportunities to transform agricultural practices in Europe and beyond, with the overarching goal of responding to the immense societal challenges of food security and climate change. However, technological innovation must be linked to practices, and practices must aim at the sustainable management of agricultural resources in order to preserve the integrity of the planet's resources for future generations.

The Erasmus+ project 2019-1-TR01-KA202-076825 "SUSTAINABLE AGRICULTURE AND LIFE & LIVING SOILS PROJECT" (Living Soils Project) aims to contribute to this overall goal by providing educational material in the form of a handbook in the field of sustainable agriculture. Education and training are essential steps to reconcile a conscious introduction of sustainable methods and modern technologies and to support daily agricultural management practices.

For DEULA Nienburg GmbH as an educational institution, it is always important to understand new developments, to experience insights and innovations in order to break them down to the teaching level. By participating in the Living Soils project as a partner, we were able to gain further experience in the field of sustainable soil cultivation at European level. Thanks to its transnational partner meetings and the learning and teaching activities excellently organized by the project partners, we have benefited greatly from participation in this Living Soil project and hope to have contributed to a mutual understanding of sustainable agriculture and soil health through our contributions.

Special thanks to the organizers and project managers for considering us as partners in this successful project. Of course, special thanks the Erasmus+ program which enables these project participations.

University of Cordoba
Preface

Agriculture faces many challenges. Not only does it have to produce more food and industrial raw materials to satisfy the increasing needs of future populations, it must also contribute to economic prosperity and social well-being whilst protecting natural resources. To address it, new technological tools and innovations need to be adopted. During the past three decades, it has become clear that agricultural productivity depends on maintaining soil health and functions which involve managing soil as a complex biological ecosystem. When a soil is used for tillage agriculture, it is not possible to sustain soil health because tillage destroys soil life and all the associated biological processes, damages soil structure and pore volume, does not permit the enhancement and maintenance of soil organic matter, and debilitates all soil functions at the field and landscape level. The symptoms of the unsustainable tillage agriculture include soil erosion and degradation, loss of crop yields and system resilience, dysfunctional ecosystem functions, and environmental pollution. To overcome these problems, it is crucial to share in a practical way the most updated knowledge, developed in different countries, because sustainability is a global issue.

The University of Cordoba (UCO), through the School for Agriculture and Forestry Engineering (ETSIAM) is committed to address global agricultural challenges. International projects, such as 2019-1-TR01-KA202-076825 "SUSTAINABLE AGRICULTURE AND LIFE & LIVING SOILS PROJECT", help share valuable knowledge.

The AGR 126 Research Group of the UCO focuses on the study of agricultural systems based on Conservation Agriculture, that improve soil health, conserve its biodiversity and sequester organic carbon in the soil, among others. Innovative digital tools and technologies for decision-making are usually considered in our research as well as best agricultural practices based on the three principles of Conservation Agriculture (Continuous no or minimum mechanical soil disturbance; Permanent maintenance of a vegetative mulch cover on the soil surface; Diversification of species in cropping system), both in annual and woody crops. In the different Transnational Project Meetings (TPM)

and Training, Teaching and Learning Activities (LTTA) we have been able to learn about new agricultural practices that are developed in other models of agriculture, sharing experiences and knowledge. All this is compiled in the Book of Best Management Practices that allows putting into practice in the future.

This Book of Best Management Practices will be the basis for farmers and field technicians who implement agricultural practices to conserve the soil and improve its characteristics in an optimal and efficient way, being a complement for many who already implement this type of agricultural practices as well as being a correct tool to meet the sustainability objectives imposed in the new CAP of the European Union.

We finish by thanking the Erasmus+ programme for the opportunity given to share knowledge, to grow both in a professional and cultural way, and to learn from all members of the different working groups that have formed this project. The development of this international project has been really rewarding and the forged bonds will be the seed of new collaborations

UNIVERSIDAD DE CÓRDOBA

ETSIAM

Legacoop Puglia
Preface

Soil protection is the key for a brand-new way of farming, for a new idea more oriented on Conservation and Sustainable Agriculture. This is probably the most important challenge for farmers in the next future; in this way, Conservation Agriculture Principles are vital not only to use responsibly land productively reaping high yields but, above all, being able to do so in the future as well, however climate change effects.

As association of cooperatives of farmers, the specific role of Legacoop Puglia regards the promotion, development, strengthening and defense of farmer's cooperation, the dissemination of the cooperative idea and experience, the representation and protection of cooperatives and of the adhering bodies for the purpose of their consolidation and development in the Apulia region. Legacoop Puglia, in the last years, is been focused on Soil Protection and conservation agriculture in order to face - beside the cooperative farmers - the real problems on the field. This role of Legacoop Puglia in this project - with the active participation of young Legacoop cooperators - represent this brand-new approach and the necessity to write and share among Apulian cooperatives Conservation Agriculture Principles.

The Legacoop Puglia active participation in the Erasmus+ project, 2019-1-TR01-KA202-076825 SUSTAINABLE AGRICULTURE AND LIFE, LIVING SOILS PROJECT was a great opportunity of work, reflection and study on Conservation Agriculture Principles and Soil Protection best practices. This Erasmus + Project create an unique opportunity to work and share best practice experiences with different culture colleagues and the LTT activities helped the partners to jump directly in the reality of the different Soil conditions and the common problems of agriculture of Europe and Türkiye.

This Project helps the partners to reflect on the effects of soil conservation practices, that may not reveal in the short-time perspective, yet they will be beneficial for the future of Farming. The project was the kay to learn and work

together on different methods of soil conservation help to mitigate erosion, keep fertility, avoid degradation, and minimize nature pollution due to chemicals by applying integrated weed and pest control techniques. Thus, soil conservation strategies greatly contribute to the sustainability of the environment and resources.

In this way, Legacoop, believes that it is necessary to continue the work carried out so far, in cooperation with the other project partners, in order to develop and deepen the topic of Soil protection, Sustainable Agriculture and food production, which will be essential for humanity.

legacoop Puglia

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PART 1

SOIL MANAGEMENT

MINIMUM SOIL DISTURBANCE: NO-TILL

1-What is it?

Modern agriculture is based on soil disturbance, at different levels of intensity. The intensification of tillage is directly related to the increase in soil degradation risk. The introduction of soil practices which avoid or minimize soil disturbance greatly helps the fight against this soil threat.

No-Till is an agronomic practice included in the first principle of Conservation Agriculture: "Minimum Soil Disturbance" (also called Zero-Tillage or Direct Drilling) and refers to the growing crop practice in which the soil is undisturbed from year to year. This practice aims to establish a crop directly into a seedbed that has not been a previous mechanical preparation (tilling or ploughing) (Kassam et al., 2009).

Figure 1. No-Till farm.

Adopting this practice, the disturbed area must be less than 15 cm wide or less than 25 % of the cropped area. It means that there should not be any periodic tillage that disturbs a greater area than the aforementioned limits.

2 – How to do it?

Firstly, the introduction of this practice in the field requires a change of mentality as it implies the total elimination of soil operations. Adopting No-Till implies the use of appropriate equipment and machinery, as well as technical and agronomic knowledge of how to operate them. No-Till practice avoids all soil operations and requires different management of the soil, the crop and the cropping system.

One of the key aspects to implement No-Till practice is correct sowing management. To introduce No-Till in the field, specific seed drills must be taken into account. The seeder has several devices for the proper placement of the seed in the soil. The aim is to place the seeds in suitable conditions that help germination and crop establishment, in terms of unploughed soil conditions and the presence of straw on the soil surface. These seed drills, called direct seed drills, are equipped with a cutting disc which plays an essential role in the successful establishment and development of the crop.

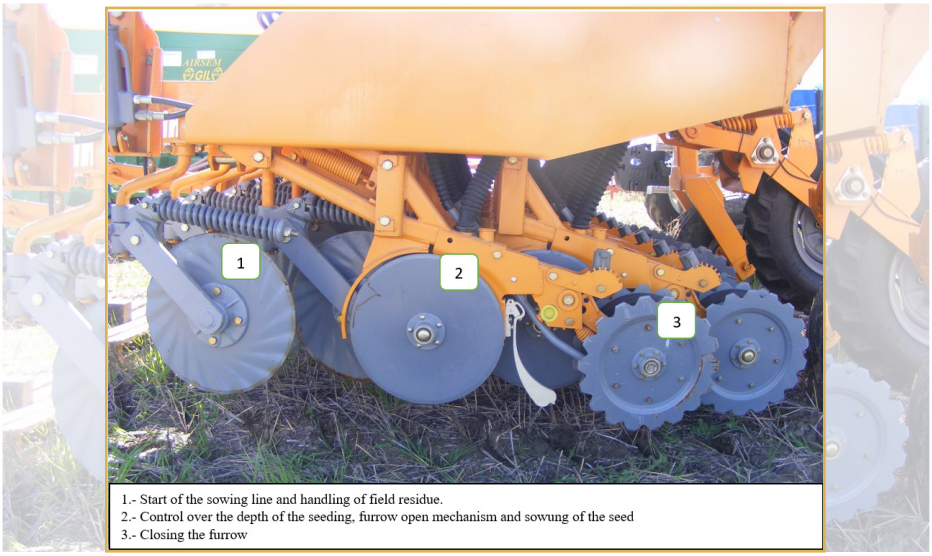

Figure 2. Direct Seeder. Components.

Two main groups of direct seeders can be used:

- **Disc coulters**

In this type of seeder, the soil openers are discs that can be single or double. In both cases, they are inclined with respect to the soil surface and mounted in the forward direction. Single-disc machines usually do not have a front cutter, since the discs perform the cutting and opening functions of the sowing furrow. The outer edge of the disc can be smooth or grooved, which cuts the straw better.

Figure 3 & 4. Disc coulters Direct Seeder.

- **Tine or knife coulters**

The other group of seeders are those that use tines or knives to open a narrow seed furrow. In this case, the seeder opens the furrow exerting the vertical cut pointed at an upward angle, which considerably reduces the necessary weight/pressure to achieve the desired seeding depth. One of the common characteristics of this type of seeder is that they need a minimum separation of 40 cm between the tine arms to avoid accumulating crop residues between the tine.

Figure 5 & 6. Tine coulters Direct Seeder.

3-What should be considered when applying the BMP?

The main challenge to get success when farmers introduce No-Till is to ensure correct sowing. Considering this issue, it is necessary to make a series of considerations on how to handle the seeders.

With regard to the difficulties of managing crops residues, it can be prevented with an effective system of residue cutting in each component unit and/or facilitating the movement of the straw between the seeding tine arms, arranging them in a greater number of lines so as to increase the separation between the

elements of the same line. If there is difficulty in cutting the surface residues a tool that separates the residues can be placed before the cutting elements to clear the sowing line.

Choosing the most suitable seeder, whether disc or tine, is one of the most important decisions for farmers. The edaphological, agronomic and economic aspects of the farm will have to be taken into account to choose the best option. Usually, when the thickness of the soil mulch cover is high, the disk seeders tend to perform better than the tine ones.

The size of the straw can also have a direct influence on sowing success depending on the type of seeder to be used. For disc seeders, it would be recommended to chop the straw long so that the straw can be cut efficiently by the discs and without the straw being pushed into the furrow which would occur if the chopping is excessively short. On the other hand, if a tine seeder is used, chopping the straw short will facilitate the movement of the straw between the sowing tine arms.

4-What are the benefits in terms of sustainability (economic, environmental, social) by adopting the BMP?

The introduction of No-Till provides a range of demonstrable benefits representing what a real sustainable agricultural system must deliver, considering the key dimensions of sustainability –environmental, social and economic–.

Regarding the benefits of adaptation and mitigation con Climate Change, No-Till favours carbon storage in soil. There is more organic carbon in the soil than in the vegetation and atmosphere combined (Lal, 2004). Tillage stimulates the production and accumulation of CO_2 in the porous structure of the soil through oxidation and mineralization of organic matter. By avoiding tillage, soil aggregates are not broken and hinder the release of CO_2 thus minimizing the emissions into the atmosphere. Several studies show that by applying the three principles of Conservation Agriculture, in which No-Till practice is included, soils under annual cropland have the potential to sequester around 0.55 tonnes of carbon per hectare per year, which correspond to 2 tonnes of CO_2 sequestered per hectare and year (González-Sánchez et al., 2018).

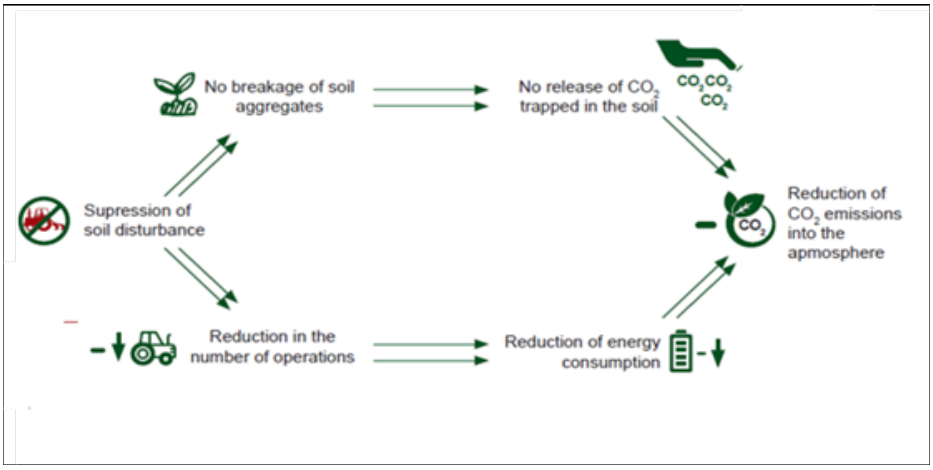

Figure 7. Benefit for Climate Change mitigation by adopting No-Till.
Source: Conservation Agriculture: Making Climate Change Mitigation and Adaptation Real in Europe. European Conservation Agriculture Federation (ECAF).

Additionally, due to the maintenance of surface biomass mulch, the soil life is fed with the organic substrate, and the content of soil organic matter increases. Root biomass as we as microbial biomass contribute to the increase in this soil organic matter pool which has beneficial effects in terms of improving soil health, structure and reducing the risk of erosion and flooding.

With regard to water benefits, by keeping soil covered with vegetative biomass and avoiding soil disturbance, organic matter content in the soil increases, and this has a direct effect on water quality. Introducing No-Till practice, soil structure is improved, and consequently increases soil infiltration capacity as well as water retention capacity. Combined with keeping the soil surface covered, helps to reduce evaporation, prevents the formation of surface crust and reduces the speed of surface water flow, reducing the risk of runoff by up to 70% and soil erosion by up to 93%.

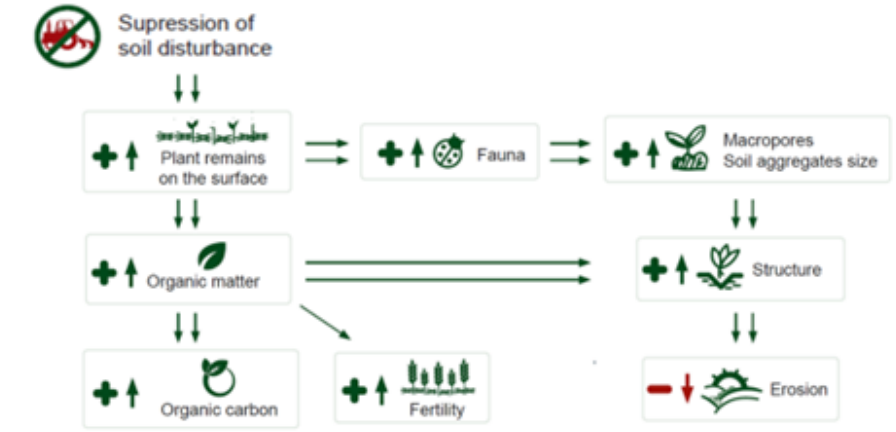

Figure 8. Benefit for soil health improvement by adopting No-Till
Source: Conservation Agriculture: Making Climate Change Mitigation and Adaptation Real in Europe. European Conservation Agriculture Federation (ECAF).

Figure 9. Well structured soil. No-Till Farm.

As already mentioned, soil structure is strengthened by avoiding tillage, and this improves the relationship between macro and micropores, leading to a higher water holding capacity in soils, especially in the first 30 cm depth.

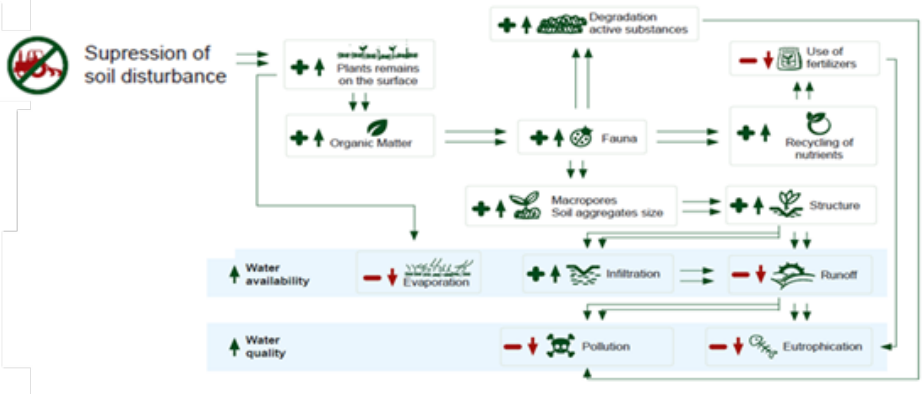

Figure 10. Benefit for water quality improvement by adopting No-Till.
Source: Conservation Agriculture: Making Climate Change Mitigation and Adaptation Real in Europe. European Conservation Agriculture Federation (ECAF).

Concerning soil Biodiversity, Soils managed under No-Till practice create an ideal environment for the conservation and development of biodiversity in agroecosystems. Undisturbing the soil and keeping mulch cover provides food and shelter for a large number of species of birds, small mammals, reptiles, and earthworms, among others. This increase in biodiversity does not mean an increase in pests and diseases that could reduce crop yields. These soils create a habitat for various species that feed on pests, which in turn attracts more insects, birds and animals and a biological balance is achieved that favours the sustainability of the production systems as well as of the agroecosystem as a whole. Also, the implantation of this BMP in the field reduces the risks of water pollution and eutrophication which help to conserve aquatic ecosystems.

Figure 11. Earthworms. No-Till Farm.

But the implantation of this practice not only offers environmental benefits. It also entails various economic benefits, some direct and relatively easy to quantify such as the improvement in the economic performance of the farm. The main economic benefit for the farmer lies in the reduction of production costs. By eliminating tillage, we significantly reduce the associated costs of this high energy operation. In this case, the economic benefit is immediate, since energy needs are reduced due to the decrease in operations and less wear and tear on machinery, and therefore savings in fuel needs are obtained as well as savings in maintenance cost of machinery. Several studies show that the reduction in production cost is around 25%.

Other benefits are indirect, but no less important, such as the reduction in the cost of public administration resulting from reduced erosion, flooding, water pollution, loss of biodiversity and the impact of increased CO_2 emissions.

Finally, the cost reduction along with maintaining or enhancing productivity implies greater profitability and economic stability for farmers and therefore an improvement in their economy and livelihoods.

If an activity is not economically sustainable, it cannot be socially sustainable. So, because of the improvement in profitability, as has been highlighted previously, the competitiveness of agriculture increases with No-Till and therefore it becomes a sustainable activity over time, offering livelihood opportunities to the population in rural areas.

Furthermore, working time per hectare decreases due to the reduced number of tractor passes. Hence it allows farmers more time for other activities (family, training, leisure, activities for the community, etc.), improving their economy and their welfare and also for their families and communities. This not only improves the well-being of the farmer and his/her family but also favours economic and social development in the rural areas.

5-What are the main constraints of introducing the BMP on the farm and how to solve them?

Choosing the most suitable seeder, whether disc or tine, is one of the most important decisions for farmers. The edaphological, agronomic and economic aspects of the farm will have to be taken into account to choose the best option. Usually, when the thickness of the soil mulch cover is high, the disk seeders tend to perform better than the tine ones.

The size of the straw can also have a direct influence on sowing success depending on the type of seeder to be used. For disc seeders, it would be recommended to chop the straw long so that the straw can be cut efficiently by the discs and without the straw being pushed into the furrow which would occur if the chopping is excessively short. On the other hand, if a tine seeder is used, chopping the straw short will facilitate the movement of the straw between the sowing tine arms.

Likewise, in monograin sowings (corn, sunflower, etc.), if correct sowing is not made, the production decrease may be greater, so it is necessary to ensure correct contact between seed and soil. For this reason, using strip-tillage for such types of crops can be an alternative in case the available machinery does not ensure proper sowing.

One effective alternative could be to make use of service companies to carry out the sowing. These companies usually have a greater knowledge of the technique and have more suitable machinery. It can help farmers to gain experience, which is key to successful crop production.

The other great constraint to starting introducing this practice on the farm is the price of the machinery. Direct seeders are more expensive than conventional ones. This can make farmers reluctant to introduce this practice on the farm. However, the reduction of production costs by avoiding tillage makes the amortisation period of the machine similar.

6-What are the frequently asked questions about BMP? Questions (Q) and Answers (A)

Q: Are yields similar to conventional agriculture?

A: Yes, yields are similar in both systems, as long as the management of the technique is appropriate and adapted to local conditions.

Q: Do direct seeders really work correctly?

A: Yes, but choosing the most suitable seeder is key to get success.

Q: Does No-Till compact soil surface?

A: No, Minimizing soil disturbance improves soil structure and makes it more resilient.

STRIP TILLAGE (ZEBRA TILLAGE)

1-What is it?

Conservation tillage is a method in which at least 30% of the field area is left to be covered with plant residues after the cultivation and the sowing is performed together with soil tillage. This method anticipates preventing erosion and conserving the soil moisture content (ASAE, 2000).

Conservation tillage is composed of the applications of reduced tillage, no-till, mulch tillage, ridge tillage and strip tillage (Çelik and Altikat, 2010).

Strip tillage is a tillage technique which combines the advantages of no-till and full width tillage. In strip tillage, the processes such as preparation of seedbed, seeding, fertilizing, and the application of pesticides can generally be applied at one pass (Wysocki, 1986). Thanks to it, while it is possible to reduce time, labour, fuel consumption, use of equipment and the number of field-pass, it is also possible to conserve the soil.

Figure 12. Soils Using Strip-Tillage Machine.

Strip tillage is defined as less than full-width tillage of varying intensity that is conducted parallel to the row direction. Generally, no more than one-fourth of the plow layer is disturbed by this practice It is the machine that is used for reduced tillage in protective agriculture techniques and that only cultivates the part defined as the seed bed.

As the name suggests, it makes a version in the form of a strip, it is also called a zebra version due to the shapes formed.

2 – How to do it?

Strip tillage is a technique which is applied generally to row-crops such as corn and sunflower after wheat and soybean. By means of this method which is also known as an adaptation of no-till for row-crops, the soil loosens in the tilled strips and water permeability and warming increase (Reeder, 2002). Strip tillage can be applied to various summer and winter plants. The most appropriate period is autumn for grains. The strips tilled in this period are softened after the moisture they get in winter and the height difference between the tilled strips and the strip intervals is reduced by pushing them mildly.

By tilling the soil in strips, the infiltration of rain and snow water into soil increases in dry farming areas and the evaporation of soil moisture in upper soil layer into the atmosphere accelerate. For this reason, depending on the place, it can be sufficient to apply shallow tillage as much as 5-6 cm (Reeder, 2002). There are also some advantages such as the tilled strips are warmer and softer and the soil is less compacted with reduced pass number than the no-till (Cruse, 2002). According to studies, strip tillage provides optimum soil conditions for high production at minimum cost with its soil and water conservation.

Figure 13. Strip-Tillage Machine.

In the field studies, the most productive working period was revealed as the autumn editions. Plowing is done in the autumn period, some of the base fertilizer to be used in the spring is left on the seed bed while the strip tillage is made. Thus, both the bed of the seed of the product to be planted in the spring period and the base fertilizer to be used are ready.

The sowing feet of the pneumatic (air) sowing machines are adjusted on the ploughed strips, sowing is carried out with seeds and necessary fertilizers. Weed control is carried out in two stages. Chemical control is carried out by using total herbicides or pre-emergence herbicides. In addition, after the output of the products, intermediate hoeing can be done easily. If the harvest residue of the field to be prepared for the seed bed is large, it should be shredded with a straw shredder, otherwise there is no need to use a shredder. In certain periods, the bottom cauldron is also recommended for strip version as in other version techniques.

3-What should be considered when applying the BMP?

In strip tillage technique, only up to 25–30% of the total field surface is tilled in strips (Wysocki, 1986 & ASAE, 2000). Generally, strip width varies between 10-30 cm and although the space between the strips varies according to the plant type, it varies between 40-100 cm (Wysocki, 1986).

There are different types of strip tillage machines. There are 4 rows, 6 rows, 7 rows, 8 rows and 12 rows types of machines according to tractor horsepower. Machines that apply chemical or solid fertilizers can be combined with a strip tillage machine to increase the amount of organic matter in the soil and to meet the nitrogen need of the planted product.

The strip tillage machine can cultivate the soil up to a depth of 30 cm. Machines that apply fermented liquid farm manure to 17 cm depth of the soil during plowing have been widely used in recent years. Strip tillage machine can be use with coordinates from the satellite and sowing can be carry out in line with the coordinates of the field by the tractor. This increases success.

In years when limited precipitation, less soil cultivation can be done. Cultivators, subsoilers, soil rotary tillers, and special tools and machines which are designed for this purpose are used in strip tillage, due to the stubbles are not mixing on the ground in the years with limited precipitation. If the stubble on the soil does not rot and mix with the soil, the seed sown with this method cannot contact the soil and fertilizer, and it causing yield losses. In addition, if the soil is not cultivated, evaporation increases because the roots of the newly planted plant will be uncovered after the corn harvest.

In this technique, tillage should be done just before sowing. It is very important to adjust the depth and time of tillage according to the plant to be sown after tillage.

Figure 14. Tillage Depth.

As a result of the field studies, it is recommended to make autumn versions especially in this version technique. It is expected that the soil will still be annealed. Because, in the absence of suitable soil structure in the spring period, clod removal occurs. The period of the soil should be followed very well and an annealed plow should be performed.

Figure 15. Plant Emergences After Strip Tillage.

If the same or different spring crops are to be cultivated, it is recommended to cultivate the same area in the following year. Because this is an important point for the continuation of the living spaces of the living things in the soil.

4-What are the benefits in terms of sustainability (economic, environmental, social) by adopting the BMP?

There are some advantages such as the tilled strips are warmer and softer and the soil is less compacted with reduced pass number than the no-till (Cruse, 2002). Strip tillage provides optimum soil conditions for high production at minimum cost with its soil and water conservation.

Strip Tillage Machine:

- It performs all of the cutting, sweeping, blasting, fertilizing, and leveling works at once, by cultivating only the soil needed for the seed.
- It is used in seedbed preparation of plants planted in rows such as corn and sunflower.

Table 1. Comparison of Strip Tillage and Plowing Methods (Sunflower, harvest date 03 Sep 2021)				
Data	STRIP TILLAGE (A)	PLOWING (B)	DIFFERENCE OF STRIP TILLAGE AND PLOWING C=(A-B)	PARCEL DIFFERENCE OF STRIP TILLAGE AND PLOWING (C/B*100, %)
Yield (kg/da^{-1})	200	140	60	43
Oil Ratio (%)	41,27	40,96	0,31	0,8
Humidity (%)	7,17	7,93	-0,76	-10
Price (TRY/kg^{-1})	2,0204	2,0084	0,012	1
Income (TRY/da^{-1})	1.010	703	307	44
Fuel expense of Seed bed preparation and sowing work (lt/da^{-1})	6,3	8	-2	-24
Service Fee of Seed bed preparation and sowing work (TRY/da^{-1})	97	167	-70	-42
Amount gained from seedbed preparation by Strip Tillage method (TRY/da^{-1})	70			

Figure 16. Sowing Season.

BENEFITS (Isermann, 2020)

- **Reduces erosion.** Less disturbance and good cover of residue reduces the potential for soil to erode from the field.
- **Warmer soil in the spring.** Removing residue just above where the seed will be planted allows for the soil to be warmed by the sun in the spring before planting.
- **More precise application of fertilizer.** The fertilizer can be applied directly into the soil in the same pass as you move across the field. Strip-till machines can be set up for both dry or liquid fertilizer. Liquid fertilizer requires less horsepower per row to inject than a dry system.
- **Reduces soil compaction.** Leaving soil undisturbed allows for soil structure to form and reduced trips across the field minimizes the compacting load on the soil.
- **Saves time.** Most strip-till systems rely on one "tillage" pass in the fall and no tillage in the springtime.
- **Conserves fuel.** When compared to conventional tilling, which often results in three to four passes, a considerable amount of fuel can be saved.
- **Improves soil health.** One of the first steps to a healthier soil is reducing disturbance. With less tillage, earthworms, fungi and other soil organisms can thrive in the soil and improve many soil health metrics including soil aggregation.
- **Better adoption of cover crops.** By leaving most of the soil undisturbed, it is possible to take a more advanced step toward soil health by allowing a cover crop to grow in between the rows. Strip-till operations can be performed after cover crop application to ensure a clean seed bed for next year's crop while maintaining cover crop on most of the field.
- **Potential erosion of the strips.** In a field with significant down slope, you risk water running down the strips (instead of moving slowly through the residue in the field). This could cause erosion and risk damaging the seed bed. This erosion can be most damaging after planting the crop. Many growers in this situation see an advantage to going full no-till.

Figure 17. Decreasing the erosion and water loss by strip tillage.

5-What are the main constrains of introducing the BMP on farm and how to solve them?

The plow habits and traditionalism of farmers create resistance for such new machines and systems. Breaking this resistance is difficult but not impossible. For extension works, which are expected to take time, applications can be made with pioneer farmers in every field, so that farmers can see and adopt them.

Figure 18. Strip-Tillage Machine with 6 and 4 rows.

The high prices of these machines cause farmers to create resistance for these new techniques. In the process of solving this problem; Common Machine Parks can be established for Protective Agricultural Machinery. Chambers of

Agriculture, Farmers' Organizations, Cooperatives or private businesses can rent these machines to the use of farmers. In this way, it is expected that both new techniques will be adopted and the use of common machine parks will become widespread.

Management Considerations To Keep In Mind

- **Time.** A wet year or a delayed harvest can restrict the amount of time available to create a strip, especially after harvest. A back-up plan of either spring strip-till or being comfortable with no-till is desirable in these situations.
- **Horsepower.** Some more aggressive strip-till machines can require a large amount of horsepower per row. These machines can be the most beneficial for removing a compaction layer and fertilizer placement, but lower horsepower units are also available that do less deep tillage.
- **Initial cost**. There is an upfront cost of additional or new equipment to transition over to the practice. However, there are a wide variety of strip-till systems available to fit the needs and budgets of a grower and, with advanced accurate auto-steer systems, units do not necessarily need to match planter widths.
- **Guidance:** If the strip-till implement matches the planter, guidance is not absolutely necessary; however, in any instance, it is highly desired to have a guidance system to help stay on your strips.

While the characteristics of the strip you create depends on the season and your region, strip-till can potentially provide the best of both worlds – no-till and conventional tillage.

6-What are the frequently asked questions about BMP? Questions (Q) and Answers (A)

Q: What is the difference between no-till and strip-till?

A: In a no-till system, farmers plant directly into the undisturbed residue of the previous crop without tillage, except for nutrient injection. In a strip-till system for row crops, seeds are planted into narrow strips (typically 6-8 inches) that were tilled and where fertilizer may also be applied.

Q: How do you strip-till?

A: Strip till is a field tillage system that combines no till and full tillage to produce row crops. Narrow strips 6 to 12 inches wide are tilled in crop stubble, with the area between the rows left undisturbed. Often, fertilizer is injected into the tilled area during the strip-tilling operation.

Q: How deep should we strip-till?

A: Typically done on flat, poorly drained soils that tend to be wet in the spring. This strip-till implement fluffs and aerates the soil, usually about 6-8 inches deep by 6-8 inches wide, and takes about 30 hp per row.

Q: Should every producer consider adopting Strip-till?

A: No. If your current no-till system works, keep it. But if you're making changes and want to consider a system that's efficient and offers solutions to many Corn Belt challenges, take a look at strip-tilling.

If you are successful and pleased with no-till, strip-till offers few improvements. Compared to conventional tillage, it has several major advantages.

Q: Most articles talk about fall strip-tilling. How should spring strip-till be managed?

A: Strip-tilling in the spring is an option, but growers run the risk of not getting strips prepared if the weather turns cold and wet. When this happens, you have to no-till or revert to tillage.

When preparing strips in the spring, focus on fertilizer depth and strip quality. Placing fertilizer too shallow can result in seedling death from fertilizer burn. Use tru-depth shanks or measure actual running depth. Building strips in the spring can result in very cloddy strips and poor seed-to-soil contact.

The advantage with fall strip-till is the clods can overwinter and mellow down. To avoid clods, prepare strips as early in the spring as possible. Place them as close to the old rows as possible to avoid wheel track problems.

Q: What's the best weed control program for strip-till?

A: It's similar to no-till. There may be more weeds and earlier weed growth in the strip-till area versus the row middle, but not enough to warrant a separate herbicide application.

The biggest factor is how the field is sprayed. Floater trucks can smash down a large number of rows, defeating the purpose of strips. When hiring custom spraying, make sure a machine with narrow profile wheels is used or do your own spraying.

Figure 19. Sunflower production by strip tillage method.

In seedbed preparation:

- 60% less tillage.
- 40% fuel savings.
- 40% less labour.
- Provides 40% less machine purchase.
- Increases soil organic matter.
- Increasing soil water retention (provides water harvesting).
- Reproduces underground creatures.
- Greenhouse gas emissions decrease as carbon emissions decrease.

NATURAL FERTILIZATION– APPLICATIONS TO INCREASE ORGANIC MATTER

1-What is it? What is Natural fertilization-applications to increase organic matter?

Organic fertilization

In addition to the supply of organic matter, organic fertilization is an important source of plant nutrients. The variety of main and trace nutrients make organic fertilizers valuable complex fertilizers. The targeted recycling of organic matter and nutrients to agricultural land makes sense and is necessary from an ecological and economic point of view.

The organic fertilizers are divided into two groups:

1. Manure: solid manure, manure, liquid manure, leachate, straw, green manure
2. Secondary raw material fertilizer (SRMF): compost, sewage sludge, meat bone meal, etc.

2) How to do natural fertilization-applications to increase organic matter?

One option is to use cover crops, mainly in organic farming.

A cover crop is defined as a close-growing crop that provides soil protection, seeding protection, and soil improvement between periods of normal crop production. Examples of cover crops include mustard (pictured), alfalfa, rye, clovers, buckwheat, cowpeas, radish, vetch, Sudan grass, Austrian winter peas, and more.

(Detaild information about cover crops you find in BMP 2)

Figure 20. Cover Crops.

Other options are to replace the nutrition of crops by manure of livestock. Meat – , milk – and egg production are nessescary in regions without long summer season or without enough moisture. Livestock is a kind of storage system without fridge. The circle of manure, gras, meat and hunters is working in pastures worldwide.

Figure 21. Dairy farm / Solid manure.

The organic manure can brought out to the fields in liquid ore solid forms. Due to aspects of animal welfare we see a development from liquid manure to solid manure for barn equipment.

By supplying organic matter, organic fertilization is an important source of plant nutrients. The variety of main and trace nutrients make organic fertilizers valuable complex fertilizers. The targeted recycling of organic matter and

nutrients on agricultural land makes sense and is necessary from an ecological and economic point of view.

Carbon farming

To achieve high yields in field cultivation, it is necessary to increase carbon farming in practice. Carbon farming is a concept of regenerative agriculture and describes the measures for carbon enrichment in agricultural soils. The basic idea lies in the return of the carbon released by humans into the atmosphere into the soil. Intensive tillage, overexploitation and over-fertilization increasingly release greenhouse gases bound in the soil. Carbon farming measures are intended to keep more carbon in the soil in the long term and return it to it.

Key procedures include:

- Soil-conserving cultivation methods for the formation of humus.
- Improved crop rotation to regenerate the soil.
- Cultivation of plant varieties with strong rooting of the soil.
- Cultivation and use of underseeding for rooting and erosion control.
- Introduction and expansion of agroforestry for rooting, erosion control and water storage.
- Storage of carbon, e.g., by introducing biochar into the soil.

https://youtu.be/R--oEEejJ8U

Terra Preta

The model for best practice is Terra Preta in ancient cultures of South America. In the rainforest, carbon degradation works year-round and results from soil degradation.

Today, we need fertile/rich soils to cope with drought and other extreme weather conditions.

On the one hand, the nutrition of the plants must be optimized, on the other hand, microorganisms and soil organisms must be fed.

Solid manure

Solid manure has a much higher dry matter content than liquid manure, as various bedding materials such as straw bind the liquid. The carbon-nitrogen

ratio is therefore wider than that of liquid manure and determines the nitrogen release from solid manure.

Solid manure improves the soil

The proportion of organically bound nitrogen in solid manure is much higher than in liquid manure. The storage period influences the nitrogen release, since the proportion of ammonium nitrogen increases with increasing storage time and increased degree of rotting. The basic nutrients in solid manure are like those in liquid manure. In addition, the straw content in solid manure improves soil properties.

Principles for the provision of solid manure and poultry manure for application on agricultural land can be found here.

Liquid manure

Manure is a mixture of feces, urine and litter, the water content of which can vary greatly. A distinction is made between solid liquid manure (liquid manure to water 1:0, mushy), half slurry (1:1, thick soup) and thin manure (1:3, watery). The nutrient content depends on the species, feeding and storage of the manure. Cattle manure is rich in potassium, pig manure in nitrogen, phosphate and copper, and chicken manure in nitrogen, phosphate, and calcium.

Figure 22. Liquid manure management.

Biogas fermentation residues

In addition to the main product methane, biogas digestate is produced during the production of biogas. This is applied to agricultural land to supply nutrients to the crops like manure manure. The fermentation process results in qualitative and quantitative changes that require an adapted professional and environmentally friendly application. In addition to the main product methane, biogas digestate is produced in the production of biogas. Biogas digestate is produced from a wide variety of starting substances. The so-called fermentation substrates are fermented in the biogas plant and are subject to different degradation rates during the fermentation process depending on the residence time and temperature in the fermentation tank. It is not possible to establish average standard nutrient contents for biogas digestates. For sensible fertilizer planning and to comply with the Fertiliser Ordinance, the digestate must therefore be examined for its nutrient content before application.

Figure 23. Fermented substrat.

The biogas digestate is spread on agricultural land to supply nutrients to the crops like manure. If the digestate is the result of the fermentation of plant materials from agricultural, forestry or horticultural holdings (also mixed with animal excrements), they are regarded as manure. If other substances (e.g. biowaste) are also fermented, these are organic fertilizers according to the Fertilizer Ordinance, which are also subject to the Biowaste Ordinance.

The fermentation process results in qualitative and quantitative changes that require an adapted professional and environmentally friendly application.

Biowaste, sewage sludge, compost

Depending on the starting products used, the nutrient contents differ significantly. Average values can only serve as indications, it is always based on the test results. At the time of application, the nutrient contents must be known. In addition to the Fertiliser Ordinance, further regulations apply to the starting product.

- **Biowaste**

Waste of animal and plant origin is referred to as biowaste. Compost and green waste are also included. Agricultural use is regulated in the Organic Waste

Ordinance, but the Fertilizer Ordinance and the Fertilizer Ordinance must also be observed. There are limits about pollutant contents, maximum application rates and the possible nutrient intake, which is regulated by good professional practice (Fertiliser Ordinance).

- **Compost**

Figure 24. Compost plant.

Depending on the starting products used, the nutrient contents differ significantly. Average values can only serve as indications, it is always based on the test results. The level of nitrogen effect in the year of application is on average 5–10 % of the total nitrogen content and depends decisively on the degree of rotting. Only after several years of use or after a few years is a significant release of nitrogen from compost fertilization to be expected. The mineral N fertilization can then be reduced by the corresponding amount.

In BMP10 (Community Composting) you will find detailed information about composting

- **Uncomposted green waste**

The application of uncomposted green waste is possible under certain conditions in accordance with the Organic Waste Ordinance, e.g. for landscape cuttings, garden waste and tree residues. In the case of nitrogen-poor material (woody plant residues), a clear nitrogen determination can occur at the beginning of rotting. However, nitrogen-rich, readily degradable materials (e.g. younger crops) release about 20% of the nitrogen in the first year. The remainder is to be regarded as firmly organically bound. If green waste is composted, it can generally be assumed that nitrogen losses occur (hot rotting phase).

- **Other biowaste**

Agricultural recovery is also foreseen for waste from rendering (e.g. meat-bone meal). This waste must be treated separately (e.g. heating > 135 °C). Special attention should be paid to the relatively good nitrogen effect (easily degradable protein) and the high phosphate and calcium content. Other waste that is not covered by the Biowaste Ordinance can be used for agricultural purposes in accordance with waste law (individual case regulation). However, this must be applied for at the responsible district office. The assessment of the nutrient effect is carried out by the Office for Agriculture and Forestry.

- **Sewage sludge**

Basin of a sewage treatment plant.

Figure 25. Sewage Treatment Plant.

Due to its origin, sewage sludge contains a wealth of undesirable substances whose effect on soil and the environment is not yet fully understood. Therefore, agricultural use must be assessed critically. However, sewage sludge also contains valuable plant nutrients and organic matter. As with other organic fertilizers, the rapid nitrogen effect is essentially dependent on the ammonium content. This is highest for liquid sewage sludge (> 30% of the total N). Dewatered sewage sludge contains little ammonium-N (about 10% of the total N). The content of ammonium-N and total nitrogen is known based on the prescribed test. Sewage sludge contains a relatively large amount of phosphate. The availability is only limited in the case of precipitation (sewage sludge treatment) with ferrous agents. Sewage sludge in the basin of a sewage treatment plant. Legally, the recycling of sewage sludge is permitted considering the requirements of the Sewage Sludge Ordinance, the Fertilizer Ordinance. According to the Fertiliser Ordinance, liquid sewage sludge must be treated like liquid manure and, for example, incorporated immediately on uncultivated arable land. The Sewage Sludge Ordinance regulates the spreading of sewage sludge on agricultural land.

In result it depends on farm location, which way the farmers are going to have long term success in fertilizing.

- **Straw**

Straw is a humus splimmer and nutrient supplier

In crop rotations with a high proportion of humus-consuming crops, the cereal straw should remain on arable land as far as possible. Humus eaters are, for example, potatoes, sugar beet and silage maize. Straw as a humus stamina counteracts this.

Furthermore, it should be borne in mind that large amounts of nutrients leave the farm with the straw. Evaluate your crop rotation for its humus reproduction and then decide if the straw can be sold.

Example: Maize straw

Figure 26. Maize Straw.

The amount of straw produced after the grain maize harvest is enormous compared to other crops. The grain-to-straw ratio is almost 1:1. This means that with peak yields of 14 to 18 tons of grain maize (14% water), 12 to 15.5 tons of dry matter of straw remain on the ground. Ideally, this mass should be incorporated in such a way that it can be optimally digested by soil life and thus contribute to humus formation. For this purpose, the area is mulched again so that corn borers do not find stems to hibernate. To ensure rapid implementation by earthworms, the length of the straw should not exceed 5 cm. After the winter, mulch sowing is drilled on this area after the maize. The depth of the mulcher in the soil is a maximum of 0.5 cm, allowing faster rotting and destruction of the vegetation points of weeds.

(Detailed information about Straw you will find in BMP 2 Straw Management)

3-What should be considered when applying the BMP ?

Manure – be sure to have the nutrients analyzed

The nitrogen content and composition depend on the species, feeding, performance of the animals and bedding. Due to this fact, you should in any case make regular examinations of your manure. Nitrogen is always present in manure as ammonium (NH_4) and as organically bound nitrogen. The ammonium content can be counted in the year of application, as it can be absorbed by the plant for the most part after conversion to nitrate. Depending on the rate of mineralization, the organic content acts in the following years and therefore contributes above all to maintaining soil fertility. From a chemical point of view, the ammonium content is equivalent to ammonium from mineral fertilizers.

Carbon-nitrogen ratio influences nutrient availability

In addition to the pH value, the carbon-nitrogen ratio is important for the effectiveness of organic fertilizers. Nitrogen can only be released from an amino compound (organically bound nitrogen) by microbial degradation. The microorganisms need nitrogen to build up the body's own protein and multiply. This requirement is met at a carbon-nitrogen ratio of less than 20, at a further ratio the microbial degradation of organic matter is inhibited. Inorganic nitrogen (ammonium and nitrate) in the soil is then bound by the microorganisms and is then not available to the crops in the short term. A nitrogen addition with straw supply therefore promotes the conversion of the cereal straw, which has a wide carbon-nitrogen ratio of 90-100 to 1.

In the case of secondary raw materials, such as compost, bone meal and sewage sludge, nutrient availability must be considered. The lower the carbon-nitrogen ratio and the higher the nitrogen content, the better the effect.

An important factor is the technical background of a farm. Technical solutions often depend on the size and fleet of a farm. In the absence of low turnover, farmers are forced to resort to technically simple solutions. Local contractors who take over field fertilization and are technically equipped are helpful in such situations. Higher yields also mean increased amounts of harvest residues, which is a clear advantage in terms of carbon input. The incorporation of the harvest residues into the soil requires an increased use of machinery or the demand for agricultural contractors.

Many farms are supported by agricultural consultants. For this purpose, it is important that the advice is adapted to the needs and sizes of the farms. Not every company can afford the financial outlay of perhaps the best technical adaptation.

4-What are the benefits in terms of sustainability (economic, environmental, social) by adopting the BMP?

Figure 27. Dung Heap.

Solid manure:

Storage of manure is helpful to have a flexible and depending on variety fertilization.

The advantage of organic fertilizers is their slow and long-lasting fertilizing effect. There is only a small risk that the plants will be damaged by too much fertilizer. The use of organic fertilizers also does not cause soil salinization.

- Subsequent delivery of all important plant nutrients
- Improvement of soil properties (nutrient retention capacity, water capacity, root ability, soil structure, promotion of soil organisms) by promoting humus formation

- Due to slow implementation, no or only a very low risk of over-fertilization or leaching; consequently, very safe and easy to use
- Grassroots in the soil
- A humid soil provides less resistance to penetrating roots. Numerous strong roots promote stability, water, and nutrient supply of the plant
- Natural long-term effect, implementation depending on temperature and humidity largely prevents a release if no plant growth takes place
- Production is less energy-intensive and therefore more ecologically justifiable, as renewable raw materials are used instead of fossil deposits.
- Also, to be used as liquid fertilizer
- Also vegan, i.e., animal-free available

-Liquid manure:

Benefits of usage liquid manure starts in barn systems, to have less handy work.

Manure has two unbeatable advantages: it usually contains all the important nutrients for the plants and at the same time provides organic matter for the soil. It ensures sustainable soil fertility. Plants need nutrients to grow and form what we want to harvest: for example, the potato tuber or the cereal grain. Here, however, it is not only the quantity that counts, but also the quality. Both are – in addition to other factors such as the choice of variety and the water supply – also dependent on the available nutrients.

The second, very important part of manure is the organic matter, which builds up the humus content of the soil. If the soil is enriched with humus, it can better retain nutrients and water and release them back to the plants (source: NRW Chamber of Agriculture).

In addition, manure helps to save mineral fertilizers and thus oil. This is sustainable and protects the environment.

5-What are the main constrains of introducing the BMP on farm and how to solve them?

-Cover crops:

a) Longterm/ stay green:

Figure 28.

In the case of intensive soil management, grassland breaks are taken to recover and reactivate soil organisms and humus input. Grass, clover, and legumes are suitable as permanent crops on grassland areas. Two cuts per year are required to control weed pressure. This means an additional cost, which can be reduced by using the clippings as animal feed or biogas plant material.

If a farmer owns an area with arable status, but uses it as grassland, he must break it down and reseed it after five years. Otherwise, the area loses its arable status and becomes permanent grassland. If the farmer misses this five-year period, he must have the change approved by the responsible agricultural office. This normally only authorises the ploughing of permanent pasture if the farmer creates new permanent pasture and thus creates a compensation area.

In practice, this means that farmers must plow and reseed land before the end of the five years, which receives arable status. Although the farmer would not break the area at all if this regulation did not exist, he must accept the negative consequences of a grassland plough.

b) Short term / freezing varieties :

In winter-hardy greening, the upper soil layers dry out early on as soon as transpiration begins in spring. In the case of freezing catch cropping, on the other hand, the plant residues on the soil surface reduce soil evaporation. However, the higher water contents in the topsoil also cause the soil to warm up more slowly in spring.

However, many arable farmers who have fields in the drier regions of Germany are still skeptical about catch crop cultivation. They are concerned that catch cropping will be at the expense of the main crop. After all, the catch crop is an additional crop that needs water. And, as the last two years have impressively shown, drought is no longer just a threat to those areas that have always had to struggle with it. According to climate models from the German Weather Service, the number of dry days will continue to increase in the future, – especially in the months of July to September. This requires special agricultural approaches that do not cause additional water consumption.

-Manure in general:

Manure – be sure to have the nutrients analyzed

The nitrogen content and composition depend on the species, feeding, performance of the animals and bedding. Due to this fact, you should in any case make regular examinations of your manure. Nitrogen is always present in manure as ammonium (NH_4) and as organically bound nitrogen. The ammonium content can be counted in the year of application, as it can be absorbed by the plant for the most part after conversion to nitrate. Depending on the rate of mineralization, the organic content acts in the following years and therefore contributes above all to maintaining soil fertility. From a chemical point of view, the ammonium content is equivalent to ammonium from mineral fertilizers.

Carbon-nitrogen ratio influences nutrient availability

In addition to the pH value, the carbon-nitrogen ratio is important for the effectiveness of organic fertilizers. Nitrogen can only be released from an amino compound (organically bound nitrogen) by microbial degradation. The microorganisms need nitrogen to build up the body's own protein and multiply. This requirement is met at a carbon-nitrogen ratio of less than 20, at a further

ratio the microbial degradation of organic matter is inhibited. Inorganic nitrogen (ammonium and nitrate) in the soil is then bound by the microorganisms and is then not available to the crops in the short term. A nitrogen addition with straw supply therefore promotes the conversion of the cereal straw, which has a wide carbon-nitrogen ratio of 90-100 to 1.

-Solid manure:

Fertilization with organic substances is less predictable. The reason: The mineralization and thus also the nutrient release depend strongly on the conditions in the soil and the weather. If the nutrients are only released after the growing season, high nutrient losses can be the result.

Problems related to organic fertilizers usually arise where livestock farming produces large quantities and storage capacities are insufficient. Or even if the subsequent supply of nitrogen and phosphorus is not sufficiently considered in the calculation of mineral fertilization. Therefore, the more organic fertilizer is produced, the harder it is to use it appropriately.

The storage of manure is helpful to have a flexible and variety-dependent fertilization. By establishing profitable soils, carbon agriculture will be possible (such as Terra Preta). An active design of humus is possible, not under time pressure and using further resources. Can be sewage systems, plant, or landscaping materials. Technology for solid manure is available everywhere, because 40-60t/ha is practicable for balanced fertilization. In the past, farmers were able to perform this type of measurement by hand. The problem may be having a suitable, well-sized storage space.

-Liquid manure:

Transport of liquid manure is very easy to handle by logistic chains. Labour productivity and low costs depend on special investments. Slurry storage tanks, even biogas plant, special used trucks, slurry tankers, eqiuipment to have soil contacts, strip till cultivator and more are available. Measurement is important, because liquid manure can be rich in fertilizer, 10–20 t/ha are practicable. Technical solution and knowledge are important to have in all parts of the field the same nutrition.

An advantageous use of manure begins with the automation of barn systems. Especially here a separator contributes to profitability. The tank and

storage volume can be reduced by 40%. Solid components from the separator can be used as bedding or peat substitutes in potting soils. The liquid content is available more quickly for the field plants, emissions and odor formation are greatly reduced.

A major problem with the spreading of manure and liquid manure, when this is carried out in large quantities and heavy equipment, is soil compaction. Two procedures are required to remedy the situation:

In modern agriculture, we want to establish fixed lanes with GPS systems. Controlled traffic farming is about to become established. Fertilizer spreaders must drive in lanes and be able to work like seed drills. First, there are high investments in high-performance tractor and fertilizer spreaders. Both machines must work with tire pressure systems to reduce 0.8 bar in the field.

6-What are the frequently asked questions about BMP? Questions (Q) and Answers (A)

Q: What kind of organic fertilizer is the best ?

A: There is no exellence of one system or biomass. The mixture of all kinds of materials promising the most soil organism and rhizoms. Fruitful soil and nutrition are two different building site. all interactions between involved factors are not fully researched and it is slightly dangerous to recommend one is the best. Possible dependent factors are farmstructure,availablity, finance. A longterm fertilizing finance plan should content lime and plant cole.

Q: How long does it take, to have success ?

A: Farming is a job to do in more than one generation. Experience in desertification processes worldwide are memorials in shortterm profits. The same time a farm is needing to rebuild humus by organic fertilizing. A farmer on his own land, with stabil conditions around farming, is able to save his soil. Whatever it takes.

Q: How to get an overview about success ?

A: Soil improvement through the introduction of organic fertilizers depends on various parameters. The most important thing to recognize is that the humus content improves or decreases.

This depends on the surface area of the farm areas and can vary between 1% (warm state) or 12% (cold state). The best parameter for determining success is the yield of crop production.

: How can leaching minimized?

A: Through solid fertilization planning and use of all available tools. In addition, by growing catch crops in autumn after harvesting the main crop, growing winter crops or incorporating straw into the soil. In general, farmers should implement the principles of good farming practice recommended by the Agricultural Advisory Service.

: How are manure, crop residues and green manure considered in fertilizer planning?

A: The available nutrient content in farm manure varies depending on the type of housing and storage, as well as the feed composition and animal species. It is usually estimated based on average values or figures of thumb which can be taken from tables, or (in the case of nitrogen) can be determined by farmers using rapid methods and thus considered in fertilizer planning.

The nutrient supply from crop residues and green manure can also be taken from tables. Such information is based on numerous field trials. For example, for nitrogen, field trials with catch crops show that a certain proportion of the nitrogen ingested by the catch crops (up to 50%) is available to the following crop.

PERMANENT SOIL COVER

1-What is it?

Maintaining year-round organic matter cover over the soil, including specially introduced cover crops and intercrops (living crops) and/or the mulch provided by retained residues from the previous crop (Figure 29). At least 30% ground cover should be maintained throughout the year, although over 60% is recommended to protect the soil in a greater degree (González-Sánchez et al., 2015). It is one of the three basic principles of Conservation Agriculture (CA) (Kassam et al., 2009).

Figure 29. Mulch of grass residue.

2 – How to do it?

This BMP can be conducted in the farm by seeding *living crops* (auxiliary crops) and/or *mulching* (residues).

Living crops

Introducing auxiliary crops either inter-temporary (cover crops) or inter-spatially (intercropping) in crop associations help keep soil covered in the farm.

Cover crops are auxiliary crops that are planted to cover the soil rather than for the purpose of being harvested. They are established temporary between two main crops (cash crops) as alternative to fallow. Depending on the purpose and the specific function developed they are also called catch crop (absorbing CO_2 and nutrients) or green manure (acting as nutrient source) the latter usually associated to legume species (Ramírez-García et al, 2015).

Intercropping is the practice of growing more than one crop simultaneously in the same portion of land (spatially) during the same season (Bitew & Agera, 2018) (Figure 30). There are multiple purposes for intercropping: saving space and resources, ensuring better yields, repelling pests, reducing weeds, providing nutrients for neighbouring plants and protect bare soil in case of wide inter-row. In woody crops are also called cover crops when the main objective is to protect the soil. To avoid terminological confusion between these covers in a sequence of herbaceous crops and the covers in the inter-rows of permanent crops, the term 'groundcovers' is recommended for the latter (González-Sánchez et al., 2015) (see the BMP 'Use of groundcover in perennial crops').

Figure 30. Intercropping of legume on grass

Mulching

Mulching is the practice of covering the soil with mulch (Figure 31). Mulch is a layer of material(s) that covers the soil surface usually organic material such as stubble, plant residues, straw, pruning residues, etc.

In annual crops, permanent soil cover can be obtained without removing or burning harvest residues from the previous crops, thus leaving protective organic mulch through a proper straw management.

Figure 31. Cereal crop growing over a mulch of straw.

3-What should be considered when applying the BMP?

In case of auxiliary living crops such as cover crops or intercropping, precipitation is the main issue to take into account. In areas with limited rainfall it could not be feasible to develop these techniques.

Cover crops are recommended when there is a gap of living crop during long time, so there is much time between the harvest and the seeding of the following crop. This might reduce the protection capacity as residues would have been decomposing for long period decreasing the soil cover. The introduction of legumes is recommendable for their nitrogen fixation effect that could reduce the use of fertilizers for the main crop. Other species also act as storage for nutrients when lixiviation and erosion risks are higher, and they supply nutrients after termination (Blanco-Canqui et al., 2015).

As stated above, cover crops can be hardly established in dry areas or dry periods. Given the cover crops are not cash crops but auxiliary ones, irrigation would not be appropriated from an economical point of view.

Intercropping establishes more biodiversity into agroecosystems and it can reduce the addition of chemicals. The secondary o auxiliary crop should not be very demanding in terms of water and nutrient to avoid competiveness with

the main crop. Sometimes, there is a temporal separation between the main crop and the second one, which is sown shortly after the cash crop. This type of intercropping is called undersown crop, and they must be performed in the gaps between the main crop rows at the proper time to avoid damages in the main crop.

In the tropical regions, intercropping is mostly associated with food grain production, whereas in the temperate regions it is receiving much attention as a means of efficient forage production. Intercropping is also a form of crop diversification in the farm.

When a *mulch* of straw is required, it should be taken into account that the first step starts at the harvest. The management of the crop residues should not make sudden changes in the ground coverage since the harvest, because the regulation of the seeder for the following season is not the same in the case of thick layer of residues and scarce amount of them. Usually the crop residues are distributed in strips by harvesters. For a homogeneous residues distribution, the necessary accessories must be available in the harvester to chop and sprinkle the crop residues (Fig. 32).

Figure 32. Harvester expelling the straw.

The harvest should be managed with straw spreader and rear deflector (Fig. 33, 34)

Figure 33. Detailed system spreader of residues in the cereal harvester

Figure 34. Rear deflector detail

For a soil protection perspective, the quality of residues should be considered. Legumes, which have low C/N ratio, could leave soil unprotected before the seeding of the new crop in the following season as legume residues are more easily decomposable. Starting the crop sequence with a grass allow enhancing soil protection with less decomposable residues than legumes ones. The residues management has a cumulative effect so the use of legumes is recommended after other crop family in the rotation by their nitrogen supply.

It is advisable to harvest the straw as high as possible and do not chop it too much. This way straw is less vulnerable to be pulled away by the wind. Anyway, crop type and the number of operations may influence greatly on straw cover.

In order to sow the crop with a mulch of straw, a no till seeder will be necessary for a proper sowing keeping the soil covered by residues (see BMP 'Use of minimum soil disturbance practices').

Weed control in no tillage systems should be conducted by spraying herbicides in an integrated weed management before seeding. The moment of weeds germination is a key factor. In some cases, delaying the main crop establishment can be a good strategy, choosing a short cycle variety, since the majority of weeds will have germinated and could be controlled by applying herbicide in seeding operations. Latency period of the weed seeds might allow them to remain in the soil for several years without germination. On the other hand, the plant residues over the soil surface help to control weeds since checking light and nutrient supply to them (Teasdale et al., 2004).

4-What are the benefits in terms of sustainability (economic, environmental, social) by adopting the BMP?

Economic

Soil mulch cover prevents the germination and establishment of weeds, by reducing surface soil temperature and light which makes it difficult for weeds to grow. Likewise, if weed seeds are placed on the soil, the straw mulch cover prevents the soil-seed contact, thus hindering and reducing weed germination.

Avoiding residue removal reduces the machinery cost in operations. Furthermore, the implementation of no till system reduces the energy cost of ploughing (see BMP 'Use of minimum soil disturbance practices').

Environmental

Mulching is a water conservation technique that increases water infiltration into the soil, retards soil erosion and reduces surface runoff (Prosdocimi et al., 2016). Firstly, it protects the soil against raindrop impact. Secondly, it reduces both the overland flow generation rates and velocity by increasing roughness, and it decreases the sediment and nutrient concentrations in runoff ending up in reducing soil erosion and nutrient loss (Fig. 35).

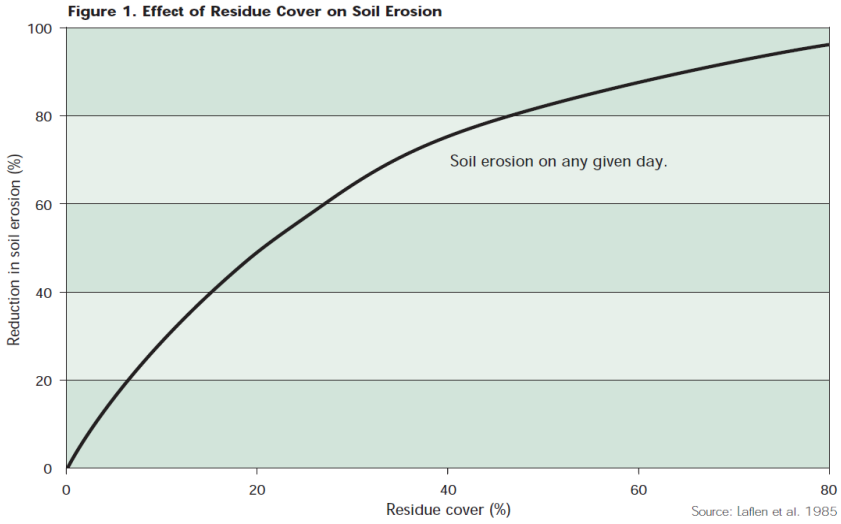

Figure 35. Effect of residue cover on soil erosion (Laflen et al., 1985)

Residue mulching increases soil moisture storage as it enhances infiltration and reduces evaporation (Klocke et al., 2009). When vegetative material is used, mulching increases soil organic matter (Xu et al., 2019), what means carbon sequestration in the soil. Furthermore, residues provide shelter for fauna increasing biodiversity (Kladivko, 2001). In conclusion, growing crops with straw mulch is a sustainable production system.

General environmental benefits are summarized below:

- Protecting soil surface.
- Improving moisture in the soil.
- Providing organic matter.
- Recycling nutrients.
- Improving soil structure.
- Carbon sequestration.
- Improving biodiversity.
- Sustainable production system.

Social

The cost reduction and improvement of profitability, due to maintaining residue, increase the competiveness and sustainability of farmers. Labour saving let farmers dedicate for other activities either in the farm or out the farm improving the welfare condition of them and their family. This helps fix population in the rural environment supporting the generational change while dynamic of rural areas is maintained.

5-What are the main constrains of introducing the BMP on farm and how to solve them?

When straw is not well spread the crop germination may decrease reducing the production. Furthermore, this can leave areas of greater amount of residues that can create a cold and humid environment around the seed prone to pest and diseases proliferation.

This constrain could be solved with a proper machine, doing the seed is placed properly (Fig. 36). In some cases, farmers practicing no tillage, seeding over residues, remove part of the residue.

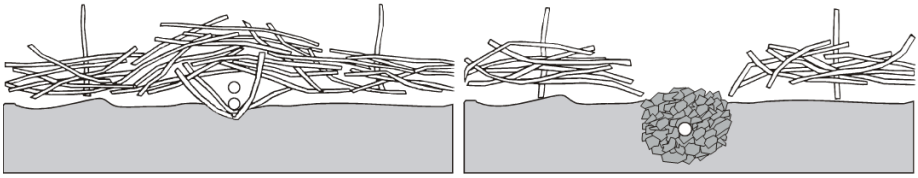

Figure 36. Scheme of bad and proper settlement of the seed

Sowing machines must not get stuck even with a big amount of stubble. Bladders and furrow cleaners can clean the strips for placing the seed. Sowing must be performed uniformly and at the proper depth for an optimal germination.

Some recommendation for a proper sowing with residues:

- Leave the stubble uncut.
- Eliminate some straw when there are a big amount of them.
- Clean rows of residues during seeding.
- Place the seed properly.

Another constrain of maintaining residue on surface avoiding or reducing tillage is the weed control. Although the residues prevent the germination and establishment of weeds by reducing soil temperature and light, herbicides treatments, in an integrated weeds management, could be needed to control weeds.

Some strategies against weeds are:

- Delaying the seeding.
- Applying weed-killers on young weeds.
- Crop rotations.

6-What are the frequently asked questions about BMP? Questions (Q) and Answers (A)

Q: How much is the cost of using defectors and residue spreaders in the harvester for a proper straw management?

A: Years ago it could be a little bit more expensive per hectare. Nowadays, it is offered with the same price by service providers.

Q: Should direct seeding be carried out to keep the residue on the surface?

A: It is recommendable, minimum tillage could be also performed keeping at least 30% of soil coverage. In case of conventional tillage, leaving the straw during the period between crop seasons is recommendable in order to keep soil covered as much as possible until ploughing.

Q: In humid areas, could the excess of moisture provided by residues be problematic for a proper sowing?

A: It should not be a problem with an appropriate direct seeder with cutting disc, residue sweeper and sowing tine coulters.

WINDBREAK (LIVE WIND CURTAIN) APPLICATION

1-What is it?

Windbreak, also known as **Shelter Belt**, is a vegetative plant consisting of living plants such as trees and shrubs planted in long and narrow strips and in different establishments in order to control the wind movement and prevent the loss of soil by wind erosion.

Windbreakers also protect crops, animals, wildlife and people from the effects of the wind.

Trees, shrubs or herbaceous plants can be used to make windbreaks. These plants are planted in single or parallel rows, perpendicular to the prevailing wind direction. It should be preferred that the plants be native and drought resistant species (See Figure 37.).

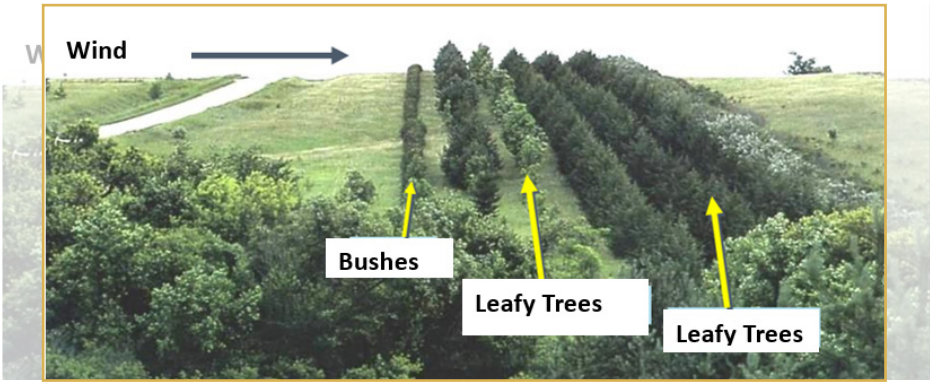

Figure 37. Use of different plants for the Live Windbreaker

Since the winds generally come from the north, at least 2-3 rows of trees are planted in the east-west direction and the lower branches of the trees are not pruned.

Thus, a barrier such as a wall is placed in front of the winds. When these obstacles are made parallel to each other and in large numbers, the speed of the winds decreases and they cannot blow the dust as before (See Figure 38.).

Figure 38. An example of planting trees directly opposite the wind

Figure Source: "Wind Curtain," Agriculture of the Future, Nature Conservation Center.

What does erosion mean? What harm does it have?

Erosion means «abrade». The soil layers on the earth are formed by the erosion of large pieces of rock by water and wind over hundreds of thousands of years.

Figure 39. Soil Erosion

Figure Source: "Wind Curtain," Agriculture of the Future, Nature Conservation Center.

Since the top 30 centimeters of the soil consists of small pieces, it is a very light and ideal mixture for agricultural production. This increases the value of the topsoil and makes it susceptible to wind and water erosion.

The loss of this layer by **wind and water erosion** can cause great economic losses in the long run and pose a great threat to the food needs of future generations. Damage caused by wind erosion is demonstrated in Fig.39-40.

Figure 40 A. Soil Erosion

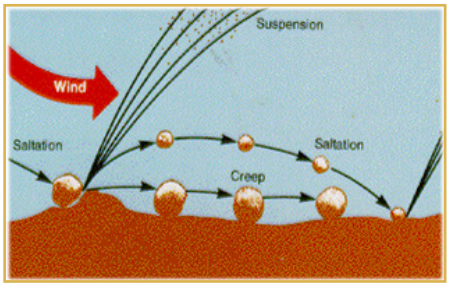

Figure 40 B. In Soil Erosion; Saltation, Creep, and Suspension

(Source: http://commons.wikimedia.org/wiki/File:Saltation- mechanics.gif)

The wind speed that initiates the first movement of the soil particle is called the threshold drift speed. With the first particle movement, the wind erosion process begins, which results in transport and accumulation in the form of Drift, Splash and Suspension.

While soil can be blown away at virtually any height, the majority (over 93%) (Leonard Khoo Wei Quan, 2013) of soil movement takes place at or below one meter. These transportation mechanisms of soil particles due to wind are shown in Fig 40.

Factors Affecting Wind Erosion

Vegetation cover, Loose soil material depth, Soil moisture content, Micro topography, Width of the area exposed to wind, Soil properties (Aggregate size distribution, organic matter content, soil texture properties)

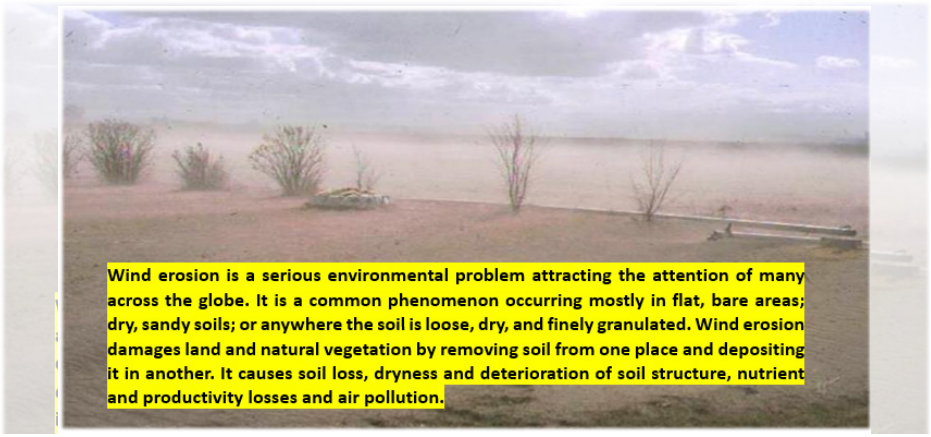

Figure 41. Wind erosion in flat, bare, dry area

What are the Protection Measures Against Wind Erosion?

1 – Control of wind speed at the surface

2 – Control of soil properties

1 – Control of Wind Speed at the Surface :

1.a) Plant based measures (Strip planting)

1.b) Tillage methods (No-Tillage Agriculture)

1.c) Mechanical measures (Live and Artificial Wind Breakers)

2 – Control of soil properties

It is the preservation of soil moisture. For this, three things must be fulfilled; Increasing infiltration, reducing evaporation, reducing plants and pests that use water unnecessarily.

Figure 42. Roughing the surface and leaving stubble in preventing wind erosion in agricultural areas

Roughing the surface and leaving stubble is of great importance in preventing wind erosion in agricultural areas.

2 – How to do it?

What should be considered in the wind breaker application?

The wind breaker application should be planned considering the soil type in the field, irrigation possibilities, livestock activities in the surrounding, climatic conditions in the region and the prevailing wind direction.

- The type of wood to be used as curtains should be suitable for the climatic conditions, so the use of native species naturally grown in the region should always be given priority.
- The depth and structure of the soil (sand, silt and clay content) are important for the trees to be planted.

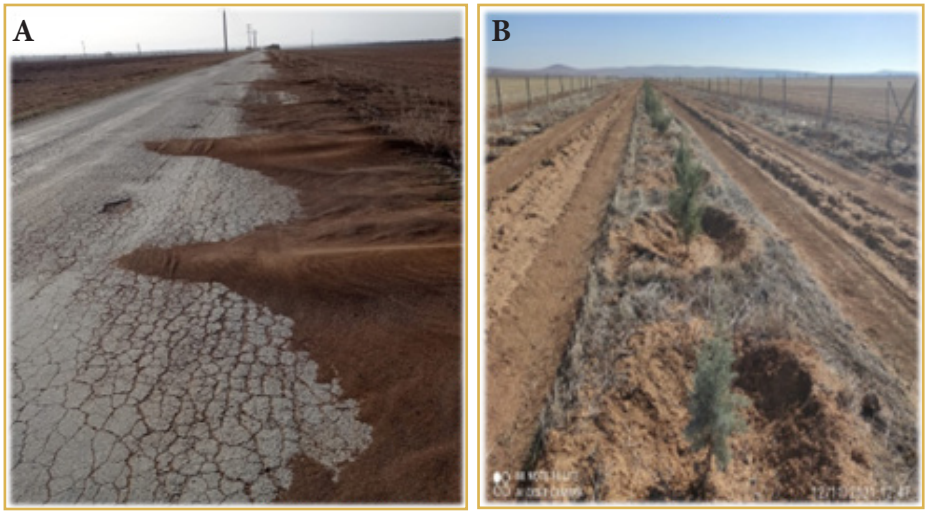

Figure 43. **A:** Soil Erosion Accumulated on Asphalt Road **B:** Saplings Planted for Live Wind Curtain

Source: Gözlü Agricultural Enterprise Directorate

In the first years after planting, especially in places where the annual precipitation is below 500 mm, the seedlings will need to be irrigated. When the sapling is planted in autumn, if the rainfall is insufficient in the spring, irrigation should be done at least once.

After planting in arid regions (300-350 mm precipitation), seedlings should be irrigated 2-3 times a month in June, July and August for 3 years.

If there is excessive grazing in the planting area, the seedlings will need to be protected from animal pressure for several years (See Figure 44.).

What should be considered in the wind curtain application?

While forming the windbreak:

Figure 44. Saplings Planted for Live Wind Curtain
(Source: Gözlü Agricultural Enterprise Directorate)

First of all, the direction in which the wind blows the most throughout the year, namely the prevailing wind direction, should be determined and the curtain should be designed against this direction (perpendicularly). However, L-shaped curtains created by taking into account the variability of the wind provide more effective protection.

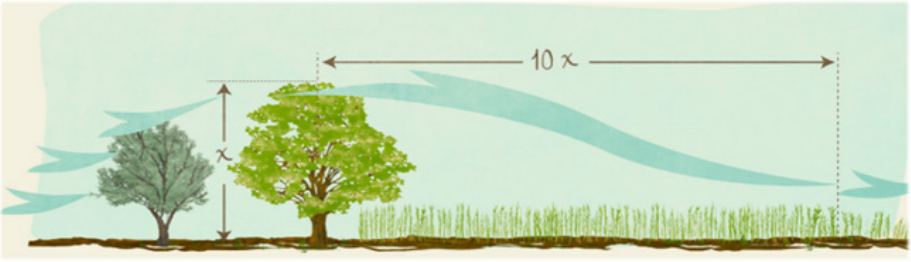

Figure 45. Tree height and protected area from wind erosion
(Figure Source: "Wind Curtain," Farming of the Future, Nature Conservation Center)

The wind curtain can protect the area up to 30 times its own height from the wind effect. The protection that can be provided in large areas such as the

Konya Plain is generally on the order of 10-20 times (Figure 45.). However, as the agricultural areas expand, the area of influence of the curtain may not be enough to protect the entire land. For this reason, it is recommended to repeat the wind curtain rows at 200-250 m intervals in agricultural areas with large fields and in a way that does not hinder land use.

In the wind breakers applied in the Konya Plain, oleaster and acacia seedlings that are compatible with the ecology of the region, resistant to drought, nitrogen fixation, and high flowering capacity were preferred. The characteristics of the tree species to be used for the wind curtain:

- Capacity to adapt to regional climatic conditions (temperature, precipitation and frost),
- Fast elongation and branch growth,
- It is easy to produce seedlings.

The reason for the selection of Silverberry and Acacia saplings in the Konya Region; the fact that they were tried in the Karapınar Erosion Protection Area, Gözlü and Altınova Agricultural Enterprise General Directorates between 1950-1960 and that they are still continuing their effects has also been effective.

For this reason, when choosing seedlings, native species or species that have been tried and adapted in country conditions for a very long time should be preferred. Different species can be considered for each climatic zone. For example, conifers should be preferred in regions where there is no water shortage, and less water demanding species should be preferred in regions with arid climates. Pine species or Cedar should not be used in arid areas.

Figure 46. Konya Soil, Water and Combating Desertification Research Institute Karapınar Erosion Protection Area

Figure 47. Conifer and wind erosion

How should the distance between trees be determined in wind breakers construction?

The distance to be left between trees during planting should be suitable for the size of the tree and bush. The distance between the trees and the distance between the rows used in the wind curtain planting plan are given below (See Table 2.).

If there is enough space, financing and labor, planting 3 rows is the most appropriate Wind Breaking method.

In 3-row planting, high-tall coniferous plants should be preferred in the middle row, and plants from the bush group (Needle, Rosehip, Mulberry, Hawthorn, Blackthorn, etc.) should be preferred in the two side rows. Planting in a single row can also be beneficial against wind erosion.

Table 2. Basic calculation values used in the wind curtain planting plan		
Plant type or windbreak type	Between the trees distance (meter)	Row spacing (meter)
Shrub or narrow-crowned deciduous species	1–2	3,5-6
Small evergreen trees	2–3.5	3.5–6
Big evergreen trees	2.5–4	3.5–6
Small deciduous trees	2.5–3.5	3.5–6
Big deciduous trees	2.5–5.5	3.5–6
Single row evergreen and two rows of high density planting	2–2.5	3.5–6

Source: "Wind Curtain," Farming of the Future, accessed November 2022. https://dkm.org.tr/uploads/yayinlar/1585519247049.pdf

3-What should be considered when applying the BMP ?

Where can the windbreak be applied?

The windbreakers can be installed around any field, farm, house or facility to protect it from the negative effects of the wind.

It should be taken into account that the life of this application will be at least 20-30 years in the selection of the tree type and the place where the wind breakers will be created.

Access and gaps: Gaps in a windbreak will cause the wind to tunnel and can increase plant damage. Access roads through windbreaks can be protected by planting an additional short windbreak at least twice the length of the gap to the windward side of the access road. If a tree dies, plant another or turbulence will occur downwind from this area.

Height: The higher a windbreak the larger the area it will protect. However, windbreaks over 6–10 metres tall often become difficult to manage and cause excessive shading of crops. Windbreaks offer good wind protection at ground level to a distance of 4 to 6 times their height and adequate protection to a distance of about 10 times their height. For example, a 10m high windbreak will give adequate protection at ground level for about 100m downwind. The protection offered to orchard, grapevine and other taller crops will be less because of their height above ground.

Setback from crop: To reduce shading and competition from tree roots, plant windbreaks at least 10m from the cropping area. Tall windbreak species

need a greater buffer area. Leave sufficient room to allow ripping of the tree roots and vehicle access and turning space. A greater distance between crop and windbreak is required when trees are planted to the north of the cropping area to minimise shading in winter.

Frost: Cold air flowing downhill can be trapped or dammed up behind a dense windbreak causing frost damage in susceptible crops. On sloping areas, a windbreak above the crop can reduce this problem by preventing cold air from flowing into the cropped area.

Windbreaks in the crop should be sited on hillsides with sufficient gradient to allow the cold air to flow downhill out of the crop. The lower end of the windbreak must not be blocked, so that cold air can move away freely. Alternatively, use deciduous trees in frost-susceptible locations.

Irrigation: Irrigation is essential for establishment. Once established, irrigation ensures sustained tree growth and reduces root invasion into the production area. Drip or sprinkler irrigation can be used. Water at about 50% of pan evaporation.

4-What are the benefits in terms of sustainability (economic, environmental, social) by adopting the BMP?

What are the benefits of wind breakers?

Wind breakers, which are built to protect houses from strong winds and the soil from the corrosive effect of the wind, have turned out to have many other benefits over time. The economic and environmental benefits of windbreaks become more diverse when they are designed with native tree species, in the right place, in the right shape, and in the right size:

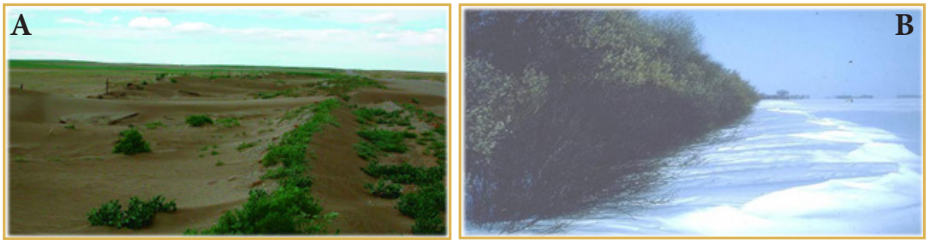

Figure 48. A: Soil carried by erosion B: Snow carried by erosion

Protection: Wind breakers protect the field from cold winds and blizzards in winter and heat waves in summer.

- Reduces soil transport by wind,
- It improves the moisture content of the soil by enabling snow accumulation.
- Reduces soil moisture loss by reducing evaporation.
- Prevents newly planted crop seeds from being blown away by the wind.
- It prevents the mature agricultural product from lying down with the effect of the wind.
- Reduces or stops dune movement invading agricultural areas, water resources and settlements.
- Eliminates noise and increases visibility (Figure 49.).

Figure 49. Example of a Live Wind Curtain

Economic contribution:

- When the trees are grown enough by the wind curtain, an increase in yield of **10-20%** is expected in the product in the field, whether it is a grain or a vineyard-garden plant. When wind curtains are used in pasture areas or in the production of forage crops, more **efficiency** is obtained from the **pasture or field**.
- Reduced **fuel costs** when applied in farmhouses or around animal shelters.
- **Branches and stems** obtained from wind curtains as a result of pruning and cutting can be used for fence, pole, fuel and compost purposes.

- If **fruit** bearing trees or plants preferred by **bees for honey** production are used to create wind curtains, additional income can be obtained from wind curtains.
- **Increase spray efficiency:** Windbreaks reduce spray drift, increasing the efficiency of pesticide applications. Reducing wind speeds also increases the number of days in the year when spraying is possible.

Figure 50. Underground view of trees

Organic matter increase:

- Trees and shrubs used as wind screens provide organic matter, ie carbon sequestration, above the ground (with their branches, stems and leaves) and below (with their roots). As the trees grow, the soil benefits more from this increase in organic matter and its yield increases (Figure 50.).

Water retention:

- The vegetation formed by the wind curtain prevents the wind from taking away the soil moisture on hot days, and slows down the flow of precipitation on the soil in winter, allowing more water to be retained in the soil.

Wildlife and biological insect control:

- Windbreaks provide habitat and food for many wildlife. Contrary to popular belief, the presence of these animals in the region provides more benefit to the farmer than harm. It is known that some bird and insect species that re-

produce naturally in areas with windbreaks are natural predators of agricultural pests, thus reducing the need for spraying in the fields. Trissolcus beetle, which prevents the reproduction of sunn by laying its own eggs in sunn eggs, prefers sea buckthorn trees to stay in winter.

5-What are the main constrains of introducing the BMP on farm and how to solve them?

- **Does the wind breaker have an effect on agricultural yield?**

The wind erodes the fertile top layer of the soil and causes it to dry faster. In areas where wind brekers are used, moisture in the soil is preserved and plants can benefit more from moisture. Studies have shown that agricultural yields increase by 10 to 20 percent owing to wind breakers.

Figure 51. Tree rows planted as windbreaks, shelterbelts, to reduce wind velocity at the soil surface and control erosion

- **How much agricultural land should be given up for windbreaker?**

If the existing inter-farm roads and access roads are used, there is no loss of agricultural area. In many places where consolidation is implemented, space is left for the application of wind curtains at the edges of the inter-field roads. In addition, there is a loss of only 1 meter along the field border in single row planting. In soils protected from wind erosion and enriched in organic matter, the amount of production per unit area increases and the abandoned area is amortized in the short term.

6-What are the frequently asked questions about BMP? Questions (Q) and Answers (A)

Q: How long does it take to see the effect of the wind curtain?

A: Depending on the type of tree and bush planted, effective protection begins in 3 or 5 years

Q: What other measures should be taken to prevent Wind Erosion?

A: Land tillage reduction (minimum level land tillage or no tillage), Stubble and harvest wastes on the land surface leaving, The tillage perpendicular to the slope, Crop Rotation

Q: Why is it important to provide windbreaks around your crops?

A:Field windbreaks protect a variety of wind-sensitive crops, control soil wind erosion, increase crop yields, and increase bee pollination and irrigation and pesticide effectiveness. Field windbreaks can also be designed to spread snow evenly across a field, increasing spring soil moisture.

Q: What makes a good windbreak?

A: The best windbreaks block wind close to the ground by using trees and shrubs that have low crowns. Dense evergreen trees and shrubs planted to the north and northwest of the land are the most common type of windbreak.

Q: What are the disadvantages of windbreaks?

A: Disadvantages include:

Money and time are needed to plant the trees.

The area in which the windbreak is planted is lost to production.

Windbreaks require maintenance if they are to function properly.

Roots and branches may need to be pruned to prevent competition with the crop.

USE OF GROUNDCOVERS IN PERENNIAL CROPS

1-What is it?

Groundcover is the most widely used Conservation Agriculture (CA) agronomic practice in perennial crops, whereby the soil surface between rows of tree remains protected against erosion. Groundcover consists of living vegetation or organic residues established in the inter-rows of orchards (Fig. 52), therefore it can be considered a type of intercropping (Morugán-Coronado et al., 2020). With this technique, at least 30% of the soil should be protected by vegetation or inert covers, such as pruning residues or tree leaves mulches (González-Sánchez et al., 2015).

Figure 52. Groundcovers in olive orchard.

2 – How to do it?

In order to establish groundcovers, they can be seeded or composed by spontaneous vegetation with the same function of covering the soil between trees (Fig. 53). Sometimes, spontaneous vegetation can be selected by applying selective herbicide, for instant with broadleaf herbicide to keep only narrow-leaved species (Fig. 54).

Figure 53. Spontaneous vegetation as groundcover in almond orchard.

Figure 54. Groundcover of spontaneous vegetation selected to gramineous in olive orchard.

As indicated above, inert material such as pruning residues or tree leaves mulch can be used to protect the soil establishing an inert groundcover after chipping of pruning material (Fig. 55).

Figure 55. Pruning residues as groundcover after chipper pass in olive orchard.

Seeded groundcovers are recommended when there is scarce seed bank the field, what is common when the soil has been ploughed continuously or the ground has been maintained without vegetation with pre-emergence herbicide (bare soil). Species locally adapted are recommended. Ideally, they should be economical and not very demanding in term of water and nutrients to avoid competition with trees. The most widely used species belong to the following families:

- Gramineous: they provide good ground protection and are not very competitive with trees, moreover they are usually easy to control. Some of commonly used species are barley, rye, ryegrass or oat.
- Cruciferous: Although they can be more competitive against trees if they are not controlled properly, brassica species provide several advantages:
  - They have fast growth and can protect the soil soon
  - The cycle starts usually in winter when the trees are less demanding of water
  - Cruciferous plants have powerful root system that help alleviate soil compaction and improve infiltration (Ren et al., 2019)

- Some species have potential to protect crop against fungal diseases (Couëdel et al., 2019)

Some typical cruciferous species used as groundcover are white mustard, rocket and radish (Alcántara et al., 2009).

- Leguminous: Thank to the symbiosis with *Rhizobium* they have the capacity to fix atmospheric nitrogen being effective as green manure (Stagnari et al., 2017). Some commonly species used as groundcover are different type of clover and vetches.
- Species mixture: Mixtures of two or more species are also used as groundcovers, they provide the benefits of the different type of species and some synergies may be also reached with more ecosystem services (Tribouillois et al., 2016). In any case, they should be specifically determined for the local conditions.

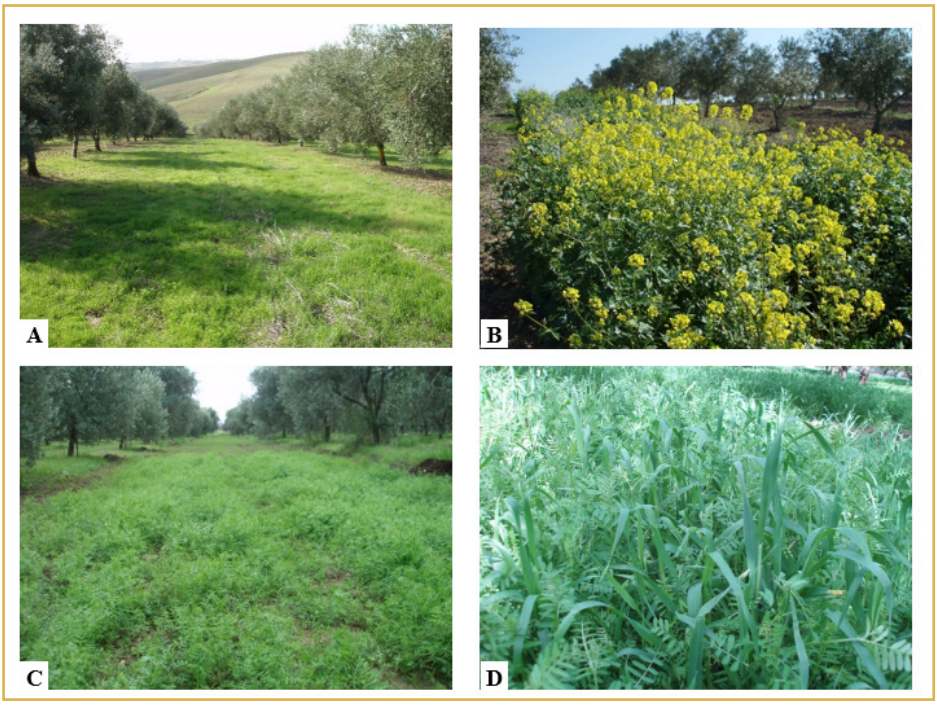

Figure 56. Seeded species as groundcover. A: *Gramineous*, *Brachipodium* distachyon; B: *Cruciferous*, white mustard (*Sinapis alba*); C: *Leguminous*, vetch (*Vicia villosa*); D: grass (barley) – *legume* (vetch) *mixture* (*Hordeum vulgare – Vicia villosa*).

The groundcover sowing usually requires the use of standard seeders and the previous tillage for seed bed preparation. Normally, the groundcover does not need to be seeded every year, a strip should be left alive to self-seed the next season, anyway the emergence must be assessed and a new sowing should be considered. In this regard there are species with more self-seeding capacity.

3-What should be considered when applying the BMP ?

In case of spontaneous vegetation, more attention should be paid as it usually is more competitive for water and nutrients against the trees. Furthermore, the farmer should ensure that there is enough seed bank to grow spontaneous flora covering at least 30%.

The groundcovers must be controlled when it competes by water and nutrients with the main crop in a sensible stage such as flowering. The groundcover can be controlled by mechanical mowing (flail mower), chemical weeding (herbicide) under an integrated weed management or grazing (livestock) (Fig. 57 ABC; Table 3). Several passes in a season could be necessary to control the groundcover avoiding yield reduction of the main crop. The control timing would change according to meteorological conditions but at least one control is usually needed in spring when lower water availability in flowering stage of the trees can determine the production diminishes.

Figure 57. Groundcover control. A: Mechanical; B: Chemical; C: Grazing.

Table 3. Pros and cons of the different types of groundcover control		
CONTROL TYPE	PROS (pluses)	CONS (minuses)
MECHANICAL CONTROL	• No need of chemical products • Fits the needs of other choices for their mainstreaming (e.g. organic)	• Higher tractor power • Regrowth • Risk of evolution towards creeping species
CHEMICAL CONTROL	• Easy to leave a seed band • Effective control	• Need of maintenance of the boom sprayer. • Attention to climatic conditions for plant protection product application.
GRAZING	• Feasible in steep plots	• Compaction if soil moisture is high when animals come into the plot.

The area under canopies (tree rows) usually is controlled by systemic herbicide, but hand mower could also be used. In vineyard or super-intensive orchards, inter-vine mower/blade is also used to remove weeds by mowing or tilling the crop row (Fig. 58). This machine has a sensor to apart the cutter/blade in the proximity of a vine or tree. In case of tilling blade it would be disturbing the soil but only in a strip of the plot.

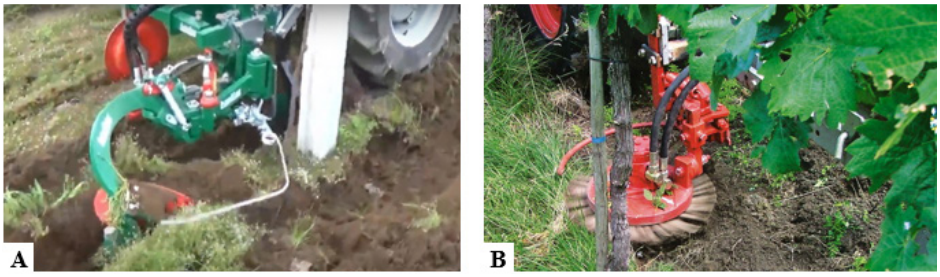

Figure 58. A: Inter-vine blade weed remover. B: Inter-vine mower

In order to keep soil protected minimizing any disturbance, tillage is not recommended to control groundcovers. After groundcover controlling, residues act as mulch providing several advantages (see BMP 'Permanent soil cover/straw management') (Fig. 59).

Figure 59. Residues of groundcover after chemical control in the inter-rows of olive orchard.

In case of pruning residues mulch, it has an allelopathic effect controlling weeds. Anyway, weed control in some areas might be necessary as well as in the trees rows. Pruning residues are normally applied on a strip corresponding to the width of the chipping machine, since these residues must be chipped in order to reduce the risk of certain pests and to facilitate the machinery transit. Assuming the width is determined by the machinery, it must be checked the degree of soil coverage provided by the pruning residues. In case of less of 30% soil cover, the pruning residues mulch must be complemented with living groundcovers.

From the soil protection perspective, the quality of residues should be considered. Legumes residues are more easily decomposable due to their low C/N ratio. This could leave soil unprotected before the new groundcover emerges in the following season. That is the critical point at the end of the decomposition period, when heavy rainfall events are also more probable.

4-What are the benefits in terms of sustainability (economic, environmental, social) by adopting the BMP?

Economic

The presence of a groundcover reduces the appearance of weeds, especially in case of seeded groundcovers. After groundcover controlling, mulch prevents the germination and establishment of weeds, by reducing surface soil temperature

and light (Teasdale et al., 2004). Likewise, if weed seeds are placed on the soil, the mulch prevents the soil-seed contact, thus hindering and reducing weed germination. All this can imply a reduction in weed control costs.

In addition, the groundcover has the capacity to recycle nutrients avoiding their loss through erosion or leaching in the living stage and releasing them by the decomposition of their residues after the control (Blanco-Canqui et al., 2015). This could reduce the use of some fertilizers, especially in case of use of legumes.

The energy cost of ploughing is higher than the use of mechanical or chemical control, therefore the use of groundcovers is more economical than conventional tillage. Furthermore, in case of spontaneous vegetation as groundcover (if it provides soil cover over 30%) the seed cost is avoided.

Other economic benefits are indirect, but no less important, such as the reduction in the cost for public administration resulting from reduced erosion, flooding, water pollution, loss of biodiversity and the impact of increased CO_2 emissions. In this regard, the high potential of groundcovers to sequester CO_2 from atmosphere is such that it is being used currently to generate carbon credits (1 t CO_2 sequestered or reduced) in the carbon market under agricultural farm programmes known as carbon farming.

Environmental

Groundcovers provides several environmental benefits such as the reduction of soil loss and diffuse pollution (Ordóñez-Fernández et al., 2007), nutrient storage during the dormant season and release when trees are actives as well as increase of organic matter and C sequestration (Repullo-Ruibérriz de Torres et al., 2021), N fertilization mainly through legumes (Ordóñez-Fernández et al., 2018), biological activity enhancement and diseases control (Abawi & Widmer, 2000), and weed control (Alcántara et al., 2011).

After groundcover controlling, residues mulch reduces evaporation improving soil water balance, in addition, the increase in organic matter improves soil structure and water holding capacity (Palese et al., 2014).

Groundcovers provide shelter for fauna increasing biodiversity (Castro-Caro et al., 2014) being a more natural and sustainable production system.

The erosion reduction improves the trafficability in the farm because the formation of gully is narrowed down. In addition, the groundcover enhances

infiltration and limits floods after precipitations allowing the pass of machinery. This is significant in crops with harvest at wet period.

Summarizing, the main ecosystems services provided by groundcover are:

- Effective protection against erosion
- Improved soil structure
- More infiltration and water availability
- Enhanced soil fertility, more organic matter and Recycling nutrients
- Climate change mitigation (soil carbon sequestration)
- Natural reservoir for species, improved biodiversity
- Improved trafficability

Social

About 40% of labour saving is reached by groundcovers compared to conventional tillage (González-Sánchez et al., 2010). This lets farmers dedicate for other activities either in the farm or out the farm improving the welfare condition of them and their family. This helps fix population in the rural environment supporting the generational change while dynamic of rural areas is maintained.

On the other hand, the use of groundcovers implies a visual change in the woody crop landscape. The picture of groundcovers in woody crops is more attractive than a tilled/bare soil picture, which can also show rills or gullies under that conventional system.

5-What are the main constrains of introducing the BMP on farm and how to solve them?

The main constrain of groundcover is the competition for water and nutrients with the main crop. Especially in rainfed systems, where a reduction in the water availability for the trees in a significant stage such as flowering would mean a reduction in production. It can be solved with an appropriate control. The control time is crucial to avoid any effect on production, which depends on the meteorological conditions and varies inter-annually. On the other hand, very early controls can leave little amount of residues to protect the soil the rest of the season as well as to take advantage of other benefits of the groundcovers.

Sometimes, high amount of residue with high C/N ratio (such as pruning residues) can immobilize the soil nitrogen availability for trees. In this case, it

can be solved by any type of nitrogen amendment such as other organic residues with low C/N ratio or fertilizers.

As mentioned above, allowing spontaneous vegetation grows could increase amount of weeds and the appearance of difficult-control species. The use of seeded groundcover minimizes this issue. In case of spontaneous vegetation groundcover, frequent monitoring would be needed and more control. Selecting toward easy-control species through selective herbicide or manual weeding can curb the appearance of more competitive weeds species.

6-What are the frequently asked questions about BMP? Questions (Q) and Answers (A)

Q: How much is the cost of seeded groundcover? It does not seem interesting from the economic point of view.

A: The sowing of the groundcover implies a cost but it is compensate with other benefits such as the reduction in weeds and the management of easy-control species. In addition, seeded species are usually less competitive for water and nutrients. Normally, the groundcover does not need to be seeded every year, leaving a strip for completing the cycle and to self-seed the next season.

Q: Can the groundcover diminish the production of the main crop?

A: No. The production is maintained if an appropriate control in sensitive stage for the production of the main crop is conducted.

Q: Can any pest or disease appear after changing the soil management with the introduction of groundcovers?

A: Any change in the soil management can affect the dynamic of pest and diseases. A change in the agri-environmental system can imply different consequences respect to the conventional system. Generally, the improved biodiversity helps keeping natural enemies of pest but it must be checked and controlled.

Q:Are groundcovers suitable for any type of permanent crops?

A: Yes. The management changes according to the main crops, the groundcover species, the location and meteorological conditions, etc. Control date and number of interventions depends on all this factors. See Annex 1 with pictures of groundcovers in different types of permanent crops.

ANNEX 1. Pictures of groundcovers in different permanent crops

Figure A1.1. Groundcover in apple orchard.

Figure. A1.2. Groundcover in pear orchard.

Figure A1.3. Groundcover in olive orchard.

Figure A1.4. Groundcover in citrus orchard.

Figure A1.5. Groundcover in vineyard.

Figure A1.6. Groundcover in almond orchard.

PART 2

CROP MANAGEMENT

CROP ROTATION

1-What is it? What is Crop Rotation Design?

Figure 60. Crop Diversity

Crop rotation is the chronological sequence of crops grown on an area. The planning of a crop rotation must observe many rules that have developed historically, and many have retained their validity to this day. Inappropriate crop rotation can significantly reduce yields. In the past, crop rotations were the basis of agricultural planning. Due to the intensification of agriculture and the possibility of purchasing inputs such as fertilizers and pesticides, the importance of crop rotation has decreased. In addition, the cultivation of low-margin crops has declined significantly, reducing crop diversity (Schneider, 2009). In organic farming, crop rotation still has a high priority, as synthetic fertilizers and chemical pesticides are dispensed with (Federal Office for Agriculture and Food, 2013).

The crop rotation is strongly dependent on the farm organization, such as: feed requirements, operation of a biogas plant, sales markets, and profitability (Schneider, 2009). In addition, the harvest date of the previous crop must ensure the timely ordering of the post-crop (Chamber of Agriculture North Rhine-Westphalia, 2022).

In natural systems, many different plant species grow side by side. As a rule, this is not the case in the field. To imitate this condition and at the same time work economically, various crop rotation models have been developed. If the same crop were always grown on the same land, pests, diseases and weed species could spread optimally (Federal Office for Agriculture and Food (BLE), 2021). The aim of a balanced crop rotation is to create the best possible growth conditions for the respective post-crops.

This includes:

- The prevention of soil-borne diseases.
- Breaking the development cycles of pathogens.
- Weed suppression.
- Soil loosening.
- Maintaining/improving the soil structure.
- Humus formation.
- Nutrient supply (Freyer, 2016).

https://www.youtube.com/watch?v=XzSchrmBt8g&t=7s

2 – How to do it? Rules for balanced crop rotation

Figure 61. Figure that demonstrates Sustainability of Crop Rotation

The self-tolerance of arable crops varies. This means that there are plants that are grown for several years in a row without any losses. Examples include rye and corn. Then there are plant species that do not have good self-tolerance and should be observed breaks in cultivation. These include the plants of the cabbage family. Intolerance refers not only to plant species, but also to plant families (Alsing, 2014).

The alternation of leafy crops and stalks, as well as summers and winter stanchions can mean higher and more stable yields (Schneider, 2009).

Table 4. Examples of leaf crop, straw, summering, wintering

Straw fruit	Leaf fruit	Summering	Wintering
Cereal	Rapeseed	Summer wheat	Winter wheat
	Turnips	Soy	Winter oilseed rape
	Potatoes	Sunflower	Winter barley
	Pea	Corn	

(i.m.a – information.medien.agrar e.V, 2022; Säsisches Landesamt für Umwelt, Landwirtschaft und Geologie, 2008).

On many arable farms, close market crop rotations have been established, with negative consequences for plant health. Due to the increase in crops such as rye, spring cereals and legumes, close crop rotations can be loosened up and stable yields generated (Kropf, 2022).

An extension of crop rotation through a combination of fodder and arable farming is also recommended. If no animals themselves are kept on the farm, a farm cooperation is one way to use the cultivated fodder (Kropf, 2022).

In the new CAP (EU Common Agricultural Policy), the extended conditionality provides for an annual crop rotation. This is also fulfilled if not more than 50 % der Fläche vom 15.10.–15.2. a catch crop or under sowing is in place (Ministry of Food, Rural Affairs and Consumer Protection Baden-Württemberg, 2022).

Crop rotation in organic farming

As already mentioned, crop rotation plays a special role in organic farming, as the aim is to feed the plants and animals on the farm through a circular economy. In addition to the provision of nutrients, the phytosanitary and weed-suppressing effect of crop rotation also plays an important role in organic farming. An important building block of organic crop rotation is the enrichment of nitrogen through the cultivation of legumes. In addition, nutrient requirements must be taken into account and breaks in cultivation must be observed in order to ensure good plant health (Federal Office for Agriculture and Food, 2013).

Table 5. Crop breaks

Crop	Cultivation break (years)	Causes
Winter wheat	2	fungal pests, cereal cyst mallaces
Oats	3-5	Cereal cyst malmales
Corn	1-2	-
Sugar beets	4	Fungal pathogens, beet cyst malmales
Rapeseed	3-4	Cabbage hernia, nematodes
Broad bean	3-5	Viruses, fungal/animal pathogens
Pea	4-6	Fungal pathogens
Dress	3-4	Clover fatigue
Grasses	-	-
Carrot	3-4	Fungal pathogens, nematodes

(Saxon State Office for the Environment, Agriculture and Geology, 2008).

3-What should be considered when applying the BMP ?

Figure 62. Intercropping with Vicia

Care of soil fertility

The soil in which agricultural crops grow is the habitat for many living beings. The number of species in the soil is at least as high as above ground in the tropical rainforest. The soil ecosystem has a major impact on agricultural production and vice versa (Jacobs et al., 2022). Agriculture is dependent on fertile soil. Weakened or damaged soils cannot provide the desired performance. Cultivated soil fertility needs a lot of care. It helps to understand the soil as a complex organism and not as a chemical-mechanical model (Berner et al., 2013). Depending on the geographical conditions, soils differ greatly in their structure (soil type), their ability to retain nutrients/water and the composition of soil organisms. Despite the different natural conditions, it depends very much on the cultivation whether soil fertility is maintained or decreased. The goal of sustainable land management should be to maintain or increase soil fertility (Jacobs et al., 2022).

The fertility of a soil is very closely related to the humus content in the soil. Humus consists of about 58% carbon and is therefore a very important carbon store. Soils can store 4 times as much carbon as surface vegetation. This makes humus an important lever in the fight against climate change (Jacobs et al.,

2018). In addition, humus is the basis for biological activity and the storage of water and nutrients. Even with low humus contents, this has a decisive effect on chemical, physical and biological processes in the soil. An increase in the humus content has a positive effect on the stability of the soil structure and the pore volume. After digestion of humus by soil organisms, many important nutrients are present in the soil solution as plant-available phosphate, nitrate, and ammonium.

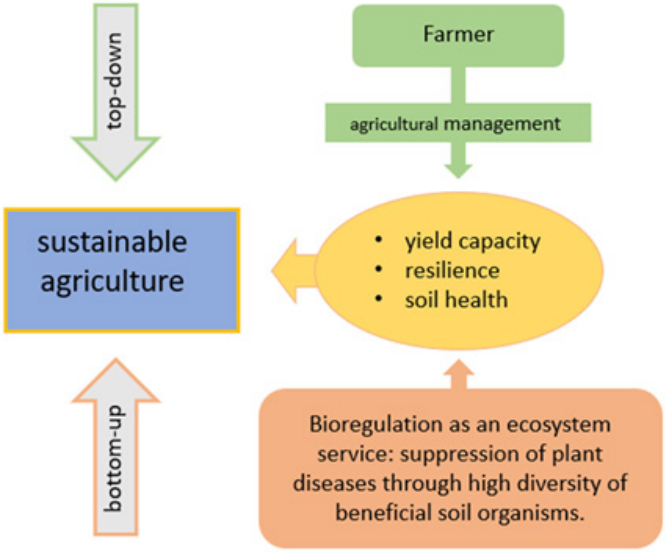

Illustration 1: interaction soil – agriculture

Particular attention should be paid to the promotion of soil organisms. These should be seen as production partners (Schrader et al., 2020). Their ecosystem services are diverse:

- Improving soil fertility
- Soil formation
- Preservation of fertility and productivity
- Regulation of harmful organisms

Soil organisms have a bottleneck function: all organic material must pass them and is converted by them. The soil organisms also have an important function in the elimination of possible pathogens (nematodes, bacteria, fungi,

and viruses) in the soil. The more diverse the composition of soil organisms, the more resistant this community is to pathogens. The soil forms a complex food web. This is a system of interconnected food chains. This involves the interaction of underground and above-ground organisms. More complex networks are found in species-rich systems than in monocultures. Problems can arise if nutrients are mineralized by soil organisms during the rainy and low-vegetation months. In this way, mineralized nitrogen can be leached into the groundwater. Due to climate change and the resulting increased temperatures in autumn/winter, this period is extended. To prevent leaching, hardy catch crops can be grown (Jacobs et al., 2022).

Microorganisms are among the very small soil dwellers. They are specifically attracted by the plant via root exudates and enter complex interactions with it.

The soil bacteria usually reside in the root area and in the humid topsoil. They break down organic and chemical substances with the help of enzymes and play a special role in the nitrogen cycle (Jacobs et al., 2022).

Soil fungi form close networks with the plants. A symbiotic compound is formed by mycorrhizal fungi and crops. The fungus forms a dense mycelium around the root and into the root. The plant feeds the fungus with photosynthesis products and receives water and nutrients in exchange (Jacobs et al., 2022).

Earthworms are among the helpers of agriculture. Organic residues that lie on the surfaces are incorporated into the mineral soil. This process is called bioturbation (see QR Code 2). Due to their activity in the soil, they bring 5mm of fresh soil material to the surface per year (Jacobs et al., 2022). The excreted material consists of stable clay-humus complexes. These increase microstructure stability and reduce compaction sensitivity (Schrader et al., 2020). Due to a high number of earthworm passages, surface water can be absorbed in the soil and does not drain above ground (Roth & Joschko, 1991)

https://www.youtube.com/watch?v=n3wsUYg3XV0

Among the larger organisms that live on the soil are the ground beetles. The oviposition and the development of the beetles take place predominantly in the soil. The beetles and their larvae usually live predatory. Especially the larger species play an important role in pest control (e.g. Colorado beetle) (Hortipendium, 2016). Ground beetles are good bioindicators of the intensity of human impacts on ecosystems, as they are very sensitive to disturbances (Jacobs et al., 2022).

Measures to improve soil fertility

Practical agriculture intervenes in the living conditions of soil organisms in various ways. These include crop rotation, tillage systems,

https://www.youtube.com/watch?v=hlchlMKSLaU

Plant protection and fertilization. The framework conditions are usually regulated by law (Jacobs et al., 2022).

The cultivation system decides how much organic material remains on the area. This mainly affects soil organisms that need organic material as food. In cereal cultivation, for example, there are different ways to use straw. It can:

- Be removed from the area.
- Remain on the surface.
- Be returned in the form of manure.

Each system affects soil life in a different way (Jacobs et al., 2022). The degree of comminution of organic matter on the field surface has a significant influence on the activity of earthworms. The more strongly the material is crushed, the easier it is for earthworms to move it (Brunotte, 2007). Rolling over a catch crop with a Cambridge roller provides good erosion protection but leaves too long stem parts for good earthworm activity (Brunotte, 2016).

Figure 63. Soil Fertility

4-What are the benefits of crop rotation?

- Promotion of soil fertility

A one-sided crop rotation design harms soil fertility. Diverse plants in the field help to build a fertile soil. The mass and quality of the material offered in the field are decisive for the effects on soil fertility.

- Supply of farm animals (clover, alfalfa) and sales-oriented crop selection (diversification of marketing)

The aim is to grow those plants that can also be used well and achieve good prices on the market. If livestock farming is coupled with crop production, fodder plants are very suitable for farm animals, as this creates a closed cycle, and no additional feed has to be purchased.

- Location-adapted choice of culture

Each soil has different characteristics, and the weather or climate can also be different from location to location. There are plants that want a lot of sun and others don't like it so hot. To achieve optimal growth and to get healthy, strong plants, you should pay special attention to the needs of the plants, which is also required by the EU organic regulation of organic farmers.

- Optimal nutrient supply (N-extraction by legumes)

Through the targeted cultivation of e.g. legumes (more about legumes here) a lot of nitrogen can be provided. This nitrogen benefits the subsequent crop on the field. Stronger plants and faster growth are the result.

- Weed control

Weeds are plants that grow in the field without being specifically grown there. By using catch crops, e.g. clover, weed pressure can be reduced. Diverse crop rotations, especially about the change between summering and wintering, mean that the conditions on the field are constantly changing. A specialization and stocking with a perennial weed, such as the sorrel or the field thistle, is not so easy possible. The diversity of weeds is increasing, which in turn has a positive effect on the field and facilitates the control of weeds (Wachendorf et al., 2018).

- Regulation of diseases and pests

Many pathogens are specialized in certain plants. They survive in the soil and/or on plant remains. By observing breaks in cultivation and breaking down plant residues, the disease and pest pressure can be significantly reduced. Crop rotation thus helps to minimize individual pathogens and at the same time has positive effects on nutrient management in the soil (Wachendorf et al., 2018). This is important, because in organic farming, many direct measures to combat diseases and pests are prohibited. Preventive, forward-looking work is an essential factor for the success of organic farmers.

5-What are the main constraints of introducing the BMP on the farm and how to solve them?

Crop rotation has a diverse effect on soil, plant nutrition and plant health. Looking at these individual positive effects in their entirety, there are positive effects on yields and quality of the plants and on the environment (Wachendorf et al., 2018). In order to achieve all these positive effects, crop rotation has to do quite a lot. Getting crop rotation right is not so easy. Therefore, there are many principles to consider:

- Choose the type of culture that suits the location. The potato, for example, does not feel so comfortable in wet and clayey soils and should not be grown there. If the soil is rather sandy, then rye and wheat are suitable (Wachendorf et al., 2018, 47).
- Keep breaks in cultivation so that diseases and pests have no chance.
- Incorporate nitrogen-fixing plants. Legumes, for example, collect nitrogen and build humus. They should be included with at least 25% in the crop rotation.

- Alternate humus multipliers and humus eaters. Humus multipliers, as their name suggests, build up humus in the soil, while the humus eaters reduce it. In the end, a balanced to positive humus balance should be achieved.
- Change between deep and shallow rooters and low-root and root-rich plants.
- Alternating between wintering and summering to achieve year-round land cover.
- Year-round vegetation to avoid erosion.
- Incorporate catch crops and under-sowing to increase diversity and reduce weed pressure.

6-What are the frequently asked questions about BMP? Questions (Q) and Answers (A)

Q: What happens if crop rotation is not adhered to?

A: Farmers rotated the crops because pests that liked one crop would find it hard to survive the following year when that crop was no longer there. They'd die out.

Q: What is good crop rotation?

A: The intervals between the most important crops are: red clover/alfalfa at least four years, six years in the medium and long term, peas at least five years, field beans at least four years.

Q: Why observe crop rotation?

A: So that the soil is not leached on one side, fungi and other pathogens do not have it too easy and you can still get the best out of the soil, a crop rotation in the vegetable garden makes sense. In this way, better yields can be achieved with less fertilizer input.

Q: How to compare crop rotation in organic farms and conventional farms?

A: In addition to all these principles for planning good crop rotation, the cultivation methods and techniques of the individual crops must also be considered. These include sowing and harvest time, fertilization, any plant protection measures, soil cultivation and the use of catch crops (Wachendorf et al., 2018). Planning good crop rotation is a major challenge and presents farmers with a difficult task. Organic farmers must have extensive knowledge of crops, soil, weather, and nature. This is the only way for them to manage their business optimally. If a crop rotation error occurs, it is only possible for organic farmers to intervene to a limited extent. The errors cannot simply be corrected by N-fertilizers and chemically synthetic pesticides.

BIOLOGICAL AND BIOTECHNICAL CONTROL MECHANISMS

1-What is it? What is Biological Control?

In order to stop or reduce the damage done by harmful insects, the processes of keeping them below the economic damage level with the help of their natural enemies are called biological control.

In other words, in order to destroy the harming organism from the environment or to reduce it below a certain level, it is to place another living thing in the environment by eating the existing living thing and/or by laying its egg inside the pest for its own reproduction.

Figure 64. Biological control agents.

What is Biotechnical Control?

Biological control; instead of killing harmful organisms directly, it is to prevent and control their normal biological and physiological behaviors with some techniques. Biological control is the intervention of harmful organisms in the natural life process by using some techniques.

Major biological control products :

- Traps (Pheromone traps, light traps, visual sticky traps, water traps and food traps).
- Attractants or repellants.
- Chemicals and hormones that disrupt insect growth.

Figure 65. Traps.

2 – How to do it?

Benefits used in biological control can be grouped into three groups

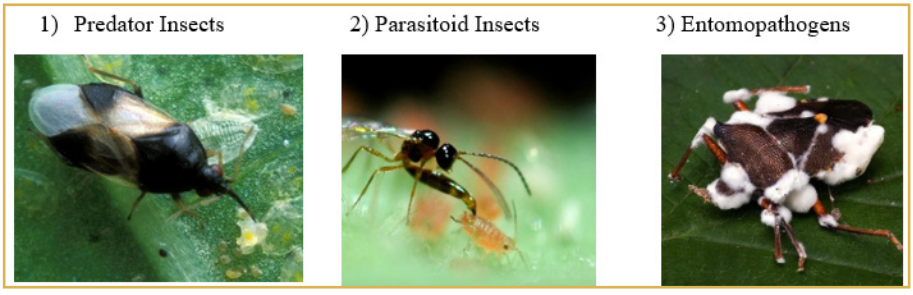

Figure 66. Useful Insect Types Used in Biological Control.

Predator Insects:

Insects that live freely throughout their lives, kill their prey by eating or absorbing body fluid, are often larger than their prey and need more than one prey to complete their development. They are creatures that feed on more than one insect and immediately kill the insect they feed on.

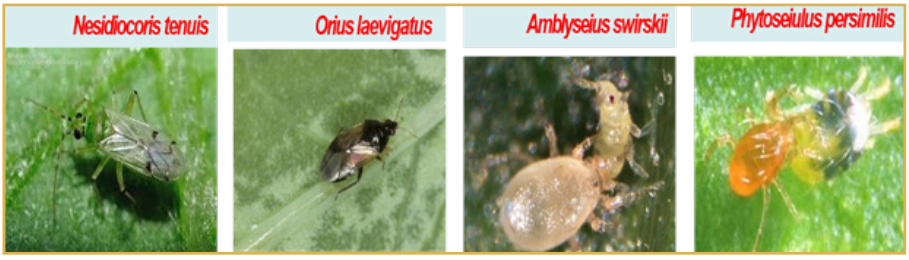

Figure 67. Predator Insect Types.

Parasitoid Insects:

It is a beneficial organism that lays its eggs in or on its host, completes its development, kills its host, and needs only one host until it becomes an adult. The most common are egg parasitoids. Larval and pupal parasitoids are also present.

Figure 68. Parasitoid Insect Types.

Entomopathogens:

Microorganisms that kill their hosts by making them sick.

Examples: ***Bacilus thuringiensis, Beauveira bassiana, Verticillium lecani***

Insects that are combatted

Figure 69. Predator insect Nesidiocoris tenuis and its target pests (Bemicia tabaci and Tuta absoluta).

How to Fight Bemisia tabaci and Tuta absoluta?

- Nesidiocoris-system is a predatory insect.
- There are 500 predators as adults and nymphs in moistened vermiculite in 500 ml bottles.
- Usually found in Mediterranean countries and Canary Islands regions.
- The plants used, tomato and eggplant types.
- Target pests; Effective in egg and larval stages of greenhouse whitefly (*Trialeurodes vaporariorum*), Tobacco whitefly (*Bemisia tabaci*), Tomato stem moth (*Tuta absoluta*).
- Additionally, they feed on the eggs and larvae of pests such as thrips, greenworms, aphids, red spiders and leaf gallery fly, in addition to the target pests in their environment.

Why Use Nesidiocoris?

- Less sensitivity to chemicals,
- Higher reproductive rate (e.g.: A female of M.caliginosus lays close to 160

eggs, while a female of Nesidiocoris tenuis lays 270 eggs)

- The reproductive rate is the same or higher than that of the pests, (eg, a white-fly female lays 200-270 eggs, a female in the tuta lays 260 eggs).
- Very much successful in suppressing pests.
- Feeding rate with pests, daily average is too high.
- The ability to hide on the plant is very high.

Traps Used in Biotechnical Control

What is a pheromone? They are the scents that the female insect secretes to attract the male insect. These scents are synthesized in the laboratory and absorbed into a rubber capsule. Capsules are placed in traps containing sticky substance, Male individuals who come to this trap are killed.

- **Pheromones are generally used in pest control in three ways.**

1. Monitoring-izleme: Tracking the emergence and population of an insect in a given area
2. Avoiding mating: Preventing the male and female of a pest species from meeting in a given area, thereby preventing mating and reproduction.
3. Mass capture : It is applied to kill the female and/or male individuals of a pest by catching as many as possible for the purpose of control.

Figure 70. Types of pheromone traps.

What are the pheromone traps, what are the benefits, what are the difficulties?

Benefits

- Since each species has a different scent, it is a great benefit to be specific to the species.

- Pheromone traps give us information about the presence of insects in very large areas, and the number if any.
- These traps are very economical and are used for an environmentally friendly struggle.
- It has no side effects.

Difficulty status?

- Perhaps the only disadvantage of these traps is that they are constantly monitored. For example, after setting the traps, they should be monitored daily until the first insects are caught.
- After the insect is caught, it should be checked once a week.
- Adhesive cards need to be changed once a week, capsules every 6 weeks.

What are the visual traps, what are the benefits, what are the challenges?

- Insects' favorite colors should be known.
- Some insects like yellow, some like blue, red and white.
- Traps in this color are prepared and sticky substance is applied on them.
- Especially used to determine whether there are pests in greenhouses.
- Used for aphids, whiteflies, thrips, leafhoppers, psylla.

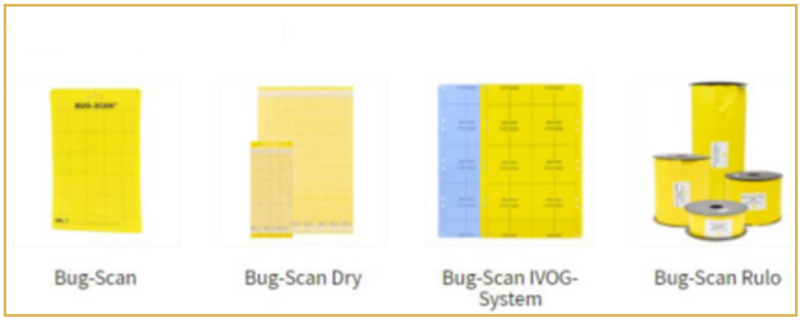

Figure 71. Types of sticky traps and rolls.

3-What should be considered when applying the BMP ?

What to Do in a Successful Integrated Challenge

- When ordering seedlings, it is necessary to inform the seedling that biological control will be done. Seedlings with chemical residues can harm beneficial insects..
- Greenhouse insulation must be done well (repairing the tulle, using the double door system). The less the harmful intrusion from the outside, the greater the success in biological control.
- Greenhouses should be disinfected before planting.
- Before planting, around of greenhouse and greenhouse cleaning should be done well.
- **Diseased and infected plants** formed after planting in the greenhouse should be removed to prevent contamination of healthy plants.
- ***Greenhouse controls*** *should be carried out together with greenhouse supervisors.*
- In biological control greenhouses, the information given other than the **technical responsible** should not be respected. Improper intervention can be harmful to beneficial insects.
- Yellow and blue sticky traps should be hung on the greenhouses, traps with tuta and thrips pheromone should be used.
- In some cases, there may be excessive pest attack on local areas and eggs and larvae are observed on the leaves. In this case, **leaves must be taken and destroyed**.
- ***Spraying tankers must be cleaned*** *before and after each spraying.*
- It is necessary to **prevent excessive humidity** that will increase diseases in the greenhouse and to do good ventilation of the greenhouse..
- ***Before chemical application,*** *it must be done in the way and time recommended by the Biological Control officer and the recommended drug. The pesticides used should not harm beneficial insects.*

Figure 72. Examples of Successful Integrated Struggles.

Importance of Observation and Counting in a Successful Integrated Combat

- By detecting the pest, the development stages of the pest are directly observed. Harm and symptoms are observed indirectly.
- Evaluations are made according to which pest it is, at what stage of development (larval stage, adult, etc.) it is, how it damages the plant, what population it is in, whether it is a fast-growing or slow-growing pest, the amount and level of the pest.
- Observation and counting is an indispensable application in all production processes.

4-What are the benefits in terms of sustainability (economic, environmental, social) by adopting the BMP?

Why Biological and Biotechnical Control?

- There is no residue problem, it is only used against targeted pests / pests (Table 6.).
- Insects that are released do not feed on plants as they are carnivorous… they do not harm plants…

- It is an environmentally friendly challenge. No harmful effects on the environment and climate change.
- It is more economical than chemicals. It does not have a problem such as the end-of-harvest waiting period as in chemical control.
- Sustainable agriculture can be done by using these control methods.
- Protects Human Health.
- Protects Environmental Health.
- Controlled, Conscious Production.
- Pests are prevented from gaining resistance to drugs.
- Protects Natural Enemies (Beneficial Insects).
- Reduces Company Struggle Cost.
- Minimizes Plant Stress.
- Increases the Market & Brand Awareness of the Company.

Figure 73. The Importance of Protecting Human and Environmental Health.

5-What are the main constrains of introducing the BMP on farm and how to solve them?

Problems and Risks in Biological and Biotechnical Control

- Having methods of struggle that require intensive technical knowledge.
- The pesticides used kill beneficial insects, pesticides that are not harmful to beneficial insects are very expensive.
- Not knowing the effect of the pheromones used on non-target organisms.
- The risk of pheromone-trapping systems polluting the environment (recycling systems).

- High labor cost (observation and application repetition required).
- Possible negative effects of color traps on beneficials.
- Low biological effect compared to chemical plant protection products.
- Difficulties in using the method in the presence of multiple harmful organisms.
- Small farmers do not want to invest due to small farm size.
- Climate Change (Pest populations increasing sometimes).

6-What are the frequently asked questions about BMP? Questions (Q) and Answers (A)

Q: What are the advantages over other methods used in plant health?

A: Biological control involves the use of another living organism to kill a pest. No chemicals are needed, there is no environmental contamination with pesticides, and the pests don't become resistant to the control method (Table 6.).

Table 6. Comparison of control methods used in plant health.

No	Criteria (Weight in total*)		Biotechnical Control		Biological Control		Chemical Control	
1	Biologic Efficiency	20	Good	15	Good	15	**Very Good**	**19**
2	Cost	15	Good	10	Good	10	**Very Good**	**15**
3	Applicability	15	Good	10	Good	10	**Very Good**	**15**
4	Residue	10	**Very Good**	**10**	Good	8	Bad	3
5	Side effect to benefits	10	**Very Good**	**9**	Good	7	Bad	3
6	Effect Time	10	**Very Good**	**10**	Good	9	Medium	5
7	Accessibility	5	Medium	3	Bad	2	**Very Good**	**5**
8	Resistance Gain	5	**Very Good**	**5**	Good	3	Medium	2
9	Environmental Awareness	5	**Very Good**	**5**	Good	4	Bad	2
10	Development Potential	5	Good	3	Good	4	Good	3
	Total score	**100**		**80**		**72**		**72**

Q: How Do I Start?

A: Identify the pests in your garden. List the control measures that will be helpful against these pests. Then develop a plan.

Q: What is most often the primary goal of biological control?

A:The ultimate goal of biological control is to suppress pest population and damage without pesticide or with reduced pesticide use. Natural enemies are utilized differently depending on the target pest, host, environmental condition, and pest life cycle.

Q: Why does biological control not sometimes work?

A: Always release a sufficient number to ensure regulation of existing insect and/or mite pest populations. Releasing too few natural enemies will likely result in poor regulation of pest populations and subsequent damage occurring to greenhouse-grown horticultural crops.

Also, the reason for the failure could be:

- Application of pesticides that directly or indirectly affect natural enemies.
- Releasing natural enemies too late.
- Not releasing enough natural enemies.
- Not conducting a quality assessment of purchased natural enemies.
- Not implementing a reliable scouting program.

VEGETATIVE FIELD MARGINS

1-What is it?

Unfortunately, agriculture, like any human activity, modifies natural ecosystems. Intensive agricultural systems have had a strong impact on the natural environment, which has led, among other things, to a decline of biodiversity in agricultural landscapes and soil degradation.

Vegetative field margins are an agronomic practice by which it is implanted strips of vegetation on the edge of the fields. This practice aims to implement a field tool capable of increasing the biodiversity of agricultural ecosystems, ensuring water quality and increasing soil health. These margins should form part of agricultural landscapes by connecting cropland areas with bordering structures, such as other crops, grasslands, forests or surface waters.

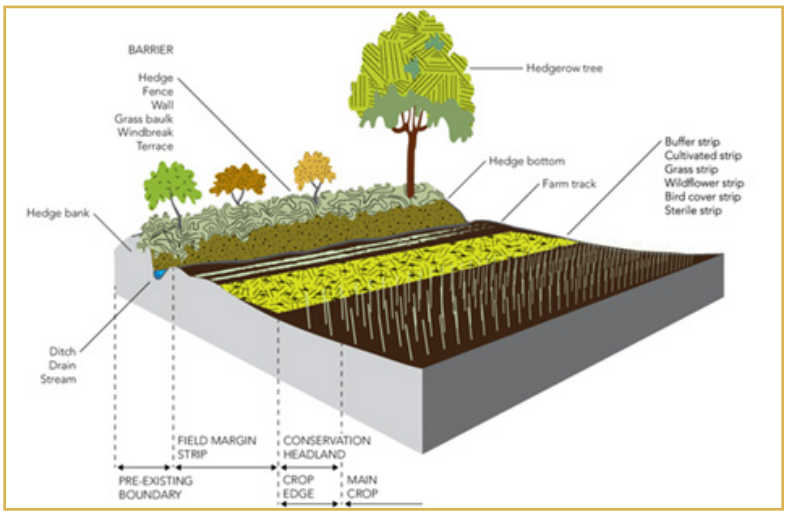

Figure 74. Componets of a vegetative field marging. Source: Marshall EJP, Moonen AC. 2002.

Figure 75. Vegetative field margin.

2 – How to do it? (How to introduce this BMP in the farm)

- **Location**

The location and size of the vegetative margin to be introduced in the field is an essential aspect to be considered. Depending on the purpose for which the

margin is introduced, it may be located in one area of the landscape or another. Therefore, its location to improve the efficiency of this practice must be assessed based on several parameters: soil permeability, slope, and other crop areas next to the plot.

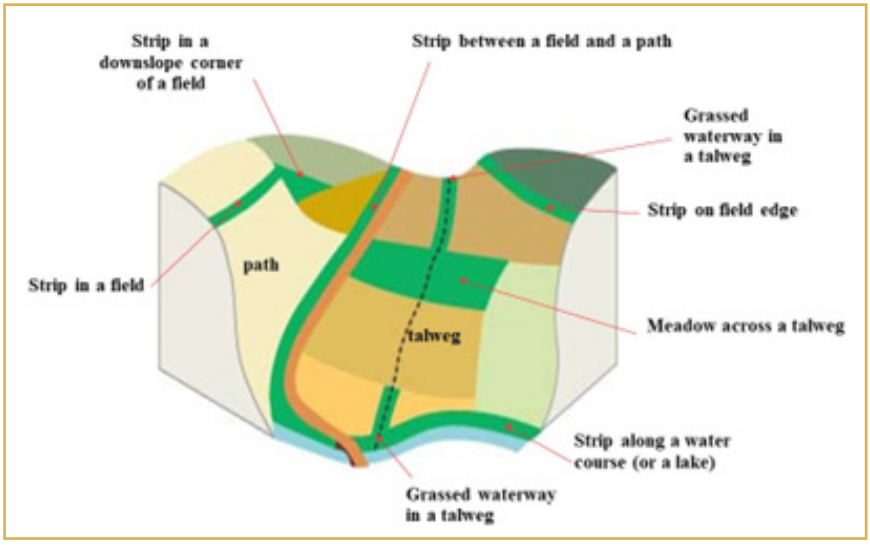

Figure 76. Vegetative field margins location. Source: Topps Prowadis project.

The most common locations for these margins are:

- **On the field edge**. Sowing a small strip of vegetation between different plots or farms to prevent the transfer of sediment and pollutants from one plot to another.
- **Along a water course**. This prevents runoff water that may be contaminated by agrochemicals and sediment from flowing into surface watercourses.

Size

The width and length of a vegetative field margin can influence the environmental benefits that can be achieved. That is why different strip sizes are specified for different purposes For example, assuming that the rate of sediment removal from runoff is proportional to the length of the vegetated margin through which it travels, the wider the margin, the greater the environmental benefit. However, the size of a margin will also affect the amount of agricultural land that must be

taken out of production, increasing the loss of income for the farmer and the level of funding.

If the objective of introducing a vegetated buffer is to avoid contamination of surface water by pesticides, the size of the buffer zones should depend on their soil characteristics and pesticide properties, as well as on the agricultural characteristics of the areas concerned. However, it is recommended to maintain a buffer of at least 5 m width along the river bank.

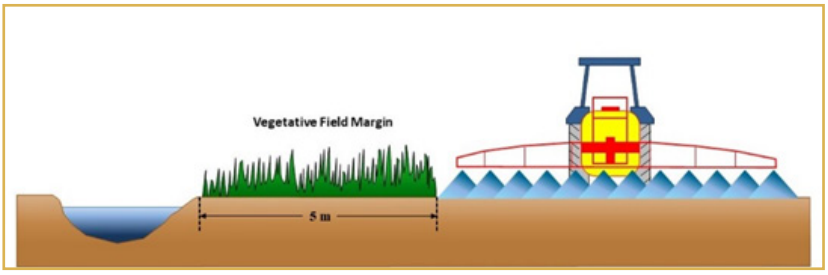

Figure 77. Vegetative field margins size to avoid transfer of pollutants to surface water. Source: Topps Prowadis project.

If we consider introducing the vegetative margin to control the transfer of pollutants and sediments between different plots, the width should be smaller. It should avoid losing too much arable land, so 1m width may be sufficient.

Finally, if the establishment of field margins is intended to create a habitat, should be taken into account whether that area should be distributed evenly across the landscape or concentrated in larger areas.

- **Selection of the species**

The other great factor to be taken into account is the type of species to be sowed in the vegetative margin. In order to choose the type of vegetation, it is necessary to consider the objectives for which the margin is planted, as well as the edaphoclimatic conditions of the location.

Different types of vegetative field margins can be implanted regarding the species

- **Spontaneous. Natural regeneration.** In this case, it will be necessary to maintain the spontaneous vegetation that emerges in the area where the margin is established. This alternative reduces the costs of margin establishment. Usually, it is necessary to do a light vertical tillage, before the emergence of

the margin, to avoid topsoil compaction, as well as to monitor frequently the margin status for mowing to control weeds.

Figure 78. Spontaneous-Natural regeneration vegetative field margin.

- **Sown Wildflower seed mixture**

The aim of this mixture is to create flower-rich areas that will provide valuable sources of food for invertebrates and birds, and greater diversity and structure of vegetation compared to grass-only areas.

For this type of margin, management becomes easier, due to the vegetation should be well known. It is important when selecting this type of margin to choose a good seeds mixture, ensuring that they are not invasive, that they are adapted to the area where the margin is planted and that they favour the biodiversity of the region.

Figure 79. -Sown Wildflower seed mixturevegetative field margin.

3-What should be considered when applying the BMP?

When introducing plant margins in the plots, the following aspects must be taken into account to avoid the fails:

- Remove any compaction in the topsoil to prepare a seedbed. This will ensure that the implementation of the margin is continuous and can offer the services for which this practice is introduced on the farm.
- Select non-invasive and local species.
- Do not use buffer strips for regular vehicular access, turning or storage. There should be no tracks or compacted areas. By avoiding compaction in these areas, we favour the improvement of soil structure, carbon sequestration and water retention in the soil.
- Do not apply any fertilisers or manures, as it is a non-productive area, it does not require management other than sowing and mowing.
- Avoid grazing to favour the maintenance of vegetation throughout the seasons.

4-What are the benefits in terms of sustainability (economic, environmental, social) by adopting the BMP?

The establishment of vegetation margins provides multiple benefits. From an environmental point of view, the implementation of this practice provides shelter for insects, birds, reptiles and other useful animals to reduce the incidence of pests. The diversity of plant species, mainly flowers (different colours and flowering times) and plants (annuals, perennials, thorny, etc.) favours pest control. Several studies from around the world show that the presence of flower strips in crop margins reduces pest incidence by an average of 16%.

Figure 80. Soil biodiversity in a vegetative field margin.

Likewise, as mentioned above, the vegetation cover provided by the introduction of vegetative margins favours the protection of the topsoil, preventing soil loss due to erosion and therefore the decline of organic matter. Finally, they are safer areas for fauna and flora than cultivated areas and facilitate the movement of organisms between semi-natural habitats. Connectivity improves the provision of ecosystem services at the agricultural and landscape levels.

Concerning social and economic benefits, the presence of vegetation margins improves the landscape of agricultural areas, making them attractive for tourists and promoting the development of rural areas.

Figure 81. Landscape with vegetative field margin. Source: ASAJA Sevilla.

5-What are the main constraints of introducing the BMP on the farm and how to solve them?

The implementation of margins has hardly any constraints since it is a practice that was used in the past and has been eliminated by the intensification of agriculture.

The biggest issue for the implementation of this practice is the farmers' perception. It may be thought that by introducing this tool in the field, crop area is lost and, therefore, the yield per hectare is lower. But this statement is not entirely true, since by favouring biodiversity in the field, we increase the ecosystemic benefits, and therefore the number of pollinators. Also, the incidence of pests is reduced, which minimises production losses due to other factors. So, therefore the production of the plots does not have to be affected. Increasing the knowledge and raising the awareness of farmers, technicians and advisors will avoid these possible production losses.

The other aspect to take into account is the election of the seed mixture to be introduced. In this case, as already mentioned, choosing local and not very invasive species is the key to success, as poor planning of the species to be introduced can affect the crop.

6-What are the frequently asked questions about BMP? Questions (Q) and Answers (A)

Q: Do weeds appear more frequently?

A: As long as the plant margin is properly managed and known seeds are used, there will be no weed problems.

Q: Does the risk of pests and diseases increase?

A: No. Over time, the incidence of pests and diseases decreases, because as biodiversity increases on the farm, there is a balance of populations that leads to fewer pests and diseases attacking the crop.

Q: Can this practice be introduced on all farms?

A: Yes, this good practice can be adopted wherever, although before implementation it is necessary to make a diagnosis of the farm in order to obtain the better results.

PART 3

INPUT OPTIMIZATION

COMPOSTING

1-What is it?

The organic fraction of municipal waste, therefore food residues, foliage, plants, grass, can be processed through the composting process, to give life to the compost. The practice of composting allows the preparation of a natural and environmentally friendly soil conditioner. It is a good example of circular economy.

Figure 82. The earthworm tanks in a composting plant. Here some of the phases of the composting process are taking place.

The practice allow introducing innovative technologies and, often, social innovation aspects, in order to transform waste into resource for farms and local communities.

It is a km 0 process that involves farms and local communities in the management of their organic waste, in order to produce compost to be allocated to agricultural activity. Farms can be involved in the process to treat their waste and those of neighboring communities.

The lack of specialized regional and local structures for managing, maintaining and expanding the use of electromechanical composters leads to considerable economic losses.

New experimental models allows us to double or triple the capacity of the electromechanical composter, thanks to combining it with earthworm cultivation, and facilitates the construction of new plants up to a capacity of 3000 t/ha.

It is a process that develops near the waste production site to transform organic waste into compost.Farmers can get together, invest together on the installation of the composter and produce compost to use together, regularly

introducing it into the practices of networks and groups of farmers. The same can be done by groups of citizens, condominiums, hotels, etc.

2 – How to do it?

As first step, we have to prepare a plan evaluating costs and advantages. To do that, we need to collect data and information (i.e. How many waste can we recover? How much soil is available? How much soil we would like to fertilize?).

Verifying the amount of waste that is produced and the land available also allows us to understand which legislation is covered and if there is a need for authorizations. Everything about authorizations and regulations depends on the different countries. In Italy, for example, the legislation is in the hands of the Ministry of the Environment and is therefore the same throughout the national territory. So, one of the preliminary steps is to check the necessary regulations and authorizations.

It will be necessary to consider having the necessary space available, not only for the composter, but also to accumulate and pack the compost.

Figure 83. The rendering of a composting plant

The plants also need a maneuvering area (especially if the plant requires the transfer by different producers, it is necessary), a canopy to cover the machinery and electrical parts.

In the composting process, the Californian red earthworms "Eisenia fetida", the most used species, can help us. The peculiarity of these wonderful annelids is that in addition to doing an excellent job in transforming organic waste into precious fertilizer, they multiply their population exponentially.

Figure 84. The compost produced at the end of the process. It is a good fertilizer

Outside the shed we have the earthworm tanks, which are covered and a container to collect the pruning waste that serves as a structuring structure. Also, we need a container to collect the mature compost. Certainly in the plant we need water and electricity.

The producer delivers the organic waste, which is weighed (and the loading-unloading registers compiled) and placed directly in the composter, which is started. The green waste is placed in the composter so that it balances the humidity of the organic waste, if it is in excess it is kept in the container for future needs.

For 30 days the organic waste completes its cycle and its treatment in the composter. It is taken out of the compost bin and placed in the earthworm tanks, where it remains for another 60 days. Periodically it will need to be moved and turned. After these additional 60 days we have the compost. The whole process lasts no less than 90 days. The compost is subjected to analysis, in order to be able to commercialize it. Californian earthworms feed on the waste that comes out of the compost bin after 30 days, they shape it and the earthworm manure is

further nutritious for the compost itself. The earthworm reproduce very quickly, allowing for sustainability after an initial investment.

Figure 85. The Californian red earthworms "Eisenia fetida" is the most used species in composting.

3-What should be considered when applying the BMP ?

When you start thinking about installing a composting plant, it is important to be aware of the starting costs and the initial investment require, as well as the management costs.

Among those, all the procedure to certify the formalities required by the legislation on waste management, which is usually accurate and complex, should be considered.

Then, the profitability of the plant should be estimated.

It is necessary to check the emissions into the atmosphere and carefully estimate all environmental impacts.

According to the combination of these parameter, it could be more convinient to have:

- A single system.
- A compost system.
- A composting network.

Figure 86. Different ways of installing a composting plant (a single system, a compost system, a composting network)

4-What are the benefits in terms of sustainability (economic, environmental, social) by adopting the BMP?

The problem of waste management continues to grow, creating both environmental, social, and economic concerns. At the same time, the composting processing can offer many benefits to farms and local communities, in terms of economic, envinronmental and social sustainability.

One of the benefit for the firms is the reduction of deliver costs of their waste: a firm, that has its own composting plant, can activate the self-composting process by itself, ensuring a certified supply chain of their agricultural products. It will be able to produce its own certified product with the use of totally natural fertilizers, with a very short supply chain.

The environmental innovation given by the on-site recovery of the organic fraction was the subject of study by the Department of Agro-Environmental and Territorial Sciences of the University of Bari Aldo Moro, which analyzed the environmental impact of the applied earthworm composting model in Melpignano, compared to other composting plants: an important fact that can be seen, among others, is that the Melpignano model produces 648.32 kg of CO_2 equivalent per ton treated, compared to other comparable plants in the bibliography that produce from 1,076 to 7,870,000 kg of CO_2 equivalent per ton.

Then, a firm can increase its green reputation and everything that can derive from it, in terms of visibility and marketing.

Composting represents a reduction of the organic waste problem right from the start: in fact, organic waste is not introduced into the collection cycle, but is eliminated beforehand.A firm can introduce another product to market by

selling compost which, with these characteristics, is very valuable and has a good value, especially if it comes from worm-composting.

An other positive impact is the reduction of transport times and costs of recovering organic waste, with a reduction of urban waste up to 40%.

Remaining on the environmental advantages, we can say with certainty that the use of compost limits the purchase of chemical fertilizers and special soils.

Compost is the first ally when you intend to embrace the causes of organic farming: in this case, in fact, compost is used as a bottom fertilizer for better plant nutrition. Compost proves useful for sowing and preparing lawns and for planting trees and shrubs or to keep the growth of weeds under control, favoring the control of the humidity level and the reintegration processes of organic substances.

Figure 87. The final result: the compost can be used as a bottom fertilizer for better plant nutrition

The compost is not properly a fertilizer, it is a "soil conditioner". This means those natural substances which, when mixed in the soil of flower beds and gardens, improve their physical and chemical characteristics. In particular, they stimulate bacterial activity, increase fertility and also the amount of water retained by the soil is greater. If integrated into exhausted or over-exploited soils, they regenerate its endowment by bringing mineral elements and excellent organic matter. The compost is a soil conditioner, because it becomes an integral part of the soil, but it also has fertilizing properties, that is, it provides nutrients in good quantity and in excellent variety.

Composting responds to the growing depletion of the soil in organic matter: the compost obtained from the biological treatment of organic waste is a renewable organic soil conditioner characterized by a good average content of organic carbon (25-27%).

Its use can therefore give a good contribution to restore the organic substance content in depleted soils or simply to mitigate the phenomena of organic carbon loss. We can say that composting helps in fighting agaist desertification.

Finally, lets'go into social impacts. Community composting can be a good practice to develop the responsibility of individual citizens, developing a different view of waste in general, not just organic waste.

Figure 88. An example of participatory process managed in local communities to lead the citizens activation and responsibility in promoting circular economy

If the composting is implemented at a municipality level, involving citizens, we can appreciate the effectiveness of participatory processes and practices of community composting to solve a common demand of bio-waste management.

The community composting model reduces the environmental impact, expressed as carbon footprint, respect to alternative landfill or incinerator scenarios, ensures the economic sustainability, also taking into account the possibility to obtain a compost appreciated by the market, meanwhile the social acceptability resulted strongly influenced by the level of information and knowledge of community.

Citizens are involved since the beginning of the process and learn to actively participate and contribute. They can use the compost for their gardens as well. The local system becomes the fulcrum of social activation.

The same participatory model can be obtained in a cooperative of farmes, for example, where members can deliver their organic waste and get the compost for their firms.

Figure 89. Citizens are involved since the beginning of the process and learn to actively participate and contribute. The local composting system becomes the fulcrum of social activation.

5-What are the main constrains of introducing the BMP on farm and how to solve them?

A first constrains, as mentioned before, is that the authorization process can be long. To manage that, you need to have a very extensive knowledge of the legislative framework of the country you are working on.

New skills need to be created: it is difficult to find people already skilled in these new jobs, and often the connection with vocational schools and Universities is not so strict. for that reasons, a long and intense training is needed, and the staff involvement is very important to build up an effective process. The main required skills are connected to the knowlede of the composting machinery and its tecnology (very often it is a recent and innovative technology), to be ready and effective in urgent interventions to be carried out on the machine.

Another constrains – that can be read as an opportunity, too – is that plants could be authomated: after a good initial investment, the automation allows us to monitor any alert situation since the beginning, – For example, if the composter slows down because the waste is heavy, you can intervene from a distance by reading the data coming from the sensors. This is important in terms of investment (we intervene on site only when necessary, saving time, work, fuel for frequent trips).

Last but not least, the relation with the local community is very important: if citizens are not engaged in the process and cannot properly identify their advantages in contributing to a compost processing, the situation could become diffocult to manage and for sure this will cause problems and limit the development and effectiveness of the project.

6-What are the frequently asked questions about BMP? Questions (Q) and Answers (A)

The most frequently asked questions concern:

Q: Bad smells (Does the plant produce bad smells that can be annoying for those who live nearby?)

A: The composting plant does not give off bad smells: the phase that presents a high odor risk takes place inside the composter, which is closed in depression. The composters are equipped with a forced ventilation system which allows a high fermentation and controls the odor risk.

Q: Economic sustainability of the model (How is it supported economically? How does the business model work?)

A: In the event that the plant is managed by a Public Administration, it is supported by the payment of the contribution fee by the citizens or everyone who uses the plant. Furthermore, a high saving is achieved compared to the usual management models due to the absence of transport costs, because the organic waste is not transferred outside the area.

In case the plant is managed by a firm, the savings come from:

- Cancellation of transport and logistic costs, and of the fee that is necessary for dismissing the organic waste
- Reduction of the expenditure incurred for the waste tax, by practicing self-composting (if required by national legislation, as occurs in Italy)
- Sale of compost, a product used as a soil improver, to other firms.

: The compost quality (Is it a good compost? How can you get a good compost? Is it difficult?)?)

A: A good quality compost is obtained with an organic fraction cleaned from extraneous parts. It is important to respect the times of the process and the balance between the phase inside the composter and that which takes place in the earthworm tank (the compost must not be removed too early from the composter, and should stay about 60 days in the composter and 30 days in the earthworm tank).

An other factor is the right dosage of the structuring fraction, the dry organic fraction (which must be a percentage of 25% of the organic matter delivered). For a quality compost, the maturation phase in earthworm farming is also important: it balances the carbon-nitrogen ratio, which is essential for the compost to provide nutrients to the soil and therefore effectively be a soil improver.

An example of compost analysis (by Innovaction Coop):

Prove Metodo	Risultato	U.M.	Incertezza / intervallo di confidenza (K=2)	Limite D.Lgs 75/2010
Ammendante compostato misto				
Carbonio umico e fulvico UNI 10780:1998 App F	7,91	% s.s.		≥7
* Densità (peso specifico) CNR IRSA 3 Q 64 Vol 2	0,550	Kg/m³		
* Inerti litoidi (ø>5mm) ANPA 4 Man 3 2001	< 5,0	% s.s.		≤5
* Materiale plastico,vetro,metalli (ø>2mm) ANPA 4 Man 3 2001	< 0,50	% s.s.		≤0,5
pH ANPA 8 Man 3 2001	8,25	Unità pH		6,0-8,8
Rapporto Azoto organico/Azoto totale Anpa 13 Man 3 2001 + Anpa 14 Man 3 2001	98,5	%	± 9,8	

Ammendante compostato misto				
Rapporto Carbonio/Azoto (C/N) UNI 10780:1998 App E + ANPA 13 Man 3 2001	12,6			≤25
Salinità ANPA 9 Man 3 2001	54,4	meq/100 g	± 5,4	
Umidità* UNI 10780:1998 App C 1	39,6	%		≤50
* **Conducibilità** ANPA 9 Man 3 2001	2630	µS/cm		
Azoto organico ANPA 14 Man 3 2001	3,16	% s.s.	± 0,32	
Azoto ammoniacale ANPA 14.2.4.2 Man 3 2001	0,0470	% s.s.	± 0,0047	
Azoto totale ANPA 13 Man 3 2001	3,21	% s.s.	± 0,32	
Carbonio organico totale (TOC) UNI 10780:1998 App E punto 6.1	40,6	% s.s.		≥20
Cadmio (come Cd) UNI EN 13650:2002 + UNI EN ISO 11885:2009	< 1,0	mg/kg s.s.		
Cromo (come Cr) UNI EN 13650:2002 + UNI EN ISO 11885:2009	< 10	mg/kg s.s.		
Cromo VI (come Cr) ANPA 16 Man 3 2001	< 0,50	mg/kg s.s.		
Fosforo totale (come P) UNI EN 13650:2002 + UNI EN ISO 11885:2009	10900	mg/kg s.s.	± 2200	
* **Mercurio (come Hg)** UNI EN 13650:2002 + UNI EN ISO 11885:2009	< 1,0	mg/kg s.s.		
Nichel (come Ni) UNI EN 13650:2002 + UNI EN ISO 11885:2009	374	mg/kg s.s.	± 75	
Piombo (come Pb) UNI EN 13650:2002 + UNI EN ISO 11885:2009	1210	mg/kg s.s.	± 240	
Potassio (come K) UNI EN 13650:2002 + UNI EN ISO 11885:2009	29900	mg/kg s.s.	± 6000	
Rame (come Cu) UNI EN 13650:2002 + UNI EN ISO 11885:2009	150	mg/kg s.s.	± 30	
Sodio (come Na) UNI EN 13650:2002 + UNI EN ISO 11885:2009	16000	mg/kg s.s.	± 4000	
Tallio (come Tl) UNI EN 13650:2002 + UNI EN ISO 11885:2009	< 1,0	mg/kg s.s.		

PRECISION FARMING: VARIABLE APPLICATION

1-What is it?

The official definition of Precision Farming or Precision Agriculture given by ISPA, International Society of Precision Agriculture, is the following: Precision Agriculture (PA) is a management strategy that gathers, processes and analyses temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production.

To better understand this concept, the PA cycle must be described:

1. Acquisition of data on soil, crop, climate...by means of sensors, sampling, et-cetera.
2. Interpretation of the data collected to make decisions. To do this, it is important to analyse and process the data using specialised software and generate an application model.
3. Application of the model to our farm. Whether in soil management, irrigation, fertilisation or staff hiring, for example.

PA is an additional tool for on-site decision making, allowing variable dosing of fertilisers, pesticides and seed, optimising agricultural production. Application rates can be adjusted according to soil potential, harvest data from the previous years and crop vigour observed from aerial or satellite images. PA is the result of smart farming, which is a general notion for adopting information

communication technologies (ICT) and other cutting-edge innovations in farming activities to increase efficiency and efficacy. Creating synergies between digital technologies, such as many keyword co-occurrence networks (Internet of Things, Big Data, artificial intelligence, robotics), which leads to a precise and timely analysis of data. We call this a digitalisation process in a sustainable agri-food sector.

What is VRA? VRA is an abbreviation for variable rate application, which is a method of applying varying rates of inputs in appropriate zones throughout a field. The goals of VRA are to maximize profit to its fullest potential, create efficiencies in input application, and ensure sustainability and environmental safety (Grisso et al., 2011).

2 – How to do it?

To understand precision farming, we must be clear about three concepts that are somehow included in the Fig. 90, in order to apply the specific technological tools in an optimal way to a real problem.

- Variable operation: technologies that allow agricultural inputs to be distributed differently to adapt to the state of the crop or the soil throughout the farm.
- Mapping: technologies that make possible to geolocate and stored information in real time by the machine or devices attached to it relating to different aspects of the work performed.
- Communication: technologies that allow a tractor to communicate with other machines and/or software from the same or other manufacturers, by means of wire or wirelessly.

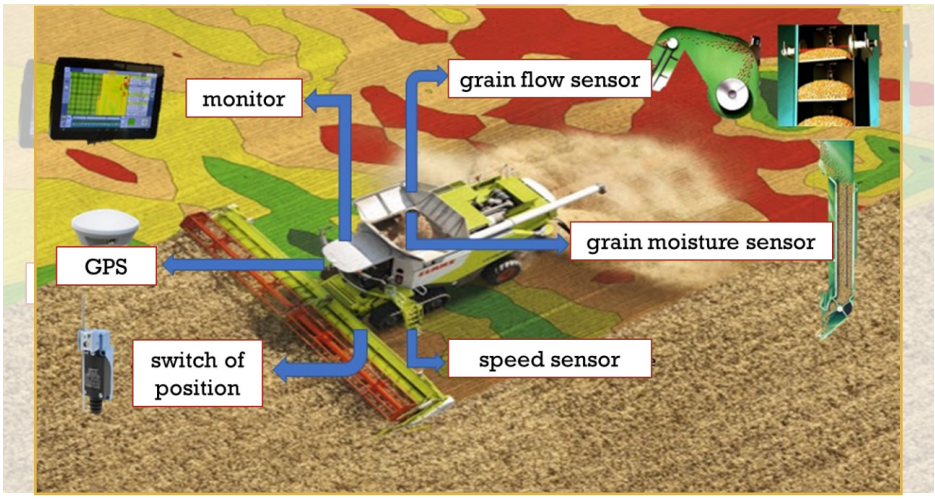

Figure 90. Precision farming concepts

Technological innovations in agriculture are advancing day by day, and different sensors can be found in the market. These sensors are coupled to the tractor or to the machinery used for the agricultural work. For instance, optical sensors used to manage spatial variability through an automatic spraying system that applies herbicide when it detects the weeds, the so-called weedseekers. Fig. 91 shows variable distribution of herbicide application under the canopy of super-intensive olive groves. The herbicide applied was reduced by 90% (Vantage Iberia Occidental, 2021).

Figure 91. Weedseeker in super-intensive olive groves

Furthermore, some solid or liquid fertiliser spreaders have optical sensors on the front of the tractor to photograph the crop or the soil and apply a variable dose of fertiliser according to the needs at a specific point (Fig. 92).

Figure 92. Optical sensors on the front of the tractor

The above examples of variable application are complementary to prescriptive maps that are created on the basis of a data package. This is another way of generating data, prescriptive maps determined by new innovations applied to agricultural machinery, such as the system for weighing and analysis of harvested cereal grains in situ on harvesters or the magnetic resonance tester to determine the electrical conductivity of the soil (Fig. 93).

Figure 93. Harvesting map

All these technological tools and many others currently available are not useful without a subsequent interpretation of the data collected. This requires previous knowledge of agronomy, computer science and statistics in order to process the information with the use of specific software.

Geostatistical applications are used to obtain maps of spatial variability of soil characteristics, crop condition, crop yields, etc.

Three examples are shown below. The Fig. 94 refers to an NDVI map, that determines the spatial vigour based on the photosynthetic activity of the crop at a specific moment. Secondly, a series of soil maps (Fig. 95) show the apparent electrical conductivity at different soil depths. And finally, a series of yield maps are shown (Fig. 96), after harvesting oilseed rape, wheat and sunflower from the same farm in different years.

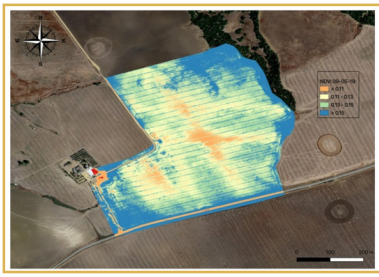

Figure 94. NVDI map.

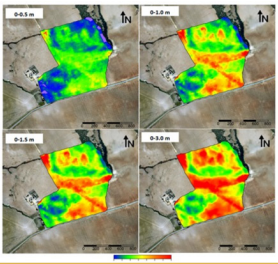

Figure 95. Apparent electrical conducvitiy map.

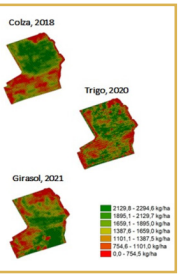

Figure 96. Yield map.

There are automatic guidance systems and application control by GNSS (Global Navigation Satellite System) to reach greater uniformity in the machinery operations. There are the so-called smart tractors, which have GNSS receivers, monitors, PCs, sensors... All this provide the location coordinates of the machine and its actual speed.

Agricultural machinery is becoming more professional and the ISOBUS standard is facilitating the connection and communication between tractors and implements (Fig. 97). ISOBUS (ISO 11783) is a serial communication protocol for agricultural and forestry machinery based on the SAE J1939 protocol, which also includes the CAN-Bus protocol. ISOBUS allows easy communication between tractor and implement that, in other case, could not be connected because they would be using different languages.

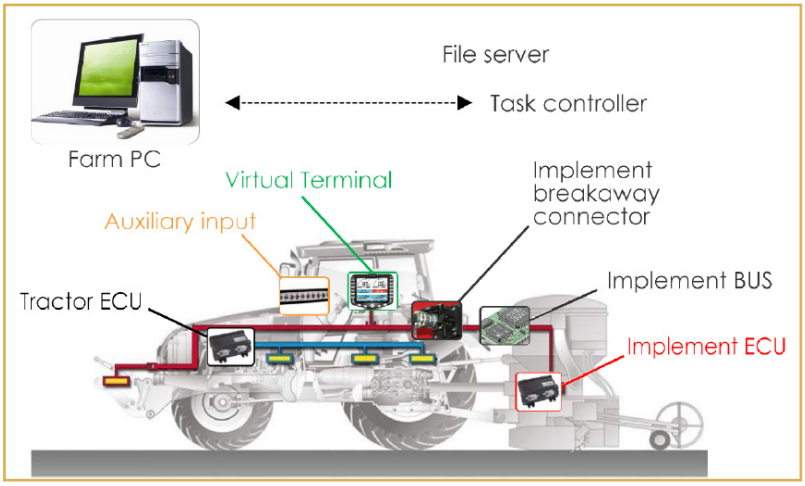

Figure 97. The ISOBUS technology

These location and speed data are interpreted by algorithms imposed thanks to the previous interpretation of data. These data are recapitulated with the optimal sensors and the prescriptive maps, in order to regulate the output flow of the product that is being applied in this agricultural operation. Therefore, the dose applied to the soil or crop is optimal, achieving greater precision than uniform application systems.

3-What should be considered when applying the BMP?

- Soil and climate variability on a farm.
- Investment cost of machinery.
- Orography of the farm.
- Specific machinery to support agricultural operations.
- The area of the farm in order to buy own machines or consider services providers.
- Type of crop.

Precision farming entails having a complete farm management system based on data and translated into actionable information with the new technologies. All the variables shown in the Fig. 98 must be considered in order to have an exhaustive control of the farm and to carry out a variable application of a chemical product in the most optimal and efficient way thanks to precision agriculture. It

is also necessary to take into account the training of the personnel who interpret the data and the information from prescriptive maps, doses, chemical products, dates and methods of application.

Soil	Plant	Climate	Other
• Moisture • pH • Nutrient • CEa	• Height • Growing	• Temperature • Moisture • Light • ETo	• Machinery • Irrigation

Figure 98. Farm Management Information System.

Precision agriculture gives us an answer to all the problems or challenges we face in the agricultural sector, especially in farms where, as we have already seen, there is a great variability of soil.

Fig. 99 shows 3 examples of variable application. Variable fertilisation can be applied depending on the vigour of the crop. It can carry out Variable sowing can be carried out depending on the characteristics of the soil. This possibility, together with Conservation Agriculture, allows an average energy saving of 20% in arable crops (Factsheet 3, 2022). In addition, variable herbicide application can be conducted, saving up to 60% (Factsheet 3, 2022).

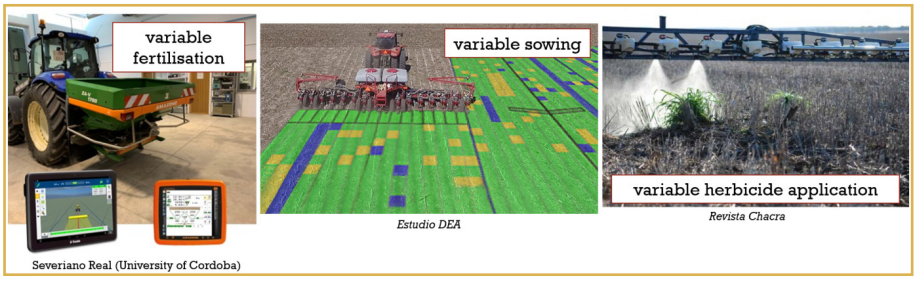

Fig. 99. Examples of variable application.

4-What are the benefits in terms of sustainability (economic, environmental, social) by adopting the BMP?

Economic

- Increased profitability
- Cost optimization
- Working time reduced (overlaps)

The following Table 5 shows the differences in overlaps between conventional agriculture and precision farming. Reducing overlaps by 30% thanks to precision agriculture in annual crops (Factsheet 3, 2022).

Table 7. Fuel and overlaps in different soil management and farming operation (Factsheet 3, 2022).

Conventional		Agriculture	Precision	
Fuel (l/ha)	Overlaps	**Farming operation**	Fuel (l/ha)	Overlaps
6,0±1,6	8,4±7,0	**Seeding**	7,7±1,0	5,5±5,9
1,1±0,4	12,7±9,7	**Pesticide treatments**	1,1±0,3	7,4±7,2
0,9±0,5	14,7±9,7	**Fertilisation**	0,9±0,4	5,5±3,6
10,0±0,7	-	**Harvestering**	11,4±0,9	-

Environmental

- Reduced soil compaction (trafficability).
- Reduced CO_2 emissions.
- Water use efficiency.
- Energy efficiency and saving.

Taking into account the main agricultural tasks in annual crops, the energy is reduced by applying precision farming by 35% in seeding, 63% in pesticide treatments and 42% fertilisation (Factsheet 5, 2022).

Social

Technological innovations applied to the agricultural sector entail a professionalisation of the entire agri-food chain, giving added value to products and therefore greater product traceability. This results in greater sanitary control of the products and therefore greater safety for consumers. Furthermore, technological innovations in agriculture make it more attractive for young users, helping fix population in the rural environment and supporting the generational change.

5-What are the main constrains of introducing the BMP on farm and how to solve them?

Firstly, the acquisition of the machinery and technological tools mentioned above entails a very high initial financial investment, which is difficult to afford for an individual farmer. This is logical for small farmers, but in many cases, it is not profitable to make this economic investment on large estates either. On the other hand, in order to use this machinery, specialised and trained personnel are needed. Thus it is important to create farmers' associations and share costs as well as to turn to external service companies that carry out specialised work with qualified personnel. In the short-medium term, this would be the most appropriate business model.

Secondly, it should be borne in mind that for many of these technological tools to work on farms, a network connection is necessary. Interference-free mobile connectivity is essential for a connection between the machinery and the farmer. Therefore, the problem of many rural areas where mobile connectivity is not available needs to be solved. In these rural areas where it is still impossible to reach with a mobile connection, there are advances in remote satellite connections, making it possible to carry out self-guided cereal sowing.

In short, the implementation of precision agriculture, or what is now known as digital agriculture, has one major premise: it needs professionals trained in the new technological tools so that farmers should be trained through courses and workshops, for example. This knowledge will be transmitted between farmers, but always with a recommendation: there must be a specialised technician, which in this case could be an agronomist.

6-What are the frequently asked questions about BMP? Questions (Q) and Answers (A)

Q: How much does precision agriculture cost?

A: It does not have a defined price, it is in accordance with the machinery to be implemented, which in turn depends on the agricultural operation to be carried out. Currently, this is constantly changing, so technology must be acquired according to the characteristics of each farmer's needs.

Q: Can the principles of precision agriculture be applied to all productive agricultural area?

A: Yes, because it has a wide variety of technological tools and new innovations that can be implemented according to the characteristics of each farmer. Each one of them being precise according to the evolution of its study and application.

Q: What do farmers need to consider making proper decisions about new equipment and technologies?

A: First, let yourself be listened to by a professional, such as an agronomist, and then adapt your needs to the technological tools offered by the PA. Always prioritising their profitability and taking as a starting point the existence of service companies that can carry out this work without having to acquire this high value machinery on their own.

Q: How does VRA increase economic potential?

A: VRA increases your economic return by strategically optimizing inputs in each management zone. VRA allows you to focus inputs on management zones that provide the highest return, while reducing inputs in lower productivity zones or where previous management has resulted in a situation for reduced input need.

AUTONOMOUS FIELD ROBOTS

1-What are autonomous field robots?

Typically, field robots mean that a vehicle moves autonomously in the field. Not the human being, but the system takes over the control of the processes and reacts flexibly to its This solution for robotic mechanical weed control is a dynamically configured team of weeder bots, and automated maintenance barns for persistent autonomous weed control, leveraging collaboration, and local and remote data sources.environment. This is now seen as an autonomous decision.

Figure 100. Small Weeding Robot between Maize rows

Autonomous field robots do cultivating and weeding for example on vegetable crops and corn.They can work on multiple types of crops. They are working fully electric powered by lithium batteries that you charge or they are charged by a solar panel system. Their work output is approxomately 4ha /day 8-10 hour, depending on soil conditions. They are guided by GPS-RTK, that gives a really good precision, centimetrie precision. Most of the robots are equiped by an additional camera guided system. Tools are guided by a camera, that gives a really good precision and the possibility to go really close to the plants.

Figure 101. Batterie powered autonomous weeding robot

2 – How to do it?

Depending on the areas of application of field robots, two systems differ, but they can also be combined: On the one hand, there are brands that use global satellite navigation systems (GNSS) for lane guidance and navigation. With Real Time Kinematics (RTK), the robots can move fully autonomously in the field.

To do this, the robots only need to know the field boundaries and obstacles. They calculate the lane and the driving pattern on the surface independently based on defined row and plant distances. Such robots can be used for sowing and mechanical weed control. The advantage of this system is that the robots record the position of the individual grain and thus know where the crops are located due to the stored sowing pattern. This makes it possible to chop weeds even before the plants germinate. At the same time, hacking within the rows is also possible.

Figure 102. Solar powered autonomous field robot

Robots also work actively at night

Another advantage of the GNSS system is that the robots can also work at night. The prerequisite for this is an appropriate energy supply, which can be secured, for example, by a sustainable photovoltaic module on the device including batteries. However, most marketable robots have a gasoline engine that drives a generator. Refilling is an advantage over models that can only fully charge their batteries when the sun is shining. In addition to GNSS-controlled devices, there are also field robots that move along the rows of plants using intelligent camera systems. For this purpose, it is necessary that they drive the entire length of the field and the headland on the field once before their use. This is usually done by remote control by the farmer. Since the robots only travel at speeds of around 1 km/h, this is very time-consuming. The advantage, however, is that any field can be cultivated, no matter how the seed was grown. At the same time, the systems can recognize individual plants, which allows weeds to be specifically controlled. Navigation using ultrasound or buttons works similarly.

3-What should be considered when applying the BMP ?

Field robots move forward fastest in a straight and flat row. “The field pieces should not be too small, as the robots lose a lot of time for turning. At around 750 m/h and a working width of 3 m, a robot needs about five to six hours for one hectare,” explains Handler, adding that the slow speed serves safety. In addition, not all robots could drive bows. This must be considered when creating the plant rows.

Another hurdle for the autonomous helpers is the slope: As soon as it rises to over 10%, many field robots no longer manage to continue driving – there is a risk that they will get stuck or lose track. The farmer then must intervene and restart the robots or get them back on track. Since a malfunction can occur at any time, farmers must always be on call to fix it. “The robots report errors or malfunctions to the farmers via SMS or e-mail. Therefore, it is a basic requirement that there is a good Internet and network connection in the fields,” explains Handler. The built-in sensors also detect when an unknown object appears. Then the robots stop immediately. The same thing happens when they cross the predefined border. The manufacturers guarantee that the robots pose no danger via a security seal. The logistics for the field robots should also not be underestimated.

Especially with small fields, it is usually time-consuming for farmers to transport the robot from one field to the next. They are not allowed to drive on public roads.

Agricultural robots pay off

Depending on the type, field robots cost up to around 150,000 euros, larger models over 200,000 euros. In addition to the investment costs, there are also ongoing costs such as Internet fees and maintenance costs. However, field robots pay off relatively quickly if labor can be saved. Targeted support measures would also give a boost to development. The fact that there has not yet been a very high demand is due to the fact that the technology is still under development and some teething troubles still have to be eliminated. Above all, there is a lack of experience with the systems. It will certainly take a few more years until the

technology will be on the road trouble-free and error-free on domestic arable land. If the robots run smoothly, autonomous field robotics will be a technique that will sooner or later be part of agricultural practice.

4-What are the benefits in terms of sustainability (economic, environmental, social) by adopting the BMP?

The advantages of field robots are just as diverse as their possible variations. The collaboration of several robots simultaneously in the field not only provides a solution to the problem of labor shortages in the industry, but also enables long-term planning and predictable yields through information about the soil, plants, and temperature values. For example, while one platform measures and determines individual plants, the other robot analyzes the data of the first and outputs, for example, a corresponding amount of water for each individual plant. In this way, individual plants can be measured individually, and their state of health and growth determined. In practice, this means saving resources and securing the yield through individual care of the plants.

Economically:

- Increase in overall productivity.
- OEE (overall equipment effectiveness) – there is added value in terms of performance, quality, availability.
- Saves time, working time is a scarce commodity.
- Better adaptation to the products.

Environmentally:

- Less weight-less soil compaction.
- Solution against resistant weed problem.
- Less/No herbicides.

Social:

- Need of qualified staff rises – Farmjobs become more attractive.

https://www.youtube.com/watch?v=ffr8iDicY9I.

5-What are the main constrains of introducing the BMP on farm and how to solve them?

The potential is promising autonomous field robots could counteract the shortage of skilled workers in agriculture by performing labor-intensive activities such as manual hoeing by robots. Soil compaction could be reduced by using many, lighter machines. The application of pesticides could also be reduced – not to mention the labor savings in organic farming in weed control. This could also significantly improve the image of agriculture in terms of the biodiversity crisis. But there are also some concerns about innovation: field robots could lead to an alienation of farmers and a greater dependence on manufacturers. The economic efficiency for different regions and operating models has not yet been sufficiently investigated. In addition, it is questionable how social acceptance of this potentially disruptive technology stands. Above all, however, it is important to clarify: What about the acceptance of practical farmers? Where do they see the advantages and disadvantages and how do they see the perspective?

Concerns on the part of practitioners are, for example, the high acquisition costs, so it is recommended to calculate in advance when the device will pay for itself. Furthermore, the development has not yet progressed so far that the autonomous field robots can be used on all plantations. Higher deployment numbers and production figures require a higher number of trained service personnel, so new specialists must be trained to ensure continuous deployment. In the same way, Europe-wide deployment requires a uniform Europe-wide legal framework.

6-What are the frequently asked questions about BMP? Questions (🌍) and Answers (A)

🌍: More efficient work through robots?

A: Ultimately, economic efficiency will determine how quickly robotics will conquer the fields. In terms of costs, the savings for cab, suspension, work light and operation are offset by the additional effort for redundant control systems and collision avoidance. At the same time, of course, the higher utilization rate

must be considered, because a robot does not need breaks, only the refilling of the operating materials and the daily maintenance prevent a 24/7 use. Setting the course at an early stage to maintain a large degree of competence in agriculture is essential for value creation at the grassroots level.

: Autonomous technology: What about legal approval?

A: Like a bang, the latest announcement from John Deere at the beginning of January caused a sensation. The company unveiled the autonomous 8R tractor at the CES technology show in Las Vegas and announced the launch of sales for America later this year. According to John Deere, a sale in Europe is currently not planned for safety reasons. A key issue for autonomous machine concepts therefore remains the legal approval, both in the field and for road transport. According to the European Machinery Directive, a hazard must be reliably excluded. For an unattended machine in the field, manufacturers therefore require a complex safety system and, in addition, travel speed, drive power and operating weight are limited.

OPTIMISATION OF PESTICIDES

1-What is it?

Pesticides/herbicides use in agriculture is very common to increase production and ensure sufficient high quality affordable food for the growing population. These pesticides are mostly produced synthetically and like almost all chemicals pose a potential risk to human health and the environment. The use of pesticide is needed in most of agricultural systems. New pesticides are being introduced continuously with improved properties, especially for selective use and less negative impacts.

Spraying is a common way of introducing pesticides over large areas of land, most of which can be carried away by wind, water runoff, and erosion, and thus up to 95% of herbicides and over 98% of insecticides may not reach their targets (weeds/pests) (The Environmental Impact of Pesticides, 2022). Although some of these herbicides can be degraded naturally in the soil, many of them are not easily degraded and remain in the environment for extended periods of time (Youssef, 2019). Pesticides and other products of daily use have been detected in surface/ground water. Irrigation and rainfall also facilitate transportation of pesticides into water streams especially those which are soluble (Sharma et al., 2019). Pesticides use is crucial in modern agriculture for food security, there would be a substantial loss of agricultural products without a proper use and management of pesticides.

Sometimes, pesticides, as well as fertilisers, are utilized in crop production more than the required amount. High quantities or concentrations can cause water pollution in croplands. The excess of chemical product remains in soil particles initially but, finally, it is washed off the soil during irrigation or by precipitation, finding their way to water resources.

Pesticides are classified in three categories: insecticide, herbicide, fungicide. More research to optimize the process for an effective, feasible, and environmentally friendly treatment is needed. Optimisation in the application is therefore as important as their chemical formulation. In this regard, an exhaustive control of the way of application and the spraying equipment should be conducted.

Figure 103. Fungicide application.

2 – How to do it?

There are several ways to carry out pesticide optimisation on a farm, they are largely related to the cropping system and the soil management techniques, such as Conservation Agriculture. When we talk about pesticides, foliar application, soil application or through irrigation water are being considered.

Regarding weed control, some agricultural practices should be taken into account to make possible a preventive weed management:

- Planting crop seeds that are not contaminated with weed seeds (certified seeds).
- Use of irrigation water free of weed seeds (control of water source).
- Curing manure and compost to avoid spreading weeds when fertilizing.
- Removing weeds from the edges of crop fields.
- Establishment of seeded (with appropriate species) field margins (see BMP 'Vegetative Field Margins').
- Controlling weeds before they set seeds and stop the spreading of perennial weeds.
- Ensuring that implements used in the fields are free of weed seeds.
- Crop rotations.
- Soil mulch cover (See BMP 'Permanent soil cover / straw management').
- Cover crops as green manure.
- Intercropping. For example, Maize cowpea intercropping as a weed management option (Fig. 104).

Figure 104. Maize-cowpea intercropping.

Furthermore, a complementary way for eliminating weeds is to use herbicides such as Glyphosate in an integrated weed management. Glyphosate is the most used herbicide to control almost all herbaceous weeds in pre-emergence. Under Conservation Agriculture systems, where tillage is limited for a better soil maintenance, it is basic to perform an accurate weed management using herbicides.

In order to use correctly herbicides, the product must be used efficiently by reading the label and applying the correct dose. The right machinery must be used and it should be correctly regulated. Understanding of the factors influencing spray drift of Plant Protection Products and what mitigation measures must be used to reduce it.

When pesticide treatment is carried out, both direct and indirect measures need to be taken. Direct measures focus on reducing product drift. About indirect measures, protected areas such as natural vegetation strips must be taken into account (Fig. 105). In addition, it is very important to consider the weather and environmental conditions in order to carry out a treatment.

Figure 105. Natural vegetation strip (buffer) as indirect measure

As far as possible, make use of new technological tools and agricultural innovations such as the use of GPS and sensor controlled sprayers, weed seeker for selective weed control (Fig. 106).

Figure 106. Sensor-based for spatial variability management

Attention should be also paid in the nozzles of the sprayer. They should work correctly and should be appropriated for the operation and product applied. The use of anti-drift nozzles is recommended (Fig. 107)

Figure 107. Comparison in the use of standard and anti-drift nozzles

3-What should be considered when applying the BMP?

Weeds compete for nutrients, water and light, so yields of the crop decrease. In addition, at harvesting the production is affected by reducing the quality of the grain and the machinery may be deteriorated.

Cultural practices that can be carried out without first applying chemical control include:

- Crop rotation to break weed life cycle.
- The more uniform the stubble distribution, the less annual weeds.
- Cover crops and groundcovers reduce weed impact.
- Choosing crops that compete better.
- Using weed-free seed and monitoring near weeds.
- Sowing in narrow strips (to shadow the soil sooner).
- Sowing date can be modified: seeding before the germination of annual late crops or seeding after the germination of annual early crops.

Weed control depends on pesticides and other management strategies. Use integrated weed management to reduce chemicals and optimise pesticides application. Develop a strategy to apply pesticides efficiently, considering adequate products and their calendar as well as the different pre-emergence and post-emergence treatments options.

The operator must possess appropriate knowledge of weeds, pests and diseases and their effect on crops to ensure selection of the most appropriate plant protection solution. It is important to take special care in the areas where plant protection products are managed, in order to reduce contamination risks. Appropriate procedure should be followed when cleaning tools and personal protective equipment, and when managing containers.

For a proper pesticides application other consideration should be taken into account:

- Wear appropriate clothing and equipment when working with pesticides.
- Rinse containers immediately after emptying because some pesticide residues will dry quickly and become difficult to remove.
- Never allow empty pesticide containers to accumulate where unauthorized people have access to them.
- The proper transportation and storage of pesticides and the proper rinsing and disposal of empty pesticides containers.

4-What are the benefits in terms of sustainability (economic, environmental, social) by adopting the BMP?

Economic

The correct use of Conservation Agriculture and the optimal application of chemicals thanks to new technology increases farm productivity. Inputs such as herbicides, fertilisers and fungicides are reduced.

Environmental

The optimization of pesticides has clear implications for the environment: reduction in the use of product that can be dangerous for the ecosystem and prevention of drift with a correct management.

Conservation Agriculture favours an optimised use of herbicides. When the 3 principles are in place: minimum soil disturbance, permanent soil cover and crop rotations and diversifications; some environmental advantages are put in place. Regarding weed control, these three principles act at different periods:

- Period before sowing: residue mulch is maintained after harvest, soil is not tilled and weeds are controlled before sowing
- Period pre-emergence: weeds are controlled for a longer period and without residual pesticides
- Period post-emergence: treatments applications up to crop needs and according to the manufacturer's recommendations

In no tillage, the seeds accumulate on the surface, so in the medium term, the pressure of weeds decreases in Conservation Agriculture compared to conventional tillage (Fig. 108) as most of weed seeds can be controlled. However, buried weed seeds can appear again to the surface with a new tillage pass, allowing their emergence. This makes weeds a never-ending issue under conventional tillage systems.

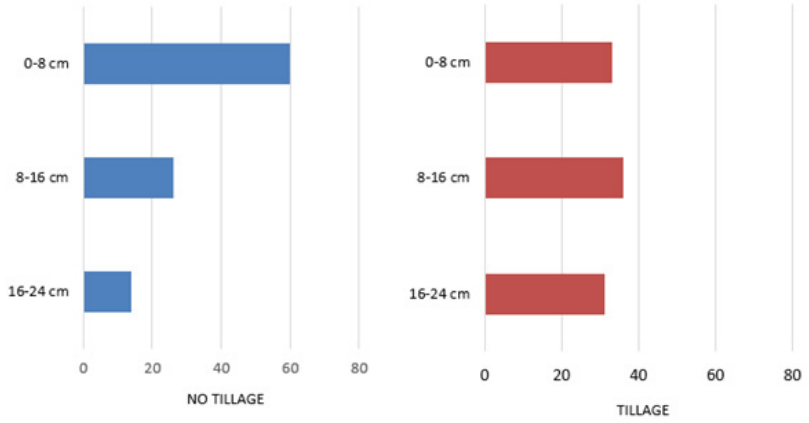

Figure 108. Effect of the pressure of weeds (Dorado et al., 1999).

The number of seedlings of weeds is reduced over time with the Conservation Agriculture (Fig. 109).

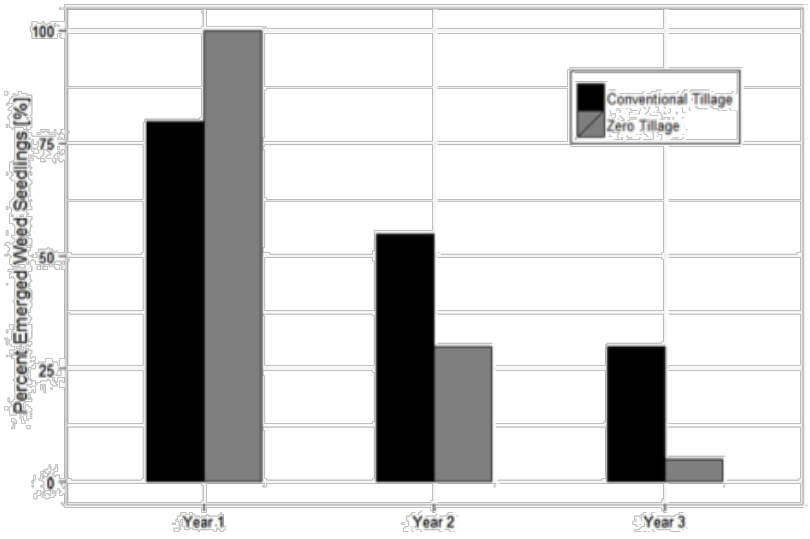

Figure 109. Theoretical effect of tillage on the number of seedlings of weeds assuming no seed bank replenishment (Nichols et al., 2015).

There is no seed dissemination or perennial vegetative structures redistribution (e.g. Rhizomes) under no tillage system.

Sustainability is achieved by combining good agricultural practices to reduce chemical drift and Conservation Agriculture. Thus biodiversity is protected as well as soil, water and air, the main supports of crops.

Social

Optimization of chemical input enhances agro-biodiversity, that is, habitats for birds, soil fauna, fauna over the soil and edaphic fauna; thus landscape diversity is improved proving ecosystem services such as pollination of crops. In addition it gives more opportunities for recreation as environment is protected and citizens are safer in these rural areas. This helps fix population in the rural environment maintaining the dynamic of this areas.

5-What are the main constrains of introducing the BMP on farm and how to solve them?

Under no tillage, the weed seeds remain in the surface. However, they are buried with tillage at different depths depending on the ploughing implement, it reduce the emergence in the short-term (although it is a never-ending issue in the medium-long term as those seeds can remain buried in dormancy). Therefore, in no tillage there would be a considerable weed seed bank at surface that could affect the production. Moreover weed seeds are also exposed to birds that spread seeds in the farm.

On the other hand, the mulch of harvest residues on surface blocks light and thus decrease seed germination what facilitates weeds to be controlled. Nevertheless, a proper no till seeder with cutting disc or coulter is needed for a successful direct sowing over residues.

With conservation agriculture the number of tillage operations is reduced. This could entail grasses or broad-leaf small-seed weed infestation.

Some recommendation or strategies to control weeds in no tillage systems:

- Keeping the soil covered by harvest residues.
- Direct sowing with a proper no till seeder.
- Crop rotations.
- Precise weed control that decreases annual weed seeds.
- Control pre-emergence weeds with a pre-emergence pesticide.
- Try to control weeds when weeds are young.

- Treat weeds when they are not covered by dew.
- Apply size-appropriate dose.

For an optimisation of pesticides training of the personnel for preparing the chemical solution and the calibration of the machinery are needed. In many regions/countries, a licence for agricultural chemical products treatments is mandatory. Training of users is a key point for pesticides optimization.

A significant constrain for the optimisation of pesticides is that many weed control strategies have to be changed as some plant protection products are forbidden. Again training of user as well as the appearance of new products are key to find solutions.

The use of chemicals can imply the appearance of resistances of weeds, pests and diseases. The use of different active substances together with genetic improvement is determinant as well as crop rotations.

The permanent training of user and combining good agricultural practices in addition to the optimized application of pesticides is crucial.

6-What are the frequently asked questions about BMP? Questions (Q) and Answers (A)

Q: What are the tips for a farmer doing Conservation Agriculture in the first year in woody crops?

A: Firstly, monitor weeds and their evolution over time and then use mechanical weeding machines to remove the weeds or where needed and possible use an initial spray of glyphosate.

Q: How much can the use of new technologies increase the cost for optimisation of pesticides?

A: Currently, the use of new technologies for pesticides optimisation is viable at long-term as use of chemicals are reduced and it would be amortisable. Many advances are being reached and progressively the new technologies are being more economical.

Q: How much is the use of pre-emergence herbicide in the different soil managements?

A: In no till systems the use of glyphosate is slightly higher but not significative (Fig. 110).

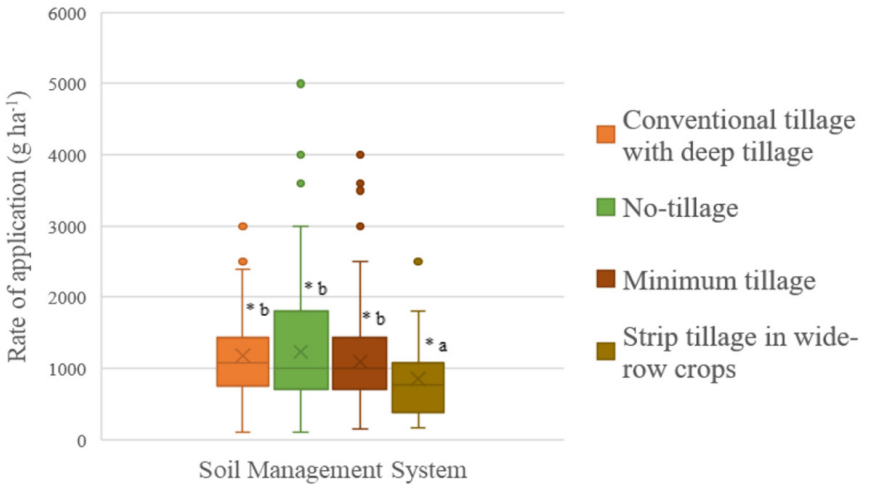

Figure 110. Use of Glyphosate. Source: Own elaboration based on the results of the survey on "Agricultural practices and the use of glyphosate" (ECAF, 2020).

REMOTE SENSING

1-What is it?

This BMP concern the use of satellite image in agricolture for crop and soil management.

There are many satellites that acquire multispectral images from space: the most common are **Sentinel-2** and **Landsat 8.**

The images obtained have a **spatial resolution** of a few meters: Landsat 8 provides data with a spatial resolution of 30 m, while Sentinel-2 of 10, 20 or 60 m.

The **temporal resolution** is in most cases regular. For example, Landsat 8 is available every 16 days, while Sentinel-2 is available every 3/5 days.

According to Ohio State University, "Remote sensed imagery can be used for **mapping soil properties, classification of crop species, detection of crop water stress, monitoring of weeds and crop diseases, and mapping of crop yield**.

There are different index that can be observed with satelite image that help us to achieve these goals.

The most used index are 8 wich describe **vigor of the plant**, providing a measure of its general health, or specific problems such as **water stress** or the amount of **chlorophyll.**

These index are called:

NDVI: The NDVI index detects and quantifies the presence of live green vegetation using this reflected light in the visible and near-infrared bands.

NDVI is an indicator of vegetation health based on how plants reflect certain ranges of the electromagnetic spectrum.

Cell structures in plants reflect the near-infrared (NIR) waves. So, when photosynthesis occurs, the plant develops and grows and contains more cell structures.

This means that a healthy plant—one with a lot of chlorophyll and cell structures—actively absorbs red light and reflects NIR. An unhealthy plant will do the exact opposite.

The value of the NDVI will always fall between – 1 and +1.

Values between – 1 and 0 indicate dead plants, or inorganic objects such as stones, roads, and houses.

NDVI values for live plants range between 0 to 1, with 1 being the healthiest and 0 being the least healthy.

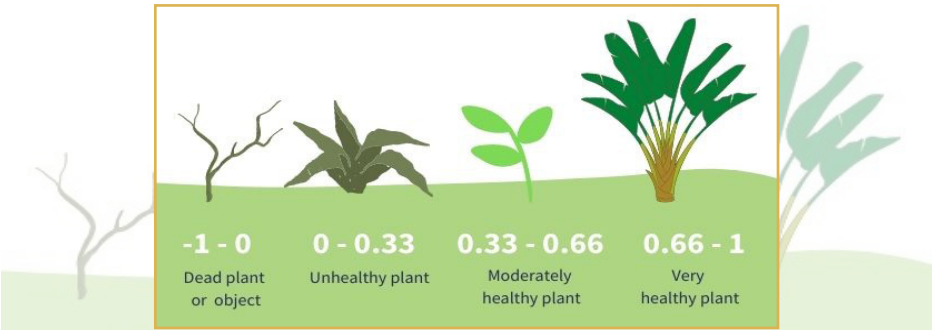

Figure 111. Explanation of ndvi index values.

GNDVI (Green-NDVI): The Green Normalized Difference Vegetation Index (GNDVI) method is **a vegetation index for estimating photo synthetic activity** and is a commonly used vegetation index to determine water and nitrogen uptake into the plant.

It provides an indication of the health of the vegetation and reduces the saturation effect when the vegetation is particularly developed.

As with NDVI, the values given by this index also range from – 1 to 1:

- Values between – 1 and 0: are associated with the presence of water or bare soil. This index is mainly used in the intermediate and final stages of the crop cycle.

GNDVI is the green vegetation index that uses the near infrared (NIR) and green band (GREEN) of the electromagnetic spectrum.

GNDVI is more sensitive to chlorophyll variation in the crop than NDVI and has a higher saturation point. It can be used in crops with dense canopies or in more advanced stages of development while NDVI is suitable for estimating crop vigor during the early stages.

Figure 112. Explanation of NIR index values

WDRVI: it analyzes the health of the vegetation and is particularly useful when the vegetation is well developed and lush and the other vegetation indices tend to saturate.

As NDVI his value is always beetwen –1 and 1: The first makes it clear that the ground is bare, the second indicates that the soil is covered and vegetation is well developed.

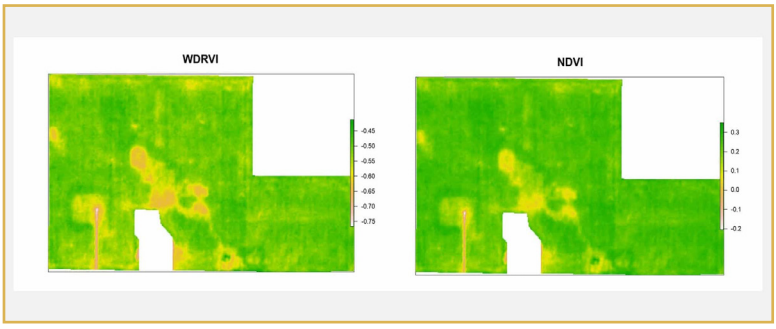

Figure 113. Index wdrvi and ndvi compared on the same field.

SAVI: The Soil-Adjusted Vegetation Index (SAVI) method is a vegetation index that attempts to minimize soil brightness influences using a soil-brightness correction factor. This is often used in arid regions where vegetative cover is low, and it outputs values between –1.0 and 1.0.

The difference beetwen NDVI and SAVI are the fact that **NDVI start saturating after the value of 0.7, while SAVI at this point is only 0.3**. This means that SAVI can be better used in dense vegetation because it saturates less fast.

NDMI: The Normalized Difference Moisture Index (NDMI) detects moisture levels in vegetation using a combination of near-infrared (NIR) and short-wave infrared (SWIR) spectral bands. It is a **reliable indicator of water stress in crops**.

Severe drought conditions not only stress the crops but can destroy the entire yield.

NDMI can *detect water stress* at an early stage, before the problem has gone out of hand. Further, using NDMI to *monitor irrigation* especially in areas where crops require more water than nature can supply, helps to significantly improve crop growth,

Like most indices, NDMI can only have values between –1 and 1, which makes it very easy to interpret. Water stress would be signalled by the negative *values* approaching – 1, while the +1 may indicate waterlogging. Therefore every value in between will correspond to a slightly different agronomic situation.

NDMI INTERPRETATION

- *-1 – –0.8 Bare soil,*
- *-0.8 – –0.6 Almost absent canopy cover,*
- *-0.6 – –0.4 Very low canopy cover,*
- *-0.4 – –0.2 Low canopy cover, dry or very low canopy cover, wet,*
- *-0.2 –0 Mid-low canopy cover, high water stress or low canopy cover, low water stress,*
- *0 – 0.2 Average canopy cover, high water stress or mid-low canopy cover, low water stress,*
- *0.2 – 0.4 Mid-high canopy cover, high water stress or average canopy cover, low water stress,*
- *0.4 – 0.6 High canopy cover, no water stress,*
- *0.6 – 0.8 Very high canopy cover, no water stress,*
- *0.8 – 1 Total canopy cover, no water stress/waterlogging*

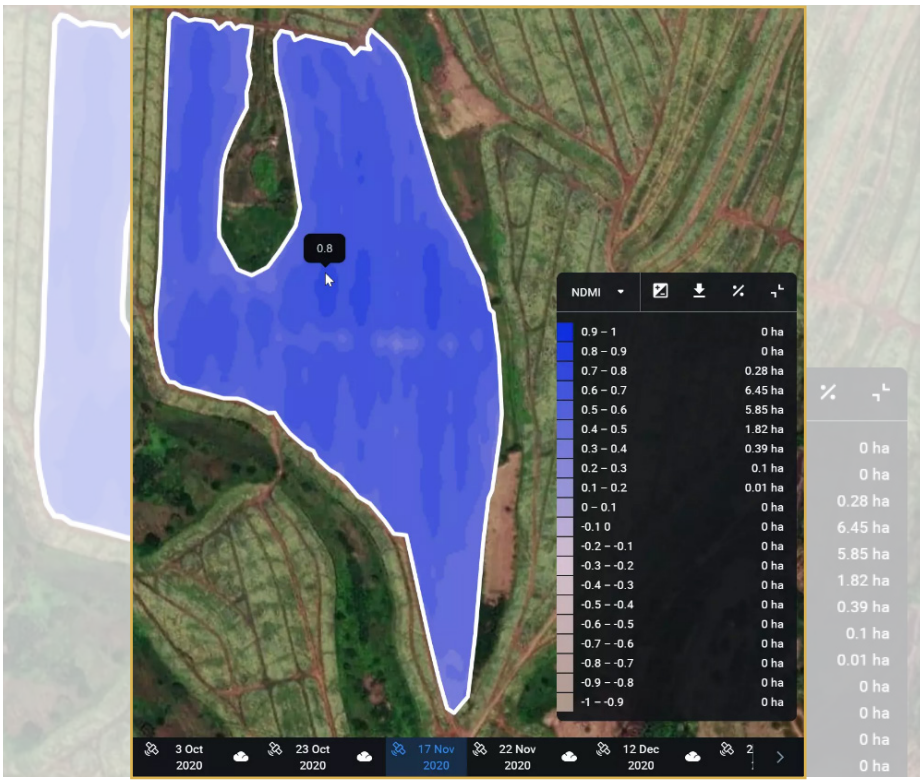

Figure 114. Example of field with ndmi index calculated on it.

NMDI: This index takes into account a soil moisture background to monitor potential drought conditions. Three specific bands were chosen because of their unique response to variations in soil and vegetation moisture. The index uses the difference between two liquid-water absorption bands in the shortwave-infrared region (1640 and 2130 nm) as a measure of water sensitivity in vegetation and soil. This index is also commonly used in forest-fire detection.

As soil moisture increases, the index values decrease. Index values range from 0.7 to 1 for dry soil, 0.6 to 0.7 for soil with intermediate moisture, and less than 0.6 for wet soil.

Regarding the soil there is a index called **Soil Zone Index** wich is a product map that can see through vegetation to focus strictly on the soil surface. Soil zone maps give growers a ground-level view of their crops' foundation with each image that's collected.

2 – How to do it?

In order to introduce this BMP to farms, the farmer needs to start learn **vegatation index** and to rethink his farm in a smarter and data-driven perspective.

The first thing you have to make the best use and exploitation of satellite imagery there is a need for software(Precision farming Software) that collects these images and through special algorithms helps the farmer to make targeted decisions.

After this purchase you are able to analyze and monitor your crop in a remote way.

The second thing you have to do is to upload your field in the software to start analyze weather, vegatation index and condition of soil.

After that you can use the vegatation index and weather forecast to optimize your activity field.

In this way you can start observe the determination of the water content in plants using the NDMI vegetation index, prevent crop disease using NDVI, NDMI, ReCI, NDRE index or identify nutrient deficiencies and reducke NPK fertilizer.

3-What should be considered when applying the BMP ?

If you want to apply this BMP in your farm, the first thing you have to considered is the level of digital skill in your organization and your knowledge about remote sesing, because in order to extract more and more useful information from remote sensing and vegatation index you have to understand well the uses case of every single index and understand the results.

So one thing you have to consider is to increase your digital agriculture skill, in this way you can run a successful digital trasformation of your company, because the main cause of failure of digital trasformation project is the lack of skills.

Another thing you need to consider is the fact that after the process of digital trasformation and when you will start to use this type of software you will have a lot of data.

They become gold for your business if you know how to analyze it, but if you don't know how to do it, its value is 0.

So one thing you should consider to do is to start learn about data analyze or hire someone that can extract the gold from your data.

4-What are the benefits in terms of sustainability (economic, environmental, social) by adopting the BMP?

Satellite imagery help in managing the natural environment within and around farms, important as farmers strive for more sustainable agricultural practices. Yield maps can allow for better targeting of fertiliser applications, so reducing the risk of contamination. Spatial analysis can ensure better understanding of riparian zones and areas of natural shelter for livestock and wild animals, allowing farmers to fence off environmentally sensitive locations and in turn reduce the risks of inter-species disease transfer.

By analysing how specific areas of a paddock are performing, farmers can potentially alter boundary lines, reducing the need to constantly move livestock from field to field.

By using remote sensing in agriculture you can Improve the nitrogen fertilization process, and optimize fertilizer applications between 50–130 kg/ha. The optimization usage of nitrogen — with the help of vegetation indices and VRA maps— **reduce the need for conventional fertilizing products** like Urea Ammonium Nitrate (UAN) and Granular Fertilizers.

Moreover, by utilizing remote farm management and monitoring, the **company's staff will reduce the time and cost spent on field trips by 80%**.

(For more information on the case study visit: **https://eos.com/blog/satellite-monitoring-to-reduce-npk-fertilizer/).**

5-What are the main constrains of introducing the BMP on farm and how to solve them?

According to literature, the remote sensing is still the lack of software tools for effective information extraction from remote sensing data.

The trade-off in spectral and spatial resolution will remain and new advanced data fusion approaches are needed to make optimal use of remote sensors for extract the most useful information.

Another limit of introducing this BMP in the farm is the technical support.

Increasing sensor applications requires increasing support for farmers, agronomists and other stakeholders.

There are concerns regarding lack of support in the agricultural industry for sensor technology.

Lack of support means producers are not equipped to leverage data insights in order to reap the rewards of their investment in such technology.

6-What are the frequently asked questions about BMP? Questions (Q) and Answers (A)

Q: What are the skills needed to introduce satellite imagery within my company??

A: The skills needed to introduce remote sensing within your farm are:

1) Knowledge of indices and how to use them.

2) Basic computer skills

3) Basic data analysis skills

Q: How much does it cost to introduce this solution?

A: Introducing such a solution is not very costly from a software point of view, there are free software on the market that allows you to calculate some indices, while it requires more effort to obtain the basic skills to be able to apply such solutions.

Q: Where can I learn the necessary skills?

A: There are a variety of options for being able to learn the skills necessary to engage in this practice.

From more traditional options such as taking undergraduate courses in agriculture to specialized courses or taking online courses such as those offered by FAO present in its eLearning section (https://elearning.fao.org/course/view.php?id=155)

FARMERS' ID DIGITAL PROFILE

1-What is it?

The current BMP concerns the development of a European or Common System of Electronic and Digital ID Profile for Farmers & Productive Fields Owners.

Before starting, it's useful to describe what Digital Identity is. This system is a worldwide electronic way of identifying someone. It consists of a digital certificate[1] containing a public key, which is viewable, and a private key, which is secret. The private key allows someone to sign an electronic document with a signature that others can verify using only a public key. Likewise, the private key can decrypt documents that were encrypted by others using a public key.

Digital ID Profiles systems exist already and are used by citizens in several nations as managing platform for financial reasons, as it allows an easy access to a net of several National services and a secure key access to the tax pay system.

- The **first aim** of this BMP: **concede farmers** (or simply the owners of productive fields) **an effective and digital tool**, free and accessible worldwide by using a smartphone or a laptop, **where all agriculture actors can easily find their identifying elements, characteristics of their own farms, any machinery information, fields data, production data & income reports or archives and all of the tools for billing and managing the economical budget**; this allows first of all (i) for a responsible management of the activity with the perfect consciousness of fields management and, following this path, (ii) for discovery of any mistakes occurred in the soil management. This is the main aim of this BMP: to **provide**

1 A *Digital Certificate* is an attachment to an electronic document that allows the safe transfer of information in the web or between digital devices.

farmers both an aid and a self-control system, to lead through a sustainable agriculture developing system (by reducing waste of water, energy, fuel, fertilizers, crop protection products) and a conscious soil management. On the other hand, this system could be a useful tool to increase the access to financial services for farmers. Farmers require access to a strong set of financial services, including credit, savings, and insurance, if they are to professionalize and grow their business. Having an official proof of identity is a prerequisite for accessing financial services and can expand the number and type of financial products available to farmers[2]. In this way, the farmers' personal account could represent an easy-access, digital platform for all public financial measures or active projects, financed by the European Union or National States.

- The **second aim** of this BMP: to create a **central system of controls and declarations to the States in order to track and monitor remotely the farmers' activities, licenses validity, certificates and other duties of the Farmers**. All of this, considering in particular the soil-prevention laws or environment protection laws. As we know, there are several law-imposed duties regarding agriculture that are linked to sustainability, soil protection, public health, environmental and landscape protection, but the problem for the States is to have an effective and pregnant control above all of these duties. This could be a whole system of control, prevention and, as the case may be, sanctioning all wrong practices about soil management and against the environmental and sustainable crimes.

Few Examples: i) we will see in the following paragraph that this ID Profile system can allow an automatic declaration (and control) of the purchase (only if you have the using licence) and register of use (who, where, when, how was used) of fertilizers and crop protection products; ii) The ID Profile as a way of declaring the purchase and use of substances could be a useful tool for authorities to control the respect of the European regulation on copper quantity use per hectare: Reg. ***EU 1981/2018*** *"Only uses resulting in a total application of maximum 28 kg of copper per hectare over a period of 7 years shall be authorised"*[3].

- The **third aim** of this BMP depends on the spreading and use of the ID Profile among farmers and territories. In fact, if it will be spread to a good number of

2 THE ROLE OF DIGITAL IDENTIFICATION IN AGRICULTURE: EMERGING APPLICATIONS, World Bank Group ID4D Identification for development.

3 COMMISSION IMPLEMENTING REGULATION (EU) 2018/1981 of 13 December 2018 renewing the approval of the active substances copper compounds, as candidates for substitution, in accordance with Regulation (EC) No 1107/2009 of the European Parliament and of the Council concerning the placing of plant protection products on the market, and amending the Annex to Commission Implementing Regulation (EU) No 540/2011

farmers in a certain area, and if the farmers agree to share some precise data registered on the personal profile, the system might automatically give some **information and statistics about production and soil management; this could be a strategic tool for the so-called "predictive analytics on soil management":** using historical data to explain and make precise predictions, by using computing software and tools. This can require large volumes of data and computing power, including big data and its use of deep learning from various types of algorithms (such as neural network algorithms, natural language processing, complex event processing, etc.).

2 – How to do it?

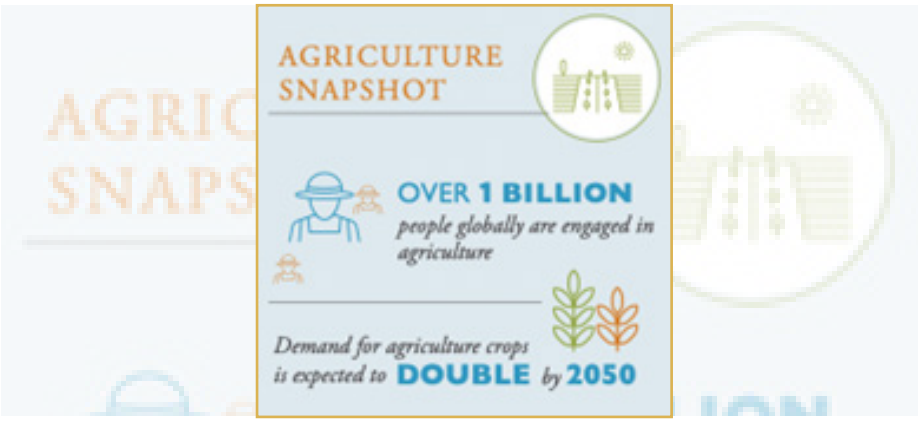

Figure 115. Agriculture Snapshot: people engaged in agriculture and expectations for future.

It is estimated that over 1 billion people globally are engaged in agriculture, accounting for approximately 29% of the workforce. This number is declining, even though the demand for agricultural crops is expected to double as the world population reaches 9.1 billion by 2050[4]. In this way, the ubiquity of mobile phones and digital devices use – grown in the last 10 years – should play a significant role in management of this growing demand of agricultural crops; and it could be a solution, as well, to make the Farmers' work easier, therefore remedying to the declining numbers of actors in agriculture. The Italian digital agriculture market

4 DIGITAL FARMER PROFILES: Reimagining Smallholder Agriculture, e Global Development Lab and the Bureau for Food Security, both within the United States Agency for International Development (USAID), 2018;

has reached the value of 540 million euros in 2020 (about 4% of the global market) and has recorded a growth of 20% compared to the previous year, in line with the pre-pandemic trend. Spending is also driven by precision farming solutions, such as monitoring and controlling systems for vehicles and equipment (36% of the market), and connected machinery (30%). There are 538 digital agriculture solutions currently available for the agricultural sector in Italy (over 100 more than in 2019), which mainly use Data Analytics systems, processing platforms or software and the so-called Internet of Things, and are applied in the cultivation phases, sowing and harvesting of products in various sectors, among which fruit and vegetables, wine and cereals stand out. Almost 60% of farms use at least one digital solution, and 38% use two or more, but only 3-4% of the agricultural area is cultivated with 4.0 tools, a sign that the market has yet to express a large part of its potential. Digital is increasingly present also in the field of food traceability, with 157 solutions. Technologies for the collection, enhancement and sharing of data along the supply chain are advancing, such as Mobile solutions (+ 65% compared to 2019), advanced data analysis (+57%) and processing platforms (+60 %). The growth of the Blockchain continues, present in 18% of traceability solutions (+59%), albeit at a slower pace than in 2019. The agri-food sector is the third sector for the number of pilot and operational Blockchain projects at an international level, initiated by companies for commercial reasons, in order to improve the efficiency of the supply chain and for greater environmental or social sustainability. The technologies that the solutions focus on are mainly **Data & Analytics (73%)**, **platforms and processing software (68%)** and Internet of Things (54%, +4%), followed by the latest generation devices (46%), mobility and geolocation (38%), vehicles and connected equipment (25%), Cloud (19%, +10%) and Artificial Intelligence & Machine Learning (12%). Most of these tools are used in remote mapping and monitoring of land (41%), in the analysis of environmental and land factors (33%), in the monitoring of machinery and equipment (23%) and in water management (19%).[5].

5 Smart Agrifood: condivisione e informazione, gli ingredienti per l'innovazione, Osservatorio Smart Agrifood 2020;

Figure 116. The growth of the digital market and 4.0 in agriculture in Italy 2017 - 2020.

As noticed before, **platforms and processing software are rapidly increasing and these are the principal tools required for Farmers' Digital ID Profiles.** In fact, Farmers require software that they are able to process, in total security and while respecting privacy laws and all required data. There are many service providers that have several software available with an in-cloud memory that is able to do all of the above. Introducing such BMP in the farm does not require a lot of devices. In fact, Farmers shall require only a digital device, such as a smartphone or a laptop to access the platform and software. In such a way, the ID Profile will require also the support of a micro-chip card, or NFC technology on the smartphone or smartwatch in order to talk to other devices.

Example: Automatic Farmers' declaration of the purchase and register of use of fertilizers and crop protection products needs a physical support card or a NFC device. The purchase of some products is allowed only by exposing the licence of use and the declaration of use by farmer by registering the purchase by ID Profile NFC or microchip card.

The **Farmers' ID Profile software platform** should contain several elements, such as:

1) **All the ID information about the Farmer or Owner**: name, surname, birth date, the starting year of the farming activity, the Curriculum Vitae of the farmer, all the certificates achieved or professional courses attended by the farmer, all the licenses requested by the European or single State law for the starting and the carrying out of the activity (and the related expiring dates

of those licenses, linked to an alert notifications system to advice the farmer about this), and other data information necessary to the ID profile account to work (Username, password, Public and Private kays). The ID Profile account could be used as a training system, with periodic courses about soil management or sustainable practices;

2) **All the productive fields data**: certificate of ownership or any rental contract on the field, geographic coordinates, GPS images, weather condition information (with smart notification alerts in case of severe weather condition, for example: severe temperature during night in spring crops), cadastral data, crop decisions archive for each field, soil analysis archive, products analysis archive), the electrical utilities and consumptions per field (by linking the electricity meters to the ID profiles), water consumptions per field (by linking the water meters to the ID profile) with smart notification alerts in order to preserve waste of resources;
3) **Use the ID profile as a Fertilizers & Crop Protection Products Treatments Register**: this should be a tool – linked to a micro-chip card (similar to a credit card) or NFC system – that allows Farmers to buy fertilizers in stores and crop protection products, by registering all of the purchases with such card and later declaring some info about the use of these products, such as: in which field they were used, the data and the aim of the treatments, the quantity used (with the smart notification alerts about the law limits of usage of that particular purchase chemical or fertilizer used). At the same time, the profile should work as an archive of the purchase bills or invoices.
4) **All workers contracts, salary, workers law-imposed declaration and tax counter**;
5) All **machineries information**, such as: certificate of ownership, Model and technical information and – if these are 4.0 ready – the machineries' data (Fuel consumptions, hours of work per day, GPS data etc.);
6) **Production data & income reports or archives and all the tools for billing and economical budget**. Concerning production data, the system should receive data from cooperatives or other buyers from the farmer who has the ID Profile. In this way, Farmers or directly the cooperatives (with a digital certificate sent to the ID Profile of the farmer) should fill in the system with the quantity data (Kg. or other unit), the quality data (% of loss or damaged product) and the price. This can be a tool for farmers to form every sale invoice. Crossing this data with the purchase bill and invoices, the electric and

water bill and workers' salary, Farmer could form his own economical budget and income report.

7) **Digital platform for all the published financial measures or active project, financed by the European Union or National States**;

In this way, an important step to implement the ID Digital Profile's use between Farmers can be to lead an average of the basic knowledge and digital skills of farmers by adopting a new policy of 4.0 courses and education.

In order to have an acceptable spreading of this BMP, in particular for the second and third aim of the BMP (**system of controls and declarations to the States, and info and statistics about production and soil management**) at the beginning, it takes a soft-law system that could help to start the development of ID Profiles for Farmers, and then slowly impose the use of ID profile for all Professional Farmers. This also includes financial helps, tax credits for the purchase of the software and cashback help by declaring fertilizers purchase by using the digital profile. An important role nowadays is played by Cooperatives. In fact, there are several Cooperatives that are investing in buying brand new management software, including licence for Smartphone ID Profile Apps shareholders.

An important step will be the development of a Public Central Database, owned by the State, that allows the various private software providers to communicate the law-imposed data to a central system database.

3-What should be considered when applying the BMP?

We need to consider that the expectations for digitalization of agriculture sector are really high and are increasing in the last years. Using mobile tools, with Farmers' ID digital Profile aggregate information, data can be directly collected from farmers using their own mobile tools, or indirectly by service providers using mobile tools to record data provided by farmers. It can then flow directly into a database. Data management processes can exceed the capacities of typical processes in the past. Data is being used to create robust farmer profiles that can be refined over time but accessed in real-time by multiple service providers—such as financial services providers, input suppliers, agro-processors, and farmer cooperatives—to understand and engage more with farmers. **Input suppliers can be more prescriptive if they have data available on soil and crop health**; **agro-processors can use data to estimate upcoming harvest volume and even**

manage traceability of agricultural products. Financial services' providers can use the data for farmer risk-profiling and can become very efficient and logical, using data on likely crop output. **Farmers can more effectively utilize fertilizers and other soil amendments, thus reducing expenses, producing higher yields, and creating more environmentally friendly farms**. All data collected from farmers through mobile tools can be made available via an ICT (information and communications technology) platform that can provide timely data to all platform users, including the farmer. Farmers will also find the solutions attractive, therefore demanding those services, contributing to a sustainable offer of products and services over the long term. Mobile technology can provide a way forward to mitigate risks, strengthen value chains, and coordinate value chain actors. However, a sustainability path for many technologies service models has yet to be established, and the coordination of different data sets has yet to be fully achieved.

In this way, it is important to consider that – nowadays – data are becoming an important asset. Data and information need to be protected against abuses, data thefts or hacking attacks. For this reason, the European Union has published a brand-new regulation, the so-called The General ***Data Protection Regulation*** (***GDPR***): it is the toughest privacy and security law in the world. Though it was drafted and passed by the European Union (EU), it imposes obligations onto organizations anywhere, as long as they target or collect data related to people in the EU. The regulation was put into effect on May 25, 2018. The GDPR will levy harsh fines against those who violate its privacy and security standards, with penalties reaching the tens of millions of euros[6]. This Regulation, in fact, "*protects fundamental rights and freedoms of natural persons and in particular their right to the protection of personal data. The free movement of personal data within the Union shall be neither restricted nor prohibited for reasons connected with the protection of natural persons with regard to the processing of personal data*"[7].

The EU GDPR application and all the National privacy laws are directly cogent for all software providers of Farmers' digital ID profile, the public databases managers and these regulations should be respected in the data communication between different platforms. In this way, Farmers should give to service providers consent to the processing of all ID Profile datas.

6 What is GDPR, the EU's new data protection law? In https://gdpr.eu/what-is-gdpr/

7 Art. 1 REGULATION (EU) 2016/679 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC.

4-What are the benefits in terms of sustainability (economic, environmental, social) by adopting the BMP?

The top benefits in terms of sustainability for farmers include:

1. **Improved management and decision-making processes**: a tool that is easily accessible where farmers can quickly find and manage all their identifying elements, characteristics of their own farms, any machinery information, fields data, production data & income reports or archives and all the tools for billing and monitoring economical budget and financial statements. This constitutes a self-control system for sustainable agriculture developing (reducing waste of water, energy, fuel, fertilizers, crop protection products) and a conscious soil management.
2. **Improved efficiency through the aggregate data of Farmers' ID Digital Profiles info**: about productivity, use of chemicals or fertilizers, use of water, machinery activity, soils management.
3. **An increase in productivity and profit**: the increase of field productivity in order to generate more income depend on a significant reduction of resources waste (water, energy, work, soil). With a constant and careful management, it is possible to save resources and money. Such benefit is included in the management of financial statements of the farm.
4. **Real-time information.** Fields will be monitored with smart notification alerts in case of severe weather condition, analysis of crop decisions archive for each field, soil analysis archive, products analysis archive, the electrical utilities and consumptions per field by linking the electricity meters to the ID profile), water consumptions per field by linking the water meters to the ID profile with smart notification alerts in order to preserve waste of resources;
5. **Advancements in record keeping**: register all purchases, seeding, soil management activity, weather trends.
6. **A reduction in regulatory burden and law-imposed duty declarations**: with a central system of controls and declarations of all law regulated farmers activities, licenses validity, certificate and some others important duties of the Farmers, including tax regulation. This should be a more effective control system for States and an easy system of declaration for Farmers in order to prevent the bureaucracy waste of time.
7. **Increasing supply-chain traceability**: There is growing global interest in agricultural supply-chain traceability and transparency required to ensure food

safety. Being able to trace produce back to a single farm of origin, and in the case of small-holder farmers, to a single farmer, is becoming increasingly important and can be greatly supported by robust, digital identification.

8. **Increasing access to Financial Services**: Smallholder farmers require access to a robust set of financial services, including credit, savings, and insurance, if they are to professionalize and grow their business. Having an official proof of identity is a prerequisite for accessing financial services and can expand the number and type of financial products available to poor farmers.
9. **Investor or donor monitoring of Farmer Activity**: Bank and some other investors are more inclined to give financials to those Production Activities who are constantly monitoring financial statements and are able to easily provide them financial numbers.
10. **Digital platform may be used to communicate the vital information to B2B or B2C actors in order to increase the "per year" turnover.**

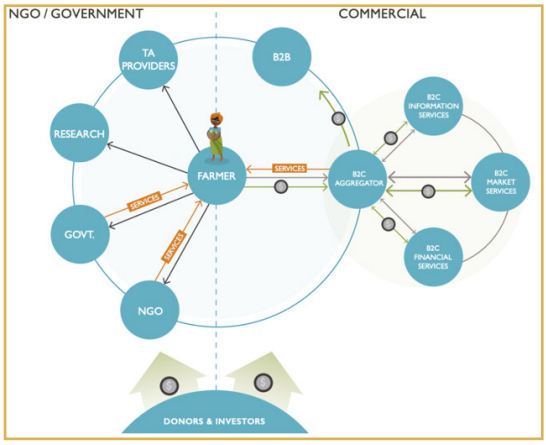

Figure 117. snapshot of farmers' interactions with investors, institutions and the commercial world;

5-What are the main constrains of introducing the BMP on farm and how to solve them?

First of all, the main limit for spreading this BMP is the **digital division of Farmers in approaching 4.0 systems and digital devices**. However, in the last years we are noticing a fast change, the use of smartphones or digital devices is spreading through different age groups of people, therefore allowing for an Intergenerational transfer.

Digital approaches are needed for accelerated and sustainable agricultural transformation. At scale, digital disruption is driven by the collection, use, and analysis of massive amounts of agricultural data, that can be digested and interpreted by advanced systems. Accessing data-driven digital transformation for farmers requires progress in three areas: last-mile infrastructure, open standards, and contextually relevant software services[8].

Another limit could be the **Data and information protection against abuses, data-theft or hacking attack**. The currently accepted model for digital identity is siloed in nature, however, considering ever-increasing data privacy concerns and liabilities on theft, self-sovereign identity on the blockchain has been recognized as an alternative to compensate for the evident shortcomings in the siloed model. **A self-sovereign identity translates into an identity that is under your ownership. Self-sovereign identities empower users with comprehensive control and consent over the personal information they are sharing and the parties they are sharing the information with**. While enabling self-sovereign identity for smallholder farmers carries its own set of contextual challenges, farmers' control over their data should be respected and protected as a fundamental right as their engagement with digital infrastructure increases. The viability of SSID is contingent on an operating model which can account for groups who do not have access to smartphones nor have reliable access to internet. Innovative concepts such as "Guardianship" enables SSID for these populations and contexts where self-management is not viable by appointing a trusted entity who can act as a fiduciary for wallets under an agreed-upon governance framework[9].

6-What are the frequently asked questions about BMP? Questions (Q) and Answers (A)

Q: Do the farmers are ready to use digital devices or they are skilled enough to use digital devices?

A: Farmers seems to be ready to use easy access digital devices. Nowadays everyone has a smartphone and has confidence with apps and social media. We have to notice that a generational change is taking place among farmers all over the world and this is helping the spread of the use of digital devices. The required

8 Antoinette Marie, Addressing the Digital Divide for Smallholder Farmers, Harvard Advanced leadership initiative, Social Impact Review;

9 Antoinette Marie Addressing the Digital Divide for Smallholder Farmers, Harvard Advanced leadership initiative, Social Impact Review;

skills depend on software and its graphic interface. The ID profile support should be easy to use; the easier is to use, the most will be used. This is a rule for an intuitive software and app for Farmer's ID Profile.

: Do farmers need to be trained in order to use appropriately digital devices?

A: A transition training is required in order to prevent incorrect use of the ID Profile support. The training period required to use this kind of support in not too long, it requires short video demonstrative in order to show the potentiality and the tools of software.

: How to menage Farmer's Digital Divide?

A: Farmer's digital divide needs to be managed with Trainings, 4.0 formation and by giving them the opportunity to use with beta test the devices and app linked to the ID Profile.

: Are farmers confident about the digital provider and do they feel confident about privacy?

A: Now Farmers are ready to be confident about the digital provider and the privacy because now we have the technology tools and the laws to prevent abuses.

: What is the average in using Digital ID Profile for Farmers?

A: The average is in the management of the farm: more consciousness about the management of resources, reduce of waste, and mora accuracy in the administration of the farm.

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APPENDIX 2. Project Activities pictures

Picture 2.1. Transnational Project Meeting -University of Cordoba Cordoba/SPAIN

Picture 2.2. Learning, Teaching and Training Activity - Deula Nienburg Nienburg/GERMANY

Picture 2.3. Transnational Project Meeting -European Conservation Agriculture Federation-ECAF Brussels/BELGIUM

Picture 2.4. Learning, Teaching and Training Activity - Konya Provincial Directorate of Agriculture and Forestry Konya/TÜRKİYE

Picture 2.5. Transnational Project Meeting -Legacoop Puglia Bari/ITALY

Picture 2.6. Transnational Project Meeting -Deula Nienburg Nienburg/GERMANY

Picture 2.7. Learning, Teaching and Training Activity-University of Cordoba Cordoba/SPAIN

Picture 2.8. Transnational Project Meeting - Konya Provincial Directorate of Agriculture and Forestry Konya/TÜRKİYE

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SPAIN	TÜRKİYE	TÜRKİYE	GERMANY	ITALY	BELGIUM	TÜRKİYE
University of Cordoba	Selçuk University	KOP (Konya Lowland Project) Regional Development Administration	DEULA Nienburg GmbH	Lega Regionale delle Cooperative e Mutue	European Conservation Agriculture Federation	Konya Karaman Agricultural Cooperatives Regional Union

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