CENTRO DI RICERCA POLITICHE E BIOECONOMIA

CLIMATE CHANGE IN AGRICULTURE

A COST-BENEFIT EVALUATION OF ADAPTATION MEASURES

Simonetta De Leo, Guido Bonati, Antonella Di Fonzo,
Marco Gaito, Sabrina Giuca

Life

ADA ADaptation in Agriculture

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Rome, 2024

Publication produced by (CREA), the Council for Agricultural Research and Economics – Policies and Bioeconomy, a partner of the ADA – "ADaptation in Agriculture" project, with support from the Life programme, an EU financial instrument | LIFE19 CCA/IT/001257.

Project manager for CREA-PB: Simonetta De Leo. Project manager for LIFE: Sabrina Giuca.

Authors: Simonetta De Leo, Guido Bonati, Antonella Di Fonzo, Marco Gaito, Sabrina Giuca.

Scientific committee for the ADA project: Simonetta De Leo (CREA-PB) – coordination, Guido Bonati (CREA-PB), Antonella Di Fonzo (CREA-PB), Marco Gaito (CREA-PB), Sabrina Giuca (CREA-PB).

Editorial Committee: Simonetta De Leo (CREA-PB) – coordination, Guido Bonati (CREA-PB), Antonella Di Fonzo (CREA-PB), Marco Gaito (CREA-PB), Sabrina Giuca (CREA-PB).

Working group: Simonetta De Leo (CREA-PB) – coordination, Filiberto Altobelli (CREA-PB), Guido Bonati (CREA-PB), Sara Carè (CREA-ZA), Andrea Di Cesare (CREA-PB), Alessio Di Clemente (CREA-PB), Antonella Di Fonzo (CREA-PB), Marianna Ferrigno (CREA-PB), Marco Gaito (CREA-PB), Antonio Giampaolo (CREA-PB), Sabrina Giuca (CREA-PB), Flavio Lupia (CREA-PB), Maria Carmela Macrì (CREA-PB), Saverio Maluccio (CREA-PB), Veronica Manganiello (CREA-PB), Massimo Morassut (CREA-VE), Giuseppe Pulighe (CREA-PB), Francesca Ribacchi (CREA-PB), Luigi Tarricone (CREA-VE), Domenico Ventrella (CREA-AA), Benedetto Venuto (CREA-PB).

We would like to express our thanks to FADN data collectors who made the survey possible by filling out the questionnaires, and to the following experts in the sector, entrepreneurs, researchers and agronomists who contributed to our research in various roles: Sylvia Azzolini, Guido Bezzi, Emanuele Blasi, Matteo Boggian, Francesco Bordini, Luca Capuzzo, Sergio Costa, Mario Cremonini, Francesca Dallabetta, Gemini delle Vedove, Raffaele Demitri, Carlo Ferrario, Alessandro Garonzi, Roberto Genovesi, Arialdo Giammusso, Ayman Kobary, Marta Mariani, Thomas Marino, Rossano Montuschi, Silvio Paraggio, Giorgio Patrizi, Tiziana Pirelli, Davide Navarro, Walter O. Righini, Salvatore Scicchitano, Luigi Torri, Emanuele Tosti, Gerardo Vaccaro, Antonio Venturi, Alberto Veronesi.

Our thanks to Beatrice Camaioni (CREA-PB) for her meticulous re-reading of the texts and helpful suggestions.

Proofreading: Francesca Ribacchi.

Graphic design and page layout: Sofia Mannozzi.

PUBLISHER: Council for Agricultural Research and Economics (CREA)
ISBN: 9788833853970

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INTRODUCTION

The issue of climate change is one of immense importance, a local and global concern that cannot be ignored. Extreme events are becoming more and more frequent, intense and unpredictable, causing increasing damage to the value of production and affecting a greater proportion of farms every year. Adverse climate events lead to reduced yields as well as negatively impacting the quality of production and, in extreme cases, can even cause the total destruction of a harvest. Moreover, the negative repercussions of climate-related damage on yield and quality in the fruit-growing industry in particular can linger for years following the occurrence of such events. In this way, the damages caused by adverse climate events put the very ability of farms to survive at risk, particularly small and medium-sized holdings.

Therefore, there is an urgent need to implement adequate climate change adaptation measures, to limit the extent of the damage increasingly likely to affect agricultural production and to safeguard farm income. Implementing these adaptation measures almost always involves a cost, which may consist of the initial investment and/or the operating costs for the action taken. In most cases, the expenses incurred take the form of the annual cost of depreciation on the investment, inputs (water, energy, etc.), maintenance and labour. As a result, the decision of whether or not to implement a given adaptation measure cannot be taken without analysing the costs and benefits it can bring.

As part of the LIFE ADA "ADaptation in Agriculture" project, which aims to increase the resilience of the agricultural sector by developing skills and planning tools which farmers and producer organisations can use to adapt to climate change, ARPAE Emilia-Romagna has identified the main measures for adaptation to climate change and compiled them in a library[1].

In this volume, the measures have been arranged into the following eight categories based on similar areas of implementation:

1. Soil management;
2. Soil improvers and fertilisers;
3. Agronomic techniques;
4. Crop protection;
5. Management of water resources;
6. Engineering, digitisation and training;
7. Innovative breeding techniques and animal welfare;
8. Wine-making techniques.

The research carried out by CREA-PB, a partner of the ADA project, made it possible to bring together information about the costs incurred through the adoption of these measures and the benefits of their implementation, and to analyse that information in detail.

For each measure in each group, an informational-analytical data sheet has been prepared based on the methodology developed, with a qualitative assessment of the cost-effectiveness of implementing the adaptation measure in question.

The data sheets presented in this book are intended to provide a point of reference for exploration and analysis of the subject, in order to support farms, professional technicians and technical-institutional bodies

[1] *https://www.lifeada.eu/en/adaptation-actions/.*

involved in the sector.
For more detailed information on the topic, bibliographic references have been provided at the end of the volume, including the recent studies by its authors.

The LIFE-ADA project: Adaptation in Agriculture

(https://www.lifeada.eu/en/), co-financed by the European Union through the LIFE programme, aims to support the agricultural sector in making plans for climate change adaptation, in order to improve risk management and prevent damages.

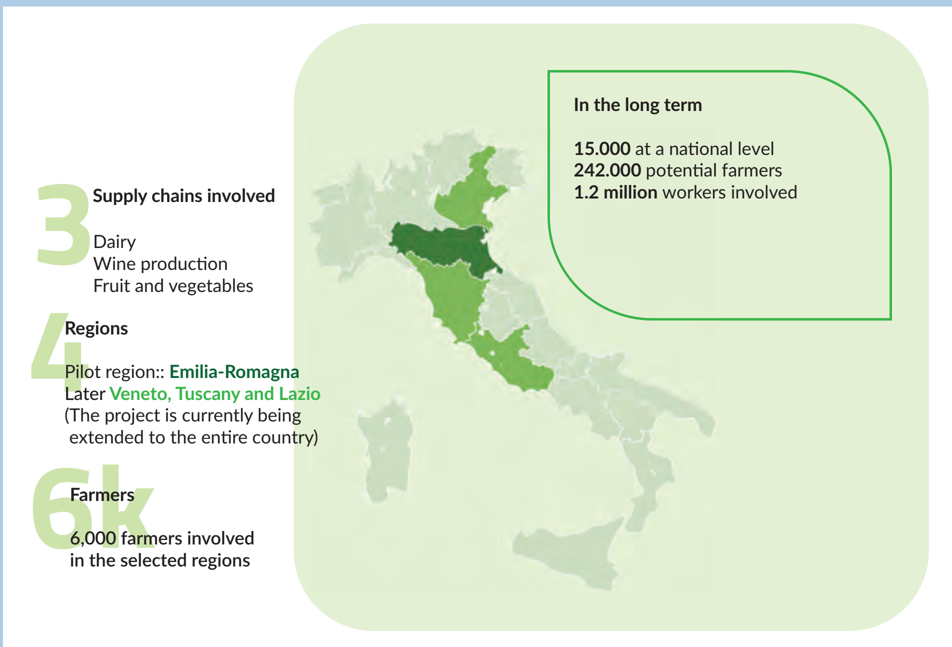
The project is a public-private partnership coordinated by UnipolSai Assicurazioni. The partners are: CREA-PB; ARPAE Emilia-Romagna; C.I.A. agricoltori italiani; Festambiente; Legacoop Agroalimentare Nord Italia; Leithà; and the Region of Emilia-Romagna.

The project is aimed at individual farmers, producer organisations and cooperatives involved in the agri-food chains of milk and dairy, wine, fruit and vegetables. Its aims are:

- to share knowledge about future climate change projections, risk management, and the adaptation measures that can better equip farmers to tackle current and future climate risks;
- to develop suitable tools to support the decision-making process in forming efficient adaptation plans;
- to foster an innovative approach among insurers, strengthening their ability to cover damages from climate-related risks (current and future) in order to maintain the long-term insurability of farmers.

Specifically, the ADA project supports farmers and producer organisations in implementing adaptation plans through the development of a web tool.

The tool is undergoing pilot testing in the region of Emilia-Romagna, after which it will be extended to the regions of Veneto, Tuscany and Lazio, and eventually spread throughout the entire nation of Italy.



METHODOLOGY

Data collection

To collect the information, a questionnaire was administered to FADN data collectors in the Farm Accountancy Data Network (FADN)[2], as experts in the sector. The questionnaire[3] was created using the CAWI (Computer Assisted Web Interviewing) methodology. In total, 82 questionnaires were administered, divided into groups of measures.

In order to obtain as much information as possible, and to investigate specific issues and topics arising from the answers, over 50 operators in the sector were interviewed: subject matter experts, agronomists, researchers and producers of agricultural inputs. At the same time, research was carried out on the literature for the purpose of determining the impact of the adaptation measures on certain production activities through existing studies.

The investigations carried out through the questionnaires, interviews and bibliographic research made it possible to draw up a data sheet for every measure, containing the following information:

General information:

- a description of the measure and the difficulty of implementing it;
- the production chain(s) to which it applies, and the climate-related risk(s) that the measure counters/prevents as described in the ARPAE library.

Information on the costs incurred:

- the cost of investment (where applicable);
- average annual cost per hectare;
- the cost compared to usual practice (where relevant).

Costs vary depending on a multitude of variables: farm characteristics (physical and economic size, location), region, altitude, pedoclimatic conditions in the area and production system. As a result, average costs, variable within a range, were calculated as a useful reference point in guiding farmers' decisions when considering whether to adopt a given measure. Where the measure involves an initial investment, the average annual cost per hectare given includes depreciation on the investment, calculated on a straight-line basis based on the average lifespan of the asset.

Information on the benefits:

- the effectiveness of the measure against climate-related risk as described in the ARPAE library: high, moderate, low;
- the influence on production yield and quality, i.e. the positive effect of the measure on these parameters even in the absence of an adverse climate event;
- environmental benefits;
- the possibility of receiving public funding.

In terms of public funds, consideration is given to each measure's potential to receive financing as provided for in the national

[2] *https://rica.crea.gov.it*

[3] *The questionnaire is included in the appendix.*

2023-2027 CAP Strategic Plan, through: direct payments, sectoral interventions and rural development interventions. The Regions and Autonomous Provinces are called upon to indicate the sectoral interventions (within the operational programmes) and rural development interventions (within the rural development complements) eligible for financing and, based upon their decisions, specific funding bands for the interventions are set out. Moreover, the potential for any funding through the NRRP is indicated for each measure.

Assessment:

Based on the information described above, a qualitative assessment of the costs and benefits of implementing each measure is provided. Moreover, an illustration representing the cost-effectiveness of the measure is also given, based on the calculation process described below.

For some data sheets, no illustrated assessment has been given because the costs of implementing the measure are heavily dependent upon the farm's crop choices. This is the case, for example, for some agronomic techniques which have become well established, and which must be assessed by individual farms. The illustrated summaries of the assessments are general in nature, providing a handy point of reference which must nonetheless be adapted to take into account the specific characteristics of farms, production value, and financial resources.

Costs/benefits evaluation illustrative model

The procedure for conducting the costs/benefits evaluation is essentially based on estimating the damage potentially caused by adverse climate events which can be prevented by implementing the adaptation measure. Adverse climate events such as drought, frost, hail, intense precipitation, and extreme high and low temperatures are increasingly common, intense and unpredictable, meaning that they can strike anywhere. As a result, the likelihood of these events occurring must always be taken into consideration. According to our research, damages vary in total from 10% to 40% of the value of production, depending on the climate event and on the crop. Naturally, these damages are not spread evenly in terms of where they occur, but can compromise anywhere between under 10% and almost all of production. Based on our investigations, we have estimated that all types of adverse climate event – drought, frost, hail, intense precipitation, etc. – are highly likely to cause damage representing 30% or more of the value of the farm's production. Therefore, in our calculations, we thought it reasonable to take 30% of the individual farm's production value as the average value of the damage caused by each adverse climate event. The damage was calculated using the three-year average (2017-2018-2019) of the gross saleable production on record for the farms in the FADN sample, based on type of production (production chain)[4] and economic size-class [5], as reference. The average utilised agricultural area (UAA) of these farms was also calculated, per pro-

[4] *The following areas of farm specialisation were considered: horticulture, fruit-growing, viticulture, farms specialising in dairy cattle.*

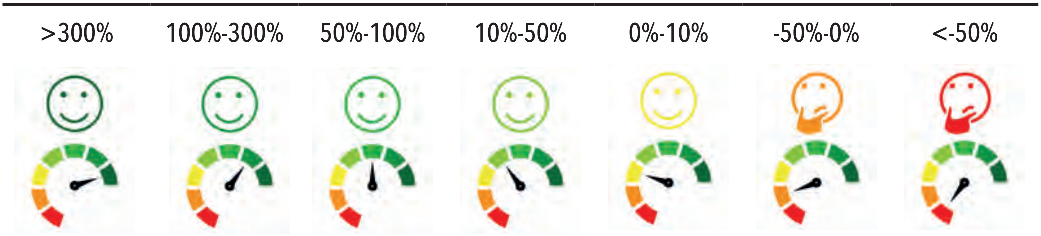
[5] *Economic size-class was defined based on Standard Production (SP): High: > €100,000 in SP; Medium: between €25,000 and €100,000 in SP; Low: <= €25,000 in SP.*

duction chain and size.
In terms of the capacity of each measure to reduce the estimated damages, the following assumptions were made based on the level of effectiveness of each measure as indicated in the ARPAE library:

- *Highly effective:* capable of preventing 70%-100% of damage
- *Moderately effective:* capable of preventing 40%-70% of damage
- *Low effectiveness:* capable of preventing 10%-40% of damage

The damage previously calculated as 30% of production value can be reduced depending on the effectiveness of the measure adopted. Based on the assumptions described above, we estimated the average reduction in damage. Hence, the benefit of each measure in terms of countering climate risk(s) consists of reducing the damage estimated above. This benefit must be weighed against the average cost to the farm of implementing the measure.
The average cost to farms was estimated by multiplying the average annual cost per hectare, determined through the investigations described above, by the three-year average (2017-2018-2019) of the utilised agricultural area (UAA) for each production chain and economic size, as per the FADN.

Based on the size of the net benefit (the difference between the benefit and the cost) as a percentage proportion of the average cost of implementing the measure, the following illustrations were used to represent the cost-effectiveness of adopting the measure.
The purpose of the illustrations is to serve as a point of reference when considering the advisability for the farm of adopting the measure. If the illustrated faces do not indicate a measure's cost-effectiveness, the other benefits that the measure could bring should still be taken into consideration. These benefits can include: improving production yield and quality; environmental benefits, which can themselves have positive economic impacts given that they are increasingly demanded and rewarded by citizens and consumers; the possibility of receiving CAP contributions; and other positive impacts on the farm. However, these extra benefits are very closely linked not just to the adaptation measure itself, but also to the unique characteristics of the farm. Therefore, assessments must be made on a case-by-case basis for the required accuracy.



DATA SHEETS FOR ASSESSMENT OF THE ADAPTATION MEASURES

1. SOIL MANAGEMENT

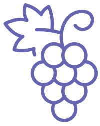
Certain soil management techniques make it possible to mitigate soil degradation issues such as erosion and compaction, to counter drought, to improve the soil's physical, chemical and biological properties, to increase its organic matter, to keep weeds under control and to combat pathogens.
These conservation agriculture techniques, which have a low environmental impact, include:

1. **MINIMUM TILLAGE**
2. **NO TILLAGE**
3. **STRIP TILLAGE**
4. **VERTICAL TILLAGE**
5. **GRASSING**
6. **COVER CROPS**
7. **GREEN MANURE WITH NITROGEN-FIXING CROPS**
8. **GREEN MANURE WITH BRASSICA CROPS**

MEASURE 1.1 – MINIMUM TILLAGE

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES



WINE

PARMIGIANO REGGIANO

DESCRIPTION

This measure addresses the climate-related risks of drought and erosion.

Minimum tillage refers to preparing the seed bed through a number of soil-management techniques which involve the fewest cultivation passes possible. In general, it involves tilling the soil to a depth of no more than 15 cm and passing machinery over the ground just once or twice to obtain a satisfactory seed bed, while retaining crop residue coverage on at least 30% of the land surface. Operations can be carried out with disc harrows or other mounted, semi-mounted or towed implements, equipped with working parts that are not moved hydraulically or by PTO. In viticulture, minimal surface tillage of the under-vine is required to break soil crusts. Furthermore, one-off minimal tillage is required to sow cover-crop species in the inter-row. Minimum tillage can also help with intense rain and wind, as these weather phenomena can intensify soil erosion.

Implementation of this measure is easy, but it does require suitable training and/or guidance.

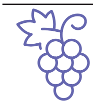
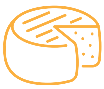
COSTS AND BENEFITS

COST OF INVESTMENT	Minimum tillage generally involves no investment costs, as farms often already have the necessary type of equipment. In some cases, investments might be necessary to replace equipment requiring the use of PTO with towed equipment. If so, the cost of investment could be offset by the sale of the farm's previous equipment. Where necessary, the investment costs of purchasing the equipment can be estimated at between €3,000 and €20,000, depending on the size of the farm and the power of the machinery it uses (tractors). The average lifespan of the equipment is between 20 and 30 years.
AVERAGE ANNUAL COST PER HECTARE	The cost per hectare of the methods involved in minimum tillage tends to be modest, as the soil is worked in just a few passes. Operating costs range between €150-250/ha (fuel costs, labour costs, etc. or, alternatively, the cost of subcontracting). If equipment is purchased, assuming a farm size of between 5 and 30 ha (bearing in mind that farms with a lot of land have most reason to apply the practice), the average cost of depreciation is estimated at €30/ha.

COST COMPARED TO CONVENTIONAL PRACTICES	Lower. The manner in which the soil is tilled, with fewer cultivation passes and equipment which, in general, consumes less energy and requires less time, reduces costs compared to conventional practices.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. The effectiveness of the measure tends to vary depending on the type of risk in question, and on the topography of the land. The measure has been found to be highly effective against the risk of erosion, and moderately effective against drought.
IMPACT ON PRODUCTION YIELD AND QUALITY	NO. Minimum tillage does not result in improvements to production quality or yield.
ENVIRONMENTAL BENEFITS	YES. It has a positive effect on the land, particularly on soil quality (soil biodiversity) and on hydrogeological disruption (erosion control). Furthermore, the practice has carbon storage potential.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRA03 – ACA3 – reduced soil processing techniques (for arable land only); SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD02 – productive agricultural investments for the environment, climate and animal welfare.

COST/BENEFIT EVALUATION

The measure permits savings in terms of operating costs (reduced energy and labour costs), offsetting the additional cost of investing in the specific equipment required for the practice. The cost of implementation is favourable, compared to normal cultivation practices. The measure does not have a significant impact on the direct effects of climate change (drought, rain, wind), but is effective against erosion and generates environmental benefits. In general, farms with larger surface areas see the greatest economic benefits from applying this measure.

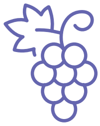
PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	FRUIT AND VEGETABLES			
	WINE			
	PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €200/ha and moderate effectiveness against climate-related risks.

MEASURE 1.2 – NO TILLAGE

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES



WINE

PARMIGIANO REGGIANO

DESCRIPTION

This measure addresses the climate-related risks of drought and erosion.

Under the no-tillage agricultural technique, plants are sown directly over the residue of previous crops, which are left on the surface of the untilled soil. Special seed drills are needed to sow directly on untilled land, with the ability to cut through residual crops, form a furrow in which to plant the seed, and cover it back over with soil. Abstaining from tillage reduces soil erosion in particular, especially on sandy, dry and sloping land. Moreover, the measure is capable of countering risks linked to drought and can help with intense rain and wind, as these weather phenomena can intensify soil erosion.

Implementation of this measure requires additional investment costs and suitable training and/or guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	This measure requires investments in special equipment. Specifically, a no-till seed drill must be purchased, the cost of which varies greatly based on the characteristics and working capacity of the model. In general, no other specific investments are required. The cost of the investment could be offset by the sale of farm equipment which is no longer necessary for tilling the soil. Depending on size (UAA or ES), the farmer may subcontract the work, where this option is available. The cost of the no-till seed drill varies greatly based on model and size. On average, this piece of equipment can cost from €5,000 to over €50,000, with the price reflecting its working capacity. The average lifespan of the equipment is between 10 and 15 years.
AVERAGE ANNUAL COST PER HECTARE	The cost per hectare of the no-tillage approach tends to be modest, as it involves no work on the soil apart from the single step of direct sowing. On average, the operating cost per hectare can range from €100 to €200. If equipment is purchased, assuming a farm size of between 5 and 30 ha (bearing in mind that the practice is mainly used on medium/large farms), the average cost of depreciation is estimated at €50-85/ha.

COST COMPARED TO CONVENTIONAL PRACTICES	Lower. The no-tillage approach reduces the costs per hectare, as there is just one single cultivation pass over the field, which results in lower costs and shorter working times.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. The effectiveness of the measure tends to vary depending on the type of risk in question, and on the topography of the land. The measure has been found to be highly effective against the risk of erosion, and moderately effective against drought.
IMPACT ON PRODUCTION YIELD AND QUALITY	NO. The no-tillage approach does not result in improvements to production quality or yield.
ENVIRONMENTAL BENEFITS	YES. It has a positive effect on the land, particularly on soil quality (soil biodiversity) and on hydrogeological disruption (erosion control).
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRA03 - ACA3 - reduced soil processing techniques (for arable land only); SRD01 - productive agricultural investments for the competitiveness of agricultural holdings; SRD02 - productive agricultural investments for the environment, climate and animal welfare.

COST/BENEFIT EVALUATION

The measure permits savings in terms of operating costs (reduced energy and labour costs), offsetting the additional cost of investing in the specific equipment required for the practice. The cost of implementation is favourable, compared to normal cultivation practices. The measure does not have a significant impact on the direct effects of climate change (drought, rain, wind), but is effective against erosion and generates environmental benefits. In general, farms with larger surface areas see the greatest economic benefits from applying this measure.

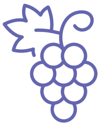
PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
FRUIT AND VEGETABLES			
WINE			
PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €200/ha and moderate effectiveness against climate-related risks.

MEASURE 1.3 – STRIP TILLAGE

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES



WINE

PARMIGIANO REGGIANO

DESCRIPTION

This measure addresses the climate-related risks of drought and erosion.

Strip tillage involves tilling the soil in 15-20 cm wide strips, at a maximum depth of 15 cm. Seeds are sown within these strips, the surface area of which should not exceed 25% of the land, with crop residues left on the remaining land. The measure mainly counters risks linked to drought and erosion. It can also help with intense rain and wind, as these weather phenomena can intensify soil erosion.

Implementation of this measure requires additional investment costs and suitable training and/or guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	This measure requires investments in specific equipment, such as a strip tiller. Depending on size (UAA or ES), the farmer may subcontract the work, where this option is available. The cost varies greatly based on the characteristics and working capacity of the model. The cost of the investment could be offset by the sale of farm equipment which is no longer necessary for conventional tilling of the soil. The cost of the equipment for this practice can vary greatly based on model and size. On average, the investment cost can range from €10,000 to over €75,000, with the price reflecting the working capacity. The average lifespan of the equipment is between 20 and 30 years.
AVERAGE ANNUAL COST PER HECTARE	The cost per hectare of strip tillage is low, as less work is carried out on the soil. On average, the operating cost per hectare can range from €150 to €250. If equipment is purchased, assuming a farm size of between 5 and 30 ha (bearing in mind that the practice is mainly used on medium/large farms), the average cost of depreciation is estimated at €100-130/hectare.
COST COMPARED TO CONVENTIONAL PRACTICES	Lower. The manner in which the soil is tilled, with fewer cultivation passes and equipment which, in general, consumes less energy and requires less time, reduces costs compared to conventional practices.

EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. The effectiveness of the measure tends to vary depending on the type of risk in question, and on the topography of the land. The measure has been found to be highly effective against the risk of erosion, and moderately effective against drought.
IMPACT ON PRODUCTION YIELD AND QUALITY	NO. Strip tillage does not result in improvements to production quality or yield.
ENVIRONMENTAL BENEFITS	YES. It has a positive effect on the land, particularly on soil quality (soil biodiversity) and on hydrogeological disruption (erosion control).
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRA03 – ACA3 – reduced soil processing techniques (for arable land only); SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD02 - productive agricultural investments for the environment, climate and animal welfare.

COST/BENEFIT EVALUATION

The measure permits savings in terms of operating costs (reduced energy and labour costs), offsetting the additional cost of investing in the specific equipment required for the practice. The cost of implementation is favourable, compared to normal cultivation practices. The measure does not have a significant impact on the direct effects of climate change (drought, rain, wind), but is effective against erosion and generates environmental benefits. In general, farms with larger surface areas see the greatest economic benefits from applying this measure.

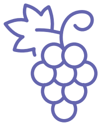
PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
FRUIT AND VEGETABLES			
WINE			
PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €250/ha and moderate effectiveness against climate-related risks.

MEASURE 1.4 – VERTICAL TILLAGE

PRODUCTION CHAINS INVOLVED


FRUIT AND VEGETABLES


WINE


PARMIGIANO REGGIANO

DESCRIPTION

This measure addresses the climate-related risks of drought and erosion.

Vertical tillage involves preparing a good seed bed by chopping crop residue and mixing it into the first 2-3 cm of soil. It also aims to prevent soil compaction, by using tools which do not cause hardpan formation. This technique involves using machinery equipped with vertical discs which are not angled, but perpendicular to the direction of travel, and which do not lift or mix the soil.

Implementation of this measure requires additional investment costs and suitable training and/or guidance.

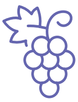
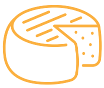
COSTS AND BENEFITS

COST OF INVESTMENT	This measure requires investments in equipment. Specifically, tilling machinery with vertical discs must be purchased, as well as special seed drills, the cost of which varies greatly based on the characteristics and working capacity of the model. The cost of the investment could be offset by the sale of farm equipment which is no longer necessary for tilling the soil. Depending on size (UAA or ES), the farmer may subcontract the work, where this option is available. On average, the investment cost can range from €5,000 to over €50,000, with the price reflecting the working capacity. The average lifespan of the equipment can range between 15 and 30 years, depending on type.
AVERAGE ANNUAL COST PER HECTARE	The cost per hectare of the methods involved in vertical tillage tends to be modest, as the soil is worked more quickly and in just a few passes. The operating cost per hectare can range from €150 to €250. If equipment is purchased, assuming a farm size of between 5 and 30 ha (bearing in mind that the practice is mainly used on medium/large farms), the average cost of depreciation is estimated at €50-90/ha.
COST COMPARED TO CONVENTIONAL PRACTICES	Lower. The manner in which the soil is tilled, with fewer cultivation passes and equipment which, in general, consumes less energy and requires less time, reduces costs compared to conventional practices.

EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. The effectiveness of the measure tends to vary depending on the type of risk in question, and on the topography of the land. The measure has been found to be highly effective against the risk of erosion, and moderately effective against drought.
IMPACT ON PRODUCTION YIELD AND QUALITY	NO. Vertical tillage does not result in improvements to production quality or yield.
ENVIRONMENTAL BENEFITS	YES. It has a positive effect on the land, particularly on soil quality (soil biodiversity) and on hydrogeological disruption (erosion control).
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRA03 – ACA3 – reduced soil processing techniques (for arable land only); SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD02 - productive agricultural investments for the environment, climate and animal welfare.

COST/BENEFIT EVALUATION

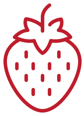
The measure permits savings in terms of operating costs (reduced energy and labour costs), offsetting the additional cost of investing in the specific equipment required for the practice. The cost of implementation is favourable, compared to normal cultivation practices. The measure does not have a significant impact on the direct effects of climate change (drought, rain, wind), but is effective against erosion and generates environmental benefits. In general, farms with larger surface areas see the greatest economic benefits from applying this measure.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
 FRUIT AND VEGETABLES			
 WINE			
 PARMIGIANO REGGIANO			

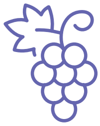
The illustrated summary of the assessment is based on a cost of €250/ha and moderate effectiveness against climate-related risks.

MEASURE 1.5 – GRASSING

PRODUCTION CHAINS INVOLVED



FRUIT



WINE

DESCRIPTION

This measure counters drought, erosion, excess water and intense rain.

Grassing is a soil-management technique with a low environmental impact, which is used as a potential solution for working land where trees are grown. By grassing the land and cutting the vegetation back to a height of 10-15 cm, much agricultural work is cut out. The result is that the land planted with trees is very effectively protected against erosion, while its structure improves significantly and transit across it becomes easier. Moreover, the grass roots also play an important role in spreading surface P and K deeper into the soil. In viticulture, sowing leguminous plants (e.g. *trifolium subterraneum*, or subterranean clover) in the under-vine is also becoming more common, allowing minimal use of fertilisers. Grassing helps to increase the organic matter in the soil, which acts to mitigate climate change. It also makes it possible to use less chemical fertilisers, thanks to the organic matter partly replacing them, and facilitates the stabilisation and consolidation of the soil, reducing surface erosion. Finally, the crops need less irrigation due to improvements in the soil structure and an increase in its capacity to retain water. The main drawback consists of competition between the grass and the tree crops; for this reason, grassing is ideal for areas where the land is particularly fertile.

Implementation of this measure requires suitable training and/or guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	This measure does not require investments in special equipment, with the possible exception of tools to cut the grass. If a specially chosen mix of grass is to be sown, as opposed to allowing grass to grow naturally, the cost of the seeds must be taken into consideration. This can vary from €600-€1,000, and the resulting grass cover can last for around 10 years if properly managed.
AVERAGE ANNUAL COST PER HECTARE	The cost per hectare of the work involved in grassing tends to be modest, as the only steps are sowing and cutting. The cost per hectare can range from €100 to €200. If natural grass cover is allowed to grow, there are no other costs. If a specially chosen mix of grass is to be sown, an annual cost of €60-€100 for the seeds must be taken into consideration.
COST COMPARED TO CONVENTIONAL PRACTICES	Lower. The grassing technique consumes less energy and requires less time (no need to till the soil), reducing costs compared to conventional practices.

EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. The effectiveness of the measure tends to vary depending on the type of risk in question, and on the topography of the land. The measure has been found to be highly effective against the risk of erosion, and moderately effective against other climate-related risks: drought, excess water, intense rain.
IMPACT ON PRODUCTION YIELD AND QUALITY	NO. Grassing does not bring a significant improvement to the quality of production, with the possible exception of some specific cases. Competition between the grass and the tree crops can lead to a small reduction in yield, of up to 5%.
ENVIRONMENTAL BENEFITS	YES. It has a positive effect on the land, particularly on soil quality (soil biodiversity) and on the erosion caused by rain and wind. It also increases organic matter.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRA05 – ACA5 – grassing tree crops; Direct payments: Ecoscheme 2 for partial grassing, inter-row only.

COST/BENEFIT EVALUATION

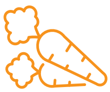
The measure permits savings in terms of operating costs (reduced energy and labour costs). The cost of implementation is favourable, compared to normal cultivation practices. The measure does not have a significant impact on the direct effects of climate change (drought, excess water, intense rain), but is effective against erosion and generates environmental benefits. The increase in organic matter in the soil constitutes a tool for the mitigation of climate change.

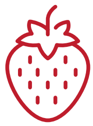
PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
FRUIT			
WINE			

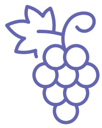
The illustrated summary of the assessment is based on a cost of €200/ha and moderate effectiveness against climate-related risks.

MEASURE 1.6 – COVER CROPS

PRODUCTION CHAINS INVOLVED


VEGETABLES


FRUIT


WINE


PARMIGIANO REGGIANO

DESCRIPTION

This measure counters drought, erosion, excess water and intense rain.

Cover crops are herbaceous species introduced into cropping systems for the primary purpose of keeping the ground covered by vegetation during periods of the year when it would otherwise have no crop cover. As such, they are not so-called cash crops, but are used to attain agronomic and environmental benefits. The agro-environmental advantages of cover crops range from improving the soil structure to increasing its organic matter and nitrogen content, and even reducing pests and leaching. In general, the species which are used belong to the legume, grass and cruciferous families. It is important to choose cover crops that will not compete with the main crop in the system. In viticulture, the use of certain clover species is spreading, including at under-vine level. This both provides nitrogen and, when the plants dry out in May, acts as a layer of mulch. Nonetheless, cover crops require some tillage of the soil, however minimal it may be, resulting in mineralisation of the organic carbon. If chosen well, cover crops can help to reduce the leaching of nutrients during periods when the ground would otherwise be uncovered.

Implementation of this measure requires suitable training and/or guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	This measure does not require investments in special equipment.
AVERAGE ANNUAL COST PER HECTARE	The cost per hectare of the work involved in cover crops tends to be modest, depending largely on the method of seeding used (conventional seeding, minimum tillage, no-till seeding, etc.) and partly on the cost of seeds and cutting. The average cost per hectare is between €250 and €350.

COST COMPARED TO CONVENTIONAL PRACTICES	Greater. Cover crops involve greater costs, due to the work of tillage and seeding. However, these increased costs are offset by the agronomic benefits.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. The measure has been found to be highly effective against the risk of erosion. It is moderately effective against the damage caused by drought, excess water and intense rain.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Cover crops tend to bring about an improvement in the quality of production, but first and foremost they facilitate increased yields.
ENVIRONMENTAL BENEFITS	YES. Use of this measure has a positive effect on the land, particularly on soil quality (soil biodiversity) and on the erosion caused by rain and wind.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRA06 - ACA6 - Cover crops (for arable land only).

COST/BENEFIT EVALUATION

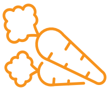
The measure is effective against erosion and generates environmental benefits. The increase in organic matter in the soil constitutes a tool for the mitigation of climate change. The costs of managing this measure are more than offset by its agronomic benefits and the increase in production quality and yield.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
VEGETABLES			
FRUIT			
WINE			
PARMIGIANO REGGIANO			

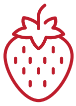
The illustrated summary of the assessment is based on a cost of €300/ha and moderate effectiveness against climate-related risks.

MEASURE 1.7 – GREEN MANURE WITH NITROGEN-FIXING CROPS

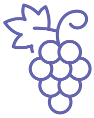
PRODUCTION CHAINS INVOLVED



VEGETABLES



FRUIT



WINE

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters drought, excess water and intense rain.

Green manure is an agricultural practice that consists of sowing a herbaceous crop for the purpose of incorporating it into the soil. It serves the function of fertilising the next crop of plants or trees planted in the same soil. The advantages of this practice are related to maintaining the fertility of agricultural soils, and to reducing the use of mineral fertilisers. In green manure crops, the development of the root system and the incorporation of plant biomass contribute large quantities of organic matter to the soil, improving its structure and its chemical and biological properties in the short term. Furthermore, in annual rotations, autumn-winter green manures serve an environmental function, covering the soil between one main crop and the next. This means that nutrients, and nitrogen in particular, are retained in the layers of soil through which the roots of the plant grow. This makes it possible to reduce the quantity of nitrates carried downwards by rainwater. These crops also help to reduce greenhouse gas emissions, through the assimilation and fixation of nitrogen in the soil. The use of such crops also reduces the phenomenon of surface rainwater run-off, mitigating soil erosion and the loss of nutrients in surface waters. One drawback of green manure is that it must be mechanically tilled into the field, and is not suitable for all soil types. It is advisable to move quickly on to the next rotation as soon as the green crop has been incorporated into the soil, in order to prevent nitrates from being leached into the groundwater. The correct use of green manure also requires shallow tillage, to retain the advantages of nitrogen fixation and prevent environmental damage.

Implementation of this measure requires suitable training and/or guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	This measure does not require investments in special equipment, with the possible exception of cutting tools.

AVERAGE ANNUAL COST PER HECTARE	The cost per hectare of the work involved in the use of green manure tends to be modest, as the only steps are cutting, sowing and incorporating the crop into the soil. The cost per hectare, including the cost of seeds, can range from €200 to €450.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater. The green manure technique involves greater costs, due to the work of tillage and seeding. However, these increased costs are offset by the agronomic benefits.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Low. It offers low effectiveness against the damage caused by drought, excess water and intense rain.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Green manure tends to bring about an improvement in the quality of production, but first and foremost it facilitates increased yields.
ENVIRONMENTAL BENEFITS	YES. Use of this measure has a positive effect on the land, particularly on soil quality.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRA06 – ACA6 – Cover crops (for arable land only).

COST/BENEFIT EVALUATION

The measure does not have a significant impact on the direct effects of climate change (drought, excess water, intense rain), but it does generate environmental benefits. The increase in organic matter in the soil constitutes a tool for the mitigation of climate change. The costs of managing this measure are more than offset by its agronomic benefits and the increase in production quality and yield. In general, medium-large farms see the greatest economic benefits from applying this measure.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
VEGETABLES			
FRUIT			
WINE			
PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €300/ha and moderate effectiveness against climate-related risks.

MEASURE 1.8 – GREEN MANURE WITH BRASSICA CROPS

PRODUCTION CHAINS INVOLVED

VEGETABLES

FRUIT

DESCRIPTION

This measure counters drought, excess water, intense rain and damage to plant health.

This measure is used particularly where the soil contains nematodes, but also to disinfect the soil environment in general. The most commonly used crops are horseradish and mustard. The biocidal substances released by brassica crops used as green manure are extremely volatile and have a relatively short half-life, which means that there are no drift or bioaccumulation phenomena. The biocidal effect of the plant in no way compromises the action of the green manure, i.e. the protection of the soil with plant cover between one main crop and the next, and the addition of organic matter. Finally, the effects are almost immediate, allowing it to swiftly act upon the largest populations in the soil microbial community without creating a biological vacuum. The effect is a sort of purification, after which the land can be repopulated in a more balanced way by the surviving organisms. The most harmonious action is obtained by mixtures of species, especially in the case of the temporary or permanent grassing of multi-annual crops.

Implementation of this measure requires suitable training and/or guidance.

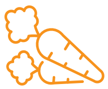
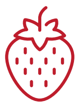
COSTS AND BENEFITS

COST OF INVESTMENT	This measure does not require investments in special equipment, with the possible exception of cutting tools.
AVERAGE ANNUAL COST PER HECTARE	The cost per hectare of the work involved in the use of green manure tends to be fairly modest, as the only steps are cutting, sowing and incorporating the crop into the soil. The cost per hectare of the seeds can range from €60 to €200, depending on the variety (mustard, horseradish, rocket, mixed) and whether they are sown in a greenhouse or outdoors in the fields. The total cost per hectare ranges from €250 to €500.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater. The green manure technique involves greater costs, due to the work of tillage and seeding. However, these increased costs are offset by the agronomic benefits.

EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. The measure offers low effectiveness against drought, excess water and intense rain, but is highly effective against the plant damage caused by nematodes.
IMPACT ON PRODUCTION YIELD AND QUALITY	NO. Green manure tends to bring about an improvement in the quality of production, but first and foremost it facilitates increased yields.
ENVIRONMENTAL BENEFITS	YES. It has a positive effect on the land, particularly on soil quality (soil biodiversity) and on the erosion caused by rain and wind. It also increases organic matter.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRA06 – ACA6 – Cover crops (for arable land only).

COST/BENEFIT EVALUATION

The measure does not have a significant impact on the direct effects of climate change (drought, excess water, rain), but is effective against plant damage and generates environmental benefits. The increase in organic matter in the soil constitutes a tool for the mitigation of climate change. The costs of managing this measure are more than offset by its agronomic benefits and the increase in production quality and yield. In general, medium-large farms see the greatest economic benefits from applying this measure.

PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	VEGETABLES			
	FRUIT			

The illustrated summary of the assessment is based on a cost of €200/ha and moderate effectiveness against climate-related risks.

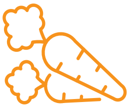
2. SOIL IMPROVERS, FERTILISERS

Some natural products make excellent soil improvers and fertilisers, with benefits which include improving the physical and chemical qualities of the land, storing carbon in the soil, increasing organic matter and biodiversity, improving water retention, promoting growth, and boosting stress response. Examples of such techniques, which are also capable of countering drought, excess water, intense rain, soil erosion, soil degradation and both high and low temperatures, include the following:

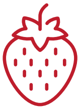
1. **COMPOST**
2. **VERMICOMPOST**
3. **REUSE OF WOOD CHIPS**
4. **REUSE OF GREEN WASTE**
5. **USE OF SLURRY WITH ECO-SUSTAINABLE PRACTICES (INJECTED INTO THE GROUND)**
6. **DIGESTATE**
7. **MANURE**
8. **BIOCHAR**
9. **MYCORRHIZAE**
10. **BIOSTIMULANTS**
11. **KAOLIN**
12. **ROCK FLOUR**
13. **ASH**

MEASURE 2.1 – COMPOST

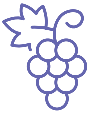
PRODUCTION CHAINS INVOLVED



VEGETABLES



FRUIT



WINE

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters drought, excess water, intense rain and damage to plant health.

Compost is the result of the bio-oxidation and humification of a mixture of organic materials (for example, clippings from pruning, kitchen waste, manure, slurry from macro- and micro-organisms) under specific conditions; i.e. in the presence of oxygen and with a balance between the chemical elements of the matter undergoing transformation. Composting, or biostabilisation, is a biological aerobic process conducted under human control, which produces a mixture of humified substances (the compost) from biodegradable residues through the action of bacteria and fungi. It can be used as a soil improver, for agronomic or gardening nursery purposes. Because it adds organic matter, its use improves the soil structure and the availability of nutrients (phosphorus and nitrogen compounds). Moreover, as a biological activator, it also increases microflora biodiversity.

Implementation of this measure is easy.

COSTS AND BENEFITS

COST OF INVESTMENT	No investment cost. The hypothesis of in-house production has not been taken into consideration.
AVERAGE ANNUAL COST PER HECTARE	Costs vary depending on the product type: bulk, bagged or pelletised. On average, the bulk product costs between €3 and €6/tonne. The quantity used also varies, depending on the crop, the soil's textural characteristics, and the percentage of basal organic matter. In fruit-growing, quantities of 10-20 tonnes/ha are used on average, resulting in a cost of between €30 and €120/ha. When it comes to the horticultural sector, although compost is not widely used, trials indicate an average of 20/25 tonnes pre-planting and 10/15 tonnes for coverage. That said, spreading compost for coverage is rare and of little interest, both for practical reasons and because such high-revenue crops require formulations which will limit the soiling of the edible product. The cost varies between €60-€300/ha. For corn, an average quantity of 60-70 tonnes/ha is estimated, resulting in a cost of €180-€420/ha. For wheat, an average quantity of 30-35 tonnes/ha is estimated, resulting in a cost of €90-€210/ha.

	Because compost releases nutrients very slowly, the quantity which needs to be spread should decline year on year, also taking into consideration the needs of the crops in the field.
COST COMPARED TO CONVENTIONAL PRACTICES	No difference. Depending on the crop and type of land, compost can wholly or partly replace non-organic fertilisation.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Low. It offers low effectiveness against the risks of drought, excess water, intense precipitation and erosion. It helps to mitigate the effects of climate change by reducing the quantities of greenhouse gas emitted into the atmosphere, produced through the working of the land and by the intensive use of pesticides and fertilisers. Mostly, thanks to a high capacity for water retention, it mitigates the impacts of extreme weather events.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. In the long term, it improves soil quality by increasing its content of organic matter, its capacity for water retention and the biodiversity of the soil, with positive effects on both quality and yield. Crop yields can also increase as a result of the release of micro- and macro-nutrients into the soil.
ENVIRONMENTAL BENEFITS	YES. Because it improves soil fertility, compost can be used to varying degrees as an addition to or replacement for chemical fertilisers. Reducing the latter can have important knock-on effects for the environment: it boosts biodiversity, favouring nitrogen transformations; it has a positive effect on plant health, by limiting plant diseases from soil-borne agents; and it gives the soil a more stable structure, making it easier and less energy-intensive to work. Moreover, compost features a high content of stabilised organic matter which, when distributed across the soil, produces two important effects: the first is a general improvement in the chemical and physical characteristics of the land, thus protecting it from problems related to erosion; the second is its function as a carbon sink, progressively sequestering carbon in the soil and helping to counter the greenhouse effect.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRA04 – ACA4 – input of organic matter to soils; Sectoral interventions: 1.4 Fruit and vegetables.

COST/BENEFIT EVALUATION

Over the medium/long term, it helps to increase the soil ecosystem's capacity to adapt to climate change, restoring its ability to produce goods and carry out services (e.g. water filtration, biodiversity). It also helps to mitigate climate change by storing carbon in the soil. The sustainability of this intervention must be evaluated at local level, taking a variety of aspects into account, including the local availability of material for the production of compost and the distance between the site of production and that of distribution. Its cost-effectiveness must be assessed in light of the value of the crops on which the product is to be spread.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
VEGETABLES			
FRUIT			
WINE			
PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €180/ha in the horticultural sector, and low effectiveness against climate-related risks. In the fruit-growing and wine sectors, a cost of €100/ha and low effectiveness was assumed; while a cost of €200/ha and low effectiveness was applied to fodder crops (parmigiano reggiano).

MEASURE 2.2 – VERMICOMPOST

PRODUCTION CHAINS INVOLVED

VEGETABLES FRUIT WINE PARMIGIANO REGGIANO

DESCRIPTION

This measure counters damage from drought, excess water, intense precipitation and erosion.

This measure counters soil deterioration due to the loss of organic matter. Therefore, it is useful in increasing the resilience of agricultural land against extreme events such as drought, intense precipitation, excess water and erosion. Vermicompost is a soil improver obtained when scrap or waste organic matter, such as manure from pigs, cattle, sheep, horses or a mix thereof, is digested by earthworms and subsequently decomposes. Organic carbon must represent at least 20% of the dry matter (according to Italian Legislative Decree 75/2010). The addition of vermicompost is a way of recycling nutrients, particularly nitrogen, phosphorous and potassium, and increasing the storage of carbon in the soil. Its use is permitted in organic farming and is most common in the case of high-value crops, such as in the horticultural sector.

Implementation of this measure is easy, but the product can be difficult to procure.

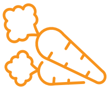
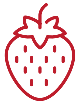
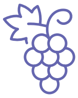
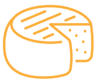
COSTS AND BENEFITS

COST OF INVESTMENT	No investment cost.
AVERAGE ANNUAL COST PER HECTARE	100 kilograms of worm humus can be bought for around €50-€60 at retail level, or around €20-€30 wholesale. The quantity required depends on the type of crop, the agricultural methods chosen, the type of farming – intensive or traditional – and the production per hectare. It can vary from 200-250 kg/hectare up to 1.5-2 tonnes/hectare for highly specialised farms.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater**.** The greater cost is partly linked to the difficulty of procuring the material
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Low**.** It offers low effectiveness against the risks of drought, excess water, intense precipitation and erosion.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. In the long term, it improves soil quality by increasing its content of organic matter, its capacity for water retention and the biodiversity of the soil, with positive effects on both quality and yield. Crop yields can also increase as a result of the release of micro- and macro-nutrients into the soil.

ENVIRONMENTAL BENEFITS	YES. It helps to improve soil health by increasing its content of organic carbon and nutrients, its biodiversity, and its capacity for water retention. It can be used to wholly or partly replace the use of chemical fertilisers.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

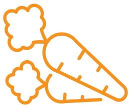
Over the medium/long term, it helps to increase the soil ecosystem's capacity to adapt to climate change, restoring its ability to produce goods and carry out services (e.g. water filtration, biodiversity). It also helps to mitigate climate change by storing carbon in the soil. The sustainability of this intervention must be evaluated at local level, taking a variety of aspects into account, including the local availability of material for production and the distance between the site of production and that of distribution. Considering the high value of the product, its cost-effectiveness must be assessed in light of the value of the crops on which it is to be spread, such as in organic horticulture, for example.

PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	VEGETABLES			
	FRUIT			
	WINE			
	PARMIGIANO REGGIANO			

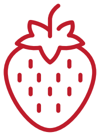
The illustrated summary of the assessment is based on a cost of €200/ha and low effectiveness against climate-related risks.

MEASURE 2.3 – REUSE OF WOOD CHIPS

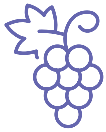
PRODUCTION CHAINS INVOLVED



VEGETABLES



FRUIT



WINE

DESCRIPTION

This measure counters damage from drought, excess water, intense precipitation and erosion.

The value of wood chips has been thoroughly reassessed in recent years. Whether in the form of pruning scraps or traditional wood chips, they can be buried in the ground to significantly increase its content of stable carbon, thanks to the high lignin content. If used in excessive quantities, without further action, they can cause a temporary loss of fertility due to the alteration of the soil's carbon/nitrogen ratio. However, the soil will enjoy numerous benefits over time, both chemical and physical in nature. Specifically, this practice improves the soil's ability to retain water, creating excellent porosity. It also helps to combat erosion by adding structure to the soil. In certain cases, wood chips can even be used as natural mulching material, drastically reducing water evaporation from the ground. However, burying wood in vineyards can sometimes provide a vector for the spread of diseases. For this reason, it may help to form them into round bales and produce biochar for application to the soil. The wood must be adequately shredded, chipped and defibrated using shredders, and the chips then promptly buried so that the soil microflora can facilitate their rapid decomposition. To accelerate and improve the decomposition of the wood chips, a few hundred kilograms of manure, or commercial products specifically designed to add micro-organisms that help with the decomposition of plant material, can be spread on the ground before the mechanical operation. With healthy plants, the practice has beneficial, soil-improving effects. However, it should not be used if there are any pathogens (fungus, canker organisms, silver leaf disease, etc.) present in the wood of the plants. As these can live as saprophytes in the ground, they can benefit from the wood chips, significantly increasing their inoculum potential.

Implementation of this measure is easy.

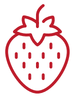
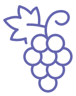
COSTS AND BENEFITS

COST OF INVESTMENT	The cost of investment consists of purchasing a shredder, which can vary from €4,000 to €6,000 on average, and has a typical lifespan of around 12-15 years. Medium-sized farms of 3-5 ha can use one shredder, while larger farms may require two or more and the smallest generally contract this work out.
AVERAGE ANNUAL COST PER HECTARE	Considering average depreciation of €50-€80/ha, the cost per hectare per year (including labour and energy costs) varies from €100 to €150. The same cost of between €100 and €150/ha/year applies if the work is contracted out.

COST COMPARED TO CONVENTIONAL PRACTICES	No difference. The cost can be considered the same, as this measure is by now common practice.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Low. It improves the ability of crops to resist environmental stress.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Balanced nutrition of the soil has a positive effect on production yield and quality.
ENVIRONMENTAL BENEFITS	YES. It enables the addition of organic, natural fertilising matter, thereby reducing the need to use synthetic fertilisers.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRA21 – Action 2 Management of pruning residues on the ground; For the purchase of shredders: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD02 – productive agricultural investments for the environment, climate and animal welfare; Sectoral interventions: 1.1 Fruit and vegetables.

COST/BENEFIT EVALUATION

This measure can introduce the correct nutritional substances into the land, improving its ability to adapt to climate change. The COST/BENEFIT EVALUATIONshows a positive effect on soil biological fertility, particularly if pruning waste is scattered over grassy strips so that the grass can be cut and woody waste shredded at the same time.

PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	VEGETABLES			
	FRUIT			
	WINE			

The illustrated summary of the assessment is based on a cost of €130/ha and low effectiveness against climate-related risks.

MEASURE 2.4 – REUSE OF GREEN WASTE

PRODUCTION CHAINS INVOLVED

VEGETABLES **FRUIT** **WINE**

DESCRIPTION

This measure counters damage from drought, excess water, intense precipitation and erosion.

Green waste refers to the growing medium component (topsoil, straw, peat, pumice) of the waste material derived from branches, green pruning, foliage, hedgerows, grass clippings and the plant substrate that makes up the soil. When shredded and left in a compost bin, it can be re-used in agriculture as compost. Larger waste can be reduced in size using a garden shredder or wood chipper, resulting in chips that can be added to the compost bin to produce topsoil. It should be noted that shredders are mainly used for this purpose in the forestry sector, as opposed to in more purely agricultural enterprises, given that compost is not commonly produced in the latter, with the exception of small organic farms. Green waste returns carbon and nutrients to the land in a balanced manner, thereby helping to increase the content of organic matter with the resulting benefits for fertility and water availability. Moreover, straw, grass clippings and leaves can also be used as mulch to drastically reduce evaporation. In terms of tree crops, it is already common practice to leave clippings from green pruning in the field to be shredded along with any grass clippings present.

Implementation of this measure is easy.

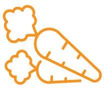
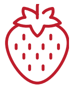
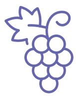
COSTS AND BENEFITS

COST OF INVESTMENT	The cost of investment consists of purchasing a shredder, which can vary from €4,000 to €6,000 on average, and has a typical lifespan of around 12-15 years. Medium-sized farms of 3-5 ha can use one shredder, while larger farms may require two or more and the smallest generally contract this work out.
AVERAGE ANNUAL COST PER HECTARE	Considering average depreciation of €50-€80/ha, the cost per hectare per year (including labour and energy costs) varies from €120 to €150. The same cost of between €120 and €150/ha/year applies if the work is contracted out.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Low. It improves soil fertility and the ability of crops to resist environmental stress.

IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Balanced nutrition of the soil has a positive effect on production yield and quality.
ENVIRONMENTAL BENEFITS	YES. It enables the addition of organic, natural fertilising matter, thereby reducing the need to use synthetic fertilisers.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRA21 – Action 2 Management of pruning residues on the ground; For the purchase of shredders: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD02 – productive agricultural investments for the environment, climate and animal welfare; Sectoral interventions: 1.1 Fruit and vegetables.

COST/BENEFIT EVALUATION

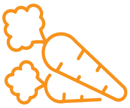
This measure can introduce the correct nutritional substances into the land, improving its ability to adapt to climate change. The COST/BENEFIT EVALUATIONshows a positive effect on soil biological fertility, particularly if pruning waste is scattered over grassy strips so that the grass can be cut and woody waste shredded at the same time.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
 VEGETABLES			
 FRUIT			
 WINE			

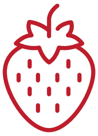
The illustrated summary of the assessment is based on a cost of €130/ha and low effectiveness against climate-related risks.

MEASURE 2.5 – USE OF SLURRY WITH ECO-SUSTAINABLE PRACTICES (INJECTED INTO THE GROUND)

PRODUCTION CHAINS



VEGETABLES



FRUIT

PARMIGIANO REGGIANO

DESCRIPTION

This measure helps to counter drought.

Implementation of this measure is easy; however, the distribution method chosen as most suitable must be based on the characteristics of the land and the presence or absence of crops.

COSTS AND BENEFITS

COST OF INVESTMENT	Investment costs consist of the purchase of self-propelled machinery, which must have a high working capacity as well as large tanks with one or more injectors and high-capacity pumps, capable of keeping slurry loading times to a minimum. The costs of machinery to spread the product, whether on bare ground or in the presence of growing crops, vary depending on model and power. The market offers machines that can create vertical slits in the soil without lifting the sod or turning over the earth, which are suitable for land with a certain amount of compaction. Costs can be reduced by employing a contractor to spread the slurry. Self-propelled machines cost between €500,000 and €700,000 on average, and are generally purchased by contractors. In the case of tankers with injectors (generally farm-owned equipment, with a lifespan of around 12 years), the average cost varies between €120,000 and €180,000. The target market of such equipment is usually farms larger than 400/500 hectares in size.
AVERAGE ANNUAL COST PER HECTARE	If availing of contractors, considering that they charge around €3 per cubic metre and spread around 60 cubic metres per hectare, the annual cost/hectare averages out somewhere between €180 and €200. If the farm produces its own slurry and already owns the necessary equipment, the estimated cost from depreciation, maintenance, fuel and labour is around €120-€150 per hectare.

COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Low.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Opting for injection as the means of spreading slurry boosts its fertilisation power, and thus leads to a better yield.
ENVIRONMENTAL BENEFITS	YES. It limits the emission of ammoniacal nitrogen into the atmosphere and contains the unpleasant odour. It is particularly effective in the context of intensive farming.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRA04 – ACA4 – input of organic matter to soils; For spreaders: SRD02 – productive agricultural investments for the environment, climate and animal welfare.

COST/BENEFIT EVALUATION

This intervention is recommended mainly for large livestock farms, on which slurry is readily available and represents a resource both economically and environmentally.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
VEGETABLES			
FRUIT			
WINE			

The illustrated summary of the assessment is based on a cost of €180/ha and low effectiveness against climate-related risks.

MEASURE 2.6 – DIGESTATE

PRODUCTION CHAINS INVOLVED

VEGETABLES FRUIT WINE PARMIGIANO REGGIANO

DESCRIPTION

This measure counters damage from drought.

Digestate is the result of the anaerobic digestion of various materials: essentially, livestock waste, plant biomass, and by-products of animal and/or agro-industrial origin. As an agricultural soil improver, digestate enhances the physical and chemical properties of the soil. It can replace some fertilisers, increasing yields while using the same amount of other resources. Digestate helps to enrich soil with carbon (in a more stable form than that from slurry) and restores moisture thanks to its high water content. Digestate should be injected below the surface to avoid the loss of nitrogen – mainly in the form of ammonia – through volatilisation. It is important to dose quantities of this soil improver correctly, in order to avoid any negative effects. Proper management of digestate (in terms of dosage and periods of use) minimises the emissions of ammonia and greenhouse gases, during both the storage and distribution stages. Moreover, spreading digestate through fertigation does not cause the nitrogen compounds to leach or percolate into the deeper layers of the soil, but keeps the nutrients within the top 50 cm without polluting the subsurface water.

Implementation of this measure is easy. However, the technique chosen to spread the digestate must take the soil characteristics and the growth stage of the crops in the field into consideration.

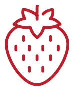
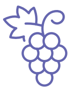
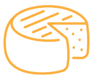
COSTS AND BENEFITS

COST OF INVESTMENT	Investment costs consist of the purchase of spreading machinery. The cost of self-propelled machinery varies based on the different models, which must have a high working capacity as well as large tanks, volumetric pumps and precision dosing, mounted with either discs or dribble bars. Self-propelled machines cost between €500,000 and €700,000 on average, and are generally purchased by contractors. In the case of tankers with injectors (generally farm-owned equipment, with a lifespan of around 12 years), the average cost varies between €120,000 and €180,000. The target market of such equipment is usually farms larger than 400/500 hectares in size.
AVERAGE ANNUAL COST PER HECTARE	If availing of contractors, considering that they charge around €4 per cubic metre and spread around 60 cubic metres per hectare, the annual cost/hectare averages out somewhere between €240 and €300. If the farm produces its own digestate and already owns the necessary equipment, the estimated cost from depreciation, maintenance, fuel and labour is around €150-€180 per hectare.

COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Low.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. The correct distribution method affects both fertilisation power and the increase in yield. Savings of up to 100% can be made on the use of fertilisers.
ENVIRONMENTAL BENEFITS	YES. Contributes organic matter and NPK nutrients, making it a valid alternative to synthetic fertilisers while minimising emissions of ammonia.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRA04 – ACA4 – input of organic matter to soils; For spreaders: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD02 – productive agricultural investments for the environment, climate and animal welfare.

COST/BENEFIT EVALUATION

Over the medium/long term, it helps to increase the soil ecosystem's capacity to adapt to climate change, restoring its ability to produce goods and carry out services (e.g. water filtration, biodiversity). It also helps to mitigate climate change by storing carbon in the soil. The sustainability of this intervention must be evaluated at local level, taking a variety of aspects into account, including the local availability of material for production and the distance between the site of production and that of distribution. Considering the high value of the product, its cost-effectiveness must be assessed in light of the value of the crops on which it is to be spread, such as in organic horticulture, for example.

PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	VEGETABLES			
	FRUIT			
	WINE			
	PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €150/ha for livestock farms and a cost of €250/ha for farms growing fruits and vegetables as well as the wine sector, combined with low effectiveness against climate-related risks.

MEASURE 2.7 – MANURE

PRODUCTION CHAINS INVOLVED

VEGETABLES FRUIT WINE PARMIGIANO REGGIANO

DESCRIPTION

This measure counters drought, excess water, intense precipitation and soil erosion.

Stable or farmyard manure comes from the solid and liquid waste of farm animals, mixed with various other materials that comprise their bedding, following a greater or lesser degree of fermentation. It undoubtedly remains one of the most widely used organic fertilisers, both because large quantities are produced on farms with livestock, and because it has significant economic value. Both the consistency and composition of the material can be more or less variable, with qualities depending on the type and quantity of bedding, the type of animal that produced it, the production techniques used, storage methods and extent of fermentation. The benefits of using this product in the fields include an increase in organic matter and an improvement in soil structure, with a greater water-retention capacity. Manure should be buried, in order to avoid many of its benefits going to waste. There are promising results when it is used together with biochar.

Implementation of this measure is easy; however, it is important to distribute the manure thoroughly, instead of simply piling it up at just a few points of the land.

COSTS AND BENEFITS

COST OF INVESTMENT	The investment consists of the purchase of manure-spreading machinery, and varies depending on whether the spreading system is on the back or side of the tanker. Costs can be reduced by employing a contractor to load the manure-spreader and to spread it in the field. The cost of a manure spreader can vary between €30,000 and €50,000 on average, and has a lifespan of around 10-12 years.
AVERAGE ANNUAL COST PER HECTARE	If the manure is produced on the farm, and is processed using the farm's own equipment, the annual cost per hectare varies between €150 and €200 on average (depreciation, fuel, equipment maintenance, labour). How much manure is spread should be determined based on how much soil improvement is needed. If the work is contracted out, the cost varies between €250 and €300/ha on average. The cost is made up of purchasing the manure, loading it, transporting it and spreading it. The cost/hectare can vary significantly depending on the needs of the land and of the crops.

COST COMPARED TO CONVENTIONAL PRACTICES	Lower/No difference/Greater: The relative cost depends on the type and cost of the synthetic fertilisers which are replaced by the manure.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Low. Providing the correct nutritional input protects against climate-related stress, particularly by providing a moderately effective counter against drought. It offers low effectiveness in countering excess water, intense precipitation and soil erosion.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. The correct distribution method affects both fertilisation power and the increase in yield. Savings can be made on the use of fertilisers.
ENVIRONMENTAL BENEFITS	YES. Contributes organic matter and NPK nutrients, making it a valid alternative to synthetic fertilisers.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRA04 – ACA4 – input of organic matter to soils; For spreaders: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD02 – productive agricultural investments for the environment, climate and animal welfare.

COST/BENEFIT EVALUATION

This measure offers monetary advantages in terms of improving yields and saving on fertilisers. The businesses which benefit most from the use of manure are livestock farms which produce it on site, and those located close to livestock farms, given the lower costs involved in transporting the manure.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
VEGETABLES			
FRUIT			
WINE			
PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €180/ha for livestock farms and a cost of €300/ha for farms growing fruits and vegetables as well as the wine sector, combined with low effectiveness against climate-related risks.

MEASURE 2.8 – BIOCHAR

PRODUCTION CHAINS INVOLVED

VEGETABLES FRUIT WINE PARMIGIANO REGGIANO

DESCRIPTION

This measure counters drought, excess water, intense precipitation and soil erosion.

Biochar is charcoal obtained through the pyrolysis of different types of plant biomass. One particularly interesting aspect of biochar is the potential to produce it from agricultural waste/by-products: clippings, corn or wheat stubble, rice husks, almond hulls, dried foliage, etc. This pyrolysis results in the production of "syngas", a synthetic gas with a heat of combustion equal to that of LPG, which can be used in production processes that need heat (e.g. for drying or the production of electricity). The by-product of pyrolysis is the charcoal known as biochar, which has a carbon content of 90% and acts as a powerful soil improver. Its high level of porosity increases the retention of water and nutrients, making them available to the plants for longer, as well as improving the structure and mechanical properties of soil. Many studies have already shown the positive effect of biochar on agricultural yields, reducing the need for water and fertilisers. The compact structure of biochar prevents it from being broken down by microorganisms in the soil, allowing it to store carbon instead of it returning to the atmosphere in the form of CO_2, as happens with compost or when waste from pruning is burnt. The use of biochar on farmland also reduces the soil's emissions of N_2O, a greenhouse gas with a global warming potential 296 times higher than that of CO_2. The combination of biochar with organic soil improvers such as manure and digestate seems highly promising, at least in viticulture. The use of biochar on alkaline soils requires careful consideration, as it could increase salinity and, in certain cases, suppress the active ingredients of herbicides. At present, there is no real biochar market in Italy, though Italian producers are taking action to bring to market products which meet the standards of the recent legislation. As things stand, this type of soil improver is not widely used. It is likely that its use would increase if the EU were to incentivise C-farming practices.

Currently, this measure is difficult to implement.

COSTS AND BENEFITS

COST OF INVESTMENT	The hypothesis of in-house production has not been taken into consideration.
AVERAGE ANNUAL COST PER HECTARE	If production is geared exclusively towards obtaining biochar, without harnessing the energy produced as part of the process, production costs are very high. The market has not yet established a reference price: as always, this will ultimately consist of striking a balance between supply and demand. Under current circumstances, the cost of using biochar depends on many variables within the supply chain, e.g. the production process, the distance between the site of production and that of distribution, the quantity distributed and the method of distribution.

	It can be distributed in a single go, or added gradually in multiple stages over time. The recommended dose is between 10/20 and 60 tonnes per hectare, depending on the characteristics of the soil. In fact, this is the optimum quantity and the highest level that should be reached, but is never distributed in a single go due to the excessively high costs from production, transport and distribution in the field (a study by ICHAR found that costs on the international market vary within a range of 40-5,000 USD/tonne). For this reason, it is usually distributed in several stages or on small parcels of land. According to Re-Cord, the Renewable Energy Consortium for Research and Demonstration which has been studying this topic for years, the cost of biochar in Italy is around €200/tonne in the case of residual lignocellulosic biomass (which has zero value, apart from the cost of transport). However, the Ichar Association (www.ichar.org) takes the view that the product may have much higher prices depending on the formulation available on the market. Therefore, the cost per hectare is very high, in excess of €8,000/year.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater: The cost is due to the difficulty of procuring the material, its low specific weight and the challenges of distributing it in the field.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Even in the short term, biochar can increase crop yields as a result of the release of micro- and macro-nutrients into the soil. The extent of this benefit varies depending on the composition of the original biomass from which the biochar was produced. In the long term, it can improve soil quality by increasing its content of organic matter, its capacity for water retention and the biodiversity of the soil, with positive effects on both the quality and quantity of the yield. However, the emergence of these benefits in the long term depends on the type of soil on which the biochar was applied, and on the biomass from which it was produced.
ENVIRONMENTAL BENEFITS	YES. Biochar helps to increase the carbon content of the soil, thereby keeping it out of the atmosphere. Moreover, it helps to increase the biodiversity and water-retention capacity of certain soils. The extent of the environmental benefits depends on the nature of the original biomass, the production process and the environmental conditions. The benefits, particularly the environmental ones, persist over the long term. If the main goal is to counter climate change through carbon storage and improving soil quality in the medium/long term, the intervention is justified. The carbon contained in biochar is extremely stable and remains fixed in the soil for hundreds of years, sequestering 3 tonnes of carbon dioxide for every tonne produced.

PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRA04 – ACA4 – input of organic matter to soils; For spreaders: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD02 – productive agricultural investments for the environment, climate and animal welfare.

COST/BENEFIT EVALUATION

This depends on the goals pursued by the farmer or public body conducting the analysis. The economic sustainability of this intervention must be evaluated at local level, taking a variety of aspects into account, including the original biomass, the distance between the site of production and that of distribution, the soil type and the value of the crops on which the biochar is to be spread. Over the short term, the effects on yield are comparable to those of good fertilisation, bearing in mind that nitrogen – an element contained in biochar only in small quantities – needs to be added anyway. Moreover, biochar is currently difficult to procure and challenging to apply in open fields. At the moment, given the high costs, the use of biochar cannot always be justified.

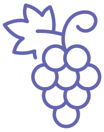
PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
VEGETABLES			
FRUIT			
WINE			
PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €8,000/ha and moderate effectiveness against climate-related risks.

MEASURE 2.9 – MYCORRHIZAE

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES



WINE

DESCRIPTION

This measure counters damage from drought.

Mycorrhizae are symbiotic associations between fungi commonly contained in the soil and plants defined as "higher". They represent the classic case of mutualistic symbiosis, i.e. a mutually beneficial interaction between different organisms. Specifically, the endophyte (the fungus) receives trophic support (nutrition) from the plant, which in turn benefits from improved absorption of water and minerals, ensuring the strength of the plant and its resistance against parasites and environmental stress. Therefore, mycorrhizae are used to accelerate the earliest stages of plant development, in order to increase the production efficiency of the crops during their growing season. In viticulture and fruit-growing, this technique is limited to use in nurseries in order to accelerate the development of the root system: tomatoes, aubergines and courgettes are among the horticultural crops that benefit most from mycorrhizae. Mycorrhizae can be applied to the soil through mycorrhizal inoculants, which come in different forms including granules, micro-granules, concentrated liquids and powders. Inoculants in the form of granules and micro-granules are generally distributed before the crops intended for mycorrhization are sown/planted. For example, when planting vines or fruit trees, they can be added to the hole and covered with a light layer of earth before proceeding with the planting. Liquid formulations and soluble powders can be applied immediately after sowing/planting, or even at a later stage of growing by using the local irrigation system, making this form useful as a secondary, top-up intervention.

Implementation of this measure is easy.

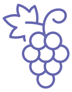
COSTS AND BENEFITS

COST OF INVESTMENT	–
AVERAGE ANNUAL COST PER HECTARE	The costs per hectare depend on the type of farm and the type of crop, on which the correct dosage must be based. The average annual cost generally varies between €70 and €200/ha.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. Moderate effectiveness in situations of drought, increases water absorbency.

IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Mycorrhized plants are better able to tolerate sudden climate fluctuations, boosting both the yield and quality of production.
ENVIRONMENTAL BENEFITS	YES. Mycorrhized plants are able to eliminate the presence of toxic metals in the soil. Moreover, they improve the structure of the soil, increasing its oxygenation and making it less susceptible to erosion.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

The economic benefits arising from the use of mycorrhizae justify the expense, making their application cost-effective and thus advisable.

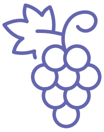
PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	FRUIT AND VEGETABLES			
	WINE			

The illustrated summary of the assessment is based on a cost of €150/ha and moderate effectiveness against climate-related risks.

MEASURE 2.10 – BIOSTIMULANTS

PRODUCTION CHAINS INVOLVED


FRUIT AND VEGETABLES


WINE

DESCRIPTION

This measure counters drought, extreme high and low temperatures, and soil degradation.

Biostimulants are substances which have the capacity to alter the physiological processes of plants, improving their growth, development and/or stress response. The EBIC (European Biostimulant Industry Council) defines them as "substance(s) and/or microorganisms whose function, when applied to plants or the rhizosphere, is to stimulate natural processes to enhance/benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress, and crop quality". Biostimulants have no direct effects on parasites or pathogens, and therefore do not fall into the category of pesticides. Among the most common biostimulants are algae, chitosan, inactive yeast extracts and anti-transpirants.

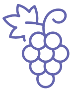
Implementation of this measure is easy.

COSTS AND BENEFITS

COST OF INVESTMENT	
AVERAGE ANNUAL COST PER HECTARE	Dosage varies depending on the crop and on pedoclimatic factors. The average annual cost per hectare varies between €50 and €300, even allowing for multiple treatments throughout the year.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. The benefits are related to the capacity of agricultural cropping systems to adapt to climate change, and to improvements in plant development and strength.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Increases both the yield and quality of production.
ENVIRONMENTAL BENEFITS	YES. Reduction of environmental stress, greater tolerance of abiotic stress, water savings.
PUBLIC FUNDING	CAP Strategic Plan – Sectoral interventions: 1.4 Fruit and vegetables.

COST/BENEFIT EVALUATION

The high effectiveness of biostimulants in relation to the capacity of agricultural cropping systems to adapt to climate change, the improvement in both yield and quality, and the cost incurred through their use all support the implementation of this measure.

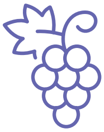
PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	FRUIT AND VEGETABLES			
	WINE			

The illustrated summary of the assessment is based on a cost of €300/ha and high effectiveness against climate-related risks.

MEASURE 2.11 – KAOLIN

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES



WINE

DESCRIPTION

This measure counters damage from extreme high temperatures

Kaolin is a clay whose white colour allows it to reflect the sun's rays away, meaning it can be used as a shield to limit the absorption of light by leaves. Kaolin requires no pre-harvest interval, is non-toxic for humans and the environment, and can be used in organic farming.
The main benefits of using kaolin include:

- A protective action against solar radiation through infra-red reflection, reducing leaf burns;
- An increase in photosynthetic capacity thanks to reduced temperatures;
- A reduction in the loss of water through leaf transpiration;
- A reduction in attacks by various pests such as olive, fruit and walnut flies, vine leafhoppers, pear psyllas and many others.

Implementation of this measure is easy, but it does require suitable training/guidance.

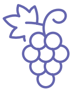
COSTS AND BENEFITS

COST OF INVESTMENT	
AVERAGE ANNUAL COST PER HECTARE	Each treatment with kaolin costs around €30-€40/ha. About 3 treatments are needed per year, varying by season. Taking into account the labour and technical means which must be used for distribution, the average annual cost is estimated at €200-€300/ha.
COST COMPARED TO CONVENTIONAL PRACTICES	No difference.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. Highly effective in preventing damage from extreme high temperatures
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Increases both the yield and quality of production.

ENVIRONMENTAL BENEFITS	YES. It alleviates the strain on crops subjected to water shortages. Treatment with kaolin preserves the plant's functionalities by lowering leaf temperatures even under conditions of serious water stress, allowing the plant to make a full physiological recovery when environmental conditions improve.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

Kaolin's high levels of effectiveness against high temperatures, its additional production and environmental benefits, and the moderate costs involved all support the adoption of this measure by farms.

PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	FRUIT AND VEGETABLES			
	WINE			

The illustrated summary of the assessment is based on a cost of €300/ha and high effectiveness against climate-related risks.

MEASURE 2.12 – ROCK FLOUR

PRODUCTION CHAINS INVOLVED

VEGETABLES FRUIT WINE PARMIGIANO REGGIANO

DESCRIPTION

This measure counters drought and soil erosion.

Volcanic rock flour is an excellent soil improver. It helps to establish ideal soil porosity, with a positive impact on the water and nutrient cycles, not to mention the assistance it provides in root development. This improvement in the underground development of plants leads to increased organic matter in the medium term, amplifying the positive effects in terms of saving water and storing carbon. It also accelerates the process of soil formation. Rock flour is a natural mineral fertiliser obtained from the mechanical crushing of various types of rocks, which can be used on crops, scattered into planting holes for fruit trees or added to compost, in viticulture and in nurseries. During the summer months, the use of rock flour also protects plants from the danger of burning, while it reduces the level of leaf moisture during autumn by drying out plant surfaces. Thanks to these characteristics, the product can be used to strengthen plants, increasing their resistance against pathogens such as fungi, bacteria, phytoplasms, insects and mites. For these reasons, it is widely used in agriculture and particularly in the organic sector, where it offers a valid alternative to fungicidal products and insecticides for horticultural and fruit crops. Rock flour is best obtained from processing activities in mining, as extraction specifically in pursuit of this material is not cost-effective.

Implementation of this measure is easy.

COSTS AND BENEFITS

COST OF INVESTMENT	The quantity, quality, and method of use vary depending on the type of land and crop. On average, 1-2 kg are spread per square metre with a cost which can vary from €2,000 to €4,000/ha. Once added to the soil, it lasts for around 10 years. After this time has lapsed, the soil exchange capacity must be checked, following which it may be necessary to restore a certain percentage of the initial dose.
AVERAGE ANNUAL COST PER HECTARE	Assuming straight-line depreciation, the average annual cost amounts to around €200-€400/ha. It should also be borne in mind that rock flour enhances the value of using fertilisers, even making it possible to eliminate one or more fertilisation cycles depending on the characteristics of the land and the crop in the field. This translates into an economic saving.
COST COMPARED TO CONVENTIONAL PRACTICES	No difference: The cost of using rock flour is balanced out by long-term savings in the fertilisers normally used.

EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Low**.** Offers low effectiveness against both the risk of drought and against erosion.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. With its micro-nutrients (iron, magnesium, manganese, etc.), rock flour helps to achieve balanced soil nutrition, an essential prerequisite for good health and increased productivity in the plants grown. It increases plant resistance against pathogens, with a resulting improvement in production quality.
ENVIRONMENTAL BENEFITS	YES. Water savings, decrease in chemical fertilisers, decrease in fungal diseases, decrease in insect infestation.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

The initial outlay of purchasing rock flour for this measure is amply offset by the many environmental and economic benefits it brings (increased yields, decreased costs for chemical fertilisation, a reduction in water requirements). Moreover, the initial expense will continue to bear fruit for around ten years, after which the cost of replenishing the rock flour will be much lower (generally a percentage of between 10% and 20% of the original expense).
For farms that are small in economic size, which may find the initial investment a major obstacle, the intervention can be carried out on one portion of land at a time.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
VEGETABLES			
FRUIT			
WINE			
PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €300/ha and low effectiveness against climate-related risks.

MEASURE 2.13 – ASH

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES

PARMIGIANO REGGIANO

DESCRIPTION

This measure helps to counter drought

Ash obtained from organic lignocellulosic residues is an extremely nutrient-rich soil improver. In fact, as it comes from wood which has not been treated chemically after being felled, from branches and pruning waste, pellets and charcoal, it is rich in potassium, phosphorous, magnesium and calcium (the last of which reduces soil acidity). In particular, the high phosphorus content stimulates the root system, which has positive effects on water requirements and on the content of organic matter. It makes an excellent fertiliser when used in the right quantities, either as basal dressing or to enrich compost, or can be mixed with maturing manure and with compost at indicative doses of 3-4 kg/m^3 of material. In fact, as it absorbs moisture, it favours the aeration of the fermenting biomass. As ash is a powdery substance, it is also excellent for use against certain parasites; specifically, it keeps slugs and snails away, as it adheres to the soft parts of their bodies and dries them out. However, it proves an ineffective barrier against such parasites under wet conditions, as it is quickly eliminated. Ash reacts spontaneously with carbon dioxide and moisture during storage, altering its chemical-physical characteristics. If the ash is being produced and used on the same farm, it should be stored in sealed bags or metal containers and used as quickly as possible, once the best method of spreading it in the fields is decided upon. Ash can be spread through the same methods normally used for fertilising fields, using machinery already at the farm's disposal, such as agricultural spreaders. One good solution to prevent ash from being blown away in the wind and lost is to mix it with slurry, spreading the result with a liquid manure spreader. The soil should promptly be tilled to a depth of at least 15 cm in order to incorporate the ash, preventing it from being blown away by the wind or reacting with water and air to form insoluble carbonates. The use of ash is comparable in all respects to the use of granular chemical fertilisers and other soil improvers such as slurry. Therefore, good agricultural practices, the regulations governing agricultural production, the instructions of the manufacturers of spreading machinery and the relevant legislation can always be referred to for guidance. The quantity of ash to be distributed should be calculated based on the extent to which the crops need the main nutrients that it supplies. On average, 2 tonnes/hectare are used, while 5-8 tonnes/hectare per year is generally considered the maximum quantity to prevent any damage to the soil or the environment. On the other hand, if the goal is to lower soil acidity, the quantities to be spread will depend upon the calcium oxide content of the ash, applying the same criteria used in agronomy for lime. A single application of ash per year is sufficient, as it is not easily washed away by rain. After spreading the ash evenly, nitrogen should be added to supplement the fertilisation. It is important to pay close attention to what has been burned to produce the ash, as otherwise there is a risk of adding harmful chemical substances such as solvents, glues and paints into the soil. This may increase the soil pH, leaving it too basic for some crops. Ash should not be used on potassium-rich soil and is too rich in mineral salts to be used in nurseries or on seedbeds. Furthermore, it must not be used in combination with fertilisers containing ammonium sulphate, urea or ammonium nitrate.

Implementation of this measure is easy, but it does require suitable training/guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	–
AVERAGE ANNUAL COST PER HECTARE	There is no real cost, as ash is a waste material produced from the combustion of woody biomass. It can also be obtained from a fireplace or stove, as a by-product of heating, in which case its use is limited to small surface areas. Many different projects have demonstrated the benefits of using ash in the agricultural sector; however, no market for ash currently exists.
COST COMPARED TO CONVENTIONAL PRACTICES	No difference.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Low. It offers low effectiveness in countering drought. It increases the ability of crops to resist environmental stress.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Ash helps to achieve balanced soil nutrition, an essential prerequisite for good health and productivity in the plants grown.
ENVIRONMENTAL BENEFITS	YES. It enables the addition of organic, natural fertilising matter.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

This measure can introduce the correct nutritional substances into the land, improving its ability to adapt to climate change. It can be hard to put into practice on medium/large farms, due to the difficulty of procuring the product.

3. AGRONOMIC TECHNIQUES

There are a variety of agronomic techniques which farmers can apply to best manage their farms. These techniques can improve the physical and chemical qualities of the land, prevent compaction, increase the organic matter in the soil and thus boost its fertility, encourage the proliferation of micro-organisms in the soil, and help to manage pests and pathogens. Not only that, but their use can also counter a wide range of climate-related risks. The following are some examples:

1. INTERCROPPING
2. COMPANION PLANTING OF TREES AND HERBACEOUS CROPS
3. CROP ROTATION
4. NATURAL MULCHING
5. BIODEGRADABLE MULCHING
6. RCW (RAMIAL CHIPPED WOOD)
7. TERRACING
8. WINDBREAKS
9. AGROFORESTRY SYSTEMS
10. AGROPASTORAL ORCHARD MANAGEMENT
11. AGROPHOTOVOLTAICS
12. KEYLINE DESIGN
13. CHANGING THE SOWING SEASON – BRINGING SPRING-SUMMER GROWTH FORWARD
14. CHANGING THE GREEN PRUNING TECHNIQUE (FOLIAGE MANAGEMENT)
15. CROP CHOICE
16. VARIETY CHOICE
17. ROOTSTOCK CHOICE
18. AGRONOMIC ACTIONS TO SYNCHRONISE PHENOLOGY WITH ENVIRONMENTAL AVAILABILITY
19. CHANGING THE CULTIVATION AREA
20. CHANGING THE TRAINING AND PRUNING SYSTEMS FOR WOODY CROPS
21. CHOOSING HALOPHYTIC OR HIGHLY SALT-TOLERANT CROPS
22. HALOPHYTIC FODDER CROPS FOR CATTLE

MEASURE 3.1 – INTERCROPPING

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES

PARMIGIANO REGGIANO

DESCRIPTION

The technique of intercropping addresses the climate-related risks of extreme high temperatures, excess water, intense precipitation, erosion and damage to plant health.

Intercropping refers to the agricultural practice of growing more than one plant species on the same plot of land at the same time. Intercropping can take many forms: a mixture of grasses, a mixture of trees, a mixture of treesand grasses in general, a mixture of trees and arable crops specifically, plus the options of multi-level or multi-storied intercropping, and permanent or annual intercropping. It can consist of different species of plants grown in a single field with no particular arrangement (mixed intercropping), arranged into distinct rows (row intercropping), or in distinct strips (strip intercropping). There are many reasons why any given intercropping system might be chosen: to improve the quality of the product, e.g. for fodder; to increase production; to have one crop provide support or protection to another; to guarantee a certain level of production even in a poor season; and to encourage cross-fertilisation. Moreover, intercropping improves the efficiency of the agro-ecosystem and overall yields, by mixing together complementary crops which use resources (water, soil, nutrients) differently. It also enables greater control of pests and pathogens. The practice of intercropping in specialised viticulture has fallen into disuse, as its economic benefits pale in comparison with the time and cost saved by mechanising activities, which intercropping hinders. Intercropping is particularly widespread in organic farming.

This measure can be implemented with training.

COSTS AND BENEFITS

COST OF INVESTMENT	There are no investment costs.
AVERAGE ANNUAL COST PER HECTARE	The cost per hectare arises exclusively from the cost of growing the different crops, and from the added difficulty in their respective agricultural practices. The cost-effectiveness of this agronomic practice, which has been well established over time, must be assessed by individual farms, as the cost varies greatly depending on the crop.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater Costs tend to be higher compared to conventional practices, though much depends on the type of intercropping. Specifically, costs are linked to the added difficulty of carrying out growing operations and to the cost of the crops chosen for intercropping.

EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate This measure is highly effective against extreme high temperatures; moderately effective against the risk of erosion, intense precipitation and excess water; and offers low effectiveness against damage to plant health.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Intercropping has a positive effect on quality and, in the case of mixed intercropping, also improves production yields.
ENVIRONMENTAL BENEFITS	YES. It reduces the use of plant protection products by restricting the spread of diseases.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

The cost-effectiveness of this well-established agronomic practice must be assessed by individual farms, taking into account the characteristics of the farm and those of the crops involved. It is often useful for the benefits that one crop can bring to another. Studies and experiments have shown the advantages of intercropping over monoculture in some cases.

MEASURE 3.2 – COMPANION PLANTING OF TREES AND HERBACEOUS CROPS

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES

PARMIGIANO REGGIANO

DESCRIPTION

The companion planting of trees and herbaceous crops addresses the climate-related risks of extreme high temperatures, excess water, intense precipitation and erosion.

The companion planting of trees and herbaceous crops, or mixed intercropping, has historically been common practice. Not only do the trees provide a windbreak to shelter the crops, but they also represent an additional source of income on plots of land where herbaceous crops would not have been cultivated. Intercropping is based on the principle that many plant species, including agricultural crops, derive benefits if grown in more complex agro-ecosystems. The plant combinations most commonly used for this purpose have traditionally been vines and olive trees along with fodder crops. The practice of intercropping in specialised viticulture has fallen into disuse, as its economic benefits pale in comparison with the time and cost saved by mechanising activities, which intercropping hinders.

This measure can be implemented with training.

COSTS AND BENEFITS

COST OF INVESTMENT	There are no investment costs.
AVERAGE ANNUAL COST PER HECTARE	The cost per hectare arises exclusively from the cost of growing the different crops, and from the added difficulty in their respective agricultural practices. The cost-effectiveness of this agronomic practice, which has been well established over time, must be assessed by individual farms, as the cost varies greatly depending on the crop.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater. Costs tend to be higher compared to conventional practices, though much depends on the type of intercropping. Specifically, costs are linked to the added difficulty of carrying out growing operations.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. This measure is highly effective against extreme high temperatures, and moderately effective against the risk of erosion, intense precipitation and excess water.

IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Intercropping has a positive effect on production quality and yields.
ENVIRONMENTAL BENEFITS	YES. Guarantees increased biodiversity.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

The cost-effectiveness of this well-established agronomic practice must be assessed by individual farms, taking into account the characteristics of the farm and those of the crops involved. It is often useful for the benefits that one crop can bring to another. Studies and experiments have shown the advantages of intercropping over monoculture in some cases.

MEASURE 3.3 – CROP ROTATION

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters drought and damage to plant health.

Crop rotation describes the practice of growing different crops in the same field over a series of growing seasons, hence "rotating" them in sequence through time and space. Assuming regular rotation, this allows a farm to support all the crops within the rotation, effectively getting more use from the same UAA. This diversification over time allows more efficient management of pests and pathogens, thereby limiting dependence on pesticides. It also increases the organic matter in the soil, boosting its fertility and reducing dependence on external inputs, as well as representing a diversification of income streams, considering all the crops in the rotation. Moreover, it allows a better and more effective use of resources, boosting both Nitrogen Use Efficiency (NUE) and Water Use Efficiency (WUE).

This measure can be implemented with suitable training and guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	Crop rotation is a well-established technique adopted by farmers, and may not involve any investment costs. However, there may be some costs involved in the choice of crops to be introduced into the rotation, the extent of which depends on the needs of the "new" crops compared to those already grown on the farm.
AVERAGE ANNUAL COST PER HECTARE	Annual costs are linked to the choice of crops to be introduced into the rotation, the extent of which depends on the needs of the "new" crops compared to those already grown on the farm. Costs/ha can range from extremely low, if any new crops introduced are similar to those already grown on the farm, to very high if, for example, an irrigated crop is to be introduced.
COST COMPARED TO CONVENTIONAL PRACTICES	In general, this depends on the crops in the rotation.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. Low effectiveness against drought; moderately effective against damage to plant health.

IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Increases both the yield and quality of production.
ENVIRONMENTAL BENEFITS	YES. Reducing problems with plant health results in a lower use of plant protection products. This measure can contribute significantly to increasing the sequestering of carbon in the soil, supporting the fight against pathogens and pests, and increasing the efficient use of resources. The extent to which these benefits materialise depends on the soil's initial fertility, and on how innovative the agronomic practices chosen by the farmer are.
PUBLIC FUNDING	CAP Strategic Plan – Ecoscheme 4: "Extensive fodder systems in crop rotation": eligible for financing if it involves the introduction of leguminous and fodder crops or restoration crops in at least a two-year rotation.

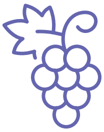
COST/BENEFIT EVALUATION

The cost-effectiveness of this well-established agronomic practice must be assessed by individual farms, as it depends greatly on the crop chosen for the rotation.

MEASURE 3.4 – NATURAL MULCH

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES



WINE

DESCRIPTION

Natural mulch addresses the climate-related risks of drought, low temperatures and erosion.

This technique consists of providing the field with plant cover. From an environmental perspective, mulch plays a fundamental role in terms of radiation and the water balance, acting as a protective shield over the ground and significantly decreasing evaporation. In the same manner, it functions as an insulating layer in winter. By helping to keep the soil warmer, it brings germination forward and protects plants during the earliest stages of their growth cycle. In summer, on the other hand, it keeps the ground cooler by deflecting some of the solar radiation and retaining more moisture, thereby keeping heat stress under control. As it decomposes, the mulch produces substances which will eventually become humus, enriching the soil with organic matter. Moreover, the beneficial effect of covering the soil with regard to erosion, particularly during episodes of intense precipitation, should not be underestimated.
The practice also offers many advantages apart from those related to climate change; for example, the coverage it provides reduces the presence of pests. This technique is suitable for smaller tracts of land such as vegetable plots, gardens and nurseries, while mulch sheets are more appropriate for larger areas. In viticulture, the practice of scattering some of the inter-row clippings in the under-row area as mulch is becoming more common.

It is difficult to implement this measure over large areas.

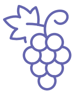
COSTS AND BENEFITS

COST OF INVESTMENT	There are a variety of materials that can be used as natural mulch: straw, dried leaves, tree bark, grass clippings, sawdust, compost, shredded branches, pine needles, etc. It is important to choose the mulch material carefully. Straw is the material used most frequently, particularly in organic settings. Due to the inherent qualities of straw, large quantities must be applied in order to prevent the phenomenon of evaporation from the soil, and to stop the growth of weeds. The drawback of this mulching technique is the cost, unless the farm already has large quantities of suitable material at its disposal. In general, if the surface to be mulched exceeds a certain area (500-1,000 sqm), it makes much more sense to use mulch sheets.

AVERAGE ANNUAL COST PER HECTARE	The only context in which natural mulch is used on large surface areas is in viticulture, where the practice of using some of the inter-row clippings as mulch in the under-row area is becoming more common. In this case, the cost is represented by the tasks of mowing, which is already necessary where land has been grassed, and of spreading the material. In relation to this specific technique alone, an average cost can be estimated: the cost of grassing varies between €150 and €300 per hectare, while a cost of between €50 and €100 per hectare can be estimated for spreading some of the clippings in the under-row area. Mulching can often take the form of shredding woody waste in conjunction with mowing the grass, and scattering the result on the under-row at an average cost of €120-€150/ha. For natural mulching of the under-row in viticulture, the estimated annual cost per hectare therefore varies between €200 and €450 on average.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater. Compared to mulching with plastic or biodegradable sheets.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. This measure is moderately effective against the risk of drought, extreme low temperatures and erosion.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. The mulch promotes ripening and boosts productivity.
ENVIRONMENTAL BENEFITS	YES. It allows reductions in the use of fertilisers, water and weed-killers.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRA21 – Action 2 Management of pruning residues on the ground; Sectoral interventions: 1.4 Fruit and vegetables.

COST/BENEFIT EVALUATION

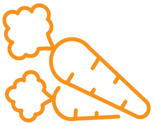
The material needed for natural mulch can be difficult to procure (tree bark, pine needles, etc.), with the result that it is mainly used on small vegetable plots or gardens which need only modest quantities. In viticulture, it is cost-effective to simply use the material already present in the field, i.e. clippings from pruning and mowing.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
 WINE			

The illustrated summary of the assessment is based on a cost of €400/ha and moderate effectiveness against climate-related risks.

MEASURE 3.5 – BIODEGRADABLE MULCH

PRODUCTION CHAINS INVOLVED



VEGETABLES

DESCRIPTION

Biodegradable mulch addresses the climate-related risks of drought, high and low temperatures, and erosion.

This technique involves the use of mulch sheet, preferably biodegradable in type, when sowing or planting. The main agronomic benefit of this technique is that it retains moisture in the soil around the root of the plant, which can develop even without irrigation under normal conditions. Moreover, the film increases the soil temperature, bringing crop development forward. As a result, it can be harvested earlier than its usual growth calendar would indicate, meaning further water savings thanks to a shift of several days in the production cycle. Crop development is also accelerated by the lack of competition from weeds, another benefit of using a mulch sheet. Between the lower levels of evaporation from the soil and the shift of several days in the plant cycle, to a period when less water is required, the water savings can be very significant. In addition, the efficiency of any form of irrigation which may be present, like a hose, is maximised.
Biodegradable sheets can be used instead of plastic sheets for all crops which are traditionally mulched. After the crops have grown, the sheets biodegrade completely without polluting the soil or leaving any residues. Some studies indicate that water savings of up to 40% can be made thanks to mulching.
Mulch sheets come in different thicknesses (measured in microns), to be chosen based on how long the crop is to remain in the field: the thinner the sheet, the less it costs and the less time it will last.

Implementation of this measure is easy.

COSTS AND BENEFITS

COST OF INVESTMENT	The price of biodegradable mulch sheets varies based on their thickness in microns. An 18-micron sheet, which will last around 6 months, will cost between €1,000 and €1,400 per hectare. A 14-micron sheet, which will last around 2-3 months, will cost between €800 and €1,070 per hectare. A 12-micron sheet, which will last around 1 month, will cost between €650 and €800 per hectare. The price per hectare also varies depending on the percentage of the surface area covered by the sheet, which in turn depends on the type of crop in the field.

AVERAGE ANNUAL COST PER HECTARE	The cost of laying the sheet, and any hose to be used, can be estimated at €100 per hectare. Therefore, adding together the cost per hectare of the sheet and the cost of applying it, the resulting total comes to between €750 and €1,500 per hectare.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater/No difference. The cost is greater compared to no mulching. There is no difference between using plastic and biodegradable mulch sheet, as the lower cost of the plastic sheet is offset by the costs of disposing of the plastic.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. This measure is very effective against the risk of drought and enables significant water savings, particularly if combined with drip irrigation. It is moderately effective in countering high and low temperatures and against erosion.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. The mulch promotes ripening, keeps the produce from coming into contact with the soil, and boosts productivity.
ENVIRONMENTAL BENEFITS	YES. It allows reductions in the use of fertilisers, water and weed-killers.
PUBLIC FUNDING	CAP Strategic Plan – Sectoral interventions: 1.4 Fruit and vegetables.

COST/BENEFIT EVALUATION

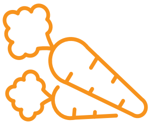
The economic benefits more than make up for the costs sustained in applying the biodegradable mulch. Moreover, the extra cost of purchasing biodegradable sheet compared to plastic sheet is offset by cutting out the additional expense of disposing of the sheet.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
VEGETABLES			

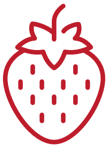
The illustrated summary of the assessment is based on a cost of €1,500/ha and high effectiveness against climate-related risks.

MEASURE 3.6 – RCW (RAMIAL CHIPPED WOOD)

PRODUCTION CHAINS INVOLVED



VEGETABLES



FRUIT

DESCRIPTION

This measure counters drought and soil erosion.

The RCW method was developed in Canada starting in the 1970s, and has become widespread in Europe over the past two decades thanks largely to the efforts of French farmer Jacky Dupety. Ramial chipped wood, or *bois raméal fragmenté* to give it its original French name, consists of wood chips from small and medium branches. RCW can be used as a surface mulching material, or can be incorporated into the soil like green manure. Ramial chipped wood is made up of twigs and branches from trees and woody shrubs, up to a diameter of 7-8 cm. These are shredded into small chips, with the resulting product proving richer in nutrients than other chipped wood products. It effectively promotes the growth of fungi in the soil, and soil formation in general. RCW is considered a soil improver and a fertiliser, capable of adding nutrition, structure and energy to the soil and of reducing or even completely eliminating the need for irrigation. The use of this product makes the ground airier and spongier, allowing it to hold on to the ideal quantity of water and resist both evaporation and compaction. It is particularly recommended for impoverished, eroded land. Its specific benefit consists of its action on life within the soil: this material triggers a sequence of complex trophic chains which structure the soil, manage the nutrients and curtail pathogens.

At the moment, the use of RCW is mostly limited to the cultivation of small areas (vegetable plots, nurseries, gardens) and is indicated for both fruits and vegetables.

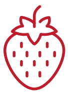
COSTS AND BENEFITS

COST OF INVESTMENT	The cost of investment essentially consists of the equipment needed to produce the chipped wood. Various types of wood chippers exist: self-propelled, with 3-point tractor hitches, engine-powered, or for use with a cardan hitch. Depending on the farm's needs, a wood chipper may cost between €5,000 and €20,000, with an average lifespan of 15-20 years. Larger, more expensive wood chippers, dedicated to the production of wood chip, are generally not suitable for the production of RCW specifically. Finally, wood chippers for hobbyist use can be found for a few hundred euro.

AVERAGE ANNUAL COST PER HECTARE	One estimate, which assumes a cost of between €15 and €30 per m^3 of RCW (Dupety, 2013), indicates that purchasing enough to completely cover a surface area of one hectare with: - a 4-5 cm layer (450 m^3) would cost between €6,750 and €13,500; - a 2 cm layer (200 m^3) would cost between €3,000 and €6,000; - a 0.5 cm layer (50 m^3) would cost between €750 and €1,500. Using a thick layer of RCW, potentially even more than 5 cm, would currently seem to make sense for smaller areas. It is mostly recommended for farms which can produce their own RCW on site, using the farm's own wood chippers on the material already present on the farm (trees, shrubs) or by planting suitable tree species. The quantity of RCW which needs to be used tends to decrease with each passing year, so the cost will be lower after the first year.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater. The costs involved are higher.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. The measure is moderately effective against the risk of drought, and highly effective in countering soil erosion.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Increases both the yield and quality of production.
ENVIRONMENTAL BENEFITS	YES. It prevents soil erosion, allows the build-up of stable humus, and improves the structure of the soil, making it airier.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRA21 – Action 2 Management of pruning residues on the ground; For the purchase of machinery: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD02 – productive agricultural investments for the environment, climate and animal welfare.

COST/BENEFIT EVALUATION

Reasonably high costs will be incurred. In general, farms with a high level of land productivity will see the greatest economic benefits from the application of this intervention. It can also be a solution worth considering for small farms which have the ability to produce their own RCW.

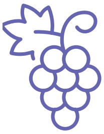
PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	VEGETABLES			
	FRUIT			

The illustrated summary of the assessment is based on a cost of €1,000/ha and moderate effectiveness against climate-related risks.

MEASURE 3.7 – TERRACING

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES



WINE

PARMIGIANO REGGIANO

DESCRIPTION

Terracing addresses the climate-related risks of erosion and flooding.

Terracing, or terrace farming, is a solution used in agriculture to enable the cultivation of land characterised by particularly steep slopes. Steps are cut into the slope, resulting in narrow, level platforms. This technique not only makes it easier to carry out agronomic operations and processes, it also limits soil erosion and surface water run-off. By doing so, it increases the fertility of the land and its ability to withstand water shortages. This technique makes even the steepest hillsides usable for farming purposes, particularly for growing olive trees and vines. Classic examples include the terraces of the Amalfi Coast and the Cinque Terre.

The technical requirements of this measure make it difficult to implement.

COSTS AND BENEFITS

COST OF INVESTMENT	This measure entails undeniably high investment costs, both in terms of materials and equipment and in terms of labour. However, it is not possible to determine a generic cost per hectare for terracing, as many different factors must be taken into consideration. These include the slope, the availability and type of construction material, the construction technique, the potential for the recovery of any earlier structures, the work of excavation and levelling, the width of the terraces, the soil characteristics, etc.
AVERAGE ANNUAL COST PER HECTARE	The cost per hectare consists of any depreciation in the construction and the maintenance required by the terraces.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater. Costs are higher than those of conventional practices. Specifically, costs are linked to the added difficulty of carrying out farming operations and to the lower potential for mechanisation.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. The measure is highly effective against the risks of erosion and flooding.
IMPACT ON PRODUCTION YIELD AND QUALITY	NO. Rather than influencing quality and yield, terracing makes it possible to farm areas which would otherwise be unusable.

ENVIRONMENTAL BENEFITS	YES. It prevents erosion and increases fertility and the ability to withstand water shortages.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD04 Non-productive agricultural investments for environmental purposes – Action 1.

COST/BENEFIT EVALUATION

The technical difficulties of implementing the measure are based on a variety of factors: the slope, the logistics (transporting materials, the potential for the use of mechanical equipment, etc.), the availability and type of material, the construction technique, the potential for the recovery of any earlier structures, the work of excavation and levelling, the width of the terraces, the soil characteristics, and the need for specialist labour. The immense variation in the factors to be considered makes it impossible to estimate an average cost per hectare. Therefore, this assessment must be made on a case-by-case basis that takes the characteristics of the farm and the soil into account.

MEASURE 3.8 – WINDBREAKS

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES

WINE

PARMIGIANO REGGIANO

DESCRIPTION

Windbreaks protect crops from strong gusts of wind, drought and erosion.

Moderate winds aid the pollination process, eliminate cold and humid air, reduce the risk of fungal diseases, etc. However, if the farm's positioning leaves it exposed to strong winds, whether hot or cold, this can pose a major problem for growers, both in tunnels and in the open field. As wind speed increases, plant growth slows down and becomes limited. Strong winds dry out flowers, interfere with the activity of pollinating insects, and interrupt the plant fertilisation process. This leads to a reduction in production quality and yield. More visible damage, like abrasion and breakages, lead to increased plant stress, loss of water and crops which cannot be sold. In addition, strong winds (over 60 km/h) can distort the support structures of any tunnels present. Windbreaks, also known as shelterbelts, consist of perennial shrubs and/or trees planted in specific row patterns for the purpose of protecting crops from the wind. Windbreaks offer protection against the wind in their immediate vicinity, but their influence also extends far beyond the rows of trees themselves, as they produce air turbulence and thereby reduce wind intensity and laminar flow speed. Therefore, windbreaks protect against strong gusts of wind while also reducing soil erosion, as they consist of perennial plants. With less wind, evapotranspiration is also drastically reduced throughout the entire year.

This measure requires additional investment costs and suitable training/guidance.

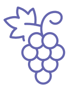
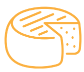
COSTS AND BENEFITS

COST OF INVESTMENT	Costs vary depending on the number of plants and the type of windbreak chosen. Considering a cost of around €10 per plant, with a tree planted every metre, the cost of 100 metres of windbreak (representing a square hectare of surface area, with trees planted along one side only) is around €1,000. This cost depends on the type and number of trees to be planted, with an estimated range of around €1,000 to €3,000.
AVERAGE ANNUAL COST PER HECTARE	Running costs relate to the care and maintenance of the windbreak, e.g. pruning operations, with the expense estimated at between €50 and €100/ha. The lifespan of the windbreak depends on the tree species, but is usually in excess of 50 years.

COST COMPARED TO CONVENTIONAL PRACTICES	Greater. In addition to the cost of setting the windbreak up, costs will also be incurred for its care and maintenance.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. Highly effective protection against wind and erosion, moderately effective against drought.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. It prevents plant damage and fruit drop, thereby increasing quality and yield.
ENVIRONMENTAL BENEFITS	YES. Reduces soil erosion, constitutes an EFA, and can be considered a landscape feature.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD04 Non-productive agricultural investments for environmental purposes – Action 1.

COST/BENEFIT EVALUATION

Depreciation of the investment is negligible, and the annual cost per hectare incurred for this intervention is low. Essentially, the expense involved consists of the initial investment, which is not excessively burdensome considering the benefits it brings. The cost may weigh more heavily on the budget of smaller farms, but the benefits nonetheless justify it.

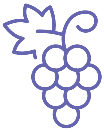
PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	FRUIT AND VEGETABLES			
	WINE			
	PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €200/ha and high effectiveness against climate-related risks.

MEASURE 3.9 – AGROFORESTRY SYSTEMS

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES



WINE

PARMIGIANO REGGIANO

DESCRIPTION

Agroforestry systems protect against intense rain, drought and wind.

Combining forestry with crops may sound like a throw-back to bygone times, but it offers interesting potential for a variety of reasons. Woodland tree species help to make the soil richer, act as a windbreak and protect against excessive radiation, while limiting water consumption and soil erosion. If the combinations are well chosen, tree crops can act as a second line of production, thus increasing productive potential even with the same consumption of resources. For example, it is possible to grow crops of nuts (walnuts, chestnuts, acorns), fibre, or timber products (e.g. wicker). Forest species can also be used for support in the context of crop systems which require it, such as traditional vineyard plantations. Such agroforestry systems mainly develop on hillsides, where they counter erosion, and are less likely to be grown on more valuable flat land.
While these systems are still little used in Italy and Europe, the following are the most common types of European agroforestry:

- Silvoarable systems: trees intercropped with arable or fodder crops (e.g. walnut trees along with wheat, corn or clover);
- Silvopastoral systems: trees combined with animal pasture;
- Hedgerows: vegetation planted in a linear manner around the field, including buffer strips, windbreaks, boundary plants and living fences;
- Improved fallows: fallow land is enriched with fast-growing vines, shrubs or trees.

This measure requires investment costs and suitable training/guidance. The measure is still undergoing trials, and is being implemented mainly in Northern Europe.

COSTS AND BENEFITS

COST OF INVESTMENT	The cost of setting up the system varies, on average, between €2,000/ha and €5,000/ha, depending on the type of agroforestry in question.
AVERAGE ANNUAL COST PER HECTARE	Morphology and soil type can affect costs. On average, maintenance costs range from €200 to €1,500/ha depending on the species planted. Overall, considering depreciation of the investment, the estimated annual cost/ha varies widely: from €300 to €1,800.

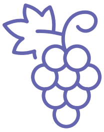
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate/Low. For a complete evaluation of effectiveness, more trials are still required.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Over the first 3-4 years, the agroforestry system causes a drop in production; however, in the long term, studies show an increase in production of the main crop.
ENVIRONMENTAL BENEFITS	YES. Agroforestry systems limit water consumption and soil erosion, help to renew the land, and increase carbon storage.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD05 – planting of afforestation/creation of woodland and agroforestry systems on agricultural land; SRA28 – support for maintaining afforestation/woodland and agroforestry systems.

COST/BENEFIT EVALUATION

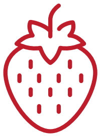
Further studies are needed to assess the usefulness of these systems, which are little used in Italy and Europe. One of the problems preventing the application of this measure is a lack of awareness among farmers. Incentives in the Common Agricultural Policy may encourage more uptake.

MEASURE 3.10 – AGROPASTORAL ORCHARD MANAGEMENT

PRODUCTION CHAINS INVOLVED



WINE



FRUIT

DESCRIPTION

This measure counters drought and soil erosion.

Grassing the inter-row areas of orchards and vineyards can be beneficial in terms of adaptation to the effects of climate change. Moreover, the grass growth can be managed through animal pasture. Cattle, sheep, goats or horses – species and number to be determined on a case-by-case basis – can be let into the field whenever the grass is becoming too high, provided that there are no active ingredients present (plant protection products, fertilisers) which are harmful for their health. This further adds to the benefits of the practice, reducing the need for mechanical mowing and enriching the organic matter in the soil thanks to animal waste. In turn, the advantages of this practice to the animals should not be underestimated. In fact, the shade provided by the tree crops is important in reducing the heat stress experienced by animals during heat waves.

Implementation of this measure is easy.

COSTS AND BENEFITS

COST OF INVESTMENT	There are no investment costs.
AVERAGE ANNUAL COST PER HECTARE	In some cases, the animals may require supervision during pasture.
COST COMPARED TO CONVENTIONAL PRACTICES	Lower. Costs are saved by reducing mechanical mowing operations.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Low.
IMPACT ON PRODUCTION YIELD AND QUALITY	NO. This measure does not increase the yield or quality of production.
ENVIRONMENTAL BENEFITS	YES. The organic matter in the soil is increased.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

When farm conditions allow, the implementation of this measure is economically advantageous, reducing mechanical mowing operations and thus saving costs. In addition, putting the animals to pasture enriches the soil with their organic waste. Finally, the animals themselves enjoy benefits in the form of feed and shelter from heat stress.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
WINE			
FRUIT			

MEASURE 3.11 – AGROPHOTOVOLTAICS

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES

WINE

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters damage from drought and extreme high temperatures.

Agrophotovoltaics enable the generation of renewable energy, while simultaneously helping crops to withstand hot, dry conditions. The measure consists of installing solar panels in combination with agriculture and livestock farming, so that no productive land is lost for the latter two activities. Indeed, such a system can provide the foundations for building a renewable energy community. What's more, the agrophotovoltaic system influences soil temperature and the distribution of water during precipitation events. In spring and summer, the soil temperature is lower than that of a field where this technique is not in use, at the same air temperature. Ideally, the solar panels should be installed on flat, south-facing farmland, which must not be located in an area bound by environmental, rural or urban planning constraints. Panels may vary in power (200-500 kW), depending on make and model, and are usually set up on steel poles of up to 5 metres in height, giving them exposure to sunlight while still leaving the soil free for cultivation. However, there is still a modest reduction in agricultural production (<20%) with this type of installation, as a result of the shadow it casts. It also involves additional costs compared to installation on the ground, though this is partly offset by the radiation reflected away from the land, if the panels use double glass. On the other hand, the new generation of solar panels feature single-axis trackers, allowing them to follow the trajectory of the sun and produce up to 20% more energy. What's more, if installed at appropriate heights and adequately spaced, they do not hinder normal agricultural activities and no single patch of soil is left in permanent shade. Latest-generation solar panels are made from monocrystalline silicon (the use of polycrystalline silicon is by now less common). High-efficiency panels, similar in size to standard panels (2 x 1 m; best suited to installation on the ground), can be found on the market: these can reach up to 550 kW in power and last up to 40 years, meaning less space is needed to install the same kWp. The installation of photovoltaic panels on uncultivated land makes it feasible to launch productions which would otherwise be uncompetitive. Given the hypothesis of a 5-MWp plant, and assuming that the energy community itself consumes 70% of the solar energy produced, i.e. roughly 4.55 GWh/year, it is estimated that the greatest advantages will be seen in horticulture, floriculture and nurseries, wine production and livestock farming. Energy produced through the photovoltaic plant can also be sold for additional profit, with the Electricity Services Manager acting as the intermediary between the energy producer and the customer. The sale price for the electricity is set on a monthly basis by the Italian Authority for Electricity and Gas, with rates varying based on the location of the plant (Northern, Central or Southern Italy) and the time when the energy is bought. A photovoltaic plant of less than 10 MWp in power is required to take advantage of this opportunity, with earnings at their highest, naturally, in summer. An annual payment must be made to the Electricity Services Manager, the amount of which depends on the power of the photovoltaic plant and the type of technology used.

Implementation of this measure is easy.

COSTS AND BENEFITS

COST OF INVESTMENT	Between 1,200 and 1,600 panels/ha are installed on average, depending on the type of installation. The cost consists of: • purchasing the solar panels, the prices of which vary based on make and model: around €150 for a 460W polycrystalline panel; around €175 for a 500W monocrystalline panel; more than €250 euro for a high-efficiency panel over 550W; • the support structures (€100-€120/kW); • set-up. In total, the investment is estimated to range from €250,000 to €560,000 per hectare. Assuming an average return of €100 per kWp per year (for the energy produced and sold in full), the average annual income per hectare can vary between €55,000 and €90,000. This return means that the entire initial investment can be made back in 5/7 years, while the lifespan of the plant is 25/30 years.
AVERAGE ANNUAL COST PER HECTARE	Assuming straight-line depreciation of the investment, plus maintenance of the plant, the average annual cost per hectare can be estimated at €10,000-€23,000. The return more than makes up for this cost.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate/High. This measure keeps soil temperature cooler during hot periods, and improves water distribution during precipitation.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Yield is reduced by 5%-20%.
ENVIRONMENTAL BENEFITS	NO.
PUBLIC FUNDING	NRRP (M2C2.1 – Investment 1.1); CAP Strategic Plan – Rural development interventions: SRD02 – Productive agricultural investments for the environment, climate and animal welfare: action A: Investments for climate change mitigation.

COST/BENEFIT EVALUATION

The measure is capable of effectively protecting production against the damage caused by drought and extreme high temperatures. Moreover, it represents a valid alternative source of income, allowing farms to diversify their activities and thus reduce market risks. However, a high initial investment must be made, meaning that application of this measure requires the availability of capital and farmland with the correct characteristics.

MEASURE 3.12 – KEYLINE DESIGN

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters drought and soil erosion.

Keyline design is an agronomic technique implemented to optimise the use of water resources in an area. With keyline design, the water resources within a given tract of land are managed, regulated and efficiently used through a series of principles and techniques. By controlling surface water flow, erosion is reduced, the availability of water for crops is increased, and micro-organisms are encouraged to proliferate in the soil.
Water management under keyline design begins with identifying a so-called keypoint, located in the primary valley of the land in question. Once this point has been identified, the water flow and dynamics of the land itself can be analysed, followed by the identification of a keyline and the geographical and topographical plotting of the entire area.
Keyline design considers the farm as a single productive unit, and seeks to have it reach its full potential based on the topographical, pedological, environmental and water-related characteristics of its lands. In general, it proves effective on surface areas greater than 20 hectares. By mapping the land, it is possible to determine the lines along which rainwater will flow. Those lines can then be followed on the land to create new tilling directions, canals, walkways, and small storage basins which act as water reserves.

This measure can be implemented, but it does require training/guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	The interventions necessary depend exclusively on the morphology and structure of the land in question. It may not be necessary to make any investments, but simply to work the land differently. However, it is necessary to acquire training and the advice of specialists.
AVERAGE ANNUAL COST PER HECTARE	As explained in relation to investments, the cost of the interventions needed must be determined on a case-by-case basis.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate/High. Moderately effective against both drought and erosion.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. The use of this technology enables better results to be obtained, in terms of both yield and quality.

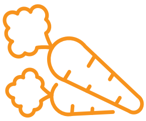
ENVIRONMENTAL BENEFITS	YES. Prevents soil erosion.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

The benefits of the increased availability of water resources and the improved results in terms of quality and yield, together with the protection from erosion and drought, can easily offset the costs sustained in implementing the measure. However, as the interventions for implementation depend greatly on the morphology and structure of the land, it is not possible to estimate the cost per hectare. Therefore, this assessment must be made on a case-by-case basis that takes the characteristics of the farm and the soil into account.

MEASURE 3.13 – CHANGING THE SOWING SEASON – BRINGING SPRING-SUMMER GROWTH FORWARD

PRODUCTION CHAINS INVOLVED



VEGETABLES

DESCRIPTION

This measure counters drought and extreme high temperatures

Bringing the development of spring-summer crops forward serves the purpose, first and foremost, of shifting the growth stage to periods when less water is needed, and which are better suited to plant growth in terms of temperature. The measure is based on sowing as early as possible, potentially with the help of fertilisers or other supplements capable of aiding the early stages of development (called the "starter effect"), in cases where it requires crops to develop in temperatures generally lower than their optimum thermal conditions, at least during the very first stages or weeks of the cycle. Obviously, the land's risk of spring frost must be assessed in such cases: the more detailed the assessment, the better.
In a warmer climate, sowing or planting earlier shifts the cycle into a cooler period of time, better suited to the crop's thermal needs and more similar to the typical growing season of such zones. In the Italian climate, this is true for all crops sown in spring, which usually benefit from this measure during the spring-summer period of particularly hot years. Naturally, bringing the crop forward in this way exposes it to a greater likelihood of spring frosts. As previously mentioned, this must be assessed on a case-by-case basis, studying the probability distribution of the "new" climate compared to that of the past. Any positive impact the measure may have on crop productivity is dependent on the crop's irrigation needs being met.
The measure is decidedly less reliable in the case of crops sown in autumn, whose development cycle stretches from autumn to the following summer. In this case, the sowing season can be optimised by postponing it, shifting some stages into cooler periods. In any case, the yield response curve based on the sowing season is decidedly flatter than that seen for crops sown in spring.

Implementation of this measure is easy.

COSTS AND BENEFITS

COST OF INVESTMENT	There are no investment costs.
AVERAGE ANNUAL COST PER HECTARE	There are no additional costs.
COST COMPARED TO CONVENTIONAL PRACTICES	No difference.

EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. Highly effective for spring crops in particular; moderately effective, with a greater level of uncertainty, for autumn crops.
IMPACT ON PRODUCTION YIELD AND QUALITY	NO. No relevant effects have been found on product quality. On average, sowing spring crops early can significantly reduce the gap in production between the "new" climate and that of the past.
ENVIRONMENTAL BENEFITS	YES. Savings of water resources.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

The measure can be highly effective for spring crops; less so for winter crops. In any case, the choice of sowing season should be based on the water-related conditions of the soil at the time of sowing and/or planting, and on the medium-term weather forecasts, with all the uncertainty that involves.

MEASURE 3.14 – CHANGING THE GREEN PRUNING TECHNIQUE (FOLIAGE MANAGEMENT)

PRODUCTION CHAINS INVOLVED

WINE

DESCRIPTION

This measure counters damage from extreme high temperatures

Usually, defoliation is carried out only on one side, the north-east side, and on basal leaves around the clusters. This improves air circulation, while at the same time preventing sunburn on the grapes. In viticulture, altering the defoliation methods can help to counter the increase in heat experienced by the grape clusters during heat waves, thanks to the greater protection offered by the leaves. Defoliation is common practice; however, in cases of high temperatures and on land particularly affected by drought, it is better not to defoliate or to do so only minimally.

This measure can be implemented, but it requires additional investment costs and/or suitable training/guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	If carried out by hand, as it usually is, there are no investment costs. The cost of a vineyard deleafer can vary from €16,000 to €30,000 depending on the model (deleafers which work on just one side of the row or on both sides, with a fixed head or reversible head, etc.), and they have a lifespan of around 15 years. For smaller farms, it makes more sense to avail of subcontractors or family labour.
AVERAGE ANNUAL COST PER HECTARE	Morphology and soil type can affect costs, which derive exclusively from labour: 50/60 hours/ha/year, if defoliation is carried out manually. If it is performed mechanically, using a deleafer, and assuming a UAA of 5 to 10 hectares, the average cost of depreciation can be around €200/ha/year. With mechanical defoliation, the labour required is estimated at 2/3 hours/ha/year. Therefore, the total cost of mechanical defoliation is estimated at around €250-€300/ha.
COST COMPARED TO CONVENTIONAL PRACTICES	No difference. This measure is common practice.

EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES.
ENVIRONMENTAL BENEFITS	NO.
PUBLIC FUNDING	For the purchase of deleafers: CAP Strategic Plan – Rural development interventions: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; Sectoral interventions: 1.7 Fruit and vegetables.

COST/BENEFIT EVALUATION

Changing the pruning technique does not involve any increase in the costs incurred. In some cases, costs may actually decrease, due to a reduction in the amount of labour needed (less foliage removal).

MEASURE 3.15 – CROP CHOICE

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters damage from drought, increases in maximum temperatures, saltwater intrusion and damage to plant health.

Due to the effects of climate change, we are witnessing shifts in the cultivation areas of certain crops. Taking temperature and precipitation forecasts into consideration, it may be advisable to choose crops to best suit any new meteorological/climate conditions. This can be the case with many types of crops.

This measure can be implemented, but it may require additional investment costs and/or suitable training/ guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	Costs may be particularly high depending on the different needs and requirements of the "new" plant species compared to that previously grown on the farm.
AVERAGE ANNUAL COST PER HECTARE	Variable, with the same factors to be considered as for the investment. Morphology and soil type can affect costs.
COST COMPARED TO CONVENTIONAL PRACTICES	Depends on the crop chosen.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES.
ENVIRONMENTAL BENEFITS	YES. Significant savings of water resources can be made.
PUBLIC FUNDING	NO.

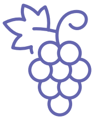
COST/BENEFIT EVALUATION

The choice of crop must be made based on an assessment of the adaptability of the species and the crop system which the farm hopes to introduce to replace a previous crop. The success of this measure depends greatly on the thoroughness of the preliminary evaluation analyses.

MEASURE 3.16 – VARIETY CHOICE

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES



WINE

DESCRIPTION

This measure counters damage from drought, increases in maximum temperatures, saltwater intrusion and damage to plant health.

Taking temperature and precipitation forecasts into consideration, it may be advisable to choose the variety that best suits any new meteorological/climatic conditions. Anomalous trends in temperature and rain, or in climate conditions generally, is good reason to study how different varieties perform in agronomy, allowing producers to achieve their primary goals by altering the varieties they choose. This measure counters the limits of plant species distribution, in order to create a system in which climate, pedological and biological factors interact to favour the growth of specific products which best adapt to the meteorological/climatic conditions of a given terrain.

Implementation of this measure requires suitable training and/or guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	In general, the measure of choosing varieties does not involve any initial investment costs.
AVERAGE ANNUAL COST PER HECTARE	The cost does not depend primarily on management, but rather on the seeds, meaning that there are no significant differences.
COST COMPARED TO CONVENTIONAL PRACTICES	Costs depend on the type of cultivar, in terms of the care and maintenance required by the species variety being grown.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate.
IMPACT ON PRODUCTION YIELD AND QUALITY	NO.
ENVIRONMENTAL BENEFITS	NO.
PUBLIC FUNDING	NO.

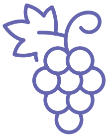
COST/BENEFIT EVALUATION

The choice must be made based on an assessment of the adaptability of the variety which the farm hopes to introduce to replace a previous variety. The success of this measure depends greatly on the thoroughness of the preliminary evaluation analyses.

MEASURE 3.17 – ROOTSTOCK CHOICE

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES



WINE

DESCRIPTION

This measure counters drought, damage from extreme high temperatures, saltwater intrusion and damage to plant health.

The rootstock is a mediator between the soil and the plant. Taking temperature and precipitation forecasts into account, it may be advisable to choose the rootstock that best suits any new meteorological/climatic conditions. The choice of rootstock must take the pedological characteristics of the soil into account, in order for the plant to make best use of the resources available to it. The rootstock must also be chosen based on its resistance to pathogens, as perfectly demonstrated by the attempts to counter phylloxera in viticulture.

Implementation of this measure requires suitable training and/or guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	In general, there are no investment costs.
AVERAGE ANNUAL COST PER HECTARE	The use of rootstocks is by now common practice. There is no major price difference between rootstocks themselves; any discrepancy in cost depends on the variety being grafted.
COST COMPARED TO CONVENTIONAL PRACTICES	As matters stand, the use of rootstocks can be considered conventional practice.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Optimisation of the variety's quantity-quality ratio.
ENVIRONMENTAL BENEFITS	YES. Benefits associated with the agronomic management of the grafted plant. Fewer interventions to maintain plant health.
PUBLIC FUNDING	NO.

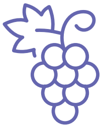
COST/BENEFIT EVALUATION

The cost-effectiveness of this well-established agronomic practice must be assessed by individual farms, taking into account the characteristics of the farm and of the pedoclimate, as well as those of the crops/varieties involved.

MEASURE 3.18 – AGRONOMIC ACTIONS TO SYNCHRONISE PHENOLOGY WITH ENVIRONMENTAL AVAILABILITY

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES



WINE

DESCRIPTION

This measure counters drought and damage from extreme high temperatures.

The goal of this action is to have crop growth overlap, for as long as possible, with the climate conditions most suitable to the crop. This serves to avoid, to the extent possible, the most difficult periods in terms of water inputs and defence against pests, parasites, pathogens and weeds. For spring-summer crops, the action consists of choosing varieties based on climate trends, and of applying all the techniques for early development in order to accelerate the growth cycle during the months prior to the height of summer, the least suitable period for growing most crops and the one which demands the highest levels of energy. In general, it can be put into action by simultaneously bringing forward sowing or planting, and replacing later-developing cultivars or hybrids.

Implementation of this measure requires suitable training and/or guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	This measure does not involve any initial investment costs.
AVERAGE ANNUAL COST PER HECTARE	Variable. It can be low, if it consists solely of bringing forward the sowing/planting season and the replacement of later-developing cultivars, or high if other techniques for early development are used.
COST COMPARED TO CONVENTIONAL PRACTICES	Variable, depending on the species involved.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES.
ENVIRONMENTAL BENEFITS	YES. Savings of water resources.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

This measure is now well-established agronomic practice, the cost-effectiveness of which must be assessed by individual farms. Its effectiveness can be seen as the combined result of bringing forward the sowing season and the use of suitable cultivars.

MEASURE 3.19 – CHANGING THE CULTIVATION AREA

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES

WINE

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters extreme high temperatures and the degradation of a soil's natural characteristics (increased temperatures).

This measure concerns setting up new plantations at higher altitudes, where the climate is cooler; for example, the grapes used for making wines which require acidity and aromas (white wines, sparkling wines, lambrusco, etc.). This phenomenon already occurs when plantations are shifted northward or to higher altitudes. The measure can be seen as another way of looking at the question of crop choice.

At least to begin with, implementation of this measure requires suitable guidance, an adequate level of training and significant financial resources for investments and management.

COSTS AND BENEFITS

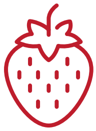
COST OF INVESTMENT	Investment costs depend on the location of the new plots of land suitable for the agricultural activity, and consist of material investments in land, buildings, plantations, etc.
AVERAGE ANNUAL COST PER HECTARE	The cost is determined by the depreciation, over multiple years, of the investment made in moving crops to suitable areas.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. This measure limits damage from drought and extreme high temperatures.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Increases both the yield and quality of production.
ENVIRONMENTAL BENEFITS	YES. Reducing problems with plant health results in a lower use of plant protection products.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

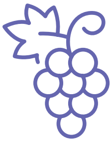
The decision to alter the cultivation area is subject to a preliminary analysis of the pedoclimatic conditions of the land where the crops are to be grown. The aim is to safeguard both the quantity and quality of production. Implementation depends on the size of the farm in financial terms (it is more common for medium-large farms). In general, it is implemented in synergy with an appropriate choice of crop/variety.

MEASURE 3.20 – CHANGING THE TRAINING AND PRUNING SYSTEMS FOR WOODY CROPS

PRODUCTION CHAINS INVOLVED



FRUIT



WINE

DESCRIPTION

This measure counters damage from drought, wind and extreme high temperatures.

The training system used, and the timing and type of the winter pruning carried out, play a very important role in adapting to a changing climate. In viticulture, the goal is to allow foliage cover to limit the exposure of the clusters to direct sunshine, thereby avoiding the high temperatures which can have negative effects on the aromatic and phenolic components of the grape. In fruit-growing, it aims to protect the fruit from direct sunshine, which can cause sunburn damage.

This measure can be implemented, but it requires additional investment costs and suitable training/guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	Swapping from one training system to another requires specific investments based on the vineyard or fruit plantation in question. In this sense, the investment costs necessary can vary immensely. In some cases, switching from one training system to another can consist of pruning. In viticulture, for example, changing from a single cordon spur to a single Guyot system entails greater costs, as the permanent cordon must be removed and a vine shoot selected to act as the new fruiting cane. After cutting away the permanent cordon, it must next be shredded. It is estimated that these operations will require 15-20 working days per hectare. Assuming an average cost of €9/hour for labour, the total cost of the pruning operation varies between €1,300/ha and € 1,800/ha on average.
AVERAGE ANNUAL COST PER HECTARE	In the case described above, additional pruning operations are required for the first 2/3 years in order to definitively switch to a new form of training system. The cost of the pruning involved in this switch decreases after the first year: a cost of €500 to €800 is estimated for the second year, while after the third year pruning costs are once again in line with the norm for the new type of training.

COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate-Low. This technique offers low effectiveness against drought, and is moderately effective against wind and high temperatures.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Increases both the yield and quality of production.
ENVIRONMENTAL BENEFITS	NO.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

Changing the training system makes cultivation operations easier and improves production quality and yield, while simultaneously offering effective protection against climate change. Adoption of this measure involves investment costs which depend on the type of plantation, and on how the training system is to be altered. The analysis must therefore take the specific characteristics of the farm into consideration.

MEASURE 3.21 – CHOOSING HALOPHYTIC OR HIGHLY SALT-TOLERANT CROPS

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters the climate-related risks associated with salt-water intrusion into soil.

A lack of water allows build-ups of salt, and the advance of saltwater intrusion in coastal and transitional zones. For this reason, it can be useful to consider the cultivation of halophytic crops, like various plants of the Chenopodioideae family for example, or varieties which are otherwise particularly tolerant to high osmotic potential. Halophytes are plants which can thrive in saline environments. This plant category includes around 600 genera and families, which feature two different strategies for resisting salinity. One small group of species absorbs salts through their roots, and has the extraordinary ability to sequester these salts in special structures within their cells, without releasing them back into the soil. The remaining halophyte varieties, meanwhile, have cellular mechanisms within their roots capable of filtering water, thereby preventing salts from being absorbed into the plant tissues. Both types of halophyte feature interesting characteristics, which offer useful advantages. Specifically, the first type is being studied in order to find a solution to a problem which affects many crops around the world: the salinisation of land and water used for agricultural purposes. This phenomenon reduces the productivity of most conventional crops, with a cost estimated by the FAO of 11 billion dollars per year. Halophytes may be useful in the bioremediation process on salinised soils, restoring them once again to productivity after many years of cultivation and removal of the saline biomass. The second group, however, do not have the same capacity for soil improvement, as the filtration mechanism in the roots means that they have no effect on the soil's salt content. Therefore, the aim of growing these species may be for food production, as in the case of quinoa, or for the production of biomass for energy, or even for both of these purposes. Within the category of halophytes intended for the production of biomass, another distinction must be made, between those which produce oil and those which produce fibres. Oil can be extracted from the seeds of the former: because salt does not accumulate in the plant itself or in its seeds, the oil from halophytes has the same qualities as any other vegetable oil. In the second case, on the other hand, studies focus on the composition of fibre in halophytic plants, as species with a greater production of cellulose are preferable due to being more suitable for the distillation of second-generation ethanol. The transition from traditional food crops to halophytes – for energy purposes or for dual use – is a climate change adaptation strategy.

Implementation of this measure requires suitable training/guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	There are no investment costs.
AVERAGE ANNUAL COST PER HECTARE	Annual production cost, particularly the cost of seeds, depends on the halophyte plant being grown.
COST COMPARED TO CONVENTIONAL PRACTICES	Depends on the plant being grown.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. Reduces the problem of salinity in soils and water for agricultural use.
IMPACT ON PRODUCTION YIELD AND QUALITY	NO.
ENVIRONMENTAL BENEFITS	YES. Water filtration; benefits to the groundwater; making highly saline land usable. Some halophytes may be useful in the bioremediation process on salinised soils, restoring them once again to productivity after many years of cultivation and removal of the saline biomass.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

The salinisation of soils and water impoverishes soil and reduces the yield of most conventional crops. It can also cause some of the land currently used for agriculture to be lost and abandoned, contributing to desertification. Growing halophyte plants is one possible solution to the problem of the growing salinisation of soils and water used for agricultural purposes. The benefits of this measure support its implementation; however, the cost-effectiveness of switching from conventional crops to halophytic crops, including as part of an intercropping or rotation system between both types, must be assessed by individual farms, taking into account the characteristics of the farm and of the halophytic crop chosen.

MEASURE 3.22 – HALOPHYTIC FODDER CROPS FOR CATTLE

PRODUCTION CHAINS INVOLVED

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters the climate-related risks associated with salt-water intrusion into soil.

Halophytic fodder crops already contain within them many salts necessary to stimulate the appetite of ruminants. Therefore, in addition to the advantages described in the previous section, the cultivation of crops which adapt to extremely difficult land can prove useful for feeding animals.

Implementation of this measure requires suitable training/guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	There are no investment costs.
AVERAGE ANNUAL COST PER HECTARE	Annual production cost, particularly the cost of seeds, depends on the halophyte plant being grown.
COST COMPARED TO CONVENTIONAL PRACTICES	Depends on the plant being grown.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. Reduces the problem of salinity in soils and water for agricultural use.
IMPACT ON PRODUCTION YIELD AND QUALITY	NO.
ENVIRONMENTAL BENEFITS	YES. Water filtration; benefits to the groundwater; making highly saline land usable.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

The salinisation of soils and water impoverishes soil and reduces the yield of most conventional crops. It can also cause some of the land currently used for agriculture to be lost and abandoned, contributing to desertification. Growing halophyte plants is one possible solution to the problem of the growing salinisation of soils and water used for agricultural purposes. In the case of halophytic fodder crops, their contribution to livestock diets constitutes an additional benefit. The benefits of this measure support its implementation; however, the cost-effectiveness of switching from conventional crops to halophytic crops, including as part of an intercropping or rotation system between both types, must be assessed by individual farms, taking into account the characteristics of the farm and of the halophytic crop chosen.

4. CROP PROTECTION

There are a variety of systems which protect crops from weather events that can cause direct damage to the plants, such as hail, intense rain, heat waves and frost. In some cases, these defence systems are also useful against drought and damage to plant health. The main forms of protection are:

1. ANTI-HAIL NETS
2. ANTI-INSECT NETS
3. RAIN PROTECTION AND ANTI-CRACKING COVER
4. MULTIFUNCTIONAL NETS: ANTI-HAIL, ANTI-RAIN, ANTI-CRACKING
5. SHADING NETS
6. FROST FANS
7. FROST-CONTROL HELICOPTERS – GROUND-LEVEL WIND MACHINES
8. ANTI-FROST CANDLES
9. ANTI-FROST PRODUCTS
10. ELECTRIC HEATING SYSTEMS

MEASURE 4.1 – ANTI-HAIL NETS

PRODUCTION CHAINS INVOLVED

VEGETABLES

FRUIT

WINE

DESCRIPTION

Anti-hail nets prevent the damage that can be caused by hail and heavy rain.

At present, anti-hail nets are the only effective form of active defence against hail. They decrease incident radiation and wind intensity, helping to reduce evapotranspiration by around 20%. Anti-hail nets must be structurally non-deformable, resistant to pulling and tearing, while also guaranteeing optimal airflow and light permeation, so that crops are able to grow and flourish.
Different types of anti-hail nets exist, with various installation methods having been developed specifically for different use cases:

- Anti-hail nets for orchards;
- Anti-hail nets for vineyards;
- Anti-hail nets for horticulture.

Implementation of this measure is easy, but it does involve investment costs.

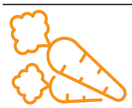
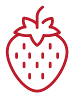
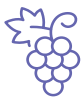
COSTS AND BENEFITS

COST OF INVESTMENT	The investment cost consists of the structure, the net, and assembly thereof. The total depends first on the pile spacing and the characteristics of the field (morphology and soil type), as well as on the type of technical solution chosen. On average, the cost of the structure with the net assembled ranges between €20,000 and €40,000/ha, with a lifespan of around 20/25 years. The cost of nets varies depending on type and size, but falls between €2,500 and €6,500/ha on average, with a lifespan of 7-10 years.
AVERAGE ANNUAL COST PER HECTARE	The running costs associated with this measure consist mainly of the manpower for assembly and removal of the net, in addition to depreciation of the investment. Morphology and soil type can affect costs. Management of the nets throughout the year, opening them in spring and closing them in autumn, is estimated to require 30-40 hours of work per hectare per year. The total annual cost/ha is estimated to fall between €1,500 and €3,000.

COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. Anti-hail nets are the most reliable and practical system for protecting fruit and vegetable crops and vines from hailstones and heavy rain. They also provide a range of additional advantages: keeping birds out; offering shade; and influencing the microclimate where the crops grow. Furthermore, they are easy to raise and replace for routine operations, and alleviate the effects of late frosts, if not too prolonged, by raising the temperature inside by around 1-1.5 °C.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. The nets protect the produce, thereby increasing its quality. Specifically, numerous scientific articles have demonstrated that photo-selective anti-hail nets can result in improvements to both the quantity and quality of production.
ENVIRONMENTAL BENEFITS	YES. They protect against hydrogeological imbalance.
PUBLIC FUNDING	CAP Strategic Plan – Rural Development Interventions: SRD06 – investments in prevention and the restoration of agricultural production potential: Action 1 – Investments for the prevention of damage caused by natural calamities, adverse events and events of biotic nature; Sectoral interventions: 1.1 Fruit and vegetables.

COST/BENEFIT EVALUATION

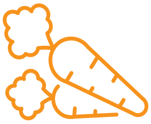
Damage from hail and intense rain not only causes produce to lose value, but also increases the costs of harvesting and sorting the produce. Harvesting can represent up to 50% of production costs, with a significant knock-on effect, therefore, on farm income. This measure can protect up to 100% of produce against the damage caused by hailstones and intense rain, as well as offering additional advantages related to crop defence and improving the quality of production. The many advantages justify the high cost of installing the nets for high value-added crops. The high cost can be a hurdle for smaller farms to overcome, but the incentives of the RDP provide valuable financial assistance towards the investment.

PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	VEGETABLES			
	FRUIT			
	WINE			

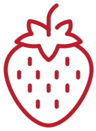
The illustrated summary of the assessment is based on a cost of €2,000/ha and high effectiveness against climate-related risks.

MEASURE 4.2 – ANTI-INSECT NETS

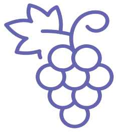
PRODUCTION CHAINS INVOLVED



VEGETABLES



FRUIT



WINE

DESCRIPTION

Anti-insect nets protect against hail and damage to plant health. To a lesser extent, they also protect against drought and extreme high temperatures.

Anti-insect nets are currently the only effective system for protecting crops against the recent invasions of harmful insects. It is important to note that different types of nets are available for different types of insects. These range from nets with a mesh size of less than one millimetre, to others with a mesh size of over one centimetre. Therefore, nets should be chosen bearing in mind the size of the insect they are intended to keep out (barrier effect). All anti-insect nets also provide protection against hail. The practice developed by the French, initially to protect against damage from the codling moth (*C. Pomonella*), has also proven effective against other insects (e.g. *Halyomorpha halys* or the brown marmorated stink bug, and *Drosophila suzukii Matsumura* or the spotted wing drosophila fruit fly). The practice consists of covering the orchard or vineyard with a net featuring a smaller mesh size than classic anti-hail nets, in order to prevent attacks by insects (particularly fruit-eating species). Two solutions have emerged: "single row", where each individual row is covered with a net; and "single block", where the entire plot is protected by a single structure.

Implementation of this measure is easy, but it does involve investment costs.

COSTS AND BENEFITS

COST OF INVESTMENT	The investment cost consists of the structure, the net, and assembly thereof. The total depends first on the pile spacing and the characteristics of the field (morphology and soil type), as well as on the type of technical solution chosen. On average, the cost of the structure with the net assembled ranges between €20,000 and €40,000/ha, with a lifespan of around 20/25 years. The cost of nets varies depending on the type of net and size of the plantation it must protect, but falls between €4,000 and €10,000/ha on average, with a lifespan of 7-10 years.

AVERAGE ANNUAL COST PER HECTARE	The running costs associated with this measure consist mainly of the manpower for assembly and removal of the net, in addition to depreciation of the investment. Morphology and soil type can affect costs. Management of the nets throughout the year, opening them in spring and closing them in autumn, is estimated to require 40-50 hours of work per hectare per year. The total annual cost/ha is estimated to fall between €2,000 and €4,000.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. Anti-insect nets are currently the only effective system for protecting crops against the recent invasions of harmful insects. Anti-insect nets also protect against hail. Protecting crops using anti-insect nets makes it possible to cut back drastically on the use of insecticides against the codling moth. In orchards where this method has been implemented, it was possible to drop 8 out of 12 courses of treatment. The nets also offer other advantages: - a drastic reduction of chemical residues in the fruit and in the environment; - making it easier to grow produce organically; - no increase in the main fungal diseases (fruit scab, pear brown spot); - a reduction in the damage caused by mirid bugs (deformed fruits); - protecting fruit against birds (damage has increased over recent years); - protecting driplines from insects and birds. Moreover, some types of nets can help alleviate low temperatures by a few degrees, offering protection against late frosts. There is no substantial difference in terms of positioning; the choice of net, based on the specific needs of the crop, is what makes the difference.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. The nets protect the produce, thereby increasing both quality and yield.
ENVIRONMENTAL BENEFITS	YES. The nets reduce the use of plant protection products.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD06 – investments in prevention and the restoration of agricultural production potential: Action 1 – Investments for the prevention of damage caused by natural calamities, adverse events and events of biotic nature; Sectoral interventions: 1.1 Fruit and vegetables.

COST/BENEFIT EVALUATION

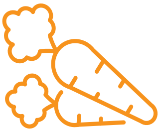
Damage from hail and intense rain not only causes produce to lose value, but also increases the costs of harvesting and sorting the produce. Harvesting can represent up to 50% of production costs, with a significant knock-on effect, therefore, on farm income. This measure can protect up to 100% of produce against the damage caused by invasions of harmful insects, as well as protecting against hailstones and offering other advantages related to crop defence. The many advantages justify the high cost of installing the nets for high value-added crops. The high cost can be a hurdle for smaller farms to overcome, but the incentives of the RDP provide valuable financial assistance towards the investment.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
VEGETABLES			
FRUIT			
WINE			

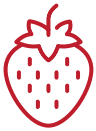
The illustrated summary of the assessment is based on a cost of €3,000/ha and high effectiveness against climate-related risks.

MEASURE 4.3 – RAIN PROTECTION AND ANTI-CRACKING COVER

PRODUCTION CHAINS INVOLVED



VEGETABLES



FRUIT

DESCRIPTION

These covers protect against hail and intense rain.

Heavy rain during the period between veraison and ripening can cause fruit to crack, representing the greatest challenge in growing cherries. Most systems now available on the market are based on different technological solutions, but almost all have the same drawback: opening and closing them requires heavy, time-consuming and costly manual work. This means that these operations are only carried out at the most critical stage (between when the fruit ripens and when it is harvested). These factors inspired the "Cap Solution" project, which aims to create an innovative system that can fully protect cherry orchards, both new and existing, using netting systems that open and close completely automatically. The project was launched about two years ago, thanks partly to financial support from the Emilia-Romagna Region as part of the 2014-2020 RDP, Measure 16.1.01; and has been largely conducted by the company Magif in Vignola (MO), with the scientific cooperation of the DISTAL University of Bologna and the technical and organisational coordination of the Plant Production Research Centre.

The measure can be implemented, but it involves high investment costs.

COSTS AND BENEFITS

COST OF INVESTMENT	The investment cost consists of the structure, the net, and assembly thereof. The total depends first on the pile spacing and the characteristics of the field (morphology and soil type), as well as on the type of technical solution chosen. On average, the cost of the structure with the net assembled ranges between €30,000 and €45,000/ha, with a lifespan of around 20/25 years. The cost of nets varies depending on type and size, but falls between €25,000 and €35,000/ha on average, with a lifespan of 7-10 years.
AVERAGE ANNUAL COST PER HECTARE	The running costs associated with this measure consist mainly of the manpower for assembly and removal of the net, in addition to depreciation of the investment. Morphology and soil type can affect costs. Management of the nets throughout the year, opening them in spring and closing them in autumn, is estimated to require 70-80 hours of work per hectare per year. The total annual cost/ha is estimated to fall between €5,000 and €7,000.

COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. The covers represent a viable system for reducing the loss of produce under particularly rainy conditions.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. The rain-protection covers protect the produce and make it possible to harvest fruit at optimum ripeness, postponing the harvest period for suitable varieties, resulting in benefits in terms of greater produce calibre and quality. Moreover, they protect the crops against fungal disease and rot.
ENVIRONMENTAL BENEFITS	YES. Prevention of hydrogeological imbalance and positive impacts on soil quality.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD06 – investments in prevention and the restoration of agricultural production potential: Action 1 – Investments for the prevention of damage caused by natural calamities, adverse events and events of biotic nature; Sectoral interventions: 1.1 Fruit and vegetables.

COST/BENEFIT EVALUATION

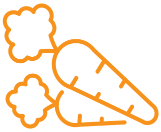
Damage from hail and intense rain not only causes produce to lose value, but also increases the costs of harvesting and sorting the produce. Harvesting can represent up to 50% of production costs, with a significant knock-on effect, therefore, on farm income. This measure can protect up to 100% of produce against the damage caused by intense rain and hailstones, as well as offering other advantages in terms of crop defence. The many advantages justify the high cost of installing the nets for high value-added crops. The high cost can be a hurdle for smaller farms to overcome, but the incentives of the RDP provide valuable financial assistance towards the investment.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
VEGETABLES			
FRUIT			

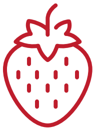
The illustrated summary of the assessment is based on a cost of €6,000/ha and high effectiveness against climate-related risks.

MEASURE 4.4 – MULTIFUNCTIONAL NETS: ANTI-HAIL, ANTI-RAIN, ANTI-CRACKING

PRODUCTION CHAINS INVOLVED



VEGETABLES



FRUIT

DESCRIPTION

These covers protect against hail, intense rain, and the damage caused by insects.

Multifunctional nets are a new form of coverage against rain and hail, designed to protect cherry trees against the *D. Suzukii* fruit fly. The system consists of a double layer of white anti-insect netting at the top (also serving to protect against rain) and a single layer of netting at the sides, which is sewn to the top in order to fully enclose the row of trees. The netting at the sides can be raised to allow harvesting and pruning in summer, and during winter. This system is only applicable to cherry trees grown in espalier formation, and is very well suited to dense plantations.

The measure can be implemented, but it involves high investment costs.

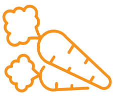
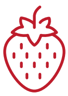
COSTS AND BENEFITS

COST OF INVESTMENT	The investment cost consists of the structure, the net, and assembly thereof. The total depends first on the pile spacing and the characteristics of the field (morphology and soil type), as well as on the type of technical solution chosen. On average, the cost of the structure with the net assembled ranges between €30,000 and €45,000/ha, with a lifespan of around 20/25 years. The cost of nets varies depending on type and size, but falls between €25,000 and €35,000/ha on average, with a lifespan of 7-10 years.
AVERAGE ANNUAL COST PER HECTARE	The running costs associated with this measure consist mainly of the manpower for assembly and removal of the net, in addition to depreciation of the investment. Morphology and soil type can affect costs. Management of the nets throughout the year, opening them in spring and closing them in autumn, is estimated to require 70-80 hours of work per hectare per year. The total annual cost/ha is estimated to fall between €5,000 and €7,000.

COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. The covers represent a viable system for countering hail, rain, and the damage caused by insects.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. The covers protect the produce and make it possible to harvest fruit at optimum ripeness, postponing the harvest period for suitable varieties, resulting in benefits in terms of greater produce calibre and quality. Moreover, they protect the crops against fungal disease and rot.
ENVIRONMENTAL BENEFITS	YES. Prevention of hydrogeological imbalance and positive impacts on soil quality.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD06 – investments in prevention and the restoration of agricultural production potential: Action 1 – Investments for the prevention of damage caused by natural calamities, adverse events and events of biotic nature; Sectoral interventions: 1.1 Fruit and vegetables.

COST/BENEFIT EVALUATION

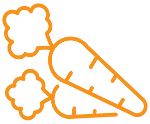
Damage from hail and intense rain not only causes produce to lose value, but also increases the costs of harvesting and sorting the produce. Harvesting can represent up to 50% of production costs, with a significant knock-on effect, therefore, on farm income. This measure can protect up to 100% of produce against the damage caused by intense rain, hail, and the damage caused by invasions of harmful insects, as well as offering other advantages in terms of crop defence. The many advantages justify the high cost of installing the nets for high value-added crops. The high cost can be a hurdle for smaller farms to overcome, but the incentives of the RDP provide valuable financial assistance towards the investment.

PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	VEGETABLES			
	FRUIT			

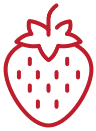
The illustrated summary of the assessment is based on a cost of €6,000/ha and high effectiveness against climate-related risks.

MEASURE 4.5 – SHADING NETS

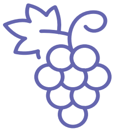
PRODUCTION CHAINS INVOLVED



VEGETABLES



FRUIT



WINE

DESCRIPTION

These nets protect against extreme high temperatures.

Light-filtering nets are now available on the market in different colours, depending on the level of shade they provide. In viticulture, they are positioned not above the plant foliage, but only at the level of the grape clusters, to reduce the direct radiation which is among the causes of anthocyanin synthesis failure and of the degradation of aromatic and phenolic components.

The measure can be implemented, but it involves high investment costs.

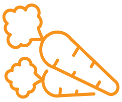
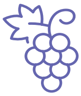
COSTS AND BENEFITS

COST OF INVESTMENT	The investment cost consists of the structure, the net, and assembly thereof. The total depends first on the pile spacing and the characteristics of the field (morphology and soil type), as well as on the type of technical solution chosen. On average, the cost of the structure with the net assembled ranges between €20,000 and €35,000/ha, with a lifespan of around 20/25 years. The cost of nets varies depending on the type of net and size of the plantation it must protect, but falls between €8,000 and €25,000/ha on average, with a lifespan of 7-10 years.
AVERAGE ANNUAL COST PER HECTARE	The running costs associated with this measure consist mainly of the manpower for assembly and removal of the net, in addition to depreciation of the investment. Morphology and soil type can affect costs. Management of the nets throughout the year, opening them in spring and closing them in autumn, is estimated to require 40-80 hours of work per hectare per year. The total annual cost/ha is estimated to fall between €2,500 and €6,000.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. The nets represent a viable system for countering heat waves.

IMPACT ON PRODUCTION YIELD AND QUALITY	YES. The nets protect the produce, improving its quality.
ENVIRONMENTAL BENEFITS	YES. They protect soil fertility, contributing to a balanced environment.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD06 – investments in prevention and the restoration of agricultural production potential: Action 1 – Investments for the prevention of damage caused by natural calamities, adverse events and events of biotic nature; Sectoral interventions: 1.1 Fruit and vegetables.

COST/BENEFIT EVALUATION

This measure can protect up to 100% of produce against the damage caused by high temperatures, as well as offering other advantages in terms of crop defence. The many advantages justify the high cost of installing the nets for high value-added crops. The high cost can be a hurdle for smaller farms to overcome, but the incentives of the RDP provide valuable financial assistance towards the investment.

PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	VEGETABLES			
	FRUIT			
	WINE			

The illustrated summary of the assessment is based on a cost of €4,500/ha and high effectiveness against climate-related risks.

MEASURE 4.6 – FROST FANS

PRODUCTION CHAINS INVOLVED

VEGETABLES FRUIT WINE

DESCRIPTION

This measure counters damage from extreme low temperatures.

Frost fans protect orchards, vineyards and large fields in general from radiation frost. They are essentially air-mixers, consisting of blades (fans) mounted on mobile or fixed towers of 6-11 metres in height, usually powered by a propane gas burner or diesel engine. The mobile models can be towed by tractor trailer. Their purpose is to intercept warmer air at higher altitudes, so that the turning blades convey it towards the ground. In some situations, however, it is not very effective, e.g. in the case of advection frosts where there is no temperature inversion. The average range covered by a frost fan set up on a tower is between 2-3 and 7 hectares, depending on the model, number of propellers, crop type and temperature, and whether suitable temperature inversion is present. To fully protect all the land, multiple units must be installed. Under ideal conditions, a frost fan can provide protection as low as -5.5°C. For advection frosts, some types of frost fans can be paired with a burner, making the system effective even in icy winds.
There are towers on the market which can be assembled and set up using an electric or hydraulic jack, eliminating the need to disconnect the drive lines.

- To make the measure even more effective:
- Identify the direction and speed of night winds using suitable tools, to position the frost fan correctly.
- In northern regions, to make the most of the heat exchange at the 45th parallel, it is best to use a frost fan with a one-piece propeller, so that the air remains on the plants for longer while the head is turning.
- Choose a frost fan whose engine is produced within the country where it is to be used, or in any case from well-known brands, to ensure swift receipt of original parts.
- Engage the services of companies that guarantee 24/7 assistance, with their own vehicles and cranes.

Adjust the propeller's angle of rotation so it adapts to the form of any land surface to be protected.
Studies and tests carried out by specialist American and French institutions on propellers with 3 or 4 blades, in an attempt to decrease noise levels, have produced poor results: noise levels dropped by just a few decibels, while the reduced speed of the engine and propeller resulted in less powerful airflow within the frost fan's field of action. In any case, it is advisable to inform yourself of the local regulations on noise pollution, to avoid any disputes in the case of fields located close to inhabited areas.

The measure can be implemented, but it requires investment costs.

COSTS AND BENEFITS

COST OF INVESTMENT	The cost consists of the advice needed to correctly choose, purchase and install the system, and varies depending on make and model (fixed or mobile, tower height, blade size and number of propellers, noise level, engine power, and type of fuel – diesel or gas). The cost of a frost fan varies between €12,000 and €70,000, depending on coverage (from 2-3 to 7.5 hectares). The investment cost per hectare varies between €4,000 and €10,000 on average, even reaching €15,000 for the largest mobile frost fans. The cost of the burner also varies, based on the model and the frost fan, but an average cost per hectare of between €2,000 and €3,000 can be estimated. The average lifespan of frost fans, both fixed and mobile, can be estimated at around 30-40 years.
AVERAGE ANNUAL COST PER HECTARE	The average cost per hectare, considering depreciation of the investment and management costs (an average of €100-€150 per hectare in fuel expenses for 3 days of operation, maintenance of around €100-€150 per hectare and variable labour costs) can range from €500/ha to €1,200/ha on average.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. Moderately effective against late radiation frosts, caused by a rapid drop in temperature at ground level as warmer, lighter air rises. To fully protect all the land, multiple units must be installed.
IMPACT ON PRODUCTION YIELD AND QUALITY	NO. However, it offers an advantage over other methods of protection against frost such as irrigation systems or anti-frost candles, in that crops are not exposed to water or smoke.
ENVIRONMENTAL BENEFITS	NO.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD06 – investments in prevention and the restoration of agricultural production potential: Action 1 – Investments for the prevention of damage caused by natural calamities, adverse events and events of biotic nature; Sectoral interventions: 1.1 Fruit and vegetables.

COST/BENEFIT EVALUATION

The investment cost is reasonably high, and farm characteristics must be considered carefully when weighing whether to make it. Farms of a larger economic size-class will find the cost more sustainable, while smaller farms may struggle more.

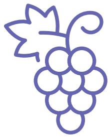
PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
VEGETABLES			
FRUIT			
WINE			

The illustrated summary of the assessment is based on a cost of €900/ha and moderate effectiveness against climate-related risks.

MEASURE 4.7 – FROST-CONTROL HELICOPTERS – GROUND-LEVEL WIND MACHINES

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES



WINE

DESCRIPTION

This measure counters damage from extreme low temperatures.

There are other viable systems, though they are less used and still experimental, which involve mixing air to prevent stratification. These include: helicopters; mobile, ground-level wind machines mounted on tractors; and special ground-based wind machines which can suck in cold air and blow it upwards, including some with heaters for the flowing air.
Using helicopters to fly low over fields of crops is undeniably effective against frost.

Implementation of this measure is easy with regard to ground-level wind machines, while the use of helicopters is still experimental and involves high costs.

COSTS AND BENEFITS

COST OF INVESTMENT	For mobile, ground-level wind machines mounted on tractors, see the section on frost fans.
AVERAGE ANNUAL COST PER HECTARE	With regard to the use of helicopters, the practice is still experimental and currently involves high costs. Hiring a helicopter is a valid option for this method at the moment, while purchasing one is considered scarcely feasible.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate.
IMPACT ON PRODUCTION YIELD AND QUALITY	NO.
ENVIRONMENTAL BENEFITS	NO.

PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD06 – investments in prevention and the restoration of agricultural production potential: Action 1 – Investments for the prevention of damage caused by natural calamities, adverse events and events of biotic nature.

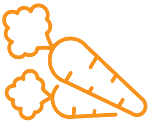
COST/BENEFIT EVALUATION

The practice is scarcely feasible, due to the extremely high costs.

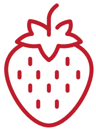
PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
FRUIT AND VEGETABLES			
WINE			

MEASURE 4.8 – ANTI-FROST CANDLES

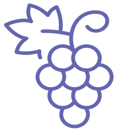
PRODUCTION CHAINS INVOLVED



VEGETABLES



FRUIT



WINE

DESCRIPTION

Anti-frost candles are a technique to actively defend against frost.

They consist of iron drums filled with paraffin wax, to be set throughout the fields (in the open, in greenhouses or covered by anti-hail canvases), concentrated particularly around the perimeter and taking the prevailing wind direction into account. In order to speed up the task of lighting the candles, it is good practice to light 50% of them in the first round, starting from the outermost parts, and to complete lighting the rest in a second round. A mixture of diesel (70-80%) and petrol (20-30%) can be poured into the drums of wax and set alight with a torch or gas blowtorch, again to make the lighting process faster. Candles can burn for 8-14 hours and more (in open fields, the maximum burn time assumes the absence of wind), or in other words 1-2 nights. They can be re-used if not fully spent. Recently, anti-frost candles are being developed which can protect plants from temperatures of as low as -7°C, characterised by low-smoke wax to mitigate the environmental impact and heat up the surrounding environment. These candles are useful for protecting such crops as cherries or yellow kiwis, which are grown inside a greenhouse or covered with canvas for rain protection.

The measure can be implemented, but it involves high costs.

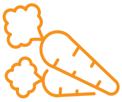
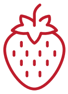
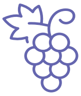
COSTS AND BENEFITS

COST OF INVESTMENT	The cost consists of the price of purchasing anti-frost candles: with 300-350 candles required per hectare, each costing between €6-€15, the average cost varies between €1,800 and €6,000/ha. If lack of frost means that they are not used during the agricultural year, but kept for a following year, they can be considered an investment.
AVERAGE ANNUAL COST PER HECTARE	The cost varies between €1,000 and over €6,000/ha, depending on use and whether multiple purchases are needed during the season.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater. The cost consists of purchasing the candles and, potentially, the manpower required to position and light them.

EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. The candles are moderately effective at temperatures as low as -4/-5 °C, assuming an absence of wind in open fields. Their use is not recommended in areas or on varieties which are highly susceptible to hoar frost, due to the high costs involved (the use of other devices is preferable in these cases), or in fields close to urban centres or roads, due to the smoke produced.
IMPACT ON PRODUCTION YIELD AND QUALITY	NO.
ENVIRONMENTAL BENEFITS	NO.
PUBLIC FUNDING	CAP Strategic Plan – Sectoral interventions: 1.9 Fruit and vegetables.

COST/BENEFIT EVALUATION

The high cost of the candles makes them suitable for use in exceptional cases, in the absence of other devices.

PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	VEGETABLES			
	FRUIT			
	WINE			

The illustrated summary of the assessment is based on a cost of €3,500/ha and moderate effectiveness against climate-related risks.

MEASURE 4.9 – ANTI-FROST PRODUCTS

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES

DESCRIPTION

This measure counters damage from extreme low temperatures (frost).

The use of products with anti-frost properties on crops limits the formation of ice on the plant's growing organs. Experiments are ongoing, including with the use of specific bacteria. The anti-frost products are added to and mixed with the fertilisers used on the plants to protect them from extreme cold. Essentially, they are natural fertilisers based on chelated iron which can be used on the soil for all types of crops, or applied directly to the leaves in the horticultural, fruit-growing and tree industries. There are a variety of plant protection products on the market with anti-frost, nutritional and biostimulant effects, which are formulated with organic components, to be used at the recommended dosages to avoid phytotoxicity problems. These products reach optimum effectiveness with repeated applications, ideally beginning a few weeks before temperatures become critical. However, treatments can be carried out as little as 6-12 hours beforehand, though they will be less effective in this case. The treatment, which should be carried out during the warmest part of the day, must be repeated at least once a week as long as the frosty period lasts. Even if temperatures rise once more, fortnightly treatments should continue until at least three have been carried out, so that the stress to which the plant has been subjected passes quickly. It is important to monitor the crops and adjust nutritional intake based on their needs. Small, preventative applications are always recommended in order to avoid problems.

Implementation of this measure is easy.

COSTS AND BENEFITS

COST OF INVESTMENT	The systems already used on the farm for the distribution of fertilisers and plant protection products can be used.
AVERAGE ANNUAL COST PER HECTARE	Costs vary based on the number of operations to be carried out in the field, which depends on the season. A cost of €30-€50/hectare is estimated for each treatment with fertilisers based on chelated iron with an anti-frost effect.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.

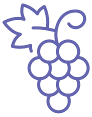
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Experiments are ongoing to determine the effectiveness of the measure.
IMPACT ON PRODUCTION YIELD AND QUALITY	NO.
ENVIRONMENTAL BENEFITS	NO. These products must be used with caution and at the correct dosages in order to avoid phytotoxicity problems
PUBLIC FUNDING	CAP Strategic Plan – Sectoral interventions: 1.9 Fruit and vegetables.

COST/BENEFIT EVALUATION

The use of anti-frost products is undergoing experimentation, and may be found cost-effective in preventing damage from late frosts.

MEASURE 4.10 – ELECTRIC HEATING SYSTEMS

PRODUCTION CHAINS INVOLVED



WINE

DESCRIPTION

This measure counters damage from extreme low temperatures (frost).

Electric heating systems provide a solution to the possibility of spring frosts. Warming cables can be installed directly on trellis wires in the vineyard. The warming cable used can vary in power, depending on the length and density of the individual rows. It is also possible to set up warming cables of different thicknesses and capacities for simultaneous use, for plants with different temperature requirements. They can be operated by a thermostat with an external temperature sensor, which switches the system on when a certain specified temperature limit is reached.

It is possible to implement this measure, but an alternative power source is in required in case of a sudden, unexpected outage.

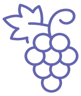
COSTS AND BENEFITS

COST OF INVESTMENT	The cost, which consists of designing, purchasing and setting up the system, is estimated to vary between €10,000/ha and €15,000/ha.
AVERAGE ANNUAL COST PER HECTARE	The operating cost of the system depends on how much it is used, based on seasonal weather trends, and on the cost of energy. Considering a lifespan of 20 years for the cables, straight-line depreciation of between €500/ha and €750/ha can be estimated. Assuming three days of frost in a year, with the system used for four hours per day with a 15W/m electrical cable, variable energy consumption of between €200/ha and €400/ha can be estimated.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. The temperature is kept constant, alleviating the effect of extreme lows.
IMPACT ON PRODUCTION YIELD AND QUALITY	NO.
ENVIRONMENTAL BENEFITS	NO.

PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD06 – investments in prevention and the restoration of agricultural production potential: Action 1 – Investments for the prevention of damage caused by natural calamities, adverse events and events of biotic nature; Sectoral interventions: 1.1 Fruit and vegetables.

COST/BENEFIT EVALUATION

This measure can protect up to 100% of produce against the damage caused by frost. The measure's high levels of effectiveness justify the significant cost of investment, as well as the operating costs. The high cost can be a hurdle for smaller/medium-sized farms to overcome, but the incentives of the RDP can provide valuable financial assistance towards the investment.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
 WINE			

The illustrated summary of the assessment is based on a cost of €900/ha and high effectiveness against climate-related risks.

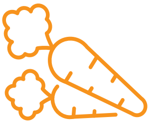
5. WATER RESOURCES MANAGEMENT

Wise water management is one of the cornerstones of making agriculture resilient to climate change. In managing water resources, it is necessary to avoid waste, increase water storage capacity, and recover water resources. The measures that can be adopted mainly address the problem of drought, though some can be useful against extreme high temperatures, frost, and the issue of saltwater intrusion. The actions that can be taken are:

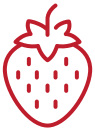
1. **OVER-TREE COOLING IRRIGATION**
2. **OVER-TREE IRRIGATION FOR FROST PROTECTION**
3. **UNDER-TREE IRRIGATION FOR FROST PROTECTION**
4. **DRIP IRRIGATION**
5. **NIGHT-TIME IRRIGATION**
6. **SUBSURFACE MICRO-IRRIGATION**
7. **SUBIRRIGATION**
8. **COCOONS**
9. **WASTEWATER REUSE**
10. **ARTIFICIAL LAKES – RESERVOIRS FOR ONE OR MULTIPLE FARMS**
11. **DESALINATION OF WATER**

MEASURE 5.1 – OVER-TREE COOLING IRRIGATION

PRODUCTION CHAINS INVOLVED



VEGETABLES



FRUIT

DESCRIPTION

Over-tree cooling irrigation systems protect against extreme high temperatures.

This technique, an alternative to traditional practices (doubling micro-irrigation lines), is based on three systems:

- convective cooling: this consists of spraying minuscule water droplets as a mist within the orchard, in what is known as a fogging system. As the droplets are subject to both solar radiation and air temperatures, they remove heat from the atmosphere, transforming into gaseous state and lowering the temperature;
- hydro-cooling: this consists of spraying water directly on the plants through over-tree irrigation. There is no change in state, but the water in its liquid state is still capable of removing heat from the plants it comes into contact with, with its own temperature rising before it falls to the ground;
- evaporative cooling: this also consists of spraying water on the plants, but unlike in the previous system, the water removes sensible heat from the plant, resulting in its transformation from liquid to gaseous state (latent heat).

Spraying water to provide cooling in orchards relies on a combination of these three processes, usually with just one of them predominant, depending the systems used. In general, fixed or self-propelled systems are used in fruit-growing, while mobile systems with hoses are used for vegetable crops.

Implementation of this measure is easy, but it does require training and investments.

COSTS AND BENEFITS

COST OF INVESTMENT	In fruit-growing, the price of the system – including design – varies between €4,000/ha and €5,000/ha. The cost of setting up the system ranges from €700/ha to €1,500/ha, depending on soil type and slope (the latter can result in a 5-10% increase in cost). In horticulture, the price varies between €3,000/ha and €4,000/ha, while the cost of setting up the system ranges from €500/ha to €1,000/ha, depending on soil type and slope (the latter can result in a 5-10% increase in cost). The estimated lifespan of the system is 10-15 years or more.

AVERAGE ANNUAL COST PER HECTARE	The average cost of maintaining the system is around €200/ha. Based on the costs of the system outlined above, straight-line depreciation over 10 years results in an average of €500 to €650/ha for fruit-growing and €350/ha to €500/ha for horticulture. Therefore, the sum of maintenance and depreciation produces an estimated total annual cost per hectare of between €700 and €850 for fruit-growing, and between €550 and €700 for horticulture. On top of this is an estimated operating cost of €40/day for 4-5 hours; if the system is used for 5 days a year, a cost of around €200/year can be estimated.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. This measure can protect up to 90-95% of produce against heat waves.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. The system can also be used to wash insects and salt off the leaves or for fertigation, thus improving the yield and quality of production.
ENVIRONMENTAL BENEFITS	NO. Large quantities of water are needed.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings: goal A; SRD02 – productive agricultural investments for the environment, climate and animal welfare Action C: Investments in irrigation; Sectoral interventions: 1.1 Fruit and vegetables.

COST/BENEFIT EVALUATION

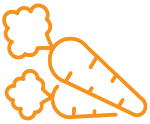
The initial investment is justified by the measure's effectiveness in countering heat waves. The expense of the measure may be a hurdle for smaller and medium-sized farms to overcome, but the incentives of the RDP provide valuable financial assistance towards the investment. As the intervention requires large quantities of water, the system should be used sensibly and efficiently to optimise and save water resources.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
VEGETABLES			
FRUIT			

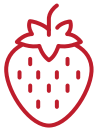
The illustrated summary of the assessment is based on a cost of €950/ha for fruit-growing and €800/ha for horticulture, combined with high effectiveness against climate-related risks.

MEASURE 5.2 – OVER-TREE IRRIGATION FOR FROST PROTECTION

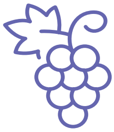
PRODUCTION CHAINS INVOLVED



VEGETABLES



FRUIT



WINE

DESCRIPTION

Over-tree irrigation systems for frost protection offer defence against cold waves. However, they are also useful for lowering the temperature in times of drought.

Over-tree irrigation is a classic and highly efficient technique. However, it requires plentiful availability of water resources, both at farm level (about 4-5 mm hourly irrigation is the estimated requirement, with an average 10-hour cycle therefore representing 40-50 mm of consumption) and throughout the entire irrigation district, as many farms in the same district may require irrigation simultaneously. Significant water savings are possible with localised over-tree irrigation that only wets the rows of fruit trees themselves, which usually occupy just 1/4 of the surface area in modern espalier orchards, without wetting the inter-row area. This system uses specific sprinklers called "flippers", which are able to act on the limited strip of the surface area under the row, allowing savings of 50-55% compared to the classic method. The continued freezing of the water sprayed across the orchard/vineyard releases heat; a process which can be harnessed in order to mitigate temperatures as low as 7-8 °C below zero. However, care must be taken not to reduce the quantity of water used too much, as the plants must be kept evenly and continuously wet, with a sprinkler rotation time of 30-40 seconds when normal over-tree sprinklers are used. There is also the option of using mini-sprinklers mounted on a pipe for each row, which only wet the plants within that row. It is important to make sure that there is no wind when either over-tree or under-tree systems are operated, in order to avoid uneven irrigation (over-tree systems) and to prevent the water from evaporating instead of freezing, or the cushion of warm air formed when water freezes and releases heat from moving (under-tree system). Over-tree irrigation is based on the principle that as water changes state from liquid to solid, i.e. as it freezes into ice, it releases heat (80 cal/g). The fruits or flowers of the plant are protected and provided with heat thanks to the ice that forms around the buds, thus preventing their temperatures from falling further. In fact, as the starting point for the flower-shoot-fruit cycle, any damage to the bud can have catastrophic effects on the future harvest.
Over-tree irrigation systems for frost protection are an effective way to form ice, and fall into the following categories:
Impact sprinklers – these sprinkler systems are the most widely used method, and offer the greatest protection against hoarfrost. They allow very short rotation times (30-60 seconds), thereby defending the plants better against frost by providing the right amount of water. On average, between 3 and 4.5 mm/h of water must be applied across the entire surface area (30-45 m^3/h/ha), a quantity which must be available for the entire duration of the process.

In general, a coefficient of uniformity of 80% is needed for crop irrigation systems. Depending on the crop, sprinklers used in fruit-growing for frost protection should be placed at distances of 12x12 m, 16x15 m, 18x18 m or 20x18 m from each other, with the greatest distances for stone fruits and actinidia plants, and with nozzles of between 3.7 and 4.5 mm in diameter. In order for the frost protection system to work correctly, it is necessary to determine the quantity of water necessary to protect each individual species. To calculate the right amount, both the size of the output opening (which proportionately affects the quantity of water emitted) and the sprinkler rotation times are particularly important. It is preferable to choose nozzle models guaranteed to work at temperatures of -8/-9 °C, and with rotation times of a minute or less. The system's main pipes, pumps and engines (5-10 HP/ha) must be large enough to irrigate the entire crop in a single go. The sprinklers should be set up at the same height as, or higher than, the plants they are to protect, with more power provided in the more exposed areas of the field. The system must be operated when there is no wind, in order to achieve the desired thermal inversion.
Fast-rotation sprinklers – fast-rotation sprinklers require less water than impact sprinklers, and can be positioned at distances of 9x9 m to 11x11 m from each other;
Static or dynamic micro-jet systems – whether or not these jet systems can be used depends on the size of the plot. Systems with static micro-jets cover 10 metres, though the newest models can irrigate larger areas; while the range of dynamic jets can reach as much as 30 metres, as well as saving water compared to static micro-jet systems. However, compared to sprinkler systems, these solutions may not constantly guarantee the effective prevention of frost damage.
In any case, over-tree irrigation systems for frost protection require large quantities of water and must be carefully managed to prevent damage to the crops. Water must be sprayed as evenly as possible across the entire surface area to be protected, with continuous irrigation for as long as protection is needed.

Implementation of this measure is easy, but it does require training and investments.

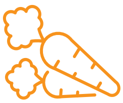
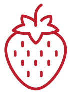
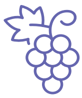
COSTS AND BENEFITS

COST OF INVESTMENT	The price of the system (design, control unit, injection system, pumping and filtration) varies between €4,000/ha and €6,000/ha. Prices depend on the size of the system and on water conditions, and are generally lower for impact/drip systems. The cost of setting up the system ranges from €700/ha to €1,500/ha, depending on soil type and slope (the latter can result in a 5-10% increase in cost). The estimated lifespan of the system is 10-15 years or more.
AVERAGE ANNUAL COST PER HECTARE	The average cost of maintaining the system is around €200/ha. Based on the costs of the system, straight-line depreciation over 10 years results in an average of €500 to € 750/ha. Therefore, the annual cost per hectare can be estimated at between €700 and €950/ha. An operating cost of €40/day can be estimated. More energy and water are consumed than in cooling irrigation. Assuming the system is used for 3 days per year, the total operating cost can be estimated at €120.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.

EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. The measure can protect over 95% of produce against frost, down to temperatures of -4 to -5 °C.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. With the right amount of water, the system can be used for irrigation on some crops, improving production yield and quality.
ENVIRONMENTAL BENEFITS	NO. Large quantities of water are needed.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings: goal A; SRD02 – productive agricultural investments for the environment, climate and animal welfare; Action C: Investments in irrigation; Sectoral interventions: 1.1 Fruit and vegetables.

COST/BENEFIT EVALUATION

The initial investment required by this action is amply justified by its high level of protection against cold waves which could pose a risk to all produce, as well as its usefulness in cases of drought. The expense of the measure may be a hurdle for smaller and medium-sized farms to overcome, but the incentives of the RDP provide valuable financial assistance towards the investment. The cost of operating the system, which requires energy and water resources, depends on seasonal needs.

PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	VEGETABLES			
	FRUIT			
	WINE			

The illustrated summary of the assessment is based on a cost of €1,000/ha and high effectiveness against climate-related risks.

MEASURE 5.3 – UNDER-TREE IRRIGATION FOR FROST PROTECTION

PRODUCTION CHAINS INVOLVED

VEGETABLES **FRUIT** **WINE**

DESCRIPTION

Under-tree irrigation systems for frost protection offer defence against cold waves. However, they are also effective in the case of drought.

They are based on the same principles as the over-tree systems, but only irrigate the grass growth in the inter-row area. They do not act directly on the buds, which are only slightly wetted if at all, and only on the lower branches. Therefore, the buds are not protected through the formation of ice. Instead, heat is transferred to the plants only through conduction and convection due to air circulation, using the heat released by the water as it changes from liquid to solid state to effectively counter the loss of heat from the land via radiation. The higher the grass, the greater the exchange area for the heat produced; in fact, the grass strips are the surface on which the irrigation water freezes. The system is compatible with all fruit and vegetable crops, and can even be used under windy conditions, by bringing the sprinklers closer together and choosing those with lower jet ranges. With intermittent use, under-tree irrigation systems for frost protection require less rainfall than over-tree systems. They also make it possible to irrigate by sector, resulting in a reduced use of fertilisers. On the other hand, if they are used continuously, they need large quantities of water and must be carefully managed to prevent damage to the crops. They are effective in raising temperatures by 2 degrees and on lower plants, particularly in more southern areas. As a partial solution to the large amounts of water resources required by classic over-tree irrigation systems, and the negative effects of applying such large quantities of water to the ground, alternative under-tree irrigation systems have been developed in which only the ground and/or the vegetation below the crops is irrigated, with the protection coming from the heat produced when water freezes. This heat spreads by convection, especially within the first few metres of the orchard. These systems can effectively add 2-3 °C, especially with radiation frost and in orchards/vineyards on flat ground. They save a moderate amount of water, requiring average rainfall of about 2-2.5 mm/h compared to the 4-5 mm/h needed for the classic over-tree system.

Implementation of this measure is easy, but it does require training and investments.

COSTS AND BENEFITS	
COST OF INVESTMENT	In fruit-growing and viticulture, the price of the system (design, control unit, injection system, pumping and filtration) varies between €4,000/ha and €5,000/ha. The cost of setting up the system ranges from €700/ha to €1,500/ha, depending on soil type and slope (the latter can result in a 5-10% increase in cost). In horticulture, the price varies between €3,000/ha and €4,000/ha, while the cost of setting up the system ranges from €500/ha to €1,000/ha, depending on soil type and slope (the latter can result in a 5-10% increase in cost). The estimated lifespan of the system is 10-15 years or more. It must be borne in mind that costs vary based on water conditions and are very closely related to the size and type of system. Indeed, it is possible for the system to be completely automated in type, with an electric air temperature sensor positioned no more than 50 cm above the ground, and an electronic control unit to operate the pump and electrovalves or hydraulic change-over valves for the irrigation sectors.
AVERAGE ANNUAL COST PER HECTARE	The average cost of maintaining the system is around €200/ha. Based on the costs of the system, straight-line depreciation over 10 years results in an average of €500 to €650/ha for fruit-growing and €350/ha to €500/ha for horticulture. Therefore, a total annual cost per hectare of between €700 and €850 can be estimated for fruit-growing, and between €550 and €700 for horticulture. An operating cost of €20/day can be estimated. Assuming the system is used for 3 days per year, the total operating cost can be estimated at €60.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. The measure is highly effective against all types of frost, raising temperatures by up to 2 °C. It is also moderately effective in the case of drought. It is useful for low-growing plants and in areas facing lower climate-related risks.

IMPACT ON PRODUCTION YIELD AND QUALITY	NO.
ENVIRONMENTAL BENEFITS	NO. Large quantities of water are needed, but if used intermittently, they can save water compared to over-tree systems.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings: goal A; SRD02 – productive agricultural investments for the environment, climate and animal welfare Action C: Investments in irrigation; Sectoral interventions: 1.1 Fruit and vegetables.

COST/BENEFIT EVALUATION

The initial investment required by this action is amply justified by its high level of protection against cold waves which could pose a risk to all produce, as well as its usefulness in cases of drought. The expense of the measure may be a hurdle for smaller and medium-sized farms to overcome, but the incentives of the RDP provide valuable financial assistance towards the investment. The cost of operating the system, which depends on seasonal needs, allows water savings compared to over-tree irrigation.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
VEGETABLES			
FRUIT			
WINE			

The illustrated summary of the assessment is based on a cost of €800/ha and high effectiveness against climate-related risks.

MEASURE 5.4 – DRIP IRRIGATION

PRODUCTION CHAINS INVOLVED

VEGETABLES FRUIT WINE

DESCRIPTION

Drip irrigation systems offer protection against drought.

They are widely used in growing fruit plants, citrus fruits, vines and vegetables, especially those located in temperate zones with a lack of water resources, and in intensive crop-growing, outside or in greenhouses. This type of irrigation is highly suited to irregularly shaped fields or lands, or where the topography or consistency of the soil is uneven. This system provides water slowly and steadily, at low pressure, through plastic pipes positioned inside or near the root area of plants, into which drippers are placed. A well designed system optimises water use by reducing run-off, evaporation, and deep percolation into loamy soil. The way in which the drippers work is rooted in their ability to standardise irrigation along an irrigation line. The market offers self-compensating drippers, which release the same amount of water every time, and no-drain drippers, which prevent air from entering the pipe. The installation of systems for automation and carefully scheduled irrigation improves performances and quality, saves labour time, and allows the flexibility to adapt to weather or production conditions. Automation devices can be used to schedule irrigation cycles as desired and with ease; they also make it easy to read the set parameters and alter them if needed, in the event of changes in weather trends or the addition of new plants.

Implementation of this measure is easy, but it does require training and investments.

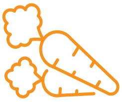
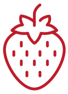
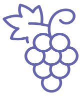
COSTS AND BENEFITS

COST OF INVESTMENT	In fruit-growing and viticulture, the price of the system (including design) ranges from €1,500/ha to €4,000/ha, depending on soil type and slope (the latter can result in a 5-10% increase in cost). The price of the systems in horticulture is lower, ranging from €1,000/ha to €1,200/ha, depending on soil type and slope (the latter can result in a 5-10% increase in cost). The cost of setting up the system in horticulture, fruit-growing and viticulture ranges from €600/ha to €1,000/ha. In fruit-growing and viticulture, the total cost of investment therefore varies between €2,100/ha and €5,000/ha on average, while the range in horticulture is €1,600/ha to € 2,600/ha. The estimated lifespan of the system is 10-15 years or more.

AVERAGE ANNUAL COST PER HECTARE	The annual cost of maintaining a drip irrigation system varies between €200 and €300/ha in fruit-growing and viticulture, and between €600 and €800/ha in horticulture, due to the need to change hoses periodically in horticulture. Considering straight-line depreciation over 10 years plus maintenance, the estimated annual cost/ha varies on average: • between €400/ha and €800/ha in fruit-growing and viticulture; • between €760/ha and €1,060/ha in horticulture.
COST COMPARED TO CONVENTIONAL PRACTICES	Lower. This system allows large savings of water and energy, around 30-40% compared to classic irrigation.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. This irrigation system allows all produce (100%) to be protected against drought, as well as keeping the inter-row area dry, reducing the growth of weeds and the risk of fire.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. The produce is healthier and more even, while yields are also greater. The creation of optimum conditions allows plants to reach their full production potential.
ENVIRONMENTAL BENEFITS	YES. Because leaves, stems and fruits have less contact with water, conditions are less favourable for the development of plant and crop diseases. This system reduces the use of plant protection products and the loss of nitrates, given that the application of water – and, by extension, fertigation – is limited to the plant's root area. Lower water consumption also entails greater energy savings.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD01 609891 – Productive agricultural investments for the competitiveness of agricultural holdings: goal A; SRD02 – productive agricultural investments for the environment, climate and animal welfare Action C: Investments in irrigation; Sectoral interventions: 1.1 Fruit and vegetables.

COST/BENEFIT EVALUATION

The initial investment required by this action is amply offset by the economic benefits it brings: complete protection against drought, improved production quality and yields, savings of agricultural inputs. The expense of the measure may be a hurdle for smaller and medium-sized farms to overcome, but the incentives of the RDP provide valuable financial assistance towards the investment.

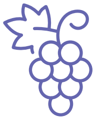
PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	VEGETABLES			
	FRUIT			
	WINE			

The illustrated summary of the assessment is based on a cost of €800/ha and high effectiveness against climate-related risks.

MEASURE 5.5 – NIGHT-TIME IRRIGATION

PRODUCTION CHAINS INVOLVED


FRUIT AND VEGETABLES


WINE


PARMIGIANO REGGIANO

DESCRIPTION

Irrigation helps to counter drought.

During the night and early morning, water evaporation is at a minimum. Therefore, watering plants during this time means that less water is required. In fact, taking advantage of the absence of sunlight during these hours gives the ground time to absorb the water, without losing a non-negligible proportion due to the intense solar radiation and higher temperatures during the middle of the day in summer. This is especially true for over-tree irrigation. This system also reduces the problems caused by burnt leaves, caused by drops of water acting as lenses and converging radiation on above-ground parts of the plant. This system has interesting potential for viticulture, if adopted along with drip systems.

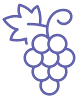
Implementation of this measure is easy.

COSTS AND BENEFITS

COST OF INVESTMENT	No investment is involved.
AVERAGE ANNUAL COST PER HECTARE	–
COST COMPARED TO CONVENTIONAL PRACTICES	Lower. As a result of lower water consumption.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High.
IMPACT ON PRODUCTION YIELD AND QUALITY	NO.
ENVIRONMENTAL BENEFITS	YES. Water savings
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

No costs are involved, only benefits; therefore, night-time irrigation is strongly recommended.

PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	FRUIT AND VEGETABLES			
	WINE			
	PARMIGIANO REGGIANO			

MEASURE 5.6 – SUBSURFACE MICRO-IRRIGATION

PRODUCTION CHAINS INVOLVED

VEGETABLES

FRUIT

WINE

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters drought and the intrusion of salt water from the sea inland through the subsoil.

Subsurface micro-irrigation is a form of drip irrigation which better satisfies the need to keep air as well as water in the soil, as the soil is where plants get their oxygen. It consists of burying driplines beneath the surface in order to allow the steady, regular release of water, as well as removing a potential obstacle to farming operations. If correctly implemented, subsurface irrigation can be more efficient than drip irrigation, reducing irrigation volumes by as much as 30%. The increasing mechanisation of orchards, decreases in the weed-killers permitted, and the sharp rise in organically farmed land – entailing the need to work the land between the rows mechanically – are all factors in favour of burying driplines, keeping them out of the way of machinery. The system is also well suited to automation, conducting irrigation during the early hours of the morning so that the water has the opportunity to percolate and spread throughout the root area, to be absorbed during the hottest hours of the day.

Implementation of this measure is easy, but it does involve investment costs. It is not widely used in horticulture, as the root system of most vegetables does not extend deeply enough to reach the water made available by the system.

COSTS AND BENEFITS

COST OF INVESTMENT	The price of the system – including design – varies between €2,500/ha and €4,000/ha. The cost of setting up the system ranges from €1,000/ha to €1,400/ha, depending on soil type and slope (the latter can result in a 5-10% increase in cost). The estimated lifespan of the system is 10-15 years or more.

AVERAGE ANNUAL COST PER HECTARE	Considering the depreciation and maintenance of the system (the latter is estimated at around €200/ha for clearing nozzles and cleaning filters), the average cost/ha varies between €550 and €740.
COST COMPARED TO CONVENTIONAL PRACTICES	Lower. This system allows large savings of water and energy, around 25-30% compared to drip irrigation.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. This irrigation system facilitates the steady, regular release of water, defending against drought and protecting an estimated 95-100% of production.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Compared to drip irrigation systems, less fertiliser is applied to the soil, with benefits for the plants. Moreover, because leaves, stems and fruits have less contact with water, conditions are less favourable for the development of plant diseases (fungal attacks in wine grapes). Thanks to the burial of the lines, the system does not pose an obstacle to harvesting fruits, improving yield.
ENVIRONMENTAL BENEFITS	YES. Increased energy savings, less waste of water resources and reduced use of fertilisers.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings: goal A; SRD02 – productive agricultural investments for the environment, climate and animal welfare Action C: Investments in irrigation; Sectoral interventions: 1.1 Fruit and vegetables.

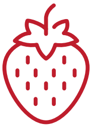
COST/BENEFIT EVALUATION

The initial investment required by this action is amply offset by the economic benefits it brings: complete protection against drought and saltwater intrusion, improved production quality and yields, savings of agricultural inputs. The expense of the measure may be a hurdle for smaller and medium-sized farms to overcome, but the incentives of the RDP provide valuable financial assistance towards the investment. Its use in horticulture must be assessed based on the crop and the ability of its root system to extend deeply enough to reach the water made available by the system.

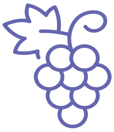
PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
VEGETABLES			
FRUIT			
WINE			
PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €650/ha and high effectiveness against climate-related risks.

MEASURE 5.7 – SUBIRRIGATION



FRUIT



WINE

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters drought and the intrusion of salt water from the sea inland through the subsoil.

Draining systems can be used for two purposes: draining, naturally, and irrigation. The irrigation function consists of using the perforated pipes normally used for draining in reverse. Use of this technique requires the availability of reasonably significant water resources and the presence of a natural aquifer, or of an impermeable soil layer which is not too deep. To achieve an even spread of irrigation, it is advisable to place drainage pipes at the correct distances, taking the characteristics of the soil into account. If the drains are located too far apart, the irrigation is uneven, with the plants watered correctly in the areas around the drains but not in the areas between. If the drains need to be brought closer together, this adds considerably to the costs of building the system; however, it is crucial on deeply permeable soils or those with a deep natural aquifer or none at all.
Subirrigation can take the following forms:

1. From below: water is entered into the drains by raising the water level in a drainage ditch located at a point lower than the system;
2. From above: water is entered into the drainage system by flooding a channel connected to the pipes which is located at a higher altitude than the system, while simultaneously closing the drains further down;
3. Under pressure with storage basins: water is entered directly into the drainage system from one or more tanks, located at higher altitudes.

It should be noted that subirrigation is not able to reach crop roots or satisfy plants' need for water during their early development, meaning that traditional sprinkler methods must be used for irrigation.
Another important point is that subirrigation only makes sense on land where drainage can help: if there is no advantage in building a soil drainage system, which represents the bulk of the investment, then there is no benefit in building the drainage network just for subirrigation.

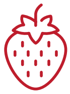
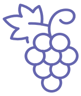
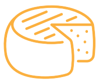
The measure can be implemented wherever the construction of a drainage system makes sense, and where conditions are suitable for subirrigation.

COSTS AND BENEFITS

COST OF INVESTMENT	1. The investment cost of subirrigation fed from below essentially consists of constructing the drainage system, which varies greatly depending on the material used, the spacing of the drains, the topography and type of soil, and the need for excavation and levelling works. Considering all the different costs, a total of €2,000 to €8,000 per hectare can be estimated. 2. For subirrigation fed from above, the estimated cost runs between €2,500 and €10,000 per hectare; while for pressurised subirrigation the range is €3,000 to €12,000 per hectare. 3. The estimated lifespan of the system is 20 years or more.
AVERAGE ANNUAL COST PER HECTARE	Considering depreciation of the system, the cost/ha varies between €100 and €600 on average.
COST COMPARED TO CONVENTIONAL PRACTICES	Lower. Pressurised subirrigation in particular can save water compared to irrigation through sprinklers.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. The system enables irrigation of the soil while protecting it from drought and saltwater intrusion.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Because leaves, stems and fruits have less contact with water, conditions are less favourable for the development of plant diseases. Thanks to the burial of the lines, the system does not pose an obstacle to harvesting fruits, improving yield.
ENVIRONMENTAL BENEFITS	YES. With pressurised subirrigation, there are greater energy savings as a result of lower water consumption.
PUBLIC FUNDING	CAP Strategic Plan – Rural Development Interventions: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings: goal A; SRD02 – productive agricultural investments for the environment, climate and animal welfare Action C: Investments in irrigation; Sectoral interventions: 1.1 Fruit and vegetables.

COST/BENEFIT EVALUATION

The initial investment required by this action is amply offset by the economic benefits it brings: complete protection against drought and saltwater intrusion, improved production quality and yield, and energy savings. The expense of the measure may be a hurdle for smaller and medium-sized farms to overcome, but the incentives of the RDP provide valuable financial assistance towards the investment. The assessment must also consider the fact that, as described above, subirrigation only makes sense on land where drainage can help: if there is no advantage in building a soil drainage system, which represents the bulk of the investment, then there is no benefit in building the drain network just for subirrigation.

PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	FRUIT			
	WINE			
	PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €400/ha and high effectiveness against climate-related risks.

MEASURE 5.8 – COCOONS

PRODUCTION CHAINS INVOLVED

FRUIT

DESCRIPTION

This measure counters drought.

Cocoons are tree incubators made from wax-reinforced cartons that can contain around 25 litres of water. With their doughnut-style shape, they surround the growing plant and have been designed to support seedlings/shoots during the first year of their life. This is a particularly critical period, as the root system is not yet sufficiently developed; the use of cocoons helps to support this process. This technology greatly boosts plants' likelihood of taking root in arid and semi-arid climates, and reduces the quantity of water that trees need to survive and grow.
The method is simple: simply dig a small hole, plant the seed in it, then position the cocoon above the seed and fill it with water, adding a lid to prevent evaporation. A system of wicks draws water from the ring into the soil where the plant's roots are to grow. In some cases, mycorrhizal fungi are added to the soil, facilitating the absorption of moisture and nutrients. Finally, a round shield is inserted inside the doughnut hole and around the plant, protecting it against excessive sunshine and other weather conditions. Cocoons provide plants with water and shelter, while at the same time encouraging the development of a deep, healthy root structure. By doing so, cocoons produce strong, independent trees which do not rely on external irrigation and can survive even under extreme conditions. So far, cocoons have been used to plant trees in over 20 countries, with a survival rate of between 80% and 95%. This system is an innovative way to restore desertified land.

Implementation of this measure is easy. No particular scientific knowledge is needed to grow plants using this system.

COSTS AND BENEFITS

COST OF INVESTMENT	The investment cost consists of buying the cocoons, with prices varying between €5 and €15 each on average.
AVERAGE ANNUAL COST PER HECTARE	This depends on the type of tree plantation, and thus the number of cocoons needed per hectare.
COST COMPARED TO CONVENTIONAL PRACTICES	Lower. The cost of planting each tree is greater when using a cocoon, but the water savings (of eliminating daily irrigation) justify the initial costs over time.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. Cocoons produce strong, independent trees which do not rely on external irrigation and can survive even under conditions of extreme drought (survival rate of 85%-90%).

IMPACT ON PRODUCTION YIELD AND QUALITY	NO.
ENVIRONMENTAL BENEFITS	YES. Water savings and improved soil quality thanks to better water retention, increased micro-organism activity and greater biodiversity, as well as adding to the soil carbon stock.
PUBLIC FUNDING	NO.

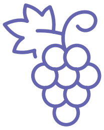
COST/BENEFIT EVALUATION

This technique is particularly valuable in Mediterranean countries susceptible to desertification. The additional cost of installing cocoons is more than offset by their many benefits: low water consumption, the biodegradability of the cocoons, survival of seedlings under critical conditions. Therefore, it is a financially and environmentally sustainable measure for the restoration of desertified land.

MEASURE 5.9 – WASTEWATER REUSE*

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES



WINE

PARMIGIANO REGGIANO

DESCRIPTION

This measure aims to counter drought.

The purification and reclamation of wastewater can make it suitable for reuse for irrigation purposes. Many different examples of excellent systems for the recovery of water that would not otherwise be usable already exist; indeed, prototypes of systems for the reuse of process water are already available in wineries. The technique of wastewater reuse is not widely used in Europe in the areas where water is a scarce resource, i.e. Mediterranean countries (Salgot, 2008).

The need to tackle the problem at EU level was recognised in the Commission's 2012 press release "Blueprint to safeguard Europe's waters" and reiterated in the Commission's communication titled "Closing the loop - An EU action plan for the Circular Economy", which contains a series of actions to promote the reuse of water, including the drafting of proposed legislation to establish minimum requirements for reused water for irrigation and groundwater recharge. For this reason, the European Parliament has adopted a new regulation on water reuse – *Regulation (EU) 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse* – which lays down minimum requirements for water quality and monitoring and provisions on risk management, common to all member states, to allow the safe use of treated urban waste water for irrigation purposes. The regulation shall enter into force from June 2023, and may help to alleviate the problem of water resource shortages throughout the EU, as one element of adapting to climate change, by increasing the reuse of treated wastewater, especially for irrigation. The regulation takes a methodological approach based on risk management. The risk management plan, Annex II to Reg. (EU) 741/2020, requires a site-specific risk analysis by area/zone, in order to allow member states and business operators to consider the risk on a case-by-case basis and, therefore, to put further measures in place in addition to those which are mandatory under the regulation, to eliminate health and environmental risks.

The studies carried out in preparation for the proposal for the regulation estimated that its implementation could lead to 6.6 billion m^3 of water being reused for irrigation per year, compared to 1.7 billion m^3/year in the absence of a legislative framework at EU level. For Italy, which is one of the Mediterranean countries (together with Spain, Portugal, Greece, France, Malta and Cyprus) that already have a regulatory system governing reuse, these studies have estimated that the use of reclaimed wastewater could potentially reach around 50% (based solely on the proximity of water purifiers to agricultural areas, without considering costs). Of course, this is just a potential value, which will depend in practice on compatibility between the type of treatment carried out at the plants and the agronomic conditions (crops) and environmental conditions (vulnerability to nitrates) of the agricultural areas around them; as well as the financial viability of transport, which can constrain implementation of the measure.

* *Text by Veronica Manganiello.*

Public funding will certainly be necessary to finance purifiers and treatment plants, as well as to modernise/ build irrigation infrastructure for the distribution of the water. The reuse of treated wastewater for irrigation offers the agricultural sector access to additional water resources which are not dependent on the season, guaranteeing greater stability for crops in the face of the risks posed by climate change, particularly in Mediterranean areas where water is an indispensable production input. At the same time, by prolonging the life cycle of water, reuse also has positive impacts on the environment by reducing both abstraction from natural bodies of water and the use of synthetic fertilisers. If implemented, managed and monitored correctly, the reuse of purified wastewater in agriculture involves no risks for agricultural operators, the crops and soils irrigated, or the end consumers.

The main critical issues are:

1. *The level of wastewater treatment pursuant to the classes identified in Annex I to Reg. (EU) 741/2020.* The new regulation allows food business operators to adopt additional water treatment options or to use other sources of irrigation as an alternative to reclaimed water, in cases where the reclaimed water available is not of suitable quality for their needs. This paves the way for the adoption of the most appropriate and economically sustainable form of treatment based on the main crops present in the area being served, with additional treatments or barriers being applied only for those crops which require higher quality classes, including for compliance with any production rules. On the other hand, this could result in extra costs for the end user if adequate consideration is not given to this eventuality within the Risk Management Plan. Because the plan is site-specific in nature, it can provide a useful tool for evaluations of this type. Therefore, the end user is guaranteed protection with regard to the quality of the water used on crops, without additional burdens for farms.
2. *Supply, distribution and storage infrastructure.* The Risk Management Plan must define the "point of compliance", which is to say where responsibility passes from one party to another. It will be necessary to verify the regulation's compatibility with the collective management of irrigation, in terms of defining roles and responsibilities related to managing purification plants and/or the network for the distribution of the treated water.
3. *Coverage of treatment and distribution costs.* The legislation currently in force in Italy, Decree 185/2003 of the Ministry for Environment, Land and Sea Protection, makes provision for pricing: treatment costs are borne by the integrated water management service (ARERA); while the end users of the reused water (farmers and consortia) are responsible for distribution costs. The company which manages the integrated water service categorises wastewater in its regulations as "other water activities", and not one of the activities included in the integrated water service. Therefore, the costs for the various sectors in which it is to be used must be determined.
4. *Educating the public.* One of the main obstacles to the reuse of water for irrigation purposes is resistance on the market and among consumers to purchasing food products irrigated with treated wastewater, partly in light of the lack of consistent regulations on the matter throughout the Union, which hinders the circulation of agricultural products.

Essentially, wastewater purification is carried out by the integrated water service, to which fees are paid by citizens through their bills. Following this purification, wastewater can be sent to reclamation facilities to make it usable in agriculture. There are currently two ways of reusing this water in agriculture: directly and indirectly. Direct reuse involves sending the wastewater for agricultural use through dedicated pipe networks; while indirect reuse sees this water stored in receiving bodies of water from which it can be drawn by the end user.

The new regulation governs direct reuse, which has not been widely implemented to date due to the various problems that can arise if wastewater is not adequately treated. Reclamation consortia act as intermediaries for the integrated water service, dealing with the needs of farmers and efficiently steering the activities of the reclamation facility manager. In addition, through the modernisation and construction of new infrastructure, they can facilitate both direct and indirect reuse. To date, there is no set price for farms for this water, as indirect use is the type mainly used. The price set must be determined based, among other things, on the type of treatment the water needs to reach suitable quality levels for the crops in the field. Therefore, it can be assumed that only farms associated with reclamation consortia or other types of public or private bodies can use the purified wastewater placed on the networks managed by such parties, as the water can only be transported through the infrastructure they themselves manage.

Implementation of this measure is easy for farms in areas where the investments necessary to build the infrastructure have been made.

COSTS AND BENEFITS

COST OF INVESTMENT	There are no investments required of the farm. Investments come from public funds: both for purification, which is the responsibility of the integrated water service and supported by citizens who pay the purification fee through their bills; and for the treatment and distribution plants, which require significant investments. The investment costs for the modernisation/construction of irrigation infrastructure to carry water from treatment plants to the farms range from €4,000,000 to €6,000,000. Irrigation bodies must make this investment in order to transport water from the treatment plant to the farms.
AVERAGE ANNUAL COST PER HECTARE	To date, there is no set price for farms for this type of water, as indirect use is the type mainly used. Therefore, in the case of indirect use, there is no difference in the cost for the farm. It can be assumed that only farms associated with reclamation consortia or other types of public or private bodies will be able to use the purified wastewater placed on the networks managed by such parties, as the water can only be transported through the infrastructure they themselves manage. As previously explained, the investments required by this infrastructure are extremely high for individual farmers.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater. In assessing the application of this measure, it is important to consider the possible discrepancy between the costs of reused water and water from the environment. Among other things, while the costs incurred for any additional treatments (further barriers) of the reclaimed wastewater before it can be used on certain crops may be a critical factor, it must be balanced against any decrease in the costs incurred from the use of external fertilisers.

EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. This is an effective climate change adaptation measure, boosting the resilience of the irrigation system against drought and water scarcity. If implemented correctly, it can provide a range of environmental, economic and social benefits. These benefits increase proportionally as the demand for irrigation grows, both as a result of reduced availability (less precipitation) and an increase in the need for irrigation (high rates of evapotranspiration), particularly in areas where the primary sector is a crucial part of the local socio-economic fabric. First and foremost among the benefits is access to water resources which are not dependent on the season, guaranteeing steady yields even under extreme climate conditions such as drought and rising temperatures, which increase the demand for irrigation. Moreover, access to these additional water resources can reduce abstraction from natural bodies of water which, under conditions of drought paired with rising temperatures, can experience excessive water loss due to greater evapotranspiration. Furthermore, there is a significant benefit in the larger production capacity enabled by the increased availability of irrigation, generating employment and additional income in agriculture. The economic benefit of the investment is greatest in areas with the worst water shortages (the PON In.Te.R.R.A. project).
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Treated waters, used in varying proportions with surface waters, have benefits for the soil's physical characteristics. Three main elements (N, P, K) can improve the chemical fertility of the soil (the PON In.Te.R.R.A. project), despite being present in highly variable concentrations and dependent upon the type of waste. As a result, these waters can improve production yield.
ENVIRONMENTAL BENEFITS	YES. Water reuse limits the need to draw from natural bodies of water, reducing the pressure of human activities on ecosystems, while also cutting down on energy costs by eliminating groundwater abstraction (the PON In.Te.R.R.A. project). Treated waters offer benefits for the soil's physical characteristics, providing the right balance of nutrients (mainly nitrogen, phosphorous and potassium) and other elements which improve soil fertility. This also means that the use of mineral fertilisers can be reduced, with environmental and economic benefits for farms. Finally, treating wastewater so that it meets the criteria required for agricultural recycling effectively reduces the quantity of wastewater discharged into the environment in impure conditions. This represents an environmental benefit by reducing the pollution of the receiving bodies of water.

PUBLIC FUNDING

Over the years, and as part of the various European rural development plans, national and EU funds have been set up to support national strategies with the construction and upgrading of purification plants for wastewater reuse. Financing has also been made available for the construction and upgrading of the irrigation infrastructure used to manage and distribute treated water for reuse in irrigation. For infrastructure: CAP Strategic Plan – Rural development interventions: SRD07 – investment in agricultural infrastructure and in the socio-economic development of rural areas; SRD08 – investments in infrastructure with environmental purposes.

COST/BENEFIT EVALUATION

One of the main obstacles to the reuse of water for irrigation purposes is resistance on the market and among consumers to purchasing food products irrigated with treated wastewater, partly in light of the lack of consistent regulations on the matter throughout the Union, which hinders the circulation of agricultural products. The new regulation aims to remove these hurdles: by establishing rules common to all member states, it creates a level playing field when it comes to reuse practices, overcoming potential obstacles to the free circulation of agricultural products irrigated with wastewater on the internal free market. At the same time, these rules aim to increase consumer trust in reuse practices, acting alongside the obligation to guarantee transparency and public access to online information about water reuse practices in their member states. Other obstacles to the implementation of the measure include the irrigation pricing to be applied to this water, and the costs of any additional treatments necessary for reuse on certain crop types. The site-specific risk management plan which the new regulation calls for must take a series of factors into account in order to incentivise the practice. Finally, public funds must be set aside for the upgrading of purifiers as well as for treatment systems and for the upgrading/construction of irrigation infrastructure to incentivise this practice. Businesses that wish to establish systems of their own will incur high investment costs, which must be weighed against the benefits of avoiding the damage caused by a lack of water for irrigation. Given the high cost, small and medium-sized farms must carefully consider how much they will benefit economically.

In terms of the direct use of wastewater in agriculture, it is not currently possible to form an evaluation, as the players, responsibilities, controls and prices are being defined by the new Reg. 721/2020, which will come into force in June 2023. Given the many benefits derived from the use of wastewater, with reference to results from various projects carried out, such as increased soil fertilisation; plus the access to additional water resources during periods of drought and the help with maintaining farm yields and income, a comparison of the costs and benefits reveals that the long-term environmental and financial benefits of upgrading systems for the purification of urban wastewater to be reused in irrigation fully offset the costs. This is true even despite the fact that the method of calculation used to form the estimate does not take into account such non-use values as the improved quality of water bodies and the future appreciation of the use value of the conventional resource available (Zucaro R. *et al.* (2012), *Valutazione tecnico-economica delle potenzialità di riutilizzo irriguo dei reflui depurati: il caso della Valpadana* [A technical-economic assessment of the potential for reusing purified wastewater for irrigation: Valpadana as a case study]). Therefore, the measure should be implemented and incentivised.

Its importance is also underlined by the interest at EU level, with the Action Plan for the circular economy identifying Reg. 741/2020 as the tool for incentivising reuse for irrigation in agriculture.

MEASURE 5.10 – ARTIFICIAL LAKES, RESERVOIRS FOR ONE OR MULTIPLE FARMS*

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES

WINE

PARMIGIANO REGGIANO

DESCRIPTION

This measure aims to counter drought.

This measure refers to activities for the collection and management of water for irrigation purposes at farm level, by building up water reserves during rainy periods. Systems for the collection and recovery of rainwater serve the purpose of reducing the abstraction of water from natural bodies (rivers and groundwater), and of allowing the water collected to be treated and reused in agricultural activities. Projects to increase the availability of water on the farm as an adaptation to climate change and to reduce the risks of drought differ in their territorial scale. Some solutions include:

Single-farm or multi-farm systems for the direct collection of rainwater. These involve the collection of rainwater from rooftops or other suitable surfaces, using small tanks serving single farms or entire rural communities in conjunction with filtering and storage systems. These are technically simple and economically sustainable systems, suitable for small enterprises.

Small reservoirs for the use of one or more farms, fed by surface water courses. In addition to the storage of water resources for productive purposes, these can also perform other productive functions (installation of solar panels) and environmental functions (particularly if constructed with nature-based solutions). A high degree of know-how is necessary for their construction, both in terms of accessing funding and for the actual construction and management of the infrastructure. Irrigation bodies can play an essential role in providing technical and administrative support to farms within their area of competence, helping them to access public funding.

Systems for the collection and recovery of rainwater help to reduce abstraction from natural bodies, by providing an alternative water source. The construction of reservoirs allows water to be drawn from natural bodies when availability is at its greatest, so that it can be used when there is the greatest demand for irrigation. By collecting the water for use at a later time, pressure on natural water bodies is reduced significantly, even though the same quantity is abstracted. It also means less competition over use (including with the environment) at the times when water is least available and farms have greatest need of it. What's more, these reservoirs also provide opportunities to improve a range of ecosystem services (sometimes in the form of artificial wetlands) and to save energy, as they can support floating solar energy plants.

The measure is easiest to implement in the form of a cooperative enterprise, to better spread the costs incurred. (NOTE: the following data refer to statistics obtained using the data from eight multi-farm reservoir projects carried out within the territory of the reclamation consortium in western Romagna, funded through the 2007-2013 Emilia-Romagna Rural Development Plan – Measure 125 and 2014-2020 – Measure 4.1.03 – investments in farms).

* *Text by Marianna Ferrigno.*

COSTS AND BENEFITS

COST OF INVESTMENT	In the case of multi-farm reservoirs, the construction cost for the sample in question (reservoir capacity of between 50,000 and 150,000 m^3 approximately) can range from €3 to €27/m^3 of capacity. This component of the cost is directly affected by the morphology and type of soil of the construction site. The cost of constructing a network for supply and distribution to the farms can range from €45,000 to €90,000/km, depending partly on the material used. Overall, the unit cost of the investment falls as the size of the reservoir increases and when greater numbers of farms take part in the project, provided that they are all adjoining and located close to the reservoir. The cost of building the network is around 2-3 times the cost of constructing the reservoir itself. The cost to be borne by the farms (i.e. the cost not covered by public subsidies) is calculated in proportion to their share of the reservoir's total volume of water. In some cases, the cost of the work borne by farms (allocated by land surface area) reached values of €2,500-€3,500/ha.
AVERAGE ANNUAL COST PER HECTARE	The annual cost/ha consists of the depreciation on the investment made (calculated based on an average lifespan of 20 years) and of maintaining and managing the system. Therefore, an annual cost/ha of €200-€300 can be estimated.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater. Around 60-70% of management costs consist of the cost of electricity used to raise the water. In the cases assessed, it should be remembered that the farms served were very often located at an altitude 150-200 m higher than that of the reservoir. These costs can be largely offset by installing floating solar energy plants on the reservoir. For the sample considered here, the expense thus covered came to 35-40%.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. Multi-farm reservoirs, particularly if constructed in hilly areas which may not easily be served by shared irrigation networks, and often fed by torrential water courses, can help to ensure access to water resources. This protects against the risk of water shortages which can arise due to the growing difficulty of relying on natural water courses during the times of greatest need. The presence of reservoirs makes it possible to draw from water courses when the water is most available, creating a reserve that can be used for times of scarcity. The greatest benefits are felt when it comes to high-value crops such as fruits and vines; during prolonged periods when rainfall is totally absent, there is a risk of compromising not only the annual production of such plants, but even their very equilibrium.
IMPACT ON PRODUCTION YIELD AND QUALITY	NO.

ENVIRONMENTAL BENEFITS	YES. The construction of reservoirs allows water to be drawn from natural bodies when availability is at its greatest, so that it can be used when there is the greatest demand for irrigation. By collecting the water for use at a later time: • pressure on natural water bodies is reduced significantly; • there is less competition over use (including with the environment) at the times when water is least available most needed; • awareness of responsible use of water resources is raised, partly because the water is paid for through a binomial tariff calculated by reading farms' meters.
PUBLIC FUNDING	YES. For the sample considered, the average amount co-financed by the farms is around 55-65%, covering expenses which are not eligible for public funding (purchasing the land, expenses exceeding the maximum amount). The measure can be financed through CAP Strategic Plan – Rural development interventions: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings: goal A; SRD02 – productive agricultural investments for the environment, climate and animal welfare Action C: Investments in irrigation; if the measure is carried out on a multi-farm basis: SRD07 – investment in agricultural infrastructure and in the socio-economic development of rural areas; SRD08 – investments in infrastructure with environmental purposes.

COST/BENEFIT EVALUATION

A high degree of know-how is necessary for their construction, both in terms of accessing funding and for the actual construction and management of the infrastructure. Irrigation bodies can play an essential role in providing technical and administrative support to farms within their area of competence, helping them to access public funding. The percentage of private co-financing currently necessary makes measures of this type attractive and sustainable only to farms dedicated to medium-high value crops, which can offset the investment needed and recoup it over the years. Moreover, the measure requires farmers with an entrepreneurial attitude and openness to innovation, willing to embark on initiatives for the creation of value.

MEASURE 5.11 – DESALINATION OF WATER

PRODUCTION CHAINS INVOLVED

VEGETABLES

FRUIT

WINE

PARMIGIANO REGGIANO

DESCRIPTION

This measure protects against drought and the intrusion of salt water from the sea inland through the subsoil. It addresses the lack of available water for irrigation.

In areas close to the sea, where saltwater intrusion is a problem, the water drawn from wells is not suitable for growing the main crops. For this reason, the use of desalination plants for irrigation purposes holds considerable interest. In fact, the use of desalinated water not only allows irrigation with water which would otherwise be unusable, but it simultaneously contributes to the restoration of optimal soil productivity, as the use of fresh water does not cause salt build-ups and reduces the salinity of the soil itself. This system is inefficient, given the high economic and energy costs involved, but can be worthwhile for high value-added crops and limited areas.
In general, two processes can be used to desalinate seawater: reverse osmosis with semi-permeable membranes, and thermally driven technologies. However, the thermal treatment plants, which evaporate water to remove the salt before condensing it again into drinking water, consume a lot of energy. Reverse osmosis, on the other hand, is a much more common process. A few desalinators designed specifically for agriculture currently exist, with lower investment costs than the industrial models.

This measure requires high investment costs and suitable training/guidance.

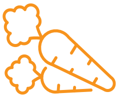
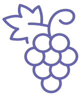
COSTS AND BENEFITS

COST OF INVESTMENT	The price of desalination systems differs, depending mainly on the quantity and type of water to be treated. For example, the average cost of a reverse osmosis desalination system for use on well water with a conductivity of 2,500 μs/cm, offering a production capacity of 480 m^3 per day, can be estimated at €85,000. Meanwhile, a system with a production capacity of 432 m^3 per day, for the desalination of well water with a conductivity of 12,500 μs/cm, will cost around €140,000. These systems can meet the needs of a farm of around 10-12 hectares with crops grown under shelter.

AVERAGE ANNUAL COST PER HECTARE	The maintenance costs for the two types of system described above can vary between €400 and €650/ha annually. Considering an average lifespan of 15 years for the system, annual depreciation of between €450/ha and €900/ha can be estimated. The cost of water production, meanwhile, is estimated at between €0.30 and €0.50/m^3.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater. The higher cost is due to increased energy consumption: the greater the salinity of the water, the more energy required.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. This is a viable system for countering drought, and in the absence of water for crop irrigation in the case of saltwater intrusion.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Another advantage of the use of agricultural desalinators lies in the fact that farmers can modify the conductivity level of the water they use for irrigation to suit the crop and its stage of growth: a useful means of control which is not normally available. Therefore, the use of desalinators makes it possible to increase both production yield and product quality.
ENVIRONMENTAL BENEFITS	YES. Preserves soil fertility while reducing the quantity of fertilisers used.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

The measure is highly effective against drought, by making adequate water resources available for agricultural needs. Costs are high, but the investment makes irrigation possible even in cases where only brackish water is available. The use of a desalinator allows optimal calibration of the water's characteristics for every type of crop. This has a positive effect on both yield and quality, which could otherwise be compromised by the constant increase in water salinity. However, consideration must also be given to the most appropriate way of disposing of the concentrate discharged. Farms with high value-added productions will see the greatest benefits from implementing this measure.

PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	VEGETABLES			
	FRUIT			
	WINE			
	PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €1,500/ha and high effectiveness against climate-related risks.

6. ENGINEERING, DIGITISATION AND TRAINING

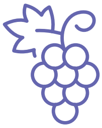
In considering the actions that can be implemented, one significant area is that of ongoing education and training, as well as digitisation and the use of new technologies in general. The measures in question, which can be put in place to help farmers to tackle all the possible risks linked with climate change, consist of:

1. **REGULAR TRAINING OF WORKERS AND TECHNICIANS**
2. **AGROMETEOROLOGICAL SOFTWARE SYSTEMS TO PREDICT PHENOLOGY**
3. **AGROMETEOROLOGICAL SOFTWARE FOR PLANT TREATMENT RECOMMENDATIONS**
4. **WATER BALANCE SOFTWARE**
5. **USE OF WEATHER FORECASTS**
6. **USE OF AGROMETEOROLOGICAL BULLETINS**
7. **USING FUTURE SCENARIOS TO CONDUCT FEASIBILITY STUDIES ON PERENNIAL CROPS**
8. **PRECISION AGRICULTURE**
9. **VERTICAL FARMING**

MEASURE 6.1 – REGULAR TRAINING OF WORKERS AND TECHNICIANS

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES



WINE

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters the damage caused by all risks posed by climate change.

When it comes to climate change adaptations, research and innovation are being conducted at extraordinary speed, thanks to the immense interest in and resources dedicated to the issue. This rapid development makes it more vital than ever for agricultural workers and technicians to undergo regular training and refresher courses, to keep their skills and knowledge of the most advanced methods to apply in various fields up to date. Forms of training can include online courses, farm advisory services, or participation in events and specialist trade fairs.

Implementation of this measure is easy.

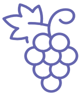
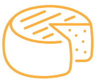
COSTS AND BENEFITS

COST OF INVESTMENT	No investment is involved.
AVERAGE ANNUAL COST PER HECTARE	The cost of this measure varies widely: some solutions, like some courses or participating in certain trade fairs, may be free of charge; while others, such as advanced courses with professionals, can run from a few hundred euro to several thousand. Farm advisory services, carried out by highly qualified personnel, are generally the most expensive option. Depending on the type of farm, its size in terms of UAA and economic class, and the level of specificity of the service, they can cost as much as €3,000-€5,000. To calculate the average cost, the frequency of training/advisory services and the size of the farm must be taken into consideration, but a possible estimate could range from €20 to €100 per hectare on average.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. The training and skills acquired by workers in the sector are essential in order to select the most suitable measures for individual farms to counter the risks posed by climate change.

IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Regular training, the acquisition of skills, and embracing innovation can have a positive influence on production processes, resulting in an increase in both quality and yield.
ENVIRONMENTAL BENEFITS	YES. Proper training paves the way for the use of farming techniques with a lower environmental impact.
PUBLIC FUNDING	CAP Strategic Plan – Rural Development Interventions: SRH03 – training of farmers, workers for businesses in the agricultural, animal husbandry and food sectors, and other private and public actors involved in the development of rural areas; SRH04 – information activities; SRH05 – demonstration actions for agriculture, forestry and rural areas; Sectoral interventions: 1.3 Fruit and vegetables.

COST/BENEFIT EVALUATION

The measure adds to the knowledge of workers in the sector, allowing them to identify the best solutions to implement. The modest cost of the measure, compared to its effectiveness, earns it a highly positive evaluation.

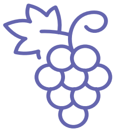
PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
 FRUIT AND VEGETABLES			
 WINE			
 PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €100/ha and high effectiveness against climate-related risks.

MEASURE 6.2 – AGROMETEOROLOGICAL SOFTWARE SYSTEMS TO PREDICT PHENOLOGY

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES



WINE

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters damage from drought, extreme high and low temperatures, and risks to plant health.

Understanding phenological data is important for many agricultural practices. For example, certain interventions (plant protection treatments, fertilisation, weed-killing, irrigation, etc.) are effective only if carried out during specific phenological stages. Moreover, plant sensitivity to external factors (frost, heat waves, hail, attack by insects and pathogens, etc.) differs depending on the phenological stage during which the event occurs. Phenological models provide useful support in monitoring potential changes in the sowing seasons or in the best periods for carrying out interventions in the field, in order to avoid the most critical parts of the year, in terms of climate, for a given crop. They are also useful for assessing whether current summer crops may become autumn-winter crops (e.g. potatoes) in future scenarios. Options available for the implementation of this measure include software services running on the service provider's own data to predict phenological stages, as well as the installation of weather stations to collect and monitor agrometeorological data, linked with a service which returns forecast data.

This measure can be implemented, with additional investment costs and/or suitable training/guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	Purchasing weather stations can cost between €1,000 and €3,000 per station. On average, it is estimated that one station will be needed for every 5 ha in hilly areas, or for every 10 ha on flat land. The expected lifespan of an agrometeorological station is around 10 years.
AVERAGE ANNUAL COST PER HECTARE	Services providing forecast data can cost less than €20/ha per year, depending on the level of detail contained in the data (farm/field/plot). With the installation of weather stations, depreciation of the investment over multiple years must be taken into account. This can be estimated at under €60/ha per year, while the cost of maintenance (usually carried out every 5 years) is around €20/ha per year. Therefore, the average annual cost is less than €100/ha.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater. The higher cost is due to the purchase of a weather station (assuming one is purchased) and payment for the forecast data service.

EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. Careful monitoring of micro-climate conditions and the risk of infection in relation to the phenological stage observed. If the practices suggested by the service are correctly applied, they can effectively counter drought, extreme high and low temperatures, and damage to plant health.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. This measure helps to increase both the yield and quality of production, as it recommends the best time frame in which to carry out agronomic practices in order to optimise production.
ENVIRONMENTAL BENEFITS	YES. Prediction of the development of diseases (pathogens and phytophagous insects); reduction of plant treatments.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: the weather stations can be financed with SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD02 – productive agricultural investments for the environment, climate and animal welfare. Software and weather stations are eligible for funding, subscriptions and support are not.

COST/BENEFIT EVALUATION

In all production chains, the benefits can be expected to far outweigh the costs. When it comes to purchasing weather stations, the investment is not excessively onerous. The measure is highly cost-effective whether it consists of installations in the field, or simply a subscription to agrometeorological services; therefore, it is highly recommended.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
FRUIT AND VEGETABLES			
WINE			
PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €100/ha and high effectiveness against climate-related risks.

MEASURE 6.3 – AGROMETEOROLOGICAL SOFTWARE FOR PLANT TREATMENT RECOMMENDATIONS

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES

WINE

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters damage to plant health.

Plant disease models estimate the risk to plant health from certain pathogens, based on meteorological trends and the plant's stage of development. These models simulate the dynamics of bacterial and fungal populations, and the main stages of development for insects which are harmful to plants. If forecast data are input, they can enable an estimate of the short-term risks to plant health, thereby making it possible to plan protective interventions. Options available for the implementation of this measure include software services running on the service provider's own data to predict risks to plant health, as well as the installation of weather stations to collect and monitor agrometeorological data, linked with a service which returns forecast data.

This measure can be implemented, with additional investment costs and/or suitable training/guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	Purchasing weather stations can cost between €1,000 and €3,000 per station. On average, it is estimated that one station will be needed for every 5 ha in hilly areas, or for every 10 ha on flat land. The expected lifespan of an agrometeorological station is around 10 years.
AVERAGE ANNUAL COST PER HECTARE	Services providing forecast data can cost less than €20/ha per year, depending on the level of detail contained in the data (farm/field/plot). With the installation of weather stations, depreciation of the investment over multiple years must be taken into account. This can be estimated at under €60/ha per year, while the cost of maintenance (usually carried out every 5 years) is around €20/ha per year. Therefore, the average annual cost is less than €100/ha.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater. The higher cost is due to the purchase of a weather station (assuming one is purchased) and payment for the forecast data service.

EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. Accurate risk estimates, i.e. the capacity to predict when infection will occur and the threshold for intervention. If the practices suggested by the service are applied, damage to plant health can be effectively countered.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Increases both the yield and quality of production by recommending the best time frame in which to apply treatments. Control of production quality.
ENVIRONMENTAL BENEFITS	YES. Prediction of the development of diseases (pathogens and phytophagous insects); reduction of plant treatments.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: the weather stations can be financed with SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD02 – productive agricultural investments for the environment, climate and animal welfare. Software and weather stations are eligible for funding, subscriptions and support are not.

COST/BENEFIT EVALUATION

In all production chains, the benefits can be expected to far outweigh the costs. When it comes to purchasing weather stations, the investment is not excessively onerous. The measure is highly cost-effective whether it consists of installations in the field, or simply a subscription to agrometeorological services; therefore, it is highly recommended.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
FRUIT AND VEGETABLES			
WINE			
PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €100/ha and high effectiveness against climate-related risks.

MEASURE 6.4 – WATER BALANCE SOFTWARE

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES

WINE

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters drought.

Water balance models estimate water dynamics within the agro-ecosystem, particularly the water content in the soil and its irrigation needs. Use of these models reveals when and where to irrigate, for a more informed and efficient use of water. Tools such as tensiometers can be used to check the soil water content and soil water tension. These enable a more accurate monitoring of the replenishment achieved by irrigation. Options available for the implementation of this measure include software services running on the service provider's own data to estimate water dynamics within the agro-ecosystem, as well as the installation of agrometeorological stations to collect and monitor the relevant data, linked with a service which returns forecast data.

This measure can be implemented, with additional investment costs and/or suitable training/guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	Purchasing weather stations can cost between €1,000 and €3,000 per station. On average, it is estimated that one station will be needed for every 5 ha in hilly areas, or for every 10 ha on flat land. The expected lifespan of an agrometeorological station is around 10 years.
AVERAGE ANNUAL COST PER HECTARE	Services providing forecast data can cost less than €20/ha per year, depending on the level of detail contained in the data (farm/field/plot). With the installation of weather stations, depreciation of the investment over multiple years must be taken into account. This can be estimated at under €60/ha per year, while the cost of maintenance (usually carried out every 5 years) is around €20/ha per year. Therefore, the average annual cost is less than €100/ha.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater. The higher cost is due to the purchase of a weather station (assuming one is purchased) and payment for the forecast data service.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. Improved monitoring for future water availability forecasts. If the practices suggested by the service are applied, drought can be effectively countered.

IMPACT ON PRODUCTION YIELD AND QUALITY	YES. The measure may increase both the yield and quality of production by recommending the correct levels of irrigation.
ENVIRONMENTAL BENEFITS	YES. Sustainable irrigation practices (limiting water stress); optimisation of water distribution; management of the soil's water parameters.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: the weather stations can be financed with SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD02 – productive agricultural investments for the environment, climate and animal welfare. Software and weather stations are eligible for funding, subscriptions and support are not.

COST/BENEFIT ANALYSIS

In all production chains, the benefits can be expected to far outweigh the costs. When it comes to purchasing weather stations, the investment is not excessively onerous. The measure is highly cost-effective whether it consists of installations in the field, or simply a subscription to agrometeorological services; therefore, it is highly recommended.

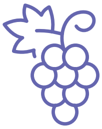
PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
FRUIT AND VEGETABLES			
WINE			
PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €100/ha and high effectiveness against climate-related risks.

MEASURE 6.5 – USE OF WEATHER FORECASTS

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES



WINE

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters the damage from extreme meteorological events: hail, wind, drought, extreme high and low temperatures, excess water and flooding, intense precipitation, erosion and damage to plant health.

Relying on weather forecasts makes it possible to mitigate damages by planning protective systems in advance, during the early stages of crop development (e.g. anti-hail canvases, frost protection, underground drainage, etc.).

Implementation of this measure is easy.

COSTS AND BENEFITS

COST OF INVESTMENT	There are no investment costs involved, as weather forecasts are freely and publicly available.
AVERAGE ANNUAL COST PER HECTARE	There are no costs involved, as weather forecasts are freely and publicly available.
COST COMPARED TO CONVENTIONAL PRACTICES	Lower. Rationalising expenditure on agricultural inputs helps to keep current costs down.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. Moderately effective against various climate-related events.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. May increase both the yield and quality of production.
ENVIRONMENTAL BENEFITS	YES. The information acquired helps with decision-making, allowing a better plant treatment schedule and greater water savings.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

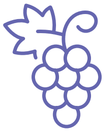
PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
FRUIT AND VEGETABLES			
WINE			
PARMIGIANO REGGIANO			

Checking the weather forecast is common practice involving zero costs.

MEASURE 6.6 – USE OF AGROMETEOROLOGICAL BULLETINS

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES



WINE

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters the damage from extreme meteorological events: hail, wind, drought, extreme high and low temperatures, excess water and flooding, intense precipitation, erosion and damage to plant health.

Relying on agrometeorological bulletins makes it possible to mitigate damages by planning protective systems in advance, during the early stages of crop development (e.g. anti-hail canvases, frost protection, underground drainage, etc.).
Agrometeorological bulletins are informational documents issued regularly by regional or national meteorological and agrometeorological services. They contain information on observed and predicted meteorological trends, the phenological and growth status of agricultural crops, risks to plant health, and the soil's water conditions. This information helps to best manage agronomic operations (fertilisation, plant health treatments, irrigation, pruning, tilling).

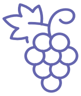
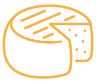
Implementation of this measure is easy.

COSTS AND BENEFITS

COST OF INVESTMENT	There are no investment costs involved, as agrometeorological bulletins are freely and publicly available.
AVERAGE ANNUAL COST PER HECTARE	There are no costs involved, as agrometeorological bulletins are freely and publicly available.
COST COMPARED TO CONVENTIONAL PRACTICES	Lower. Rationalising expenditure on agricultural inputs helps to keep current costs down.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. Moderately effective against various climate-related events.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. The measure may increase both the yield and quality of production by enabling the planning of protective systems.
ENVIRONMENTAL BENEFITS	YES. The information acquired helps with decision-making, for better control of plant health, phytopathological analysis in agriculture, and a better plant treatment schedule as well as water savings.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

Checking agrometeorological bulletins is common practice involving zero costs. If this practice is consistently followed, it can effectively counter damage from adverse climate events.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
 FRUIT AND VEGETABLES			
 WINE			
 PARMIGIANO REGGIANO			

MEASURE 6.7 – USING FUTURE SCENARIOS TO CONDUCT FEASIBILITY STUDIES ON PERENNIAL CROPS

PRODUCTION CHAINS INVOLVED

FRUIT

WINE

DESCRIPTION

This measure counters the damage caused by all risks posed by climate change.

Future climate scenarios can be used to conduct feasibility studies when establishing new plantations of perennial crops. Perennial crops, particularly tree crops, have a lifespan of several years, or even decades. For this reason, it is important to check whether a given zone is still suitable for its traditional crops, or whether climate change has made it advisable to alter crop choices.

The measure can be implemented, but it requires the acquisition of technical skills.

COSTS AND BENEFITS

COST OF INVESTMENT	There are no investment costs.
AVERAGE ANNUAL COST PER HECTARE	The future climate scenarios modelled as part of research studies, which are freely available for consultation, make it possible to make decisions regarding the type of production to be adopted on farms. There are no costs involved, apart from the time required to acquire the information.
COST COMPARED TO CONVENTIONAL PRACTICES	No difference.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderately effective.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. May increase both the yield and quality of production.
ENVIRONMENTAL BENEFITS	YES. Growing suitable crops guarantees a more balanced use of environmental resources (e.g. the use of water resources).
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

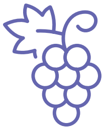
As there are no costs or hurdles involved, researching future climate scenarios to support farming decisions is a cost-effective measure.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
FRUIT			
WINE			

MEASURE 6.8 – PRECISION AGRICULTURE

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES



WINE

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters the damage from extreme meteorological events: hail, wind, drought, extreme high and low temperatures, excess water, intense precipitation, erosion and damage to plant health.

Precision agriculture is a farm-management strategy which uses information technology for the acquisition of data. These data can then be used to make decisions about agricultural production, enabling best management of agronomic resources (water, fertilisers, plant protection products) and practices, taking action exactly where and when needed at the level of individual plots. This is why the strategy has been termed "precision" agriculture: thanks to the most modern tools, it is possible to take the right steps, in the right place, at the right time, satisfying the specific needs of individual crops and parcels of land with a high degree of precision. There are many tools at the disposal of precision agriculture; the most modern technologies are employed in an integrated manner, collecting data and intervening with suitable actions to improve productivity and counter adverse climate events.
Specifically, the following tools are available to precision agriculture:

- Data-collection tools:
  - Satellite monitoring of crops;
  - Sensors and drones.
- Tools for interventions in the field:
  - Variable rate control: the distribution of different quantities of fertilisers and plant protection products, tailored by need;
  - Assisted and automatic driving systems for tractors and agricultural machinery.

The most recent technologies, still under development, include the use of robots in agriculture. These are capable of tending to crops in an increasingly accurate manner, combined with the possibility of collecting data on soil health. They can automate the sowing and harvesting processes, thanks to sensors to detect the level of ripeness in agricultural produce and grippers capable of handling fruit and vegetables without damaging them.

This measure can be implemented, but it requires investment costs and suitable training/guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	Costs are highly variable, and depend on the type of investments made in purchasing new machinery and cutting-edge technologies.

AVERAGE ANNUAL COST PER HECTARE	The current costs connected with the measure mainly concern the depreciation of the investment. The size of the farm, its morphology, soil type and production system can all affect costs significantly.
COST COMPARED TO CONVENTIONAL PRACTICES	No difference. The reduction in consumption and waste, together with the decrease in hourly costs thanks to the quicker and more efficient rate of work, offset the greater costs involved in implementing the new technologies.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. Highly effective against various climate-related events. Precise management, in terms of the timing and manner of interventions, allows crops to react better to adverse climate events.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. The goal of the measure is to increase the productivity of the land, with smaller quantities of resources, while keeping quality standards high.
ENVIRONMENTAL BENEFITS	YES. Less fertiliser and plant protection products are wasted, emissions are decreased, and soil compaction is reduced thanks to a more rational use of resources.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD02 – productive agricultural investments for the environment, climate and animal welfare; SRA24 – ACA24 – precision agriculture practices, an intervention which finances the PA technique rather than the necessary investment, which can be financed with SRD01; Sectoral interventions: 1.1 Fruit and vegetables; NRRP (M2C1.2 – Investment 2.3: Innovation and mechanisation in the food and agriculture sector): capital grants for the modernisation of machinery to allow the introduction of precision agriculture techniques.

COST/BENEFIT EVALUATION

Implementation of the measure has high investment costs; however, these are sure to fall over time, as always happens with innovations. These costs are highly variable, depending on the choice of tools being implemented. In Italy, precision agriculture is taking hold relatively slowly, for a variety of reasons. These include the use of older agricultural machinery, and the large proportion of small to medium-sized farms which struggle to make the investments needed to purchase new machinery and cutting-edge technologies. Public contributions, including those of the RDP, can help even small and medium farms to improve their production thanks to investments in innovative technologies.

MEASURE 6.9 – VERTICAL FARMING

PRODUCTION CHAINS INVOLVED

FRUIT AND VEGETABLES

DESCRIPTION

This measure counters the damage caused by all the main risks posed by climate change: drought, wind, hail, extreme high and low temperatures, excess water, flooding, intense precipitation, soil degradation, saltwater intrusion, erosion and damage to plant health.

Vertical farming generally refers to growing crops in the absence of soil (aquaponics, hydroponics, aeroponics) and arranged in levels at different heights, in climate-controlled, automated greenhouses, dedicated buildings or specially converted plants. This method of cultivation is far more productive than traditional agriculture, both in open fields and in greenhouses, and consumes very little water – over 90% less. One notable advantage of vertical farming is the elimination of geographic limitations, as it is possible even in urban or industrialised areas. The main limitations of this method of cultivation are the investment costs necessary to start it up, and the energy costs needed for management. The controlled environments of vertical farms mean that less fertiliser and plant protection products can be used, while they also recycle water and can even achieve zero impact.

This measure is difficult to implement, requiring significant investments and suitable training/guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	Investment costs are very high. Among the most significant are those for the infrastructure that will be used to house the crops. Those who already have suitable greenhouses or other buildings at their disposal can greatly reduce costs by converting them. However, the costs of the equipment and machinery necessary for cultivation must still be considered (the growing containers, fertigation systems, solar energy plants, lighting systems, etc.). Moreover, costs vary based on the cultivation method adopted (aquaponics, hydroponics, aeroponics) and the crops chosen. Some estimates suggest an average investment ranging between €700 and €1,500 per square metre, but this can grow to over €2,000-€2,500/sqm in the most highly automated cases. (Source: Verticalfarmitalia).
AVERAGE ANNUAL COST PER HECTARE	The average annual cost of production per hectare is highly variable and depends on both the type of vertical farming and the level of automation. Particularly large components of the cost are those of energy, personnel, seeds and nutrients.

COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. Vertical farms keep crops safe from the effects of climate change, protecting the plants and creating an environment favourable to their growth regardless of climate conditions. In doing so, they guarantee continuous, consistent production.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. With vertical farming, farms are able to enhance both the yield and quality of production. Controlled environments give farmers the ability to determine the nutritional substance, light and temperature settings.
ENVIRONMENTAL BENEFITS	YES. The use of pesticides and plant protection products can be optimised and reduced, the addition of fertilisers rationalised, and water saved compared to growing in open fields.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

Vertical farming is one of the new frontiers in the primary sector. It has the advantage of effectively countering the risks associated with climate change and, if it can be combined with a source of renewable energy on the farm, the environmental impact of the large demand for energy can be fully offset. This production technique requires a limited amount of space. In fact, it is now possible to set up significant productions in just 100 square metres, thanks both to the vertical layout and the possibility of increasing production cycles. For example, as many as 10-15 cycles of salad crops can be grown in one year. However, this high productivity and excellent control over quality levels are dependent on high investment costs and suitable, ongoing training.

7. INNOVATIVE BREEDING TECHNIQUES AND ANIMAL WELFARE

One issue which has really come to the forefront in recent decades is that of animal welfare, with both public opinion and EU agricultural policy placing particular emphasis on the topic. Various studies have shown that animal welfare goes hand-in-hand with increased productivity and quality in the livestock production sector. Techniques aimed at increasing animal welfare, as well as taking steps towards adapting to the risks posed by climate change – particularly the risk of extreme high temperatures – include:

1. **FANS FOR OPTIMISED CLIMATE CONTROL IN FARM BUILDINGS**
2. **NATURAL SHADING FOR FARM BUILDINGS**
3. **USE OF SPRINKLERS IN COWSHEDS**
4. **PROVIDING SHADE IN LIVESTOCK AREAS**
5. **DESIGNING AND/OR RESTRUCTURING LIVESTOCK BUILDINGS**
6. **GENETIC IMPROVEMENT OF CATTLE**
7. **ALTERING CATTLE'S NUTRITIONAL INTAKE**
8. **IMPROVED MANAGEMENT OF ANIMAL REPRODUCTION**
9. **MANIPULATION OF THE RUMEN ECOSYSTEM**
10. **OBSERVATION OF ALTERED ANIMAL BEHAVIOUR**

MEASURE 7.1 – FANS FOR OPTIMISED CLIMATE CONTROL IN FARM BUILDINGS

PRODUCTION CHAINS INVOLVED

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters damage caused by extreme high temperatures.

The installation of fans inside livestock buildings increases the animals' comfort during hot periods, keeping them healthy and maintaining a steady rate of milk production in the case of cattle. Installation of the fans requires certain investments, and the fans themselves need additional energy to work.

The measure can be implemented with additional investment costs.

COSTS AND BENEFITS

COST OF INVESTMENT	The investment cost of purchasing the fans varies between €2,400 and €2,600, depending on whether they are helicopter-style or vertical. The fans have an average lifespan of 10 years, and each fan can serve an estimated 10 LU. Less expensive fans are also available on the market, but with a lower capacity, meaning that they can serve fewer LU.
AVERAGE ANNUAL COST PER LU	The estimated annual cost of energy is around €2,200 per fan, bringing the annual cost per LU to €220 on average, plus an average annual depreciation of €25. Overall, this results in an estimated average annual cost of €250/LU.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater. The greater cost is due to the purchase of fans and the energy consumed to run them.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. The benefit of using climate-control systems is the managed reduction of the THI (Temperature-Humidity Index) in the buildings, to achieve the climate conditions most conducive to animal welfare.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Increases both the quality and yield of production. Milk production is heavily affected by the microclimate in cowsheds.

ENVIRONMENTAL BENEFITS	YES. The installation of fans in livestock buildings reduces humidity, keeps bedding dry, decreases the consumption of hay, reduces microbial fermentation in the bedding and, as a result, reduces emissions of ammonia (NH_3) and nitrous oxide (N_2O) from build-ups of dung.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD02 – productive agricultural investments for the environment, climate and animal welfare – Action D: Investments in animal welfare; SRA30 – animal welfare.

COST/BENEFIT EVALUATION

The cost of the fans is sustainable for farms specialising in dairy cattle, as the economic benefits resulting from installation of the fans significantly outweigh the costs incurred.

PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €250/LU and high effectiveness against climate-related risks.

MEASURE 7.2 – NATURAL SHADING FOR FARM BUILDINGS

PRODUCTION CHAINS INVOLVED

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters damage caused by extreme high temperatures.

Planting trees around livestock buildings in order to protect them from the heat is a measure which becomes effective once the trees are sufficiently grown to offer a significant cooling effect. The temperature around the livestock buildings is lowered thanks to transpiration in the trees, which creates a favourable microclimate for animals. If the tree plantation has to be set up from scratch, the measure can be difficult to implement, due to the lack of available land surface on most farms and to competition with the land used for feeding the animals. However, if planning a new farm, it is possible to include the planting of trees around livestock buildings or paddocks, where present, as part of the design. Good shade coverage can be achieved by planting rows of trees on the southern and western perimeters. Given the difficulty of setting up a tree plantation around existing buildings, and the high variability of costs depending on the type and characteristics of the buildings, no cost assessment has been provided.

COSTS AND BENEFITS

COST OF INVESTMENT	-
AVERAGE ANNUAL COST PER LU	-
COST COMPARED TO CONVENTIONAL PRACTICES	-
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. The benefit consists of creating the climate conditions most conducive to animal welfare inside the buildings. To best achieve this, the layout should be planned so that sunlight reaches through the windows of the buildings as much as possible during the coldest months of the year, and as little as possible during the warmest months.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Lowering the temperature inside the livestock buildings thanks to adequate shading can help to improve animal welfare. This increases both the quality and yield of production, as milk production is heavily affected by climate conditions.

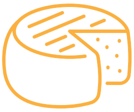
ENVIRONMENTAL BENEFITS	YES. Growing rows of trees outside livestock buildings doubles as a measure for increasing the farm's carbon sequestration.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD02 – productive agricultural investments for the environment, climate and animal welfare – Action D: Investments in animal welfare; SRA30 – animal welfare.

COST/BENEFIT EVALUATION

The intervention improves animal welfare with a resulting increase in the quality and yield of production, which has knock-on benefits for the farm's revenues. However, the solution is difficult to implement around existing buildings, as explained above. It is certainly a factor worth considering during the planning stage.

MEASURE 7.3 – USE OF SPRINKLERS IN COWSHEDS

PRODUCTION CHAINS INVOLVED



PARMIGIANO REGGIANO

DESCRIPTION

This measure counters damage caused by extreme high temperatures.

On dairy cattle farms, ventilation is often paired with an evaporative cooling system consisting of sprinklers spraying water in a high-pressure airflow (7-15 bar). To achieve this, the system must have one or more nozzles at each fan, spraying water which then evaporates to reduce the air temperature.

The measure can be implemented with additional investment costs.

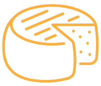
COSTS AND BENEFITS

COST OF INVESTMENT	The cost of the sprinklers varies between €37 and €70 per linear metre, depending on whether they are in the feed bunk or waiting area. It is estimated that one sprinkler and an average of 3 linear metres are needed to serve 4 LU, with an estimated average cost of between €30/LU and €55/LU. Their average lifespan is 10 years.
AVERAGE ANNUAL COST PER LU	Assuming straight-line depreciation, an average annual cost per LU of between €3 and €6 can be estimated. Considering the cost of the electricity needed to run the control unit that schedules the sprinklers in the cowsheds, plus water consumption, the result is an average cost of €10-€20 per LU.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. Appropriate climate control in animal housing improves the air temperature, reduces heat stress in cattle (calculated using the Temperature-Humidity Index, or THI), and improves conception rates among the animals.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Appropriate climate control in animal housing, thanks to the use of sprinklers, limits deterioration in the productive and reproductive capacity of cattle.

ENVIRONMENTAL BENEFITS	YES. The improvement in animal welfare brought about by a cooler environment results in increased milk production, which is closely linked to the quantity of emissions produced by the animals (Gerber *et al.*, 2011).
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD02 – productive agricultural investments for the environment, climate and animal welfare – Action D: Investments in animal welfare; SRA30 – animal welfare.

COST/BENEFIT ANALYSIS

The benefits anticipated far outweigh the costs of purchasing and using the sprinklers, meaning that the measure can be considered cost-effective.

PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €30/LU and high effectiveness against climate-related risks.

MEASURE 7.4 – PROVIDING SHADE IN LIVESTOCK AREAS

PRODUCTION CHAINS INVOLVED

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters damage caused by extreme high temperatures.

To limit the negative effects of heat stress on milk production as much as possible, sunlight should be reduced and effective natural ventilation encouraged. For this reason, an increasingly open style of cowshed has become common in recent years, particularly in terms of the long sides of the sheds. However, excessive air circulation within cowsheds during winter can be dangerous for the animals, making them too cold and increasing rates of respiratory diseases. To prevent this, the open parts of the sheds can be blocked off with windbreaks and shade netting in order to keep the air temperature inside the shed from deviating too much from that outside. This also has benefits in summer, when the sun's rays can cause high temperatures inside the shed, potentially leading to considerable stress for the animals due to excessive heat. Shading measures block the sunlight, while ensuring the heat generated by the animals can get out.

The measure can be implemented with additional investment costs.

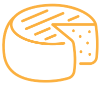
COSTS AND BENEFITS

COST OF INVESTMENT	The cost of the shade netting varies between €80/m^2 and €120/m^2 depending on whether it is fixed or motorised. The average lifespan is 10 years.
AVERAGE ANNUAL COST PER LU	It is difficult to estimate a cost per LU, as it depends greatly on the type of shed; however, it is generally very low. The use of shade netting also allows additional portions of the shed to be covered, thus increasing the shade available to the animals. The average cost is expected to be no greater than €50/LU.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. This measure can limit the negative effects of heat stress in dairy cattle.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Improving animal welfare can lead to an increase in the quantity of milk produced.

ENVIRONMENTAL BENEFITS	YES. The improvement in animal welfare brought about by a cooler environment results in increased milk production, which is closely linked to the quantity of emissions produced by the animals (Gerber *et al.*, 2011).
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD02 – productive agricultural investments for the environment, climate and animal welfare – Action D: Investments in animal welfare; SRA30 – animal welfare.

COST/BENEFIT EVALUATION

The benefits anticipated far outweigh the costs of purchasing and using the netting, meaning that the measure can be considered cost-effective.

PRODUCTION CHAINS		ECONOMIC SIZE-CLASS OF FARMS		
		LARGE	MEDIUM	SMALL
	PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €50/LU and high effectiveness against climate-related risks.

MEASURE 7.5 – DESIGNING AND/OR RESTRUCTURING LIVESTOCK BUILDINGS

PRODUCTION CHAINS INVOLVED

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters damage caused by extreme high temperatures.

Control of climate parameters is a very important factor which must be taken into consideration when designing or restructuring livestock buildings. In fact, these parameters influence animal welfare and production, particularly in flat environments where high temperatures are combined with high humidity and low wind levels for much of the year. This makes the structure of the housing, along with its systems and equipment, a production factor in every sense, capable of affecting both the quality and quantity of production results. Neglecting this measure would therefore mean compromising the profitability of the livestock farm. Climate control can be achieved by adopting technical-construction solutions linked to the structure's geometry and layout, to the thermal properties of the construction materials used, and to the shape, orientation and position of the building: all allowing optimum climate conditions to be guaranteed for the animals.

The measure can be implemented with additional investment costs.

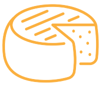
COSTS AND BENEFITS

COST OF INVESTMENT	Determination of the investment cost for restructuring/designing a shed for dairy cattle (based on a classic "free stall with mattresses" set-up) must take into account the size of the shed (size of the herd), of the milking areas, and of the external works for effluent management. Total cost: €2,800-€7,000/head (the difference in cost depends on the type of housing: bedding/mattresses; waste removal and effluent treatment techniques). – *Reference: CRPA "I costi di costruzione dei ricoveri zootecnici" [The costs of constructing livestock housing].*
AVERAGE ANNUAL COST PER LU	Considering an average lifespan of 30 years and straight-line depreciation, an annual cost ranging from €90/head to €250/head can be estimated.
COST COMPARED TO CONVENTIONAL PRACTICES	-
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. This measure can limit the negative effects of heat stress.

IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Improving animal welfare leads to an increase in the quantity and quality of milk produced.
ENVIRONMENTAL BENEFITS	YES. Latest-generation construction materials, with a lower environmental impact, can be used in building a new shed.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD02 – productive agricultural investments for the environment, climate and animal welfare – Action D: Investments in animal welfare; SRA30 – animal welfare.

COST/BENEFIT EVALUATION

Implementation of the measure requires an initial investment which is more likely to be within the reach of medium/large farms, while smaller farms may find it less affordable. However, the intervention has significant benefits which prove cost-effective over time.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
 PARMIGIANO REGGIANO			

The illustrated summary of the assessment is based on a cost of €250/LU and high effectiveness against climate-related risks.

MEASURE 7.6 – GENETIC IMPROVEMENT OF CATTLE

PRODUCTION CHAINS INVOLVED

PARMIGIANO REGGIANO

DESCRIPTION

This measure can counter damage caused by extreme high temperatures.

This approach aims to identify and select for the genetic traits of animals with high heat tolerance, which are able to maintain good production levels even at high temperatures. High environmental temperature, combined with high relative humidity, results in a phenomenon known as Heat Stress (HS). HS has a negative impact on both the productive and reproductive capacity of dairy cattle, which in turn reduces the profitability of livestock farming. Not all animals are affected by heat stress in the same way: in fact, numerous scientific publications have shown the Friesian breed to have moderately heritable heat tolerance (Aguilar *et al.*, 2009; Bernabucci *et al.*, 2014). This means that animals with a higher heat tolerance than others can be selected, bearing in mind that most of Italy's Friesian cattle live in areas that experience hot, humid summers. In Italy, ANAFIBJ (the National Association of Holstein Friesian, Brown, and Italian Jersey Breeders) has developed a Heat Tolerance (HT) Index for effects on milk traits. The study is still ongoing, and the possibility of extending it to the animals' fertility traits and quality-related milk characteristics is being considered.
Significant time is needed to determine the effect that genetic selection for a specific trait has on the population, meaning that a result will only emerge in the long term. Therefore, it is not currently possible to determine the cost-effectiveness of this measure.

COSTS AND BENEFITS

COST OF INVESTMENT	-
AVERAGE ANNUAL COST PER LU	-
COST COMPARED TO CONVENTIONAL PRACTICES	The cost per dose of semen from bulls genetically selected for resistance to heat stress, to be used for the artificial insemination of cows, will probably increase. However, this increase cannot currently be quantified, as the scientific research is still ongoing.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High.

IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Increased yield and quality of production, improved fertility for the entire herd.
ENVIRONMENTAL BENEFITS	YES. Increased milk production leads to a reduction in emissions (Gerber *et al.*, 2011).
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

It is not currently possible to provide an analysis. However, this measure is of significant importance. From an economic perspective, the impact of heat stress on Italy's average milk production (considering a population of 1,000,000 head of Italian Holstein cows) can be quantified as a production loss of 2,700,000 quintals (over a period of 180 days, the six hottest months of the year). In monetary terms, this represents €95,400,000 in lost income or almost €100 per cow, a value which might in fact be even greater if the loss of premiums or payments for milk quality is taken into consideration (Marusi *et al.*, 2022).

MEASURE 7.7 – ALTERING CATTLE'S NUTRITIONAL INTAKE

PRODUCTION CHAINS INVOLVED

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters damage caused by extreme high temperatures.

Nutritional approaches are the tactic most frequently adopted in animal husbandry to reduce acute heat stress, and indeed there are various nutritional strategies that can be considered to this end. One of the most common involves increasing the energy density and nutrient concentration of summer rations (reducing the NDF content, higher levels of concentrates in general, adding lipids in particular) to satisfy increased dietary needs despite decreased consumption during this time. However, this strategy must be applied with extreme caution, as the animals may suffer sub-acute or even clinical rumen acidosis. To avoid this eventuality, additives can be used to improve the ruminal fermentability of the organic matter ingested, as well as providing valuable help in encouraging appetite and increasing feeding efficiency. An alternative nutritional strategy involves encouraging the process of heat dissipation through evaporation (sweating) based on the use of potassium and sodium, the main regulators of the water balance in animals. Enzymes from fungal cultures (*Aspergillus oryzae*) can be used, which serve to make the rations more appetising and increase both the digestibility of the nutrients and the feeding efficiency. It is also possible to use vitamins such as niacin, which favours increased peripheral circulation, thereby helping the heat carried in the blood to move towards the surface of the body and dissipate through the skin, as well as boosting the activity of the animals' sweat glands (Pirondini and Vandoni, 2019).

This measure can be implemented with training and/or guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	-
AVERAGE ANNUAL COST PER LU	There is no cost that can be expressed in terms of LU: the nutritional strategies are very different from each other, and can even change depending on the intended use of the milk (high-quality fresh milk, parmigiano reggiano, grana padano, etc.).
COST COMPARED TO CONVENTIONAL PRACTICES	A possible increase in the dietary cost for every animal, due to the introduction of new "ingredients" or alteration of the raw materials used, which are not contained in the standard rations. This additional cost must be assessed on a case-by-case basis.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate.

IMPACT ON PRODUCTION YIELD AND QUALITY	May lead to an increase in the quantity and quality of milk produced.
ENVIRONMENTAL BENEFITS	YES. Increased milk production leads to a reduction in emissions (Gerber *et al.*, 2011).
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRA30 – animal welfare.

COST/BENEFIT EVALUATION

Changing animals' feed is moderately effective in countering heat stress. The costs incurred vary depending on the nutritional strategy and the intended use of the milk (high-quality fresh milk, parmigiano reggiano, grana padano, etc.) and can affect the farm's management costs. Therefore, assessments must be made on a case-by-case basis, taking into account the possible impacts in terms of increasing the productivity of individual animals.

MEASURE 7.8 – IMPROVED MANAGEMENT OF ANIMAL REPRODUCTION

PRODUCTION CHAINS INVOLVED

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters damage caused by extreme high temperatures.

Not only does heat stress cause considerable economic losses due to decreased production, but it also has long-term impacts on animals' reproductive capacity. The repercussions of high temperatures and humidity on herd fertility arise later than the fall in production, which is immediately evident. In fact, some studies have shown that cows inseminated in late summer have a conception rate as much as 30% lower, a situation which can even linger on into the autumn months, despite the fact that the cows are no longer exposed to heat stress. Heifers can also have fertility problems caused by heat stress, which may extend the unproductive period of the animal's life and further add to the farm's economic losses. Therefore, improving micro-climate conditions for this category once again means a general improvement in their welfare and an increase in their fertility.

Research is underway with the goal of mitigating the decline in conception rates during hotter periods.

COSTS AND BENEFITS

COST OF INVESTMENT	-
AVERAGE ANNUAL COST PER LU	-
COST COMPARED TO CONVENTIONAL PRACTICES	-
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. The measure may lead to increased milk production.
ENVIRONMENTAL BENEFITS	YES. Increased milk production leads to a reduction in emissions (Gerber *et al.*, 2011).

PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD02 – productive agricultural investments for the environment, climate and animal welfare – Action D: Investments in animal welfare; SRA24 – ACA24 – precision agriculture practices, an intervention which finances the PA technique rather than the necessary investment.

COST/BENEFIT EVALUATION

The herd's reproductive stage can be controlled through suitable precision livestock farming tools (such as pedometers and collars, for example). The use of these devices represents a cost to the farmer, but in the long term the cost is offset by the revenue achieved through increased production.

MEASURE 7.9 – MANIPULATION OF THE RUMEN ECOSYSTEM

PRODUCTION CHAINS INVOLVED

PARMIGIANO REGGIANO

DESCRIPTION

This measure counters damage caused by extreme high temperatures.

The purpose of rumen manipulation lies in the opportunity it provides to make incremental, positive changes to optimise fermentation and performance, without leading to digestive disorders. Therefore, the advent of technology enabling large-scale studies of not only the ecology of micro-organisms in the rumen, but also of their functional capacity, is key to adapting rumen activity to different climate conditions, for the preservation of animal welfare.

Research on the microbiome of the rumen is ongoing.

COSTS AND BENEFITS

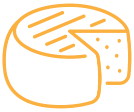
COST OF INVESTMENT	-
AVERAGE ANNUAL COST PER LU	-
COST COMPARED TO CONVENTIONAL PRACTICES	-
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate.
IMPACT ON PRODUCTION YIELD AND QUALITY	-
ENVIRONMENTAL BENEFITS	YES. Nutritional and microbial manipulation to reduce the enteric CH_4 (methane) emissions of the animals.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

It is not currently possible to provide an economic assessment, as research on the microbiome of the rumen is ongoing.

MEASURE 7.10 – OBSERVATION OF ALTERED ANIMAL BEHAVIOUR

PRODUCTION CHAINS INVOLVED



PARMIGIANO REGGIANO

DESCRIPTION

This measure counters damage caused by extreme high temperatures.

Altered animal behaviours are indicators which farmers can observe and use to help identify any deterioration in the animals' health and welfare. For example, the amount of time that a cow spends lying down on mattresses can provide valuable insight into the animal's well-being, and how it is interacting with its environment. Generally, dairy cattle spend around 11-14 hours/day lying down under conditions of thermal comfort; however, when the environmental temperature rises, the animal spends 30% less time lying down. This is due to the need to increase the amount of body surface available for heat dissipation. When animals spend more time standing, they consume more energy for their subsistence, lose more water through sweating, produce less milk, are more more susceptible to foot diseases, and lose nutrients in the mammary gland, which can compromise milk production.

This measure can be implemented with training and/or guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	-
AVERAGE ANNUAL COST PER LU	-
COST COMPARED TO CONVENTIONAL PRACTICES	-
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Increases both the yield and quality of production.
ENVIRONMENTAL BENEFITS	YES. Increased milk production leads to a reduction in emissions (Gerber *et al.*, 2011).
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRA30 – animal welfare.

COST/BENEFIT EVALUATION

Adequate training is needed to encourage animals to adopt strategies for their own well-being. Many actions derive from interventions described within this document (for dealing with heat waves). Animal welfare is vital to improve production yield and quality; therefore, care should be taken to encourage positive behaviours and habits, in the interests of farm profitability.

8. WINE-MAKING TECHNIQUES

The risks posed by climate change in the wine production chain arise in particular from rising temperatures and the resulting soil degradation. A number of innovative technologies can be adopted in the wine-making process to counter the potential damages:

1. **USE OF FOOD-GRADE INERT GAS (SOLID CO_2) FOR COOLING**
2. **NEW YEAST STRAINS FOR FERMENTATION**
3. **USE OF ACIDIC MUST**
4. **MEMBRANE TECHNOLOGIES**
5. **CONTROL OF KEY WINE-MAKING OPERATIONS**

MEASURE 8.1 – USE OF FOOD-GRADE INERT GAS (SOLID CO_2) FOR COOLING

PRODUCTION CHAINS INVOLVED

WINE

DESCRIPTION

This measure counters damage caused by extreme high temperatures.

If this measure, which is already adopted as good practice in grape processing, is applied organically to the stages of grape harvesting, transferring the grapes to the winery and starting the wine-making process, it can counter the negative effects caused by above-average seasonal high temperatures. Food-grade CO_2 in the form of carbon dioxide snow or dry ice provides for the cooling and deoxygenation of the raw material.
HARVESTING. Cooling the grapes, particularly if they are not in perfect sanitary condition, slows down undesired microbiological processes and the enzymatic oxidation processes produced by the phenolic and aromatic compounds. It is particularly beneficial when mechanical means are used in harvesting, and in cases where it is not possible to shorten the time that lapses between manual harvest and wine-making.
WINE-MAKING. Cooling/deoxygenating the grapes at the start of the wine-making process helps significantly in protecting the must from later chemical-microbiological alterations, particularly in relation to oxidative processes. Carbon dioxide snow can easily be produced on the farm using its own small system, consisting of a cylinder of compressed CO_2 and a small snow-maker which turns the CO_2 into carbon dioxide snow. This system can be used as an *in-situ* or mobile device. Dry ice, on the other hand, must be purchased from specialist suppliers and stored on the farm. It is distributed through a CO_2 distribution grid and has a greater cooling capacity, while also being able to reduce temperatures automatically.

The measure can be implemented, with investment costs. Its use is seasonal. Carbon dioxide snow can be produced on the farm, while dry ice must be purchased from specialist suppliers and stored on the farm. Personnel must be trained for the implementation of this measure.

COSTS AND BENEFITS

COST OF INVESTMENT	1. Carbon dioxide snow: Manual, mobile system for the transport of cannisters and condensation snow-makers, limited to the harvest and certain stages of wine-making. In the case of carbon dioxide snow, the investment cost for the snow-maker is estimated at around €500-€1,000/ha, with an average lifespan of 8-10 years. 2. Dry ice: Fixed, automated systems for the storage of CO_2 and its distribution to the points of use (grape-receiving hoppers, crushers, destemmers, pumps). The investment cost varies based on farm size, with larger farms better able to minimise fixed costs, and climate conditions. Costs also increase in line with the desired reduction in temperature: a decrease of 5 °C at harvest for a production of 10,000 kg/ha varies from a minimum of €2,000/ha to a maximum of €5,000. The automated system enables economies of scale both in the vineyard and in the winery. Personnel training is required.
AVERAGE ANNUAL COST PER HECTARE	Carbon dioxide snow: €400/ha is the estimated consumption required to lower temperatures by 5 °C for 10,000 kg of grapes, plus an average depreciation cost of €100. Dry ice: €800/ha to lower temperatures by 10 °C for 10,000 kg of grapes. This second case includes the depreciation and maintenance of the system, as well as training for personnel. Ten years is the period assumed for depreciation.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Improves technological conditions in the wine-making process, and increases the quality of production.
ENVIRONMENTAL BENEFITS	YES. The overall environmental benefits consist of optimising the cooling methods used in the production process in general, resulting in a potential reduction in the need for chemical stabilisation treatments on grapes, must and wine (sulphites). On the other hand, the measure also directly increases the CO_2 emitted by the production process.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD13 – investments in the processing and marketing of agricultural products; Sectoral interventions: W002 – investments in tangible and intangible assets in viticulture. Industry 4.0 Bonus (extended for the years 2023-2025 through the NRRP as Transition 4.0): funding and tax breaks for investments in capital, tangible and intangible goods.

COST/BENEFIT EVALUATION

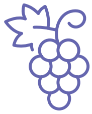
Large farms, which can take advantage of economies of scale, will find it easier to use the automated system both in the vineyard and in the winery. The use of CO_2 brings benefits to multiple stages of the transformation process. The measure is extremely beneficial in the event of a heat wave. For medium-large farms, the economic benefits of using dry ice outweigh the expense involved. If smaller farms find the investment required for the production and distribution of dry ice out of their reach, they may find it worthwhile to implement this measure with a carbon dioxide snow system.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
WINE			

The illustrated summary of the assessment is based on a cost of €800/ha and high effectiveness against climate-related risks.

MEASURE 8.2 – NEW YEAST STRAINS FOR FERMENTATION

PRODUCTION CHAINS INVOLVED



WINE

DESCRIPTION

This measure counters damage caused by extreme high temperatures and soil degradation.

The goal of this measure is to select yeast strains of the *Saccharomyces* and other genera, originating on the farm itself, for use in the vineyard and/or winery. The fermentation characteristics of these strains make it possible to best manage variations in the composition of grapes due to the effects of climate change, as well as fermentation processes, particularly in grapes which ripen early during periods of high average temperatures. Specifically, this makes it important to select yeasts which produce a lower alcohol content during fermentation, and characteristics which can improve subsequent stabilisation processes.

The measure can be implemented with additional costs for external consultancy.

COSTS AND BENEFITS

COST OF INVESTMENT	Based on new techniques of genetic identification and specific protocols developed for microvinification, it is possible for farms, with the support of a specialised external consultant (public or private), to isolate, identify, store and reproduce new, non-commercial strains for their own exclusive use as starters (on grapes, must and wines). Including research and development, the cost varies in the region of €5,000-€8,000 per strain identified.
AVERAGE ANNUAL COST PER HECTARE	The cost mostly consists of the upfront investment, plus a small expense for maintenance of the strain. The cost reduces in linear fashion as the farm size in hectares grows.
COST COMPARED TO CONVENTIONAL PRACTICES	Lower. Additional costs consist only of the initial investment and paying to have the strain stored at an external laboratory. Therefore, the expense is lower than the costs of purchasing active dry yeast on the market, and decreases further as production volumes increase.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	High. Potential strengthening of the unique character of the farm's production, and optimisation of technological processes.

IMPACT ON PRODUCTION YIELD AND QUALITY	YES. Potential improvement of the organoleptic profile of the wines produced and of the technological processes.
ENVIRONMENTAL BENEFITS	NO.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

Today, it is easier and more economically feasible for individual farms and/or farm associations to use their own yeasts. The potential advantages consist of helping to define a signature unique to the farm or territory, as well as optimising the processes. However, the selection process may fail to identify yeasts which can guarantee an improvement. Therefore, the measure is exploratory in nature, and must be refined progressively based on results. The high costs of implementation mean that large farms are more likely to find it cost-effective, while small and medium-sized farms joined together in associations may benefit from it. The measure is certainly advisable for large farms, while smaller farms should consider its in relation to their own characteristics.

MEASURE 8.3 – USE OF ACIDIC MUST

PRODUCTION CHAINS INVOLVED

WINE

DESCRIPTION

This measure counters damage caused by extreme high temperatures and soil degradation.

The practice of early thinning results in grapes particularly rich in malic acid and polyphenolic components. This makes it possible to obtain an "acidic must", which can be used as a natural acidifier in musts and wines. This kind of blending is a way of correcting the acidic component of musts and wines to produce more balanced, harmonious wines, as well as decreasing production waste. As a natural product originating in the wine-making process, this acidic must is a viable alternative to purchasing the organic acids (tartaric acid, malic acid, etc.) permitted for use for acidification in the wine industry.

This measure can be implemented, but it does require suitable training/guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	No specific costs. The measure can be implemented using machines for manual harvesting and other equipment and techniques already at the winery's disposal.
AVERAGE ANNUAL COST PER HECTARE	Considering around 50 hours of labour per hectare, and the preparation of the manual harvesting process, plus wine-making and storage of the must, the average total cost of all operations comes to €1,500/ha.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater. Over €900/ha approx.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. Balances the macro-components of the wine (alcohol and organic acids, which can be skewed by high temperatures and heat waves), starting from the same inputs, for a potential improvement in quality and optimisation of the fermentation and stabilisation processes.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. The option of altering the acidic component of musts and wines using acidic musts can make it possible to improve the chemical-microbiological stability of fermentation processes.
ENVIRONMENTAL BENEFITS	YES. Productive reuse of production waste, increased circularity of the production process, reduction in the use of products of external origin.
PUBLIC FUNDING	NO.

COST/BENEFIT EVALUATION

This measure enables the recovery and reuse of waste products, putting them back into the production cycle and making an alternative technology available to the transformation process, with the potential to improve quality. The farm's specific characteristics must be taken into account when considering whether to implement the measure. The economic benefits outweigh the cost of implementation for medium and large farms; however, these costs may pose an obstacle for smaller farms.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
WINE			

The illustrated summary of the assessment is based on a cost of €900/ha and moderate effectiveness against climate-related risks.

MEASURE 8.4 – MEMBRANE TECHNOLOGIES

PRODUCTION CHAINS INVOLVED

WINE

DESCRIPTION

This measure counters damage caused by extreme high temperatures and soil degradation.

This measure aims to alter the effects on grapes of ripening at extreme high temperatures. Various types of agronomic interventions in the field can alter the conditions under which the grapes reach phenolic and aromatic ripeness, changing their original distinctive traits, which are best expressed with a high concentration of sugar. For this reason, for example, subsequent de-alcoholisation using membranes can ensure an improved balance. Moreover, non-porous membrane technology makes it possible to alter other parameters in wines, such as sugars, pH, and tartaric and protein stability.

This measure can be implemented, but it requires investment costs and suitable training/guidance.

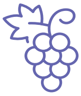
COSTS AND BENEFITS

COST OF INVESTMENT	The cost of acquiring a non-porous membrane system depends on the volumes processed and the flexibility of the system. Below a certain threshold (2,000 hl), it is possible to engage an external service, ensuring effectiveness, efficiency and cost-effectiveness. In any case, the cost of acquisition starts from a minimum of around €30,000, possibly more depending on various parameters.
AVERAGE ANNUAL COST PER HECTARE	Considering a minimum purchase cost of €30,000 and a lifespan of 10 years for the membrane system, for a farm between 10 and 20 hectares in size, the average annual cost of depreciation can vary between €150 and €300 per hectare. In addition, management costs can be estimated at around €150/ha per year.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate. Distinctive traits are maintained by reducing the alcohol content in wines, or the sugars content in grapes, which can rise due to a greater number of growing degree days while the grapes are ripening.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. This technology enables greater control of the wine-making process, and improves the physical-chemical and microbiological stability conditions of the wines with respect to their aromatic and taste characteristics.

ENVIRONMENTAL BENEFITS	NO.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD13 – investments in the processing and marketing of agricultural products; Sectoral interventions: W002 – investments in tangible and intangible assets in viticulture. Industry 4.0 Bonus (extended for the years 2023-2025 through the NRRP as Transition 4.0): funding and tax breaks for investments in capital, tangible and intangible goods.

COST/BENEFIT EVALUATION

The measure helps to increase the technological resources at the winery's disposal, and allows greater control over wine-making processes in the form of a useful tool for mitigating the effects of climate change. The economic benefit is indisputable for medium and large farms, while smaller farms may find the cost of investment to be an obstacle. However, in order to limit the costs, such farms can engage a specialised external service.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
 WINE			

The illustrated summary of the assessment is based on a cost of €400/ha and moderate effectiveness against climate-related risks.

MEASURE 8.5 – CONTROL OF KEY WINE-MAKING OPERATIONS

PRODUCTION CHAINS INVOLVED

WINE

DESCRIPTION

This measure counters damage caused by extreme high temperatures and soil degradation.

This measure aims to implement a control system for the production processes. If well structured, this system also offers a way to mitigate the effects on grapes of ripening at extreme high temperatures, and to subsequently monitor the effectiveness and efficiency of processing to ensure optimal use of energy, water, materials and equipment, all under safe conditions. The measure involves adopting specific protocols, with related operating instructions, to monitor all stages of wine-making through measurable parameters.

This measure can be implemented, but it requires investment costs, suitable training for personnel and guidance.

COSTS AND BENEFITS

COST OF INVESTMENT	The cost of investment varies greatly, depending on the extent of the intervention. Interventions can involve the installation of fixed or mobile sensors based on IoT technology, or of variable-speed frequency converters with networking capabilities for the electric motors of the various pieces of equipment. Three levels of intervention can be identified: LOW: use of sensors for basic parameters (T°/H%/CO2), environmental sensors for the grapes, mass sensors, and sensors on wine vats, pumps, and for the control of electric motors. MEDIUM: use of sensors for basic parameters (T°/H%/CO2); environmental sensors for sugars and alcohol; sensors for grape delivery, monitoring of fermentation and the control of electric motors; and sensors on wine vats, pumps, presses and mixers. HIGH: use of sensors for basic parameters (T°/H%/CO2), sugars, alcohol, pH, acidity, nitrogen, ions, density, turbidity and environmental SO2; sensors for grape delivery, monitoring of fermentation, cold stabilisation, storage, filtration, the wastewater cycle, adjuvant dosing and the control of electric motors; and sensors on wine vats, pumps, presses, mixers, augers, compressors, crushers and dosers. The initial cost varies depending on the extent of the intervention, the volumes, training support and external skills. However, the low costs of IoT technologies mean that sensors for basic parameters can be purchased and installed at marginal costs, assuming no further interventions, from as little as €2,000-€3,500/ha.

AVERAGE ANNUAL COST PER HECTARE	Considering a lifespan of 5-7 years for the investment, the annual cost of depreciation, in the case of low-intensity tools, varies from €300-€700/ha. The cost increases as the extent of the tools used to control operations increases.
COST COMPARED TO CONVENTIONAL PRACTICES	Greater.
EFFECTIVENESS AGAINST CLIMATE-RELATED RISKS	Moderate/High. Effectiveness varies from moderate to high, based on the extent of the intervention. An effective system for controlling processes always makes it possible to optimise the use of resources, and to effectively verify and correct anomalies of any origin, including those caused by ripening under extreme temperature conditions.
IMPACT ON PRODUCTION YIELD AND QUALITY	YES. The implementation of a system for controlling processes based on the systematic and accurate monitoring of parameters increases the overall quality of the product and contributes to optimising the use of resources, all the way from the pre-fermentation stages through to bottling and storage, while preserving the distinctive characteristics of the products.
ENVIRONMENTAL BENEFITS	YES. Protection of the products' distinctive characteristics and strengthening of their special relationship with and suitability for the territory.
PUBLIC FUNDING	CAP Strategic Plan – Rural development interventions: SRD01 – productive agricultural investments for the competitiveness of agricultural holdings; SRD13 – investments in the processing and marketing of agricultural products; Sectoral interventions: W002 – investments in tangible and intangible assets in viticulture. Industry 4.0 Bonus (extended for the years 2023-2025 through the NRRP as Transition 4.0): funding and tax breaks for investments in capital, tangible and intangible goods.

COST/BENEFIT EVALUATION

The wine-making process benefits from close control of all operations. Today, technology makes it possible to implement efficient and effective control systems at relatively modest costs, particularly under extreme and unpredictable conditions, such as those created by rapid climate alterations. The economic benefit is indisputable for medium and large farms, while smaller farms may find the cost of investment to be an obstacle. However, smaller farms can take advantage of public funding. A vast array of technology is on offer, making it possible for all farms to find solutions to suit their financial means.

PRODUCTION CHAINS	ECONOMIC SIZE-CLASS OF FARMS		
	LARGE	MEDIUM	SMALL
WINE			

The illustrated summary of the assessment is based on a cost of €600/ha and moderate effectiveness against climate-related risks.

CONCLUSIONS

The informational-analytical data sheets presented in this volume provide information on the costs and benefits of the climate change adaptation measures included in the ADA project, along with an assessment thereof.
In addition to preventing/limiting damage, climate change adaptation measures can play a part in improving farm performances. Evidence of economic sustainability is fundamental in encouraging farms to implement the climate change adaptation measures. To this end, the authors have estimated the cost-effectiveness of implementing each measure to counter climate risks, based on the assumption that the damage caused by an adverse climate event is highly likely to rise to 30% or more of the value of the farm's production.
The results obtained and represented in the form of a graphic are based on average data for both the value of production for farms in each production chain, and the costs that the farms would incur in order to adopt the measure. It is our belief that the data sheets produced provide a helpful frame of reference concerning the cost-effectiveness of implementing the adaptation measures, despite the immense variability in the primary sector: indeed, the physical, economic and financial size of farms, the specialisation of their production, their location, their capacity for innovation and the level of training involved all have implications for the costs of implementing the measures. The data sheets can provide the starting point for a more detailed analysis of the cost/benefit ratio of implementing climate risk adaptation measures, taking the characteristics of a specific farm and its cultivation processes into account.
Due to the number and variety of the factors in play, the results of our model provide valuable information for the implementation of the adaptation measures which represent a significant component of financial interventions in public policy.
The analysis shows that, in most cases, it is beneficial to take concrete adaptation actions. Even when the results suggest a lower level of cost-effectiveness, it is always worth making an assessment for the farm's specific circumstances.
When deciding which measures to adopt, it must be remembered that costs depend not only on the farm's characteristics, but also on the method of implementation chosen and the training of personnel. Moreover, in terms of the investments required to implement a measure, it should be noted that the market offers a large number of alternatives at a wide variety of costs. All these options should be taken into account in order to identify the most suitable solution for each farm.
In general, it is fair to say that all farmers have the opportunity to find a suitable solution for tackling the risks of climate change by taking the many technical solutions included within each measure into account, including the costs involved.
Therefore, it is our hope that this volume will help to support and bolster the resilience of farms in overcoming the impacts of climate change in a constantly evolving scenario, as well as providing a useful point of reference for technical professionals, trade organisations and policy-makers.

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APPENDIX

QUESTIONNAIRE

1) **Is the measure easy to implement?**
   - Yes, it is easy to implement;
   - It can be implemented, but it requires additional investment costs and/or suitable training/guidance;
   - It is difficult to implement, due to the high investment costs;
   - It is difficult to implement, due to the lack of suitable training/guidance;
   - It can be implemented in the form of a cooperative enterprise, to better spread the costs incurred.
2) **Only where relevant, in cases involving the purchase of machinery/equipment/systems, indicate the initial cost of the investment per hectare, in euros:** ....
3) **Indicate the average cost per hectare of this measure (excluding the initial investment cost):**
   - <€50/ha;
   - €50/ha-€100/ha;
   - €100/ha-€250/ha;
   - €250/ha-€500/ha;
   - €500/ha-€1,000/ha;
   - >€1,000/ha.
4) **Compared to conventional practices, and excluding the cost of investment, will farms implementing this measure** incur:
   - The same cost per hectare;
   - A greater cost per hectare. Indicate the increase in cost per hectare: .... %;
   - A lower cost per hectare. Indicate the decrease in cost per hectare: .... %.
5) **Please show how the average cost per hectare of this measure is spread across the following items, as percentages (the total of the percentages for each measure must be 100).**
   - Fuel: .... %;
   - Labour: .... %;
   - Machinery use: .... %;
   - Agricultural inputs (seeds, protection, fertiliser, etc.) ....%.

6) **Does the cost incurred for this measure depend on:**

- The morphology of the land (e.g. altitude; slope):
  - YES (Add more...)
  - NO
- Company size (UAA):
  - YES (Add more...)
  - NO
- The soil type (clay, sandy, peaty, etc.):
  - YES (Add more...)
  - NO
- Other (Specify Other...)

7) **Which adverse climate events can this adaptation measure address? (multiple answers can be chosen)**

- Increase in average temperatures;
- Drought;
- Intense rain;
- Hail;
- Frost;
- Snow;
- Extreme temperatures (high and low);
- Wind;
- Other (Specify Other...).

8) **Does this measure affect production quality (e.g. organoleptic properties, nutrients, etc.)?**

- YES, it improves the quality;
- YES, it lessens the quality;
- NO, it makes no difference.

9) **Does this measure have a positive influence on the land?**

- YES, on soil quality;
- YES, on groundwater;
- YES, on hydrogeological imbalance;
- YES, on "Other aspects" (Specify the other aspects....................................);
- NO.

10) Does this measure bring economic benefits:

- YES, in the short term (the current year's crop cycle);
- YES, in the medium term (after 3-5 years of consistently applying the measure);
- YES, in the long term (after more than 5 years of consistently applying the measure);
- NO, it has no such benefits.

11) Does this measure bring environmental benefits:

- YES, in the short term (the current year's crop cycle);
- YES, in the medium term (after 3-5 years of consistently applying the measure);
- YES, in the long term (after more than 5 years of consistently applying the measure);
- NO, it has no such benefits.

12) What benefits are expected from the introduction of this measure?

ISBN 9788833853970