



Farming & Adaptation

**SUSTAINABLE ADAPTATION OF TYPICAL EU
FARMING SYSTEMS TO CLIMATE CHANGE**



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01 Introduction

It is the late spring of 2016 in Europe, wheat and rapeseed have had a good growing season so far. The ears of wheat are in place and pollinators are rejoicing on the rapeseed flowers. However, it is getting very cloudy... the wind picks up and it starts to rain. Although rain is normally welcome, it is not at this time of year, and certainly not in this way. This **intense rainfall** batters the crops with incredible strength, damaging them, causing lodging in cereals and affecting pollination. Yields will not be the same this season.

When the time came to harvest the crops in 2016, some places of the European Continental region had lost up to 50% of the yield.

Vineyards and fruit orchards in France luckily escaped from the impact of this heavy rainfall event in 2016... but it is 2017 now. In April, vineyards are sprouting and fruit trees are in the flowering period, or they may even have plenty of small fruit hanging from their branches, already. Temperatures in April are usually warmer, the **risk of frost** and, most of all, the amount of days in which frost occurs should be low. However, the weather forecast is predicting very low temperatures for five consecutive days. The young leaves, the blossoms and the tiny fruits may not be able to deal with this adverse situation.

Indeed, after the cold was over, a significant part of the leaves and blossoms were damaged, and many tiny fruits laid wrinkled on the ground. Yields were not the same that year either.



IMAGE 01. Heavy rain damage in cereals. Source: Photo Max Pixel, own work, CCO Public Domain.

We have talked about heavy rainfall and late frost events, but in 2017 an **exceptional drought** was registered in southern Europe with terrible consequences for all farming systems, a drought which repeated itself in 2018 in the northern half of Europe, bringing along great yield losses one more time.

Is this ever going to stop? Well, unfavourable climate events have always occurred, but with the effect of climate change, these events are going to be more frequent in the near future and, worst of all, more extreme. As seen in Image 3, water scarcity and drought events have already been recurrent in Europe during the last decade, affecting all regions and showing that, unfortunately, no place in Europe seems to be escaping them.

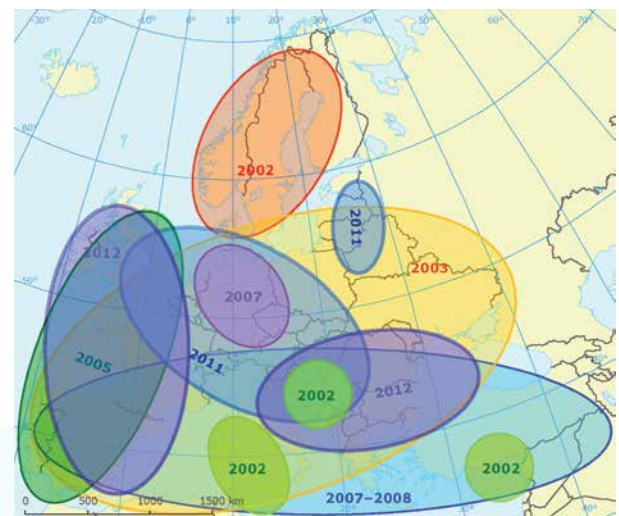


IMAGE 03. Water scarcity and drought events in Europe during the last decade. Source: EEA, 2012.



IMAGE 02. Drought damage in corn. Source: Photo CraneStation, own work, CC BY 2.0.

IMAGE 04. The four climate risk regions in the EU and the resulting risks from climate change in each of them. Source: EEA, 2016.

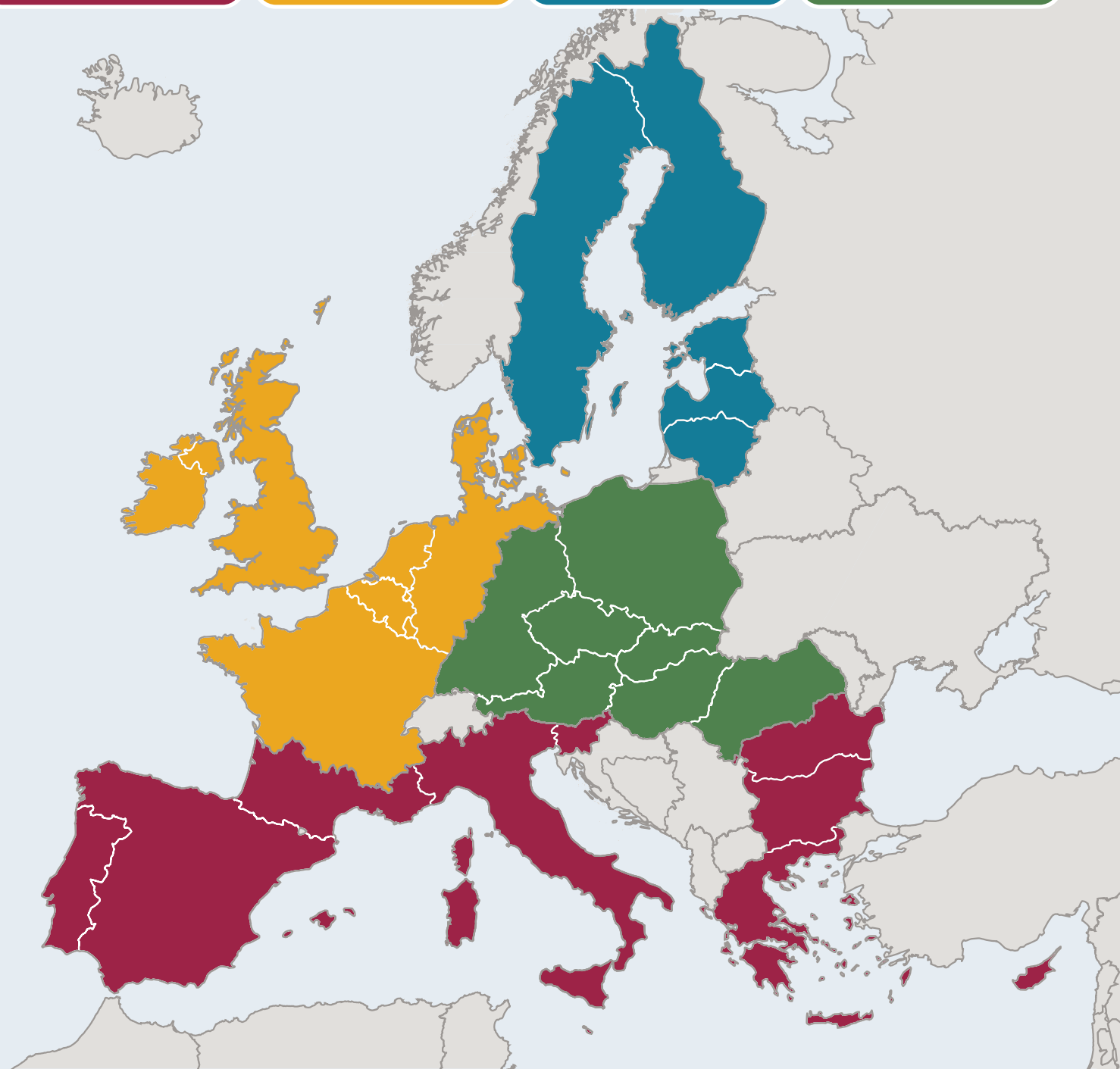
- Red: Southern climate risk region
- Yellow: Atlantic climate risk region
- Green: Continental climate risk region
- Blue: Northern climate risk region.

- ↘ Water availability
- Risk drought, heat spells
- Risk soil erosion
- ↘ Growing season, crop yields
- ↘ Optimal crop areas

- Floods risk
- Hotter and drier summers
- Sea level
- Risk crop pests, diseases
- ↘ Animal health, welfare

- ↘ Summer rainfall
- Winter storms, floods
- Length growing season, yields
- Suitable farmland
- Pests, diseases risks

- Winter rainfall, floods
- ↘ Summer rainfall
- Risk drought, water stress
- Soil erosion risk
- Yields, range of crops



Even though extreme weather events may be difficult to forecast, nowadays and thanks to rigorous scientific research, information regarding future projections under different models and RCPs (Representative Concentration Pathways) have become available. We can quite accurately foresee the main trends for different climatic variables such as temperature, rainfall or evapotranspiration. By knowing these trends, farmers are able to decide which **sustainable adaptation measures suit their agrarian systems best, in order to reduce climate change impact and gain resilience.**

Climate change is one of the greatest challenges the world is currently facing and, although some climatic changes may have a positive impact on European agriculture, most will have a negative impact and will affect regions already suffering from environmental degradation.

This is the case of the European **Southern region**. Water availability will decrease in the near future, along with the growing period, the yields and the optimum areas to grow crops. Besides this, the risk of heat waves will increase, together with the risk of soil erosion (EEA, 2016. See Image 4).

But not only is the Southern region seriously threatened. The **Atlantic region** will also suffer from a higher risk of flood events, a higher frequency of pests and disease occurrence and warmer and drier summers. The **Continental region** will also be having less rain during the summer, with an increased risk of droughts and water stress and more heavy rains and floods during the winter. On the upside, these factors may bring an increase in yields and crop diversification in this region (EEA, 2016. See Image 4): the longer vegetation period allows for the growing of later ripening varieties (e.g. maize or grapes) and of new crops that are better adapted to the increasing summer droughts, such as *Camelina sativa*, soybeans, sorghum, Sudan grass and sweet potatoes. This may offer new market opportunities, and especially for the viticulture of new varieties, originally from southern Europe, which will now be suited for growing in the Continental region (e.g. Cabernet Sauvignon). However, it is unclear if in global terms these positive effects will be counteracted by other negative ones.

The European region that will certainly profit the most from climate change will be the **Northern region**, where the yields and the growing period of the crops will increase, along with the agronomic potential of the area. Nevertheless, rainfall during the summer will decrease, heavy rain and floods during the winter will increase and the impact of pests and diseases on the crops will be higher (EEA, 2016. See Image 4). So even in the best case-scenario, climate adaptation is needed.

In order to help overcome the negative effects of climate change, the partners of the LIFE AgriAdapt project have developed a **methodology to assess the climate risk** at farm level using past weather data and climate projections. Once the risks have been identified, **sustainable adaptation measures are proposed and implemented at farm level, in order to increase the resilience of the farm and help mitigate the impact of the weather-related changes** on livestock, arable land or permanent crops. In addition, this project explores how the implementation of adaptation measures can have further positive effects on nature and the agrosystem, which represents an added value for the farms.

Adaptation measures will have to be sustainable and go beyond mere adjustments in current agricultural practices. Furthermore, these measures can simultaneously lead to an increased effectiveness, lower costs, new market opportunities and better preparation for future legal requirements... so **adaptation is worth the effort!**

With AgriAdapt, the partners aim at achieving **transferable and practical results** and communicate them to farmers and experts. To this end, information and teaching materials for agricultural education and training are being developed together with experts and specifically passed on to educational institutions and advisory systems.

In this manual, the partners of the LIFE AgriAdapt project introduce the methodology and tools of the project, describe the pilot farms and their adaptation potential along with climate projections, and finally guide you through all the sustainable adaptation measures together with the case studies of pilot farms.



02 An Approach

to Assess Climate Risk at Farm Level

"Suppose . . .

... we didn't know what climate change entailed a couple of years ago."

"Suppose . . .

... we recently inherited our family farm and are not aware of the main climate-related issues affecting yields in the past."

"Suppose . . .

... we still had the perception that certain changes in weather patterns are not new and have always happened, or that, despite being suspicious of the abnormalities occurring, we still needed some assurance of that what we are interpreting is real."

What if a methodology supported by an assessment tool were able to look into the recent past, match the low-yield episodes with certain climatic factors and identify the main Agro-Climatic Indicators affecting our crops? What if that very same tool were able to look into the near future and, by using climate projections, identify which of those Agro-Climatic Indicators affecting our yields are going to keep on happening or even increase in the future? In the frame of the AgriAdapt project, tools that can do this were developed. Thanks to these tools, sustainable adaptation measures are proposed to overcome climate change effects on the farm.

But let's start from the beginning. What has actually been described above is called a **climate risk assessment** conducted at farm level. We made it for each of the four main climate risk regions in Europe and we covered the most important European farming systems, that is, arable lands, livestock farms and permanent crops.

In technical terms, this climate risk assessment combines the probability of the frequency of occurrence of climatic stress (exposure) with the severity of the consequences (impact), such as yield reduction. The matrix, developed to quantify the risk level of the farm can be seen in Image 5 below, in which the exposure is crossed with the yield loss to quantify the risk.

The climate risk assessment performed consists of four steps: **the first step** evaluates the current climate risk of the farm, considering climatic data from the past 30 years, historic yields and specific information collected in an interview with the farmer. The **second step** consists of assessing the climate risk of the farm in the coming 30 years. In the **third step**, all the possible adaptation options at farm level are presented. Last but not least, the **fourth step** elaborates an action plan for suitable adaptation to climate change for the farm assessed.

Frequency	Exposure Score							
>50%	6	6	12	18	24	30	36	
41-50%	5	5	10	15	20	25	30	
31-40%	4	4	8	12	16	20	24	
21-30%	3	3	6	9	12	15	18	
11-20%	2	2	4	6	8	10	12	
<10%	1	1	2	3	4	5	6	
		1	2	3	4	5	6	Impact Score
		0-10%	10-20%	20-30%	30-40%	40-50%	50%	% Yield Reduction

IMAGE 05. AgriAdapt Climate Risk Matrix. Source: AgriAdapt.

The basis for this assessment is the annual yield during the past 15 years, which can either be provided by the farm or otherwise taken from the statistical office of the corresponding district. This yield data is compared against the climatic records of the past 15 years so they can be correlated to the Agro-Climatic Indicators, which are the climatic parameters (or combination of parameters) that are able to explain the low yields. Agro-Climatic Indicators can be found in scientific literature in some cases or must be discovered during

the assessment process, but in all cases, they have to be calibrated for each farm and area studied.

The tool making this possible is the so-called **ACZ tool (AgroClimaticZone tool)**. This instrument brings yields and climatic records together on a 25x25 km grid and can represent over 65 Agro-Climatic Indicators for the recent past and the near future (e.g. precipitation in July/August and number of hot days with temperatures above 25 °C in May/June – Image 6).

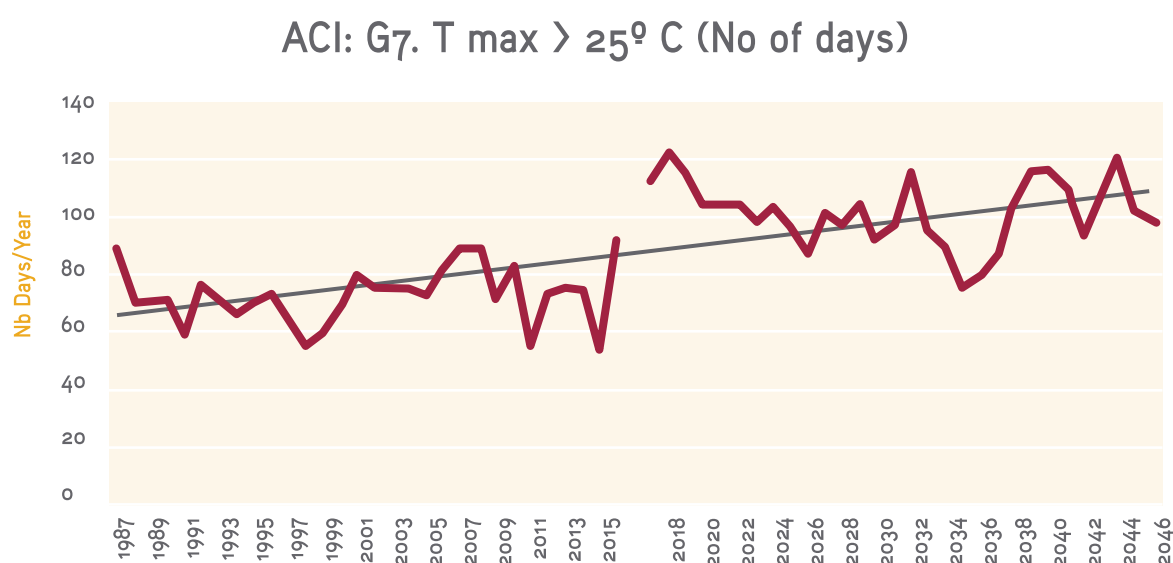


IMAGE 06. Example of ACI projection calculated in a 25x25 km grid through the ACZ tool. Source: AgriAdapt.

The source of the meteorological data used in the climate risk assessment is the data portal Agri4Cast1, from the European Commission (JRC). This is a platform that has homogenous meteorological data for the whole of Europe. Past data is available from 1975 to the last calendar year with a total of 12 climate variables (with daily frequency), including the variable of evapotranspiration, which is essential for agricultural questions. However, these 12 daily variables can be combined to obtain new variables (for example, hydric stress, winter recharge and heat waves are in the end a combination of several of those variables). Data for the near future (coming 30 years) is available for climate projections with the SRES scenario A1B and three models, as well as modelled data from the past 30 years. A total of nine climate variables are available for each of these climate models.

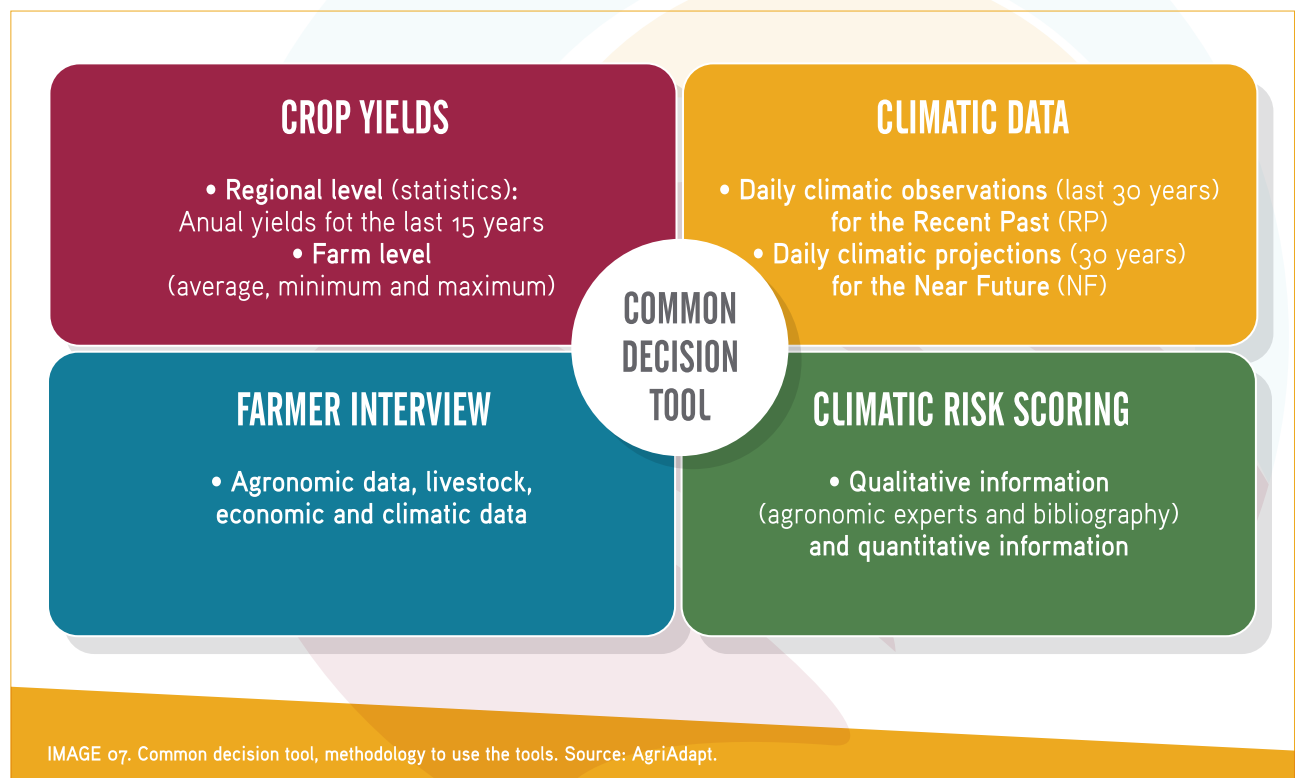
But this first approach only comprises the assessment at agro-climatic zone scale. Now it is time to make sense of these results at farm level. In order to do that, other information such as the Utilised Agricultural Area (UAA), cultivated crops, rotation practices, livestock management and weather events and their effects on the farm is also gathered through an interview with the farmer. With this information and the one resulting from the ACZ Tool, another instrument called the **Farm Vulnerability Tool** provides

the current climate risk score. This is calculated with the impact and exposure for the main crops or activities in the ACZ Tool and, more importantly, updates this score for the near future to show what will come next in terms of climate risk at farm level. This step helps make a difference between two farms with the same crop and in the same 25x25 km area, and better understand how different management can increase or decrease the risk detected.

The second tool also provides a set of sustainable adaptation measures to be implemented at farm level. These measures will help reduce risk and improve the resilience of the farm. Both instruments combined form what we call the **Common Decision Tool** (Image 7).

These tools are also available through a simplified **online version** (AWA Webtool) which helps farmers get some insights into their adaptation possibilities, although the results it provides are not as detailed as with the abovementioned conventional assessment.

What is remarkable about these tools and the methodology to assess the climate risk, is that the process allows to meet the specificities of a single farm anywhere in Europe, which provides a very practical approach to the issues that farmers are facing in a very specific location. The specificity of the assessment enables the proposal of adaptation measures which will suit the farm best.





03 Climate Risk

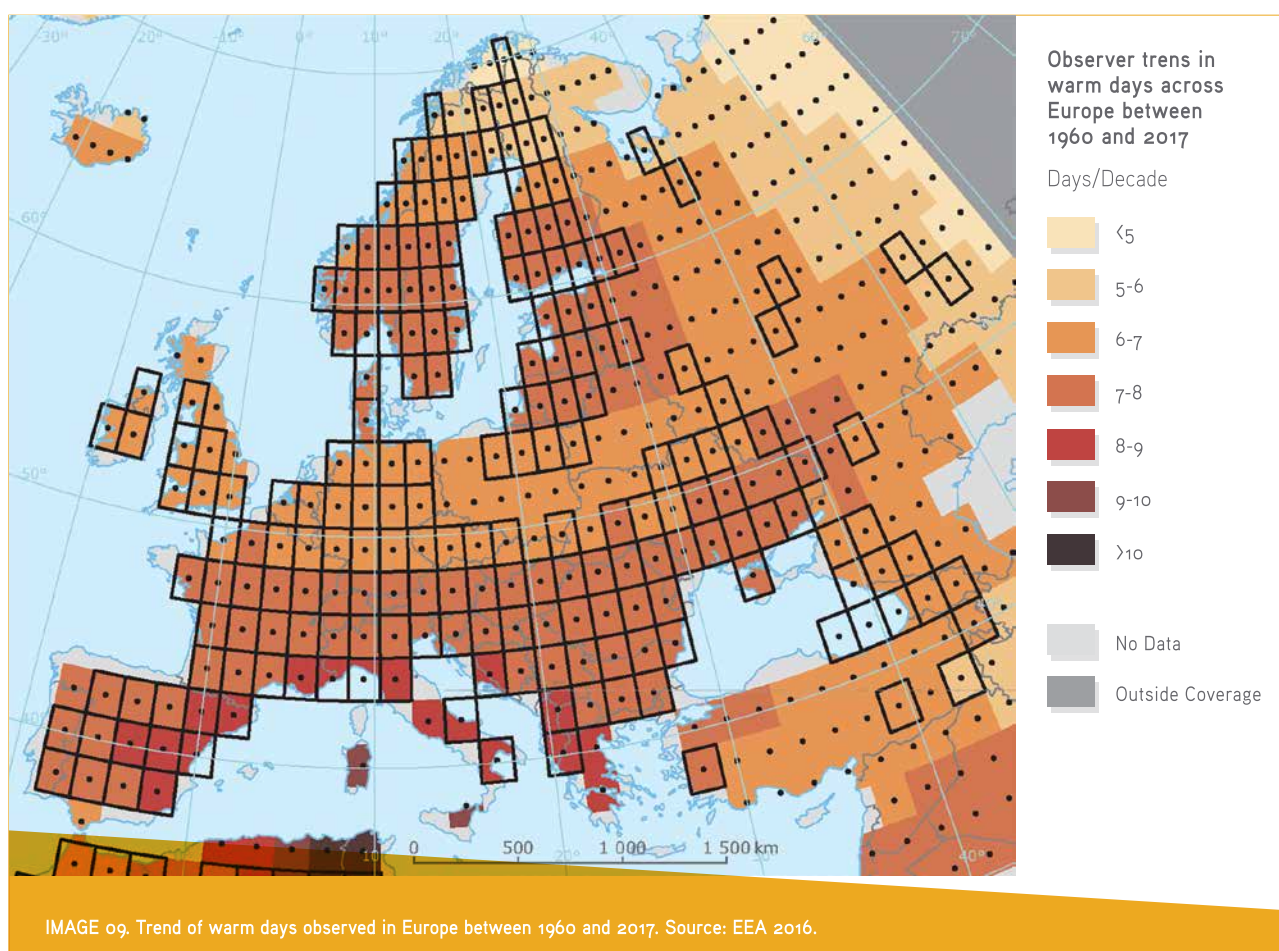
Assessment at Farm Level

In order to test the methodology developed and fine-tuned, at farm level, AgriAdapt collaborated with 126 farmers across Europe. For three years, this methodology was tested and farmers were supported in the implementation of adaptation solutions at farm level that, if possible, were also consistent with climate change mitigation. All the information is included in individual Action Plans; that is, roadmaps with both short-term and long-term measures address climate change successfully. During a three-year period, the progress is individually assessed using the tool to evaluate the improvement in resilience.

The 126 pilot farms are distributed over the four main European Climate Risk Regions: Spain (Southern region), France (Atlantic region), Germany (Continental region) and Estonia (Northern region), and cover eight different farming systems. Most pilot farms, 57 in total, were arable farms. 30 of the pilot farms were dairy farms, 10 were vineyards, 8 orchards, 8 beef cattle farms, 6 processing tomato farms, 4 pig fattening farms and 3 sheep farms. In total, there are 97 conventional and 29 organic pilot farms, the number of organic farms being around 30% in each country.

There is a high variability in the size of the pilot farms, as well as in the farming practices used, since the pilot farms were chosen to be as heterogeneous as possible in order to depict the variation within each climatic zone.





3.1. CLIMATE OBSERVATIONS

According to the IPCC report from 2014, in the last decades, the effects of climate change have clearly been noticed in Europe. Without a systematic analysis, it is difficult to know which climate variables changed or affected a specific production. However, farmers in most cases do notice changes that affect their production. For example, the average annual temperature of the European land area for the decade from 2006–2015 was around **1.5 °C above the preindustrial level**. This makes it the warmest decade on record. Moreover, 2014 and 2015 were **the joint warmest years in Europe** since instrumental records began (EEA, 2016).

High-temperature extremes (hot days, tropical days and heat waves) have become more frequent since 1950, while **low-temperature extremes** (cold spells, frost days) have become less frequent (IPCC, 2014). Furthermore, the average **length of summer heat waves** over western Europe has doubled, and the frequency of hot days has almost tripled since 1880. In the case of **the number of warm days** (those exceeding the 90-percentile threshold of the baseline

period 1971 – 2000), these **have almost doubled** since 1960 across the European land area (EEA, 2016).

Since 1950 the **annual precipitation has increased in Northern Europe** (up to 70 mm per decade) and **decreased in parts of Southern Europe** (up to 70 mm). Seasonal precipitations trends show an increase in **winter precipitation in Northern Europe** and a **decrease** in Southern Europe as well, albeit with large interannual variations (EEA, 2012).

3.1.1. Climate Events at Farm Level

By crossing the yields of the recent past with climatic data and weather events of the same period, it has been observed that the most relevant climate events affecting yields over all climate zones are hail, high temperatures and droughts. Hail is mainly problematic for permanent crop farms. High temperatures and droughts are a problem for all pilot farms, especially in the southern and Atlantic regions, but occurring more and more often in the Continental and northern regions as well. Estonia is the country with the lowest frequency of occurrence of drought (27%). These climate events, their regularity and repercussions can be seen in Table 1.

CLIMATE EVENT	SOUTHERN	ATLANTIC	CONTINENTAL	NORTHERN
HAIL 	<ul style="list-style-type: none"> • REGULAR: 75% of cereal farms • IMPACT: 5-50% yield reduction 	<ul style="list-style-type: none"> • CONCERNED: 80% of farms • REGULAR: 25% of farms • IMPACT: 5-100% yield reduction 	<ul style="list-style-type: none"> • CONCERNED: 60% of farms • FREQUENCY: Low • IMPACT: 10-80% yield reduction 	<ul style="list-style-type: none"> • FREQUENCY: Low - medium • IMPACT: 2-60% yield reduction
INTENSE/LATE FROST 	<ul style="list-style-type: none"> • REGULAR: 75% of cereal farms • IMPACT: 30%-70% yield reduction 	<ul style="list-style-type: none"> • CONCERNED: 93% of the farms • FREQUENCY: Low • IMPACT: Significant 	<ul style="list-style-type: none"> • CONCERNED: 23 % of farms • FREQUENCY: Low • IMPACT: High in permanent crops 	<ul style="list-style-type: none"> • FREQUENCY: Low • IMPACT: 5-100% yield reduction
DROUGHT 	<ul style="list-style-type: none"> • FREQUENCY: Increasing • IMPACT: 20-100% yield reduction (most limiting climate factor for permanent crops and pastures) 	<ul style="list-style-type: none"> • CONCERNED: 60% of farms • FREQUENCY: Increasing • IMPACT: Potentially significant 	<ul style="list-style-type: none"> • CONCERNED: 50% of farms • FREQUENCY: Medium 	<ul style="list-style-type: none"> • FREQUENCY: Low • IMPACT: 5-35% yield reduction
HIGH TEMPERATURES 	<ul style="list-style-type: none"> • FREQUENCY: High • IMPACT: Significant for animals, permanent crops and tomatoes 	<ul style="list-style-type: none"> • CONCERNED: 78% of farms • FREQUENCY: Increasing • IMPACT: Punctual 	<ul style="list-style-type: none"> • CONCERNED: 100% of farms • FREQUENCY: Medium 	<ul style="list-style-type: none"> • FREQUENCY: Low • IMPACT: 10-30% yield reduction
STORMS AND INTENSE RAINFALL 	<ul style="list-style-type: none"> • IMPACT: 5-30% yield reduction in arable crops 	<ul style="list-style-type: none"> • IMPACT: North of France, 50% yield reduction in 2016. South of France, drought impact strengthened by wind 	<ul style="list-style-type: none"> • CONCERNED: Especially maize and cereal farms 	<ul style="list-style-type: none"> • FREQUENCY: Low • IMPACT: Low

Table 01. Frequency and impact of selected climate events on pilot farms in the southern, Atlantic, Continental and northern climate zones.

3.1.2. Agro-Climatic Indicators (ACIs)

For the main above-mentioned climate events affecting agricultural production, measurable Agro-Climatic Indicators have been identified for each crop and region. These indicators are the measurable factors behind the low yields of the past 15 years and, most importantly, will be the measurable factors behind the lowest yields in the near future. Over 65 Agro-Climatic Indicators have been corroborated or newly identified within the frame of this project, and a practical example of how they might affect our crops can be seen below:

"It is autumn ...

... and we have just sown our cereal. Everything has gone as planned! Soil well tilled, manure properly applied, first-quality certified seeds... it seems that this year is going to be a good one! But this autumn is being especially rainy, and after a month of waiting, the emergence of the seeds is not as good as we would want it to be... What is the matter? It turns out that the first Agro-Climatic Indicator has just struck, since more than 100 mm of water a month right after sowing affects emergence in cereal crops!

Well, the small plants kept on growing and the emergence rate was luckily not that bad after all. However, something is wrong with the stem elongation and heading of our plants... they seem to be low in height and the ears are rather small! Unfortunately, this is the second time we have suffered the effects of an Agro-Climatic Indicator this season. In this case, the water deficit (P-ETP) from March to June has been of -300 mm, and that affects cereal growth and heading.

Luckily, the ears are already formed and in the grain filling phase the water requirements are not particularly high. The grain is finally ripening and we grab a couple of ears to rejoice in the quality of our production but... Some of the grains seem wrinkled and their size is not the most desirable. Could it be that, for the third time this season, another Agro-Climatic Indicator has affected our crop? Precisely—spring has been warm and the maximum temperature has been higher than 25 °C (or 30 °C if you are in southern Europe) on more than 20 days between May and June! This caused the shriveling of the grain."

These are just three examples of factors involved in the quantity and quality of our harvest and how they can affect our yields. In chapter 4, "Case Studies and sustainable adaptation measures", more Agro-Climatic Indicators will be talked about, which are applicable for other crops and conditions. The most interesting part is that these ACIs can be fine-tuned not only to the crop, but also to the varieties used and the geographical area. ACIs can be common, for example, to all wheats, but their fine calibration (e.g. water deficit threshold) will change from one farm to another.



IMAGE 10. Water deficit in wheat, very small ears. Source: FGN.

3.2. CLIMATE PROJECTIONS

Once the climate observations of the past 30 years have been gathered and over 65 Agro-Climatic Indicators (ACIs) affecting our crops in the recent past (RP) have been successfully identified, it is time to see how those indicators are going to develop in the near future (NF), that is to say, in the coming 30 years.

In order to illustrate the effects of climate change on agriculture in the different climate zones, we have selected representative points throughout Europe covering the different climate regions. The data for the climate observations (1987–2016) and projections has been taken from the platform Agri4Cast, using the SRES scenario A1B for the projections, which is the same data we used for the climate risk assessment on the pilot farms.

For the assessment, only one climate model has been used in order to illustrate the impact of climate change in a simplified way to the farmers taking part in the pilot. It is clear that this is just one illustration of the future projections and that using just one climate model has its limitations. However, although the model used is the warmest and driest out of the models available on Agri4Cast, it represents a very moderate climate change compared to the RCP scenarios.

In this chapter, we describe some relevant **Agro-Climatic Indicators** that we have selected in order to illustrate their development from the recent past (RP, 1987–2016) to the near future (NF, 2017–2046).



IMAGE 11. Transect from southern to northern Europe (red pins) to illustrate the climate observations and projections in the four different climate zones. Source: AgriAdapt.

ACI: C1. Heat stress, cereals (Tx. >25°C. 15/04 to 15/07)

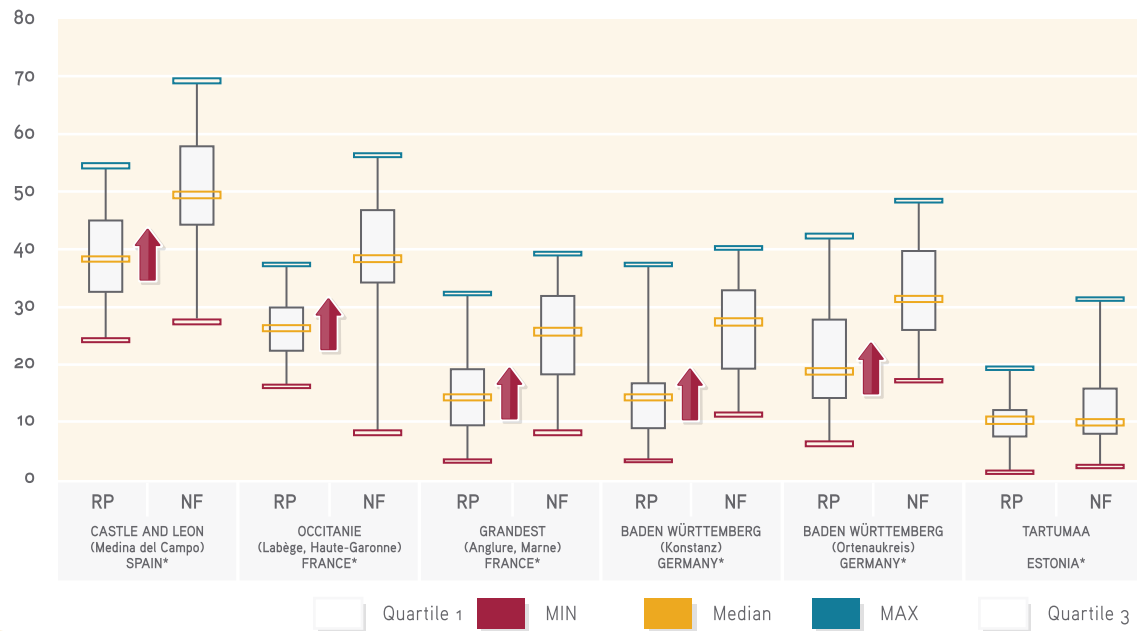


IMAGE 12. Development of days > 25 °C in the period 15/04–15/07 from the recent past (RP) to the near future (NF). Relevant indicator for cereal crops. Source: Agri4Cast.

ACI: M2. Annual water balance (May to August)

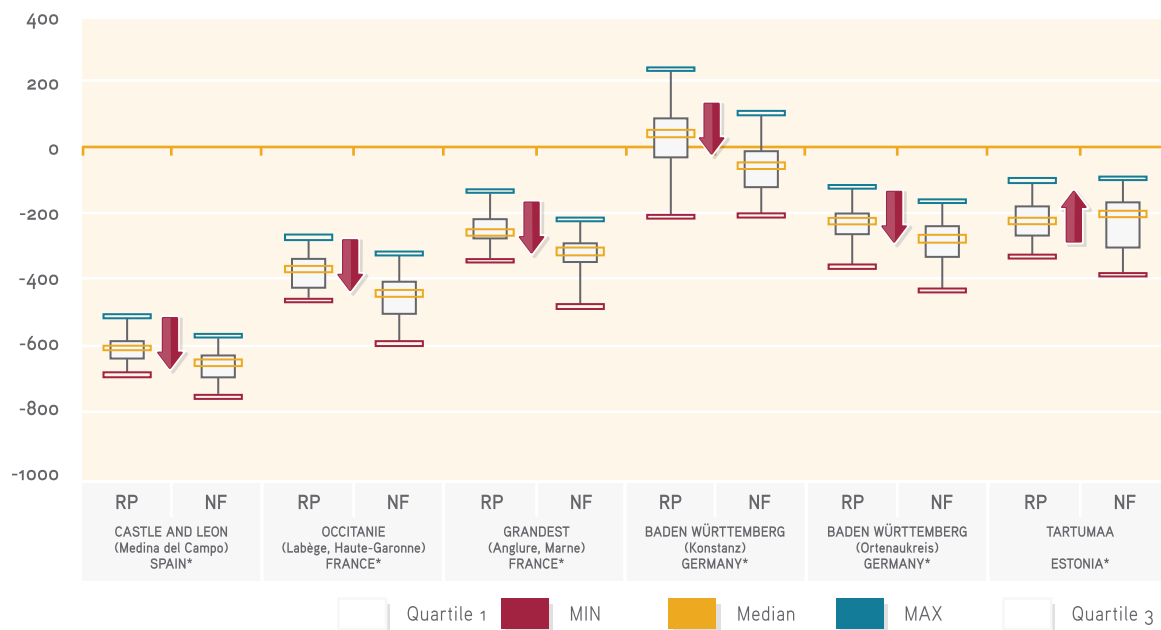


IMAGE 13. Development of average annual water balance from May until August from the recent past (RP) to the near future (NF). Relevant indicator for cereal crops. Source: Agri4Cast.

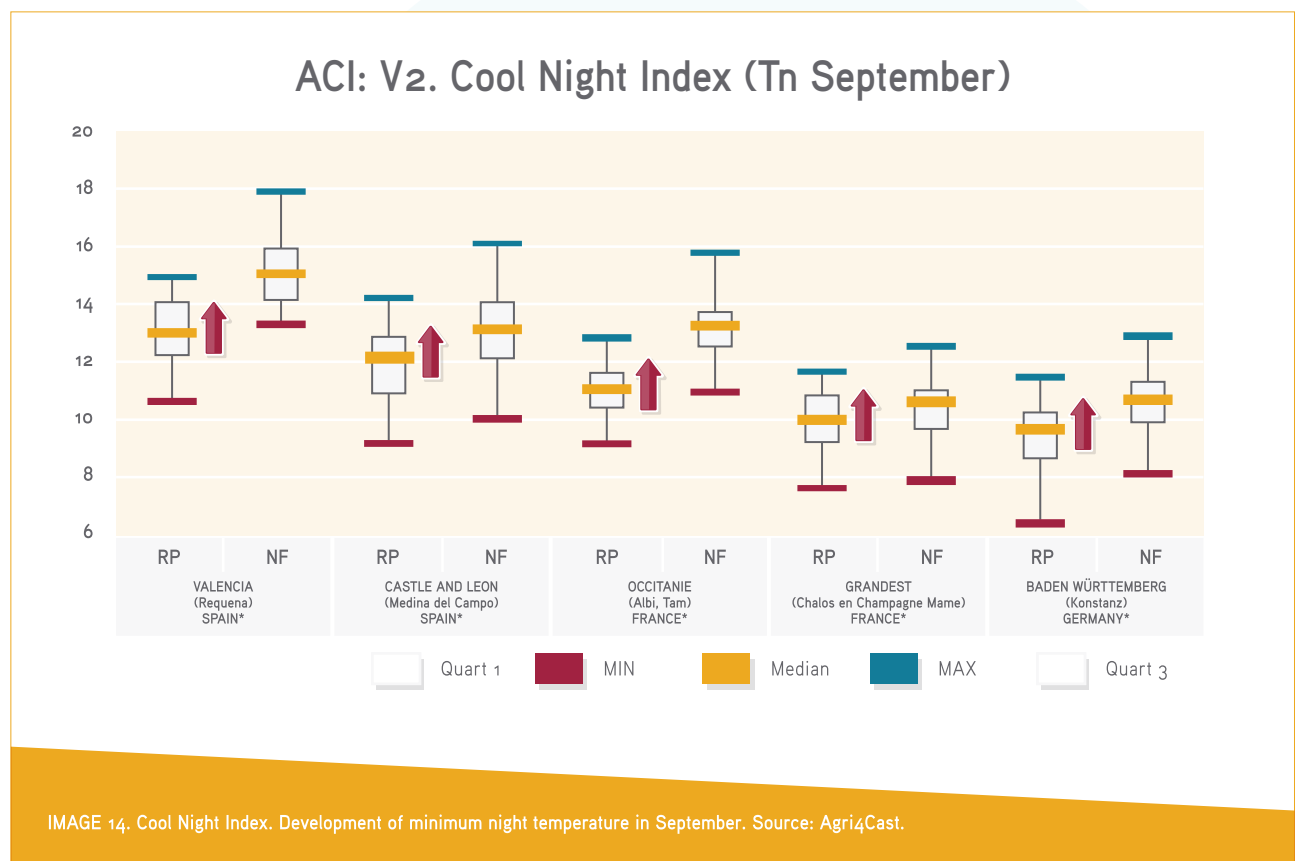
The first indicator affects cereal crops and is measured as the **number of days with temperatures above 25 °C between the 15th of April and the 15th of July**. With an increase in days above 25 °C (30 °C in southern regions), the vulnerability of cereal crops in northern and temperate regions increases. Temperatures above 25 °C during the flowering or grain-filling phases of cereal crops can lead to lower yields, in part due to a phenomenon known as shrivelling. According to the model used, this will increase by around 10 days in all regions in the NF, except in the region of Tartumaa (Estonia) (see Image 12).

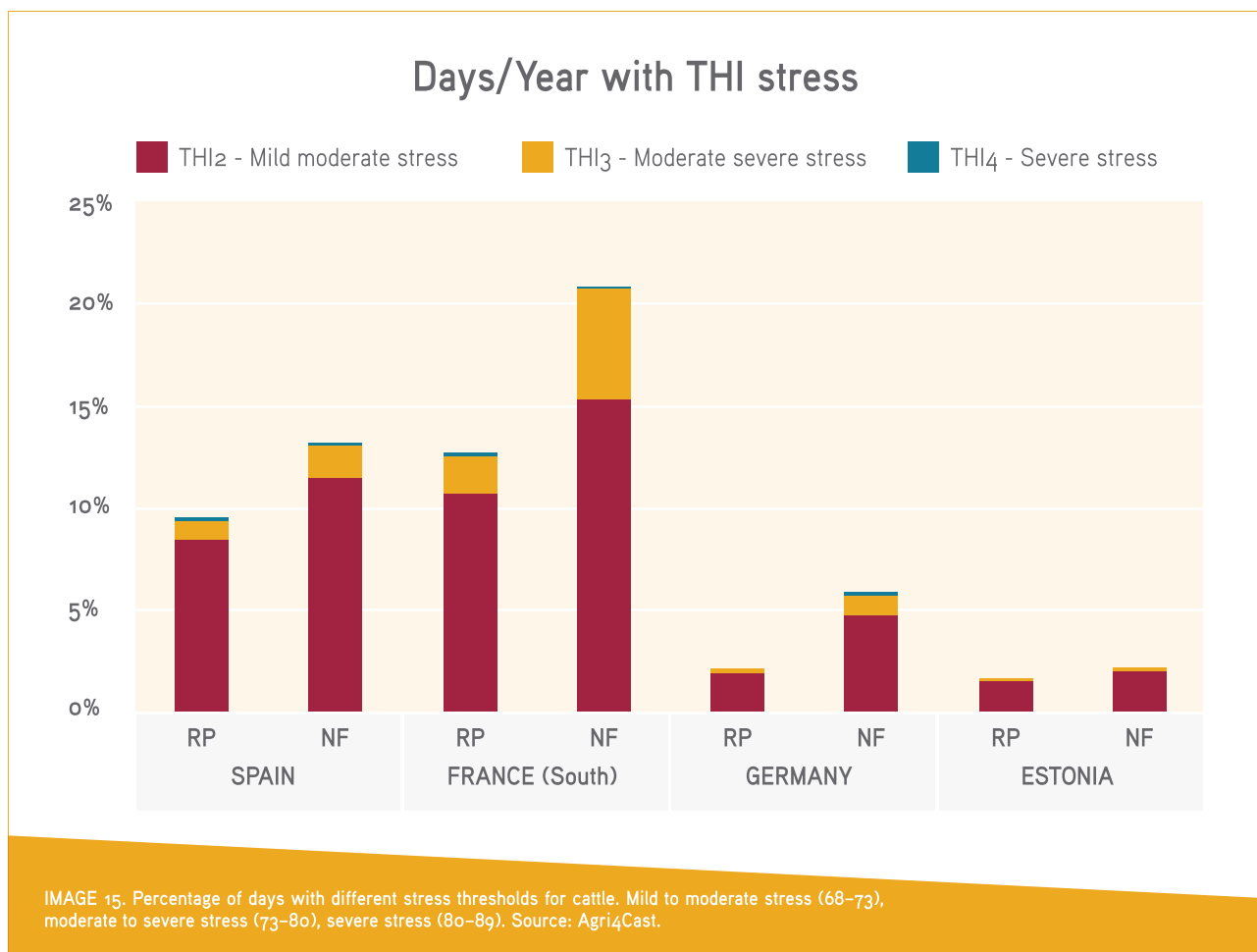
Regarding water issues related to cereal crops (as seen in Image 13), the overall **average annual water balance in the period from May to August** will decrease significantly in all regions (except in the region of Tartumaa), also leading to lower yields.

In the case of permanent crops, especially vineyards, the **Cool Night Index** is an important factor during the ripening of the grapes. Minimum night temperatures

need to be reached in order to produce a good quality wine. As seen in Image 14, which shows the development of the minimum night temperature in September, there is an increase in night temperature in all regions, especially in the south of Spain and France (region of Valencia and Occitanie). This may lead to the cultivation of varieties better suited to the altered conditions so that the quality of the wine will not be compromised.

In livestock farms, a relevant indicator for cattle (both dairy cows and meat cows) is the **Temperature-Humidity Index (THI)**, which assesses the risk of heat stress. For our pilot farms, the amount of days with a stress factor of 73–80 (moderate to severe stress) has been calculated. Image 15 shows the development of the different stress thresholds. This indicator will increase in all regions, but most importantly in Spain and the south of France, which entails a problem, since moderate to severe stress levels increase the respiration and heart rate of the cows, causing a small reduction in milk production and fertility, and decreasing fodder consumption.





3.3. PILOT FARMS SWOT ANALYSIS

Having seen the climate projections, we might think that the situation in our region does not look good in the near future, or perhaps it looks better than we actually thought it would! Regardless, it depends on many factors and those are different depending on the

region we are located in. In order to help us, a **SWOT analysis** for every region has been performed. It is an analysis in which we identify what our **strengths** are, so we can use them; where our **opportunities** lie, so we can make the most of them; we become aware of our **weaknesses**, so we can work on them; and we are warned of our **threats**, so we are able to prevent them. In Table 2, we can look at the results for each region involved in this project.

REGION	STRENGTHS	WEAKNESSES
SOUTHERN	<ul style="list-style-type: none"> • Agricultural insurance • Well adapted varieties • Farming systems with diverse crops, extensive agroforestry systems 	<ul style="list-style-type: none"> • Increasing dependence on monocultures • Insufficient management of grasslands
ATLANTIC	<ul style="list-style-type: none"> • Diversified cropping systems • Good fodder management • Irrigation 	<ul style="list-style-type: none"> • Inadequate crops cultivated and/or low genetic diversity • Irrigation restrictions • Insufficient thermal comfort for animals
CONTINENTAL	<ul style="list-style-type: none"> • Use of catch crops before spring crops • Income from various pillars • High fodder autonomy of dairy farms 	<ul style="list-style-type: none"> • High share of one specific crop • Inadequate use of plough as main soil tillage management • Only three crops in rotation (especially dairy farms)
NORTHERN	<ul style="list-style-type: none"> • High crop diversity and suitable soils for permanent crops • Range of varieties grown • High fodder autonomy 	<ul style="list-style-type: none"> • No irrigation used in permanent crops • Low availability of suitable fallow fields for arable farms • Poor soil drainage on livestock farms
REGION	OPPORTUNITIES	THREATS
SOUTHERN	<ul style="list-style-type: none"> • Higher productivity in temperature-limited areas if water is ensured • Increased pasture production in autumn/winter due to increased temperature • Possibility for new crops through warmer winters 	<ul style="list-style-type: none"> • Increase in heat waves in spring and summer: increase in yield variations and heat stress for animals • Less rainfall in winter-spring • Increase of hydric deficit in spring and summer
ATLANTIC	<ul style="list-style-type: none"> • Better climatic conditions in autumn • Significant decline of the number of frost days/year • Possibility for new crops through the increase in GDD 	<ul style="list-style-type: none"> • Increase in yield variations due to climate stress in May/June • Increase of hydric deficit in spring and summer • Increase in heat stress for animals
CONTINENTAL	<ul style="list-style-type: none"> • Opportunity for new crops or varieties • Longer vegetation period positive for grassland and tuber crops • Reduction of moisture loving pathogens 	<ul style="list-style-type: none"> • Higher variability in yields • Increase in heat stress for dairy cows • Risk of more and new pests/diseases/weeds due to higher temperatures and longer vegetation period
NORTHERN	<ul style="list-style-type: none"> • Longer growing period, potential increase of yields and quality • Diversity of crops and varieties increased • Energy needed to heat livestock buildings is reduced 	<ul style="list-style-type: none"> • More climatic extremes expected, higher risk for permanent crops • Increasing risk of new pests and diseases with new cultivars • Lower performance of livestock due to heat stress, especially outdoors

Table 02. SWOT analysis for the four main EU Climate Risk Regions.



04 Case Studies

and Sustainable Adaptation Measures

Up until now we have given an overview of the project, its aims, methods and climatic data analysis. In order to make all this theory more tangible, we are going to travel to pilot farms in Spain, France, Germany and Estonia through various case-studies. Here we will find out about the climatic issues

the pilot farms are dealing with and which Sustainable Adaptation Measures (SAM) they are implementing to face these issues. The trip will lead us to some of the most representative pilot farms in the assessed farming systems.



SUSTAINABLE ADAPTATION MEASURES (SAM)

Throughout this manual, texts with the Sustainable Adaptation Measures icon show how farmers in Europe are putting adaptation strategies into practice.

4.1. ARABLE CROPS: CEREALS, LEGUMES, FODDER, CROPS, OILSEEDS, VEGETABLES

Let us start our trip paying a visit to the arable lands in Europe. Unlike other farming systems, arable lands are very dynamic and their very nature allows us to enrich the landscape with a mosaic of different crops. In arable lands there is room for cereals, legumes, fodder crops and oilseeds, but also for vegetables such as tomatoes, sugar beet or potatoes.

4.1.1. Crop diversification and improved soil management in Melque de Cercos · SPAIN

CROPS ASSESSED: six-rowed barley, durum wheat, rye, fodder vetch, sunflower.



And here we are in the middle of Spain, a little bit to the north-west of Madrid. We have just arrived to Melque de Cercos, a village located in a province called Segovia. We have met with the owners of a rainfed organic farm of 110 ha of Utilised Agricultural Area (UAA). Their main crops are winter six-rowed barley, fodder vetch (*Vicia monantha*), rye, sunflower and durum wheat. Additionally, 5% of the UAA is lain fallow every year. The farm has light sandy loamy soil and no flooded areas; it has also low erosion rate, since it is worked with chisel. The cultivated plots are small and some are in contact with semi-arid vegetation.

The main climate change challenges affecting this farm are droughts, desertification, soil degradation, extreme temperatures (heat waves), more frequent pests and disease attacks and biodiversity loss due to the increasingly extreme conditions.



IMAGE 16. Barley field in Melque de Cercos. Source: FGN.

As deduced from these projections, sustainable adaptation measures to climate change are clearly needed! Resulting from the climate risk assessment of this farm performed in the frame of the project, a set of adaptation measures has been proposed and some of them are already being implemented.

Main Agro-Climatic Indicators (ACIs), projections in the near future (NF) and impact														
No	ACIs	CALENDAR												NF
		01	02	03	04	05	06	07	08	09	10	11	12	
01.	WATER DEFICIT (P-ETP) < -300mm													↑ 9%
02.	DROUGHT PERIODS > 15 days without rain													↑ 100%
03.	DROUGHT PERIODS > 15 days without rain													↑ 33%
04.	T MAX > 30°C (No of days)													↑ 150%
05.	THERMAL STRESS > 30 °C													↑ 92%
IMPACTS ON CROPS: <ul style="list-style-type: none"> ACIs 1 and 4: shrivelling of the grain. Lower yields. ACI 2: affects heading, grain development and grain filling phases. Lower yields. ACIs 1 and 4: slows down growth. ACI 2: affects growth rate. Lower yields. ACI 2: affects growth rate. Lower yields. ACIs 3 and 5: negative impact on the fattening of the pipes. Lower yields. 														



One of the first measures to be adopted has been the **improvement of rotations**. The farmer now performs rotations with five different crops (durum wheat–vetch–barley/oats–sunflower). The legume in rotation (vetch) ensures a better resistance to climate change improving the nutrient content of the soil and its structure.

Another one of the first adaptation measures adopted was the **association of legumes and cereals as forage crops** to improve yields, since these species have different nutrient requirements and legumes may actually grow better by climbing along the stalks of the cereal. Some examples of this measure are the association of barley and vetch or oats and alfalfa.

Following those, **early sowing** of spring crops to reduce hydric and thermal stress at the end of the growth cycle; **the use of traditional varieties** well adapted to the local climate; and the **sowing of a shorter cycle crop** (such as oats) in January-February if autumn has been too dry and the emergence of the first crop sown has been compromised, were also implemented.

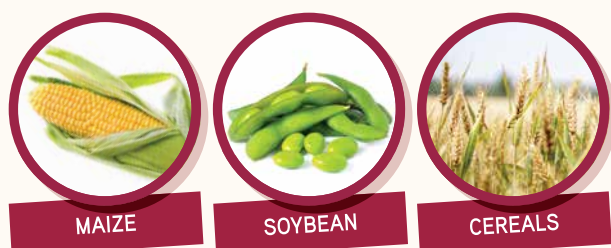
Soil management measures were also adopted. In this case, bare soil was avoided by leaving the stubble standing, applying organic fertiliser at least every two years, and using it to feed livestock (80 sheep, native breed) on fallow lands to further fertilise these soils. These measures aim at increasing their resilience and quality. Also, multifunctional field margins were implemented to reduce soil erosion and enhance biodiversity (pollinators and beneficial insects, among others). *“There were some weed issues found in multifunctional margins during the first two years, but they stopped once the vegetation was well established”*, reported the farmer.



IMAGE 17. Association of vetch and barley harvested together.
Source: FGN.

4.1.2. More diversification and early sowing for more resilience and stability · SOUTH OF FRANCE

CROPS ASSESSED: maize for grain (irrigated), soybeans, winter barley and winter soft wheat.



From Spain we are moving into the south-west of France, where we are visiting Mr. De Vulpière and his 80-hectare family farm (EARL des Canongesses), located 40 km south of Toulouse. In the past, this farm was focused on dairy cattle with a complementary wine-growing activity. However, the vines were uprooted in 1976 encouraged by some CAP subsidies, and an irrigation system (pivot) was implemented covering the whole UAA (about 170 000 m³ of water per year). The farm therefore became specialised in arable crops, even stopping all livestock activity in 1982, which demanded more manpower.

Within their specialty in arable crops, they grow maize (40 ha), soybeans (22 ha), winter barley (22 ha) and winter soft wheat (12 ha) under conventional practices. Most of the farm's soils are sensitive to drought and show a low fertility level, and a no tillage system has been implemented for the past 10 years. The farmers also share some land with their neighbors, where they grow green asparagus (3 ha) and five varieties of field strawberry (0.5 ha), with the aim of marketing them in small circuits.

Main Agro-Climatic Indicators (ACIs), projections in the near future (NF) and impact

No	ACIs	CALENDAR												NF
		01	02	03	04	05	06	07	08	09	10	11	12	
01.	WATER DEFICIT (P-ETP)													↑ 22%
02.	DROUGHT PERIODS (No sequences of 10 consecutive days without rain)													↑ 13%
03.	T MAX > 25°C (No of days)													↑ 55%
04.	T MAX > 32°C (No of tropical days)													↑ 240%
05.	NO OF FROST DAYS													↓ 50%
06.	SUM OF TEMPERATURES (Base 0°C)													↑ 9%

IMPACTS ON CROPS:



ACIs 1, 2 and 3: less biomass produced, earlier ripening, smaller seeds and lower yields.
ACI 5: less risk of crop damage, but still there.



ACIs 1, 2 and 4: flowering, grain development and grain filling phases may be compromised. Increase in irrigation requirements.
ACI 5 and 6: early sowing can be implemented with fewer risks since an increase in temperatures during the full cycle allows it to finish earlier, therefore avoiding summer climate stress.



ACIs 1, 2 and 4: flowering, grain development and grain filling phases may be compromised. Increase in irrigation requirements.
ACI 5 and 6: early sowing can be implemented with fewer risks, double crop success more frequent (sowing of soybeans after an early harvest of winter barley).

Thibault (Mr. De Vulpière's son) is in the process of taking over the farm and, according to him, this climate risk assessment will be very useful to make a good start!

What local climate projections for time horizon 2035 (Near Future) tell us is that annual precipitations are going to decrease (about 8% on average), especially during the summer (-18%); although they will be increasing in the period between October and December (+13%). The average annual temperature will increase (about +0.3 °C every decade), the number of heat waves will double (about 4 sequences per year on average) and the water deficit will also increase (+25%), especially during spring and summer. At least, the number of frost days is going to decrease and will be very low with an average of only 11 days per year. The main Agro-Climatic Indicators affecting crop yields can be seen below (drought, extreme temperatures), and it is considering these factors that they need to work on adaptation measures aimed at minimising their impact.



IMAGE 18. Harvesting field strawberry. Source: Solagro.



Considering the size of their UAA (80 ha) and the importance of irrigated maize at farm level (50%), one of the main adaptation measures to be implemented is to **increase the number of main crops** within the farm (one or two extra crops). Also, **increasing the number of varieties grown for the two main crops** (taking into account the main climatic hazards, which are heat and water stress) is worth considering. **More diversity leads to more resilience and stability.**



IMAGE 19. Early maize variety. Source: Solagro.

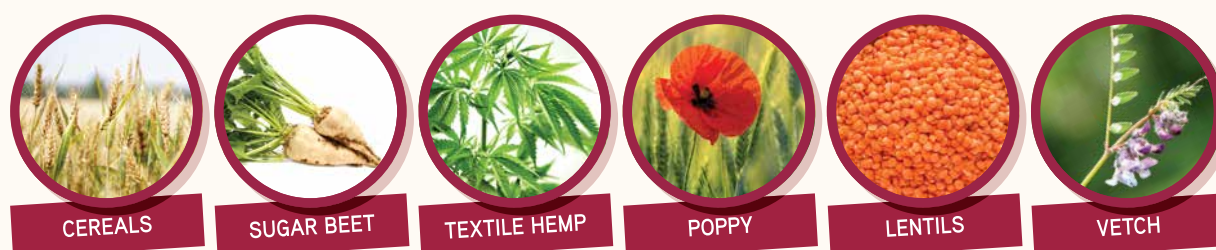
Due to the fewer risks of late frosts, **early sowing in March** (within the first 10 days of the month) of maize and soybean is being implemented. This measure allows the crops to start their growth cycle earlier, escaping thus some of the climatic issues encountered in the past summer months: higher water deficit, high temperatures and droughts. Complementing this adaptation measure, the farmer is now growing **maize varieties characterised by certain precocity** so that the stress derived from the climatic conditions during the summer is minimised.

Saving water helps reduce direct costs and, in the near future, overcome water shortages. Decision support tools such as **tensiometric probes** are helping Mr. De Vulpinière to achieve an improved management of water in which irrigation is being performed only when the crops are clearly in need of it. To go further, the next step would be to substitute part of the maize surface irrigated (such as chickpeas) to reduce the water dependency of the farm.

Last but not least, the farmer is developing a **hedgerow planting** project in the windiest area so that the crops are better protected from the cold, the heat, evapotranspiration and strong winds. Also, the system of hedgerows will create new biodiversity spots, which will host natural enemies of pests, for biological control, and pollinators, indirectly improving yields and crop health.

4.1.3. No-tillage, cover crops and wide rotations for arable crop adaptation · NORTH OF FRANCE

CROPS ASSESSED: winter soft wheat, winter barley, spring barley, sugar beet, textile hemp, poppy, lentils and alfalfa.



In the north-east of France, Mr. Chambrillon owns a 97.5-hectare farm (EARL Arc en Ciel) in the Champagne region (among the best soils in France), where the number of different crops being grown is impressive! They began their activity in 1996 and work with 6 different crops: winter soft wheat (33 ha), sugar beet (15 ha), textile hemp (10 ha), poppy (9 ha), spring barley (9 ha), lentils (8 ha), alfalfa for dehydration (7 ha) and winter barley (6 ha). Complex rotations are in place, maximising thus the benefits of such a wide mosaic of crops. In order to avoid a decrease in the soil's organic matter and a loss of nutrients, they use a mix of mustard, vetch, radish, phacelia and oats as cover crop,

avoiding bare soil most of the year. They have also been implementing a no-tillage system since 2010 in order to improve soil structure and reduce labor costs.

In the north of France, the climate is friendlier than in the south. However, Mr. Chambrillon's farm is not escaping climate change either. Following the climate risk assessment performed for this location, climate projections show that annual mean temperatures (+0.4 °C every decade), water deficit (+39%) and the number of hot days (+66%) have an increasing trend (time horizon 2035). Luckily, the number of frost days per year will be reduced (-66%), extending the growth cycle of some crops.

Main Agro-Climatic Indicators (ACIs), projections in the near future (NF) and impact

No	ACIs	CALENDAR												NF
		01	02	03	04	05	06	07	08	09	10	11	12	
01.	WATER DEFICIT (P-ETP)													20%
02.	T MAX > 25°C (No of days)													92%
03.	T MAX > 32°C (No of tropical days)													300%
04.	AVERAGE TEMPERATURE													11%
05.	NO OF FROST DAYS													50%

IMPACTS ON CROPS:



ACIs 1 and 2: earlier ripening, smaller seeds and lower yields.

ACI 4: higher risk of weed, insect and pathogen pressure due to warmer conditions.

ACI 5: less risk of crop damage.



ACIs 1 and 3: lower growth rate, lower biomass and yields.

ACI 4: higher risk of weed, insect and pathogen pressure due to warmer conditions.



ACIs 1, 2 and 3: lower growth rate, lower biomass and yields.

ACI 4: higher risk of weed, insect and pathogen pressure due to warmer conditions.



ACIs 1 and 2: reduction in the number of flowers and seeds.

ACI 4: higher risk of weed, insect and pathogen pressure due to warmer conditions.



ACIs 1 and 2: fewer flowers, lower fertility and reduction of yields.

ACI 4: higher risk of weed, insect and pathogen pressure due to warmer conditions.



ACIs 1 and 2: less biomass, lower yields.

ACI 4: higher risk of weed, insect and pathogen pressure due to warmer conditions.



Implementing a **no-tillage system from 2010** onwards has been a great advantage for this farm. In this region and under these climatic conditions, an undisturbed soil develops a better structure, a more complex biological activity and the farmer can benefit from an important cost reduction. **Direct sowing** was thus implemented and, therefore, the acquisition of new machinery was needed. However, this machinery has been paying itself back considering the lower labour costs and improved soils.

Such a **wide mosaic of different crops and varieties** growing on the same farm represents adaptation in itself. Each crop and variety will be affected differently by certain climatic issues, lessening the risk of important yield losses which might compromise the farm's profitability.

Also, a carefully planned **rotation** of these varieties (so that they do not grow on the same plot year after year) breaks weeds, pests and disease cycles and allow Mr. Chambrillon to save in pesticides and herbicides, among others. With these wide rotations, soil fertility is enhanced as well, consequently meaning savings in fertilisers.

For the coming years, the challenges for the farmer will be to pay attention to conserve such an important number of crops at farm level, improve the complementarity of the different varieties cultivated for the main crops and develop under-sowing cover practices to improve the farm's resilience to climate change.



IMAGE 20. Poppy almost ready to harvest. Source: Solagro.

4.1.4. Improving soil structure in hilly Kraichgau · GERMANY

CROPS ASSESSED: winter soft wheat, sugar beet, winter rapeseed, soybean, potato.



CEREALS



SUGAR BEET



RAPESEED



SOYBEAN



POTATO

Further north we reach Germany, more specifically the district of Heilbronn, 50 km north of Stuttgart. In this occasion, we have met in the hilly region of Kraichgau with the owner of another arable crop farm. This farm is located 120–250 m above sea level. 80% of the soil is loamy clay with a high water-storing capacity. The focus of the farm is on irrigated potatoes and sugar beet production. However, from the 240 ha of the Utilised Agricultural Area (UAA), 90 ha are cultivated in the Rhine plain, where the average temperature is 1 °C higher. This condition allows the farmer to focus on early potatoes and soybeans in this area. The yearly average temperature on the main production site is about 10 °C with around 720 mm yearly precipitation. The main crop rotation is (in order): sugar beet, winter soft wheat, winter rapeseed, winter soft wheat, potatoes and winter soft wheat. In the case of the Rhine plain: soybean, winter soft wheat, winter rapeseed, winter soft wheat. Other income pillars of the farm are direct marketing, photovoltaic energy and Christmas tree cultivation.



IMAGE 21. Diverse catch crop mixture.
Source: Lake Constance Foundation.

Main Agro-Climatic Indicators (ACIs), projections in the near future (NF) and impacts

No	ACIs	CALENDAR												NF
		01	02	03	04	05	06	07	08	09	10	11	12	
01.	WATER DEFICIT (P-ETP)													↑ 42%
02.	T MAX > 25°C (No of days)													↑ 80–100%
03.	T MAX > 30°C (No of tropical days)													↑ 27%
04.	AVERAGE TEMPERATURE													↑ -
05.	RISK OF LATE FROST T min < -4°C (No of days)													↑ -

IMPACTS ON CROPS:



ACIs 1 and 2: earlier ripening, smaller seeds and lower yields.
ACI 4: higher risk of weed, insect and pathogen pressure.



ACIs 1 and 2: lower growth rate, lower yields, lower sugar content.
ACI 4: higher risk of weed, insect and pathogen pressure.



ACIs 1 and 3: halting of tuber growth, greater dependency on irrigation, lower quality. During harvest, hard soil clusters resulting from dried out soil may damage the potato peel.
ACI 4: higher risk of weed, insect and pathogen pressure.
ACI 5: dying off of the leaves in their juvenile phase, which means a delay in development.



ACIs 1 and 3: reduction of the oil content of the seeds and earlier ripening. Lower yields.
ACI 4: higher risk of weed, insect and pathogen pressure.



Due to all the above-mentioned climate changes, the farm is focusing on improving the soil structure as a way of facing the challenges of climate change. It is very important to have a good soil structure with an active and diverse soil life as it can then absorb the (heavy) rain and store it over a longer period, avoiding nutrient loss and reducing wind or water erosion. In order to improve the soil structure, the farm is already using four different and very **versatile catch crop mixtures** with 15 different components in total (e.g. tillage radish, clover, phacelia, pea, *Avena strigosa*, vetch and mustard). All the species have different characteristics in root development, root exudates, resistance against pests and diseases and different nutrient requirements.

The risk of soil erosion in spring when the potatoes are planted is especially high. Besides the improvement of soil structure, the farmer has developed a **special technique, with which he can pile up the soil between the potato rows**. Another measure being implemented on the farm to reduce soil erosion is to till the hilly sites perpendicular to the slope and to use **reduced tillage** on the rest of the farm (except before potatoes). Moreover, the farm is **sowing wheat between the rows** after the potato planting to avoid the washing away of the soil during (heavy) rainfall. The **tyre pressure of the vehicles used on the field is also being adapted** for this work, so the good structure of the soil is not destroyed when driving on it.

Apart from improved soil management, other measures such as the **inclusion of new varieties better adapted to climate change** are also being implemented. As stated above, the climate conditions in the Rhine plane are up to 1 °C warmer and also drier. As a consequence, the farm replaced clover grass by **alfalfa grass**, as alfalfa has the ability of rooting very deep and therefore is more drought-tolerant than clover. In this area, the farm also grows an **earlier-ripening winter soft wheat variety** —“**Rubisco**”— to avoid the mid-summer heat in August. This variety has a high yield potential even under dry conditions and its long awns protect the plant from heat stress. Apart from the early-ripening one, every year around six different winter soft wheat varieties are cultivated on a smaller plot to find out the most suitable one for the farm.



IMAGE 22. Alfalfa crop. Source: Solagro.



IMAGE 23. Soybean crop. Source: Pixabay.

Apart from the improved soil management, other measures such as the **inclusion of new varieties better adapted to climate change** are also being implemented. As stated above, the climate conditions in the Rhine-plane are up to 1°C warmer and also drier. As a consequence, the farm replaced clover-grass by **alfalfa grass**, as alfalfa has the ability of very deep rooting and therefore is more drought-tolerant than clover. In this area, the farm also grows an **earlier ripening winter soft wheat variety “Rubisco”** to avoid the mid-summer heat in August. This variety also has a high yield potential even under dry conditions and its long awns protect the plant from heat stress. Apart from that, every year around six winter soft wheat varieties are cultivated on a smaller plot to find out the most suitable variety for the farm.

Due to the warmer conditions in the recent past, the farm has also started producing **soybeans**, which prosper under warmer conditions like in the Rhine plane. It has worked very well, and therefore production will be expanded.

The **sowing dates are also being adapted** to the increase in temperature in autumn and spring. With a later sowing date, the plants will not grow too much before the winter season, reducing the sensitivity of plants to pests, such as aphids and cicadas, which could be vectors of pathogens. An earlier sowing in spring will lead to an earlier harvest, and so avoid the summer heat and drought.

A big advantage is that the farm is already fitted with **irrigation equipment**, which is usually used for potatoes. The water comes from the farm's own well, a nearby creek and a self-made water basin (around 2000 m³). Irrigation reduces the risk of very high losses in potato yields. In hot summers, like the one in 2018, when there were, unusually, many days in July/August with temperatures above 30 °C, the farm had the possibility to cool down the potato ridges to avoid the overheating of the tubers.

Being up to date with new agricultural techniques and products is also an advantage when adapting to climate change. The farm uses **algae products** for better rooting of the main crops. Especially in dry years, this increases the farm's resilience.

4.1.5. Agrotechnology and a carefully selected crop structure in Haage · ESTONIA

CROPS ASSESSED: winter soft wheat, spring barley, winter rapeseed, broad bean, field bean.



At the end of our trip through the European arable lands, we arrive to the northernmost location assessed within the frame of this project, the Tartumaa County in Estonia. We are now in Haage, looking at a rainfed intensive cereal, oilseed and protein crop farm of 1510 ha of Utilised Agricultural Area (UAA). The company was founded in 1993 as a mixed production farm (animal husbandry and crop production), but in the middle of 2015, the farmer decided to end the livestock business. Their main crops are winter soft wheat, spring barley, winter rapeseed and broad bean; about 10% of the UAA is under permanent grassland and about the same proportion under temporary grassland. The majority of the

fields have light sandy/loamy soil (867 ha), with some clay-sand (390 ha) and other types (sand/loam 30 ha, sand 85 ha and peat 140 ha). In 26% of the farm there are hydromorphic issues, whereas only less than 2% has remained without drainage system. The risk of erosion is low, except for some wind erosion taking place in dry autumns (20% of the years) and, to a lesser extent, water erosion occasioned by heavy rains.

Main Agro-Climatic Indicators (ACIs), projections in the near future (NF) and impact

No	ACIs	CALENDAR												NF
		01	02	03	04	05	06	07	08	09	10	11	12	
01.	PRECIPITATIONS													
02.	AVERAGE TEMPERATURE													
03.	LATE FROST													
04.	T MAX > 30°C (No of days)													
05.	WATER DEFICIT (P-ETP)													
06.	STRONG RAINFALLS (possibility of hail)													
07.	STRONG RAINFALLS (possibility of hail)													

IMPACTS ON CROPS:

- ACIs 1, 6 and 7: significant loss of quality, lodging, yield loss and interruptions in harvesting. Also hampering of sowing.
- ACI 2: deficiency of snow cover and exposure of the plants to occasional frost spells. Frost damage during 2-3 leaf and tillering phases.
- ACI 3: frost damage in spring cereals.
- ACIs 4 and 5: affects negatively heading and grain filling phases in winter cereals, and tillering phase in spring cereals.
- ACI 1: significant loss of quality, yield loss and interruptions in harvesting. Also hampering of sowing.
- ACI 2: deficiency of snow cover and exposure of the plants to occasional frost spells. Frost damage.
- ACIs 6 and 7: damage due to hail and strong rainfall, shattering of the pods and crop failure.
- ACIs 1, 6 and 7: significant loss of quality, yield loss and interruptions in harvesting.
- ACIs 4 and 5: lack of fertilisation. Yield and quality loss.
- ACI 2: deficiency of snow cover and exposure of the plants to occasional frost spells. Frost damage.
- ACIs 6 and 7: challenges regarding sowing.

The climatic conditions of the zone are extremely variable, which makes it difficult to make all-round correct management decisions to secure the yields. Snowless winters coinciding with strong winter frosts or freeze-thaw cycles may threaten the viability of the vegetation as well as the yield and the profitability of the production. Apart from that, the main regional vulnerabilities are drought and excessive precipitation. For instance, the field bean crop has failed in several consecutive years: in 2017 due to continuous precipitation (+172% of the norm) and in 2018 because of summer drought (precipitation -62% of the norm). Even though rising temperatures and a longer vegetation period may bring some advantages in yield quantity or quality, risks are higher due to the increasing variability and unpredictability of the weather. Regarding the potential yield variations, these are of $\pm 68\%$ for spring barley, $\pm 65\%$ for winter soft wheat, $\pm 41\%$ for spring field bean, $\pm 200\%$ for winter rapeseed and $\pm 47\%$ for spring rapeseed... so the scenario in northern Europe is very uncertain!

But with difficult situations come creative solutions... and so are the ones being implemented by this farmer.



IMAGE 24. Harvesting cereal. Source: Enn Lauringson.



First of all, special attention is being given to the **optimisation of crop structure** in order to avoid excessive winter crop surface, which may cause delayed sowing and consequently immaturity of plants that grow over the winter, or harvest overlaps. In this sense, a **late-maturing spring barley variety** has been introduced to use the harvest window after the spring wheat.

Regarding harvesting again, the selection of **varieties characterised by stem lodging resistance** is of great importance for this farm, as well as **varieties with higher resistance to pre-harvest sprouting within the head**. Other great initiatives are **improvements on the technology** used, for example by employing track or half-track harvesters (which are better suited for wet terrain and reduce soil compaction); or optimising the grain-drying process to allow the utilisation of short breaks between long rain periods. Overall efficiency can be increased as well by equipping the harvesters with precision agriculture tools (yield mapping) and increasing the harvesting capacity (e.g. changing into more efficient rotor harvesters).

As we have already seen in other case studies, this farmer is also implementing **late sowing** (for winter crops) and **early sowing** (for spring crops) to avoid the overgrowth of overwintering plants or shortening the growth period and heat stress in spring crops. Therefore, an optimal proportion of winter and spring crops has to be maintained, to keep the surface manageable by the available technical capacity.

Another adaptation measure implemented in this farm is the **diversification of crops and selection of new crops/varieties better adapted to climate change**. For example, rye is more suitable for lighter soils for its stronger root system and novel hybrids have shown good productivity and may be used instead of wheat if marketing conditions so afford. Also, the selection of different and earlier varieties of field beans in order to diversify risk is being implemented. In regions vulnerable to drought, winter rapeseed may be replaced by turnip rape, which is less productive but faster in development, escaping therefore the critical summer drought.



IMAGE 25. Faba bean field. Excellent crop for nitrogen fixation in the soil. Source: Enn Lauringson.

Talking about heat stress (temperatures above 25 °C), careful consideration is given to **reduce the exposure of crops to additional abiotic stressors** such as growth regulators and other agrochemicals (e.g. pesticides). If the product must be applied either way, the process takes place at night.

Improving or adjusting sowing technology is also giving its benefits. In the case of field beans, a deeper sowing in light soil (7–8 cm depth) is helping by improving the use of soil moisture and developing a more vigorous root system. Also, the optimisation of pre-winter agrotechnology to achieve stronger plants in winter rapeseed (e.g. Horsch Focus) is providing the seeding furrow with optimal shape to reinforce better viability in winter.

The **optimisation in the use of fertilisers, growth regulators and biostimulants** must also be considered to provide healthy plants and fertile soils with higher buffering capacity for adverse weather conditions. For example, in the case of plant biostimulators, special care is being given to their application in cereals, since they prolong their growth phase, which may endanger the plants during the drought period. In the case of growth regulators and pod sealants, those are being applied in winter rapeseed to reduce winter damage (fungal diseases) and increase plant resistance.

Finally, overall efficiency is being increased by **equipping machinery with precision agriculture tools** (yield mapping, GPS sprayers and fertilisation by nutrient requirements indicated in digital soil maps, among others). Crop sprayers are especially beneficial to avoid spills and excessive dosage and consequent damages (e.g. lodging).





4.2. PERMANENT CROPS: VINEYARDS

Permanent crops are a long-term investment. Once the main crop is established, it normally takes several years before it becomes productive, and some more years until production reaches its peak. You may think that adaptation measures will not be as dynamic as in arable crops due to the lack of crop diversity within the system. However, there are plenty of possibilities for soil sustainability, pest, nutrient and water management. Besides, secondary crops may also be grown between the rows of the main crops, acting as green covers, catch crops or green manure, apart from providing new sources of income (e.g. fodder production).



4.2.1. Quality winemaking and soil care, the best bet to adapt to climate change in Terres dels Alforins · SPAIN

CROPS ASSESSED: vineyards.



We are going back to Spain to address permanent crops. Let us greet the farmer at Los Frailes, a farm located in Terres dels Alforins (Valencia), a family business which includes 130 ha of organic vineyards and a winery. 400 tones of grapes per year are produced at 700 m of altitude, with just 450 mm of rain per year and not a single hectare irrigated. The farm consists of mainly small and medium plots with the following varieties: Monastrell 60 ha, Cabernet Sauvignon 25 ha, Garnacha tintorera 15 ha, Marselan 20 ha, Sauvignon Blanc 3 ha, Viognier 1 ha, Muscat 2 ha and Verdil 1 ha. This location still offers good conditions for grapevines (cold winters, moderate summers), but it is very close to other areas which are becoming critical for wine production. Luckily, the new generation in charge of the farm is very concerned about soil management and climate evolution, and of course on how to deal with changes.

In this area, variations in precipitations are very high and winter recharge (rainfall during autumn-winter-early spring) becomes critical to ensuring good yields. Summers are becoming warmer as well, with more days with maximum temperatures above 35 °C, which is also critical for yields (quantity and quality).

Main Agro-Climatic Indicators (ACIs), projections in the near future (NF) and impact														
No	ACIs	CALENDAR												NF
		01	02	03	04	05	06	07	08	09	10	11	12	
01.	HELIOTERMIC INDEX (HI)													6%
02.	COOL NIGHT INDEX (CI)													7%
03.	WATER DEFICIT (P-ETP)													20%
04.	HEAT WAVES (No of days T max > 35 °C)													6%
05.	LATE FROSTS (No of days T min < 0 °C)													-

IMPACTS ON CROPS:



- ACI 1: overripening of grapes, earlier ripening dates. It may lead to changes in the type of viticulture and varieties suitable for the area.
- ACI 2: may influence negatively color and aroma of the grapes.
- ACI 3: quality and ripening potential may be compromised.
- ACI 4: decouples technological (sugar) and polyphenolic (aroma) maturity of grapes.
- ACI 5: affects quality and production.

In this area, as in many wine areas in the World, there are two approaches to farming: one is to produce large quantities of grapes to be sold to wineries, and the other is to produce for your own processing. In the first case, the priority is set on obtaining very high yields to have the best possible revenues. In the second case, the goal is to produce high quality material to work with, and quantity is not that critical. Los Frailes decided to take the second route, and their bet for organic and biodynamic production more than a decade ago is proof of it. The good news is that this decision was not only the wiser to become differentiated in the market, but also in terms of climate change adaptation. When the vineyard is not forced to have high yields, the system's vulnerability decreases and the revenues coming from high quality wine are able to support this management system.



IMAGE 26. Vineyard Los Frailes. Source: FGN.



First of all, more than 50% of their vines are **local varieties** (e.g. Monastrell, Garnacha tintorera, Verdil) which have shown in the yield records of the last decade to behave like long-distance runners: they are not super productive, but they are much more stable even in the worst years. Funnily enough, Los Frailes also has 20 ha of Marselan, a natural crossbreed between Cabernet Sauvignon and Garnacha coming from Mediterranean areas in the south of France, that have perfectly adapted to this climate and perform like the native ones. This demonstrates that both local varieties and **others coming from similar areas** are good options for farmers.

The vine management is also of great importance. That is why they perform **green pruning** during the growth phase to balance the rate fruit-to-leaf, as well as **thinning of the bunches** to control production and adjust it to the physiologic possibilities of the plants, which vary from year to year. The **management of the canopy** also has a role, which is controlling in each moment the amount of radiation getting to the grapes as well as the temperature. This means for some varieties preserving their traditional way of growing (goblet-bush) or adjusting how they grow in the trellises (i.e. not using the last wire to let the canopy hang and shade the grapes). In other farms, the **application of kaolinite** to reduce high temperatures (and reducing green mosquito damages) has also been successful. Either way, all these options entail higher production costs due to the manpower needed on account of the lack of mechanisation, but they are worth it to get a high-quality production.

Regarding the management of the soil, their main concern, Los Frailes carried out a study in the farm to understand better the characteristics and challenges of their soils. From this moment on, the increase of organic matter and the biological revitalisation of the soil has been their priority. In such Mediterranean conditions and in the case of rainfed vineyards, the balance of organic matter may easily be negative: low input of organic materials, low humidity, limited possibilities of installing cover crops due to water competition... This is why Miguel and María José use different strategies, all aiming at balancing gain and loss of organic matter: **sheep grazing** on the vineyard in winter, applying **compost from sheep bed and winery leftovers**, trying **composting crop residues** (vine canes) with other local resources, implementing spontaneous **winter cover crops** and testing sown cover crops. From a climatic approach, such soils are much more resilient to temperature changes, have the capacity of holding more water in the long term, are better prepared to face diseases coming from stressful conditions and, of course, offer a better nutrition to the plants. Also, this year they will conduct a study about halting macro and micro erosion processes that can wash off, in a single day of heavy rain, all the fertility gained in years.



IMAGE 27. Winter cover crop in a vineyard.
Source: FGN.

According to Los Frailes and other wineries in Terres dels Alforins, the **winemaking** process also offers some possibilities for adaptation. There is actually a thin line between standard winemaking processes which have evolved to produce better wines (e.g. colder maceration, which increases the aromatic profile) to more advanced ones (e.g. pH correction using cation exchange resins, use of yeast strains) that allow for adaption of the wine profile and reduce the effects of climatic factors. How far each winery goes in this direction is a personal choice. Quality wine makers, as seen above, have more chances to get to the winery with a good quality must and do not fear offering to consumers wines that naturally change from year to year. Finally, winemakers are aware that consumers' preferences change over the years. In that sense, **changes in the type of wine** may offer some flexibility. For example, in a scenario where the alcohol content of red wines may increase due to new climate conditions, an early harvest increases acidity and makes the wine much more drinkable.



IMAGE 28. Compost from sheep bed and winery leftovers.
Source: FGN.



IMAGE 29. Detail of compost. Source: FGN.

4.2.2. Mulch, compost and decision support tools on the Höri peninsula · GERMANY

CROPS ASSESSED: vineyards.




A vineyard farmer opens the doors and lets us in. He manages a conventional farm of 5.5 ha in the district of Constance/Baden-Württemberg (his plots are located on the Höri peninsula) where grapevines are grown and his own wine is produced. The farm lies at an altitude of 450 m above sea level and has a yearly average precipitation of 912 mm.

The farm is already suffering from low precipitation, severe droughts and an increase in temperatures. Especially problematic are 1.3 ha of his land where there is a gravelly subsoil with very poor water retention. On that

site, the vines are sometimes irrigated using a water barrel connected to a hose system. In 2018 he lost about five tons of grape mass within three weeks due to severe drought. He was very surprised about the speed and the extent of the loss. This gives us an idea of the consequences that weather-related changes may bring to this area.

What strategy is the farm following? A warmer climate with less precipitations is actually calling for an improved water storage capacity of the soil and a much more efficient irrigation system, which should include decision support tools for irrigation.

Main Agro-Climatic Indicators (ACIs), projections in the near future (NF) and impacts														
No	ACIs	CALENDAR												NF
		01	02	03	04	05	06	07	08	09	10	11	12	
01.	HELIOTERMIC INDEX (HI)													29%
02.	AVERAGE TEMPERATURE													25%
03.	PRECIPITATIONS													9%
04.	LATE FROSTS (No of days T min < 0 °C)													6%
CROP IMPACTS:  ACI 1: overripening of grapes, earlier ripening dates. It may lead to changes in viticulture management and varieties suitable for the area. ACI 2: higher risk of weed, pest and disease pressure. ACI 3: quality and ripening potential may be compromised. ACI 4: affects quality and production.														



To improve the water-retaining capacity of the soil, **compost** is applied every year to increase the organic matter content. A **mulch layer between** rows, made of landscape maintenance material, is also helping to reduce water evaporation and to prevent excessive soil radiation (which could increase the temperature at surface level).

To avoid repeating the losses of 2018, **tensiometers** are being used to measure soil moisture, so that the farmer can react in time during drought periods and provide the vines with sufficient water.

The farm is also considering growing **new grape varieties with late burst of buds** (e.g. Sauvignon Gris) in order to avoid the impacts of late frost; **late season varieties** (e.g. Cabernet Sauvignon and Cabernet Franc) to reduce the impact of heat stress during the summer in the last stages of the grapevines; or **varieties better suited to warmer climates**.



IMAGE 30. Cabernet sauvignon. Source: Pixabay.

A **delay in pruning** is also being considered to delay grape ripening and preventing the heat stress impact during the summer on the almost-ready-to-harvest clusters. A delay of one week in the pruning date performed after bud burst/break delays ripening by one week.

Different types of frost protection measures, such as **frost-protection candles** or **mobile gas turbines** are also suitable to reduce the risk of late frosts.



4.3. LIVESTOCK FARMS: DAIRY AND MEAT FARMS

On livestock farms there are different approaches for sustainable adaptation to climate change. On the one hand, improving directly the health and comfort of the animals can be translated into more milk/meat production: proper ventilation, improved hygiene or better quality fodder, among many others, are factors that have a direct impact on them. On the other hand, most of the farmers also rely on producing their own fodder; and it is in this second approach where they are able to implement sustainable adaptation measures, more related to arable crops production than livestock farming, that will have an enormous influence in the farm's resilience.




4.3.1. Improving sustainability in dairy farms while becoming more resilient · SPAIN

FARM SYSTEM ASSESSED: dairy cattle.



European dairy farmers have seen in the past years big changes. For the younger generations, this business has nothing to do with what their parents managed, and it will probably be very different in a few years. Climate change projections are an added difficulty for this sector. Fundación Global Nature is cooperating with one of the most important dairy companies in Spain: Calidad Pascual. This company sources milk from 330 small and medium farmers, in most cases family businesses with a long relationship built over the last 30 years. Average number of animals per farm is 120 (from 27 to 851), and production ranges from 6000 to 14,000 kg/year/cow. A few years ago, Calidad Pascual decided to launch a program to extend the concept of quality beyond the milk itself. It covers efficient transport but also protein efficiency and animal welfare... the latest phase being an ambitious sourcing protocol to mitigate impact at

farm level that covers aspects such as food self-sufficiency, sustainable agriculture, biodiversity, water management, energy and climate change. At the time of writing, this protocol is already established in 100% of the farms. Funnily enough, what was initially foreseen as an opportunity to promote sustainability, was found to be an interesting pathway also to explore adaptation options.

Main Agro-Climatic Indicators (ACIs), projections in the near future (NF) and impact														
No	ACIs	CALENDAR												NF
		01	02	03	04	05	06	07	08	09	10	11	12	
01.	FODDER PRODUCTION SELF-SUFFICIENCY													-
02.	GRAIN PRODUCTION SELF-SUFFICIENCY													-
03.	ANIMAL THERMAL COMFORT													-
<div><p>IMPACTS ON FARMING SYSTEM (EXCLUDING ACIS SPECIFIC TO CEREALS AND FODDER):</p><p>ACI 1: explains economic autonomy in one of the most vulnerable agricultural productions under Mediterranean conditions. May entail significant additional expenses in adverse years.</p><p>ACI 2: same as above, although less critical due to easier access to markets even in adverse years.</p><p>ACI 3: direct impact on milk production, may also have an impact on quality.</p></div>														

In terms of climate change, dairy farmers have to face two kinds of challenges. On the one hand, they are agricultural producers (grains and fodder), so they have to face the same uncertainties than other farmers. But on the other hand, they have to consider other specific challenges related to feed production and animals' stress conditions. Six farms in different climatic scenarios (from dry Mediterranean to Atlantic conditions) were analysed. For all of them, we could assess agricultural production, animal housing conditions and a complete 10-year register of daily milk production.

Regarding the agricultural challenges, fodder system resilience is critical, especially for farms in drier climates. Producing fodder requires, in most cases, having irrigated land, which is not always accessible. Increasingly adverse climate conditions (higher

temperatures, less rainfall) will demand more water in scenarios in which it may not be available. However, these Mediterranean farms have high levels of self-sufficiency in terms of concentrated production. Unfortunately, this is not a big advantage as, even in adverse years, grain purchase is still affordable for farmers, while fodder is even more expensive when things go wrong and is also more expensive to transport.

Regarding animal welfare, there is a common agreement among farmers that heat waves decrease milk production. For these reasons, all the farms assessed have active ventilation (fans), which, in some cases, mean a significant energy cost in the summer months. However, measuring the real impact of heat waves in milk production is challenging, as the milked animals in farms change from week to week, as do other conditions that may affect production (e.g. ration composition). The challenge was also to find patterns to correlate milk quality and THI levels. For this, the farms in more critical conditions (less convenient design of barns) were selected, as well as the periods in which THI was higher and there were peaks in T max (seven-year period with daily data). Considering these periods and then milk quantity (litres) and quality parameters (fat and protein content, dry fat content, somatic cell count, solid-non-fat content), correlations were tried. Although farmers assert that heat stress periods result in lower milk production, no correlation was found (due to the above-mentioned aspects). In terms of quality, mild correlations (but not exhaustively explored) were found in some situations with fat content and with solid-non-fat content.

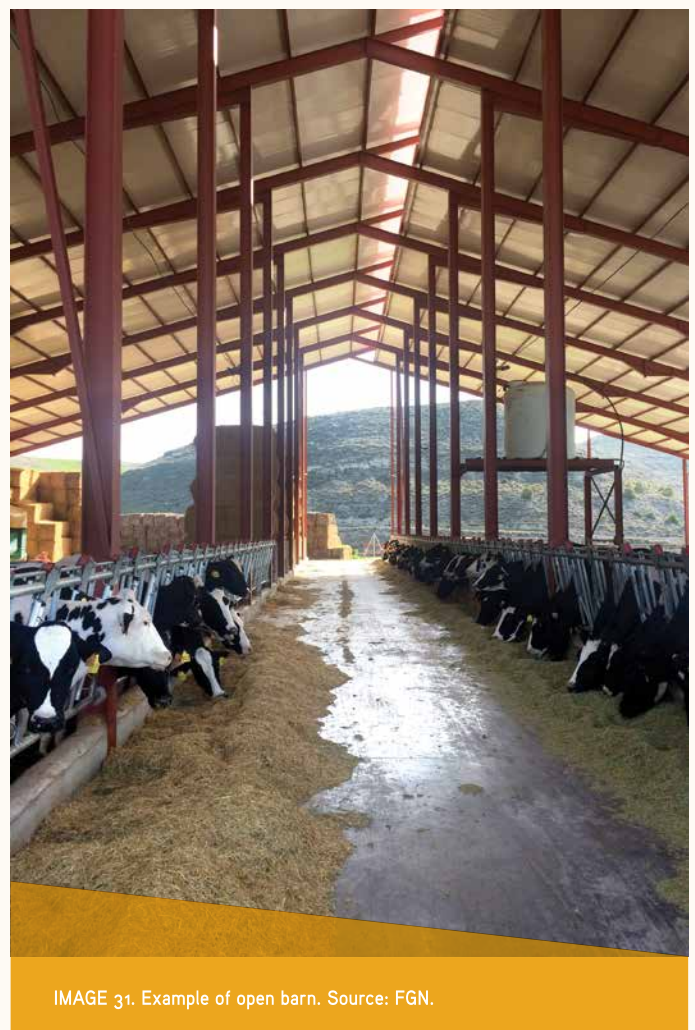


IMAGE 31. Example of open barn. Source: FGN.



In regard to adaptation options, thermal stress is, surprisingly, a simple option in technical terms, but with some limitations when it comes to its implementation. The new generations that are taking over have invested in new facilities for the animals. Barns are not closed anymore, but are designed as high structures (eight meters) completely open in the four directions. Straw bales and other removable barriers can be used to prevent cold winds in winter, but they have realised that ensuring **passive ventilation** is a must and that addressing heat waves is of higher priority under this climate than cold winds. Such structures reduce thermal stress significantly, according to three of the farmers that invested in new barns, but they mean a huge investment that is not always feasible. **Flexible structures that can be opened or closed** are also a good option if a complete refurbishment is not possible. **Insulation of roofs and shading some barn areas** has also proven to be effective. Active ventilation is a solution implemented in most farms, but energy consumption may increase and works against farm competitiveness (up to 220€/month in one of the farms assessed, fans running 24/7 from May to September). **Animal density in barns** is also a key aspect that contributes to reduce animals' stress. In other arid countries, **water sprayers** have been used to increase animal comfort, although not in these pilots. With a little experience, a good proxy to assessing animal comfort is the smell of urine in the barn. In warm days, an excess of ammonia odour indicates bad ventilation and/or high density of animals. The **accessibility of the drinking points** is another important adaptation option. This means not only having enough of them, but also wisely distributed, to allow non-dominant animals to drink. Under heat waves, water consumption increases to keep animals' comfort at a certain level—by giving them more water or making accessing it easier—thus partially counteracting the reduction in milk production present during summer due to climatic stress. **Genetic improvement** is also a longer-term option, and several studies with Frisian breed (the most used) show significant differences in heat stress sensitivity.



IMAGE 32. Passive ventilation example. Source: Calidad Pascual.



IMAGE 33. Silage barley. Source: FGN.

Regarding feed vulnerability, the discussions with farmers revolved mainly around fodder production and **greater fodder autonomy**, which were perceived by farmers as much more critical issues than grain production. In many places, fodder production is linked to irrigation. Rainfed fodder production and richer rotation in such conditions raised more interest. **Double-purpose grain crops** was, at least in one of the farms assessed, a good solution. Barley can be harvested for silage if other fodder production is at risk, or can be kept for grain if the farmer has enough. In Atlantic areas, with more suitable conditions for fodder production, the challenge was to **diversify production**, clearly dominated by maize for silage, which yields high

amounts but entails a risk of being the single fodder source in some cases. Some good examples were found in maize for silage, which was combined with grass and peas for silage, or even the production of alfalfa grown under rainfed conditions (with lower yields than irrigated but still allowing an excellent source of fresh fodder or the possibility of using it for silage). Almost all the pilot farms had **good silage techniques and facilities**, as this point is critical to improve autonomy. **Adjustments of the rations** are also in the spotlight. Nutritionists from Calidad Pascual developed an ambitious program to improve protein efficiency and foresee the potential of reducing thermal stress by changing ration composition and balancing fibre, fat and protein content on rations to reduce excess temperature from digestion during heat waves.

Finally, **improved insurance models** to cover the impacts of climate change, which are beginning to be known, are demanded by the sector. A system with an objective assessment system, thresholds for critical climate events and measurable impact would allow farmers to cover exceptional climate events that affect their agricultural production and animal welfare.

4.3.2. Grazing management plan and Keyline Design in El Baldío · SPAIN

DEHESA: extensive livestock in an agroforestry system with natural grasslands.



Still in Spain, it is time to assess the issues regarding climate change found in an extensive system. We travel to Talaván, a village located in the region of Extremadura, in the west of Spain. Here, Fundación Global Nature owns a dehesa of 232 ha. It is used for extensive livestock production of local cattle and sheep breeds. The farm has a very healthy oak open forest but very poor soil, with a high percentage of bare soil, which means high risk of erosion and a low water holding capacity.

The main climate change challenges affecting this farm are droughts, fewer number of rain days, desertification, soil degradation, extreme temperatures (heat waves), more frequent pests and disease attacks and biodiversity loss due to the increasingly extreme conditions.



IMAGE 34. Blanca Cacereña cows, El Baldío. Source: FGN.

According to these projections, sustainable adaptation measures to climate change are clearly needed. Resulting from the climate risk assessment performed for this farm in the frame of the project, a set of adaptation measures was proposed and some of them are already being implemented.

Main Agro-Climatic Indicators (ACIs), projections in the near future (NF) and impact

No	ACIs	CALENDAR												NF
		01	02	03	04	05	06	07	08	09	10	11	12	
01.	PRECIPITATION < 159mm													↑ 5%
02.	PRECIPITATION < 97mm													↑ 18%
03.	PRECIPITATION < 25mm													↑ 21%
04.	DROUGHT PERIODS (no sequences of 12 days without precipitation)													↑ 30%
05.	AVERAGE TEMPERATURE < 8°C													↓ 12%

IMPACTS ON GRASSLAND PRODUCTION:



ACI 1: affects autumn grassland growth which means 25% of annual production.

ACIs 2 and 3: affect spring grassland growth, which involves 75% of annual production. The growing season for grasslands is going to be reduced due to the combination of lower rainfall and higher temperatures.



ACI 4: affects grassland quality. Legumes need periodic rainfall for proper growth due to their roots being very superficial—the top of the soil should be moist.

ACI 5: affects grassland production increasing the quantity, but decreasing the quality due to the vernalisation of legumes.

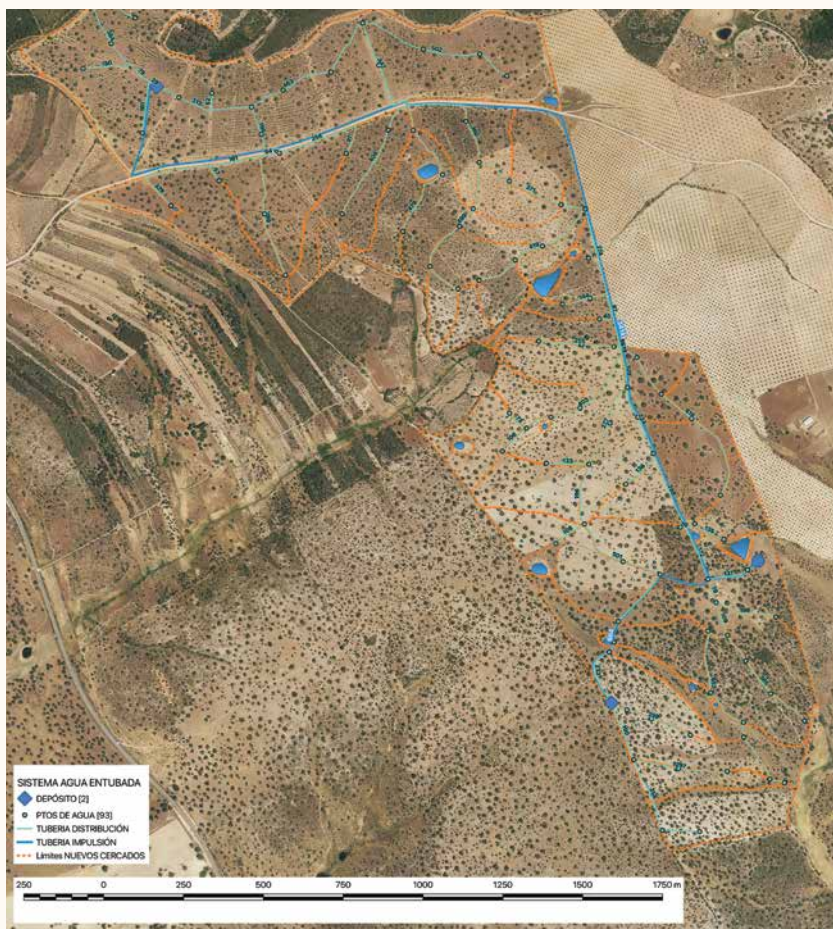


IMAGE 35. Paddock system and water point design for El Baldio. Source: FGN.

One of the first measures to have been adopted was ensuring a better soil performance and water cycle through a **Keyline Design**.

Keyline Design is a landscaping technique to maximise the use of water resources at farm level. The central idea behind Keyline Design is to capture water at the highest possible elevation and distribute it to the drier parts by using gravity. The goal is to maximise the time that water remains in the farm by evenly distributing it and avoiding rapid loss by run-off. This design is based on an exhaustive topographic analysis and its implementation is based on precise plough lines performed with specific equipment—Yeoman's plough, a subsoiler with very thin and straight shanks.

Secondly, an **improved grazing management plan** has been adopted as well—a plan focused on reducing the size of the plots where the animals feed and rest (more paddocks) and the time they remain there. These shorter grazing periods in a smaller surface ensure a very high impact on grasslands but in a very short period of time, which brings along a better grass response, less disease problems (parasites mostly require seven days to complete their life cycle) and has a positive impact on the animals (i.e. less compaction). Also, enough recovery time is provided to all plots after the grazing period.

4.3.3. Fodder sorghum, fodder meslin and a focus on dairy cattle for adaptation · FRANCE

SYSTEM ASSESSED: dairy cattle, beef cattle, fodder and grain production,



CATTLE



CEREALS



MAIZE



GRASSLANDS

From Spain we travel north again to the south-west of France. Mr. Assemat and his son own a cattle farm of 360 ha of UAA. At the moment, they raise 240 dairy cows (producing 23 million litres of milk per year) and 80 beef cows. Apart from their 145 ha of permanent grasslands, they perform crop rotations in the rest of the area with irrigated silage maize (80 ha), meslin (60 ha), soft wheat (60 ha) and temporary grasslands (35 ha). They use annually 2000 m³/ha of water for silage maize irrigation, which adds up to 170,000 m³ in total. They are 100% self-sufficient regarding fodder production, and they operate under a conventional farming system. Recently, a biogas plant has also been implemented to diversify the farm's income and valorise energy created from livestock manure.

Once again, as a result of climate change, the climate projections (time horizon 2035) used to support the climate risk assessment show that the farm is going to suffer from lower precipitations (-6% per year and a decrease of 66



IMAGE 36. Biogas plant. Source: Solagro.

mm during summer), higher temperatures (+0.3 °C every decade for annual temperature, average temperature of about 20 °C during summer), higher water deficit (+24%) and more frequent heat waves (the number of days above 25 °C per year is expected to double).

Main Agro-Climatic Indicators (ACIs), projections in the near future (NF) and impact

No	ACIs	CALENDAR												NF
		01	02	03	04	05	06	07	08	09	10	11	12	
01.	WATER DEFICIT (P-ETP)													↑ 22%
02.	T MAX > 25°C (No of days)													↑ 67%
03.	T MAX > 32° C (No of days)													↑ 167%
04.	PRECIPITATIONS IN SPRING													↓ 15%
05.	THI STRESS (no of days per year)													↑ 68%



IMPACTS ON CROPS AND LIVESTOCK:

ACIs 1, 2 and 4: earlier ripening, less biomass, smaller seeds and lower yields.



ACIs 1, 3 and 4: flowering, grain development and grain filling phases may be compromised.



ACIs 1 and 4: grass production may drop by 10%.

ACIs 2 and 3: limiting their growth during the summer.



ACI 5: THI corresponds to the thermal stress induced by high temperatures, which means less milk production and a possible degradation of the milk's quality.



The trend of quantity of fodder biomass produced annually from permanent and temporary grasslands is going to decrease in the near future, mostly due to climate stress during the spring-summer period. That is why one of the adaptation measures being considered is to **stop raising beef cattle** and, with that reduction in the number of cows, being able to feed dairy cows better by increasing the proportion of pasture in their diets. With the increasing variability in fodder quality due to climate disruptions, the farmers can now valorise it for energy (biogas plant) when its quality is not enough to feed the animals. Furthermore, strategies to avoid bare soil are developed at the farm by implementing cover crops for energy valorisation, which at the same time protect the soil from erosion and improve its fertility.

Taking also into consideration the problems derived from the high water needs of silage maize, the farmer is thinking about **introducing sorghum** for silage and gradually substitute maize for this less water-demanding crop. Also, less surface of maize will ensure that the farm has enough water in the future for irrigation, thus better meeting the needs of cereal crops, achieving sufficient yields and being less dependent from external feedstuff purchases.

When talking about animal nutrition and milk/beef yields, protein is a key factor. **Therefore, substituting soft wheat by meslin** (with a higher protein content) will ensure better nutrition with less amount of food.

Regarding the deterioration trend of cows' thermal comfort due to the increase in heatwave frequency (THI, Temperature-Humidity Index), it has been decided to improve the building's ventilation through **air brewers or fans** and even **fog systems** to reduce the impact on livestock (loss of milk, fertility failure), especially since the price of milk is higher in summer. Similarly, the farmers will pay more attention to the management of the herd during these critical periods (feeding at night and adapting the diet's energy content).



IMAGE 37. Dairy cow. Source: Solagro.

4.3.4. Improved comfort and more sustainable fodder production in the Bodenseekreis · GERMANY

SYSTEM ASSESSED: dairy cattle, fodder production and breeding.



CATTLE



CEREALS



MAIZE



GRASSLANDS

We are heading to Germany for the last time on this journey, to a farm situated in the district of the Bodenseekreis about 460 m above sea level. The focus of this farm is on dairy cattle farming and breeding on 100 ha of UAA. There are about 115 dairy cows (Fleckvieh breed) on the farm and the average milk production is about 8600 litres of milk/cow/year. The whole UAA is used for fodder production and the soil is covered nearly year-round. The crop rotation performed is (in order): maize for silage, winter wheat and winter barley; growing one variety per cereal crop and several maize varieties. The farm has a low erosion risk, a good water storing capacity and a medium to high organic matter content. 40% of the UAA is ploughed (before maize) and the rest of the UAA (including catch crops) is managed with reduced tillage (cultivator and disc harrow). 25% of the farm includes boggy grasslands, the rest of the land mostly being sandy/loamy deep soil.



IMAGE 38. Calf being fed in the farm Markus Ziegler. Source: Lake Constance Foundation.

Main Agro-Climatic Indicators (ACIs), projections in the near future (NF) and impacts

No	ACIs	CALENDAR												NF
		01	02	03	04	05	06	07	08	09	10	11	12	
01.	WATER DEFICIT (P-ETP)													↑ 132-160%
02.	T MAX > 25°C (No of days)													↑ 70%
03.	T MAX > 28°C (No of days)													↑ 122%
04.	AVERAGE TEMPERATURE													↑ 17%
05.	PRECIPITATIONS													↓ 8-15%
06.	THI OF MEDIUM STRESS (No of days)													↑ 325% 9 days



IMPACTS ON CROPS AND LIVESTOCK:

ACIs 1 and 2: earlier ripening, smaller seeds and lower yields.

ACI 4: extension of growth period, but also increase in pest, disease and weed pressure.



ACIs 1, 3 and 5: flowering, grain development and grain filling phases may be compromised.

ACI 4: extension of growth period, but also increase in pest, disease and weed pressure.



ACIs 1, 3 and 5: affect growth negatively and even cause failure of cuttings.

ACI 4: extension of growth period, but also increase of pest, disease and weed pressure.



ACI 6: more stress due to high temperatures, resulting in lower milk production.

Since 2017, the farm has added another income pillar through direct marketing in a self-service machine. In it, they offer different products for the clients (milk, sausages, meat, honey, eggs...). The main climate challenges for the farm are the increase of the yearly average temperature, the increase in days over 25 °C and the decrease of water balance (P-ETP).).



In order to deal with these impacts, the farmer is thinking of introducing **clover grass** to widen the crop rotation, which has a positive effect on the soil, improving its fertility and organic matter content. Clover grass is also better adapted to the effects of climate change in the region, which could improve the resilience of the farm.

An **extension of the reduced tillage** on the farm could help protect the soil structure and soil microorganisms and improve the water-storing capacity. Some of the driest pasture areas have been **sown or reseeded with drought-tolerant species and varieties**.

Another adaptation measure implemented at farm level has been the **use of drought-tolerant and early-ripening cereal varieties**, to avoid heat stress in July and August. This measure has been accompanied by the earlier sowing of maize in spring and the use of **late-ripening varieties** to help the crop cope with heat and water stress during the summer, avoiding the impact of this stress during their most vulnerable stages.



IMAGE 39. More ventilators. Source: AgriAdapt.

Regarding the comfort of the cattle, the installation of **more ventilators** for the dairy cows and young cattle and sprinklers—in the barn and outside the milking parlour—could help in reduce the heat stress of the animals. **More outdoor area and pastures to graze on** will be provided, as well as **additional mineral feed** (+20%) and salt for the **cattle** during heat periods.

4.3.5. New barn and higher stock density in Valgamaa Region • ESTONIA

SYSTEM ASSESSED: beef cattle.



We have reached our last destination in this journey. Again in Estonia, we visit an organic farm, where they have been raising beef cattle for about twenty years.

Located in the south of Estonia (close to the Latvian border), this 1200-hectare farm includes 600 ha of semi-natural grasslands (100 ha of them within Natura 2000 Network) and 57 ha of forest; it raises 160 Hereford cows (a breed with considerable horns) and 7 horses (draught animals). Most of the lands are located in the Koiva-Mustjõe Landscape Protection Area, which is covered by rivers, river-side meadows and forests. The meadows in the protected area are the result of centuries-long mowing and grazing. “The protection of natural areas is our main activity and final goal, being beef production secondary”, states the farmer.



IMAGE 40. Lots of trees and bushes—typical grazing environment for beef cattle. Source: Estonian University of Life Sciences.

After the climate risk assessment was performed, it was found that the main climate change challenges for this farm are going to be related to an increase in the annual average temperature and the increase of the number of hot days. During the spring floods and heavy rainfalls, the river-side meadows become too wet. The specific Agro-Climatic Indicators can be seen in the table below.

Main Agro-Climatic Indicators (ACIs), projections in the near future (NF) and impact														
No	ACIs	CALENDAR												NF
		01	02	03	04	05	06	07	08	09	10	11	12	
01.	AVERAGE TEMPERATURE													14%
02.	T > 25° C (No of days)													11%
03.	DATE OF FIRST GRAZING													5 days earlier
04.	STRONG RAINFALLS													11%
05.	THI													Peaks
<div> IMPACTS ON GRASSLAND AND LIVESTOCK: ACIs 1 and 2: affect growth positively, extending the growth cycle and increasing production. ACI 3: grasslands may start to be grazed earlier, meaning savings in fodder and feedstuff. ACI 4: flooded areas cause a significant loss of yield, interruptions of grazing and harvesting. ACIs 1, 2 and 5: THI values remain stable, but there will be considerable peaks affecting the comfort of the cows and therefore the milk production.</div>														



Due to the more favourable conditions regarding grassland production and the date of the first grazing, they are considering the addition of more cows. The use of a **higher stock density** grazing on a **smaller surface** during a **shorter period of time**, followed by a **longer recovery period** increases the amount of grass produced in pastures, and therefore the quality and productivity of the forage. Better forage recovery also improves root depth and quality, being this system suitable for habitat conservation as well as farm profitability.

The farm increases its fodder storage capacity to be used during long drought periods in the summer. Fodder reserves are also needed more often during spring and autumn when the riverside meadows are affected by heavy rain or floods.

Although temperatures are going to increase in the near future, having a **proper barn** will help keep all animals indoor during winter or during extreme weather conditions, increasing daily weight gain during the winter and, as a consequence, the profitability of the farm. A proper barn will also reduce nutrient leaching into the soil during the winter.

Calving time should be also planned for early spring, when there are not so many horse flies and other ectoparasites.



IMAGE 41. Increased fodder storage capacity. Source: Estonian University of Life Sciences.University of Life Sciences.





05 Conclusions

and Guidance through the Sustainable Adaptation Measures (SAM)

There are many more examples of sustainable adaptation, but the idea is already well founded: sustainable adaptation to climate change in Europe is going to be necessary one way or the other (no matter the region), and it is the duty of the agricultural sector to be ready for that. Firstly, for yield stability; secondly, to contribute to food security worldwide; and lastly, to ensure the continuity of the environment human beings and many other creatures depend on. The farming sector will surely play a key role in facing the economic, social and environmental challenges climate change brings along.

Although there are differences in the way climate change is going to affect each climate risk region in Europe, Sustainable Adaptation Measures tend to be very similar, with small adjustments depending on the region, farm or farming system concerned. This allows for the proposal of plenty of Sustainable Adaptation Measures that can be implemented all over Europe, easing the adaptation process and concentrating efforts.

Basically, Sustainable Adaptation Measures tackle seven crucial components for adaptation: soil management, nutrient management, water management, pest and disease management, yields and profit, risks and animal comfort. The importance of each of these elements is explained below:

- **SOIL MANAGEMENT:** soil plays a key role in plant nutrition, water storage and the health of our crops. Therefore, its structure, organic matter content and biota (beneficial fungi, bacteria or arthropods, among others) must be well cared for. Living soils with a high amount of organic matter can absorb and store water more effectively and are able to offer resistance against certain climate constraints.

- **NUTRIENT MANAGEMENT:** nutrients are essential for plant development. However, soil fertility should not be understood as an isolated factor tackled by the use of chemical fertilisers, but an integrated element in which nutritional needs, organic matter (cover crops, crop residues or organic amendments, among others), soil biota and soil structure work together in plant nutrition.

- **WATER MANAGEMENT:** water is a fundamental, scarce and vulnerable resource. Due to climate change and the increasing demand of water for human and industrial consumption, the improvement of farming systems to be less water-dependent will be of great importance. Water management is not just about irrigation. Techniques to reduce water needs, improve water retention and storage in the soil, and improve water use efficiency will have to be implemented.

- **PEST AND DISEASE MANAGEMENT:** since the “green revolution”, chemical plant protection products were trusted to be the answer for better yields and profit. But the use of chemicals is connected with risks like resistance development by many pests and diseases (with critical outbreaks of pest populations), as well as an important decrease in beneficial fauna (predator and parasitic arthropods, beneficial fungi or birds, among others) due to the very same chemicals meant to act as biological control to prevent any pest or disease from becoming dominant and dangerously affecting the yields. The aim should be to get the plants and farming systems more resistant against pests and diseases through an Integrated Pest Management-IPM.

- **YIELDS AND PROFIT:** due to climate change, extra production costs will be necessary in order to maintain or improve yields. Although almost every adaptation measure will result in the end on better yields or profit (for example, through savings in water, fertilisers or man work, among others), measures specifically destined to improve yields and profit will help greatly.

- **RISKS:** extreme weather conditions, especially during critical growth stages of the crops, may bring along huge yield losses. In this sense, adaptation measures to climate change must also be able to balance these risks and, in case they cannot be sufficiently reduced only through farming adaptation practices, an insurance policy could guarantee economic protection.

- **ANIMAL COMFORT:** thermal stress in livestock also results in lower milk or beef production and a negative health impact. The Thermal-Humidity Index (THI) is the factor measuring the stress of the animal considering temperature and humidity. Every measure destined to lower this stress and increase animal comfort will help with adaptation.

Besides, there is **an eighth component tackled by these Sustainable Adaptation Measures: biodiversity**. Biodiversity can be considered as the number and diversity of organisms sharing an ecosystem (plants, birds, mammals or reptiles; but also small arthropods, fungi, bacteria or even the very same crops we are growing), and it is present in each and every one of the other seven components: better soils ensure more biota associated to our crops, a green cover ensures a higher diversity of organisms, crop diversification introduces more species in the ecosystem, and a higher efficiency in irrigation prevents water bodies from drying out. That is why this eighth element has not been considered as an isolated factor, but an important element integrated within the rest.

The case studies presented in the last chapter include different Sustainable Adaptation Measures. Many more of them can be found on the webpage of the LIFE AgriAdapt project (www.agriadapt.eu), divided into regions and farming systems. It can be consulted very easily or even downloaded in the form of factsheets. The different measures are illustrated in a very practical way, as well as their benefits, the climate risk region of implementation, the meteorological events to which the farm is adapting, the conversion time (long-, mid- or short-term), and the information regarding how these measures can affect several sustainability components (GHG emissions, soil, air quality, water, biodiversity, animal welfare, economic viability, social viability and technical viability).

To give an idea of it, some of the most implemented measures are shown in the table below. It presents the adaptation components of each measure and farming systems in which they can be implemented. As it can be seen, most of the measures tackle several components and can be implemented in more than one farming system.



IMAGE 42. “El Baldío” livestock farm (Spain). An improved pasture with more diversity of species prevents erosion, allows more water to infiltrate into the ground, ensures better animal nutrition and enhances beneficial fauna (pollinators, birds, reptiles, beneficial arthropods, fungi or bacteria, among others). Also, those big oaks provide some shade which can be used by the animals to lower their heat stress and by some of the grassland species in order to keep on growing during the summer in spite of the high temperatures. Biodiversity is the key! Source: FGN.

The farming systems in this table are represented:

- Red for arable crops
- Yellow for permanent crops
- Blue for livestock

MEASURES	SOIL MANAGEMENT	NUTRIENT MANAGEMENT	WATER MANAGEMENT	PEST and DISEASE MANAGEMENT	YIELDS/ PROFIT	Risks	ANIMAL COMFORT	FARMING SYSTEM
Diverse crop rotations								● ●
Increase crop diversification								● ● ●
Multifunctional margins with native vegetation, hedgerows, windbreaks and solitary trees								● ● ●
Cultivation of new crops and varieties coming from similar climatic areas (e.g. soybeans, sunflower)								● ● ●
Use of locally adapted and traditional varieties								● ● ●
Focus on quality instead of quantity								● ● ●
Adaptation of sowing, pruning and harvesting dates								● ● ●
Green pruning to balance leaf and fruit surface								●
Thinning of fruits/bunches								●
Use of catch crops, cover crops, undersowing and ground covers to avoid bare soil								● ● ●
Low tillage								● ● ●
Increase of organic matter applications								● ● ●
Keyline technique								● ● ●
Efficient irrigation systems								● ● ●
Substitution of irrigated crops								● ●
Use of decision support tools								● ● ●
Hail and frost protection (windbreaks, candles)								● ● ●
Taking advantage of new technological improvements								● ● ●
Appropriate density of animals in buildings								●
Improved cooling systems (open barns, ventilators, shading of barns, shelter for animals outdoors)								●
Increase in fodder storage capacity								●
Increase in fodder autonomy								●
Improve accessibility to drinking points								●
Improve grazing management to increase quantity and quality of pastures								●
Genetic improvements (crossbreeding, crosspollinating, grafts)								● ● ●

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