Vulnerability assessment in Southern European pilot farms. LIFE AgriAdapt

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Abstract

With the LIFE AgriAdapt project, the four partner organizations from France, Spain, Germany and Estonia, representative of the four main climate zones in Europe (Atlantic, Southern, Continental and Nordic) illustrate the state of agriculture in Europe. This illustration is done in terms of the current vulnerability to the effects of climate change, how the climate will develop over the next 30 years, and how farms can reduce their future vulnerability through sustainable adaptation measures.

To this end, in Spain, a vulnerability assessment has been developed and is conducted on 32 pilot farms (covering the Southern climate risk regions). The most relevant climate events for the pilot farms are hail and frost days, hydric deficit, droughts and high temperatures. Hail is mainly problematic for permanent crop farms. High temperatures are a problem for all pilot farms, with drought increasing in frequency. In the near future, the days over 30°C in May-June will increase, as well as the number of days with heat stress for cattle and the minimum night temperature. For arable farming and permanent crops, the focus of the sustainable adaptation options is on the improvement of soil structure and fertility. Sustainable adaptation options for livestock focus mainly on the reduction of heat stress and on grazing management plans to increase quantity and quality of pasture in extensive livestock systems.

Introduction

In a context of a solid evidence of climate change with increasing impacts for agriculture, European farmers and advisors from diverse farming organizations are interested in finding out indicators for assessing farms' vulnerability as well as considering options to increase their resilience. Abundant research literature, numerous models and various large-scale evaluations on the long-term climate change impacts on European agriculture exist. However, very little has been done so far for supporting farmers in implementing practical solutions at farm level for halting current impacts and for anticipating the near future ones.

The LIFE AgriAdapt demonstration project, bringing together representatives of the four main climate zones in Europe (Atlantic, Southern, Continental and Nordic), aims at bridging this gap. Over the past two years, Fundación Global Nature (FGN) has realized an adaptation assessment process in more than 30 pilot farms within the Southern Climate Risk Region of Europe. The project methodology has been developed by Solagro and applied by all the partners in their Climate Risk Regions.

The LIFE AgriAdapt project reveals the strong need for specific and local agro-climatic indicators for helping agricultural stakeholders to better understand farm vulnerability better. This first step seems essential to engage them into an adaptation process of their farming practices. As numerous sources of climate projections are now available in Europe, there is a need of capitalising them, in particular by connecting them in a comprehensible way to crop or animal production indicators and to farmers. The AgriAdapt web-tool aims at filling the missing link between climate services or providers and farming sector end-users to facilitate the implementation of adaptation processes.

Material and methods

During the project, FGN has assessed the vulnerability of 32 pilot farms in Spain and has developed farm-specific action plans with sustainable adaptation measures. Throughout the project, the action plans are revised and updated. The results are summarised according to the feasibility of sustainable adaptation measures. Recommendations of sustainable adaptation measures are made for the three main farming systems.

Before the vulnerability assessment, a baseline report was elaborated. The overall effect of climate change, the climate change specific consequences in the four European climate risk regions, as well as its effects on agriculture were described. In parallel, a catalogue of measures was drawn up, listing sustainable adaptation measures for the three farming systems. The sustainability of the measures was assessed by evaluating the synergies with other environmental challenges at farm level, such as greenhouse gases emissions, water, air, soil, biodiversity, etc. Economics, technical feasibility and social aspects were also taken into account. The aim was to make sure that the adaptation options proposed did not contradict such aspects. Furthermore, in order to assess the impact of climatic indicators on different crops, crop passports were compiled. These describe the sensitive phases of the plants and the critical agro-climatic indicators that may have an impact on yields or quality of the yield, which will play an important role during the vulnerability assessment.

The aim of the vulnerability assessment is to raise awareness among farmers on the topic of climate change and its effects, and to reduce agricultural and economic vulnerability to climate change by recommending sustainable adaptation measures. The vulnerability assessment is conducted on farm level and can be used in the four main climate risk regions of the EU. Following farming systems and farms were assessed: Arable, permanents and livestock

The vulnerability assessment includes four steps:

1. What is the current farm vulnerability to climate change? (2000-2016)
2. What is the farm vulnerability to climate change in the near future? (coming 30 years, without adaptation measures)
3. Awareness raising of all possible adaptation options available at farm level
4. Elaboration of an action plan for the sustainable adaptation to climate change

The extent of the vulnerability (risk) of a farm combines the probability of the frequency of occurrence of climatic stress (exposure) with the extent of the consequences (impact), such as yield reduction. The vulnerability is represented by a matrix, which combines exposure and impact. The baseline information for assessment is the yield in the last 10-15 years, which can either be provided by the farm or, when not available, taken from the statistical information. This yield data is evaluated against the climatic records of the last 30 years, the aim being to explore the climatic reasons behind the years with the lowest yields. The ACZ tool (AgroClimaticZone) layouts, developed by the French partners, are able to bring this information together and can represent automatically over 65 agro-climatic indicators for the past and the near future (e.g. precipitation in July/August, number of hot days >30°C in May/June...)

The source of the meteorological data used in the vulnerability assessment is the data portal Agri4Cast of the European Commission. This is the only, to us known, platform which has an easy access to get homogenous meteorological data for the whole of Europe. For the project, we used recorded recent past climatic data and climate projections. The past data is available from 1975 to the last calendar year with a total of 12 climate variables (daily frequency), including the variable of evapotranspiration. Data for the near future (NF) - coming 30 years - is available for climate projections with the SRES scenario A1B and three models. A total of nine climate variables are available for each of these climate models. During the first pilot farm visit, information such as UAA, cultivated crops, livestock, weather events and its effects on the farm was gathered. Then, the vulnerability assessment was conducted. With this assessment, the current and near future vulnerability can be shown for arable crops, livestock and permanent crops. This assessment was shown during the second pilot farm visit, at which possible sustainable adaptation options were discussed with the farmer.

RESULTS AND DISCUSSION

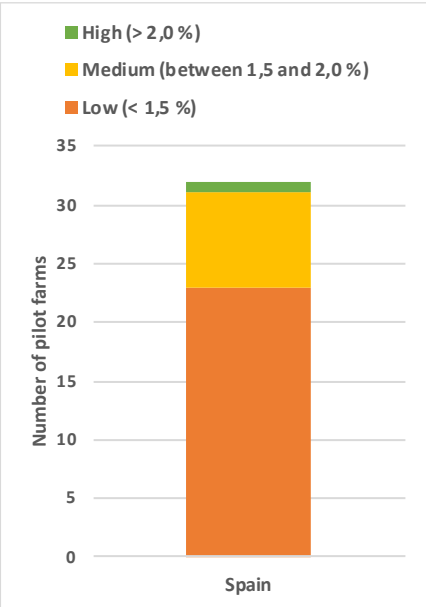
Description of pilot farms

The pilot farms are distributed over the farming systems arable, permanent and livestock. In total there are 32 farms, 26 conventional and 6 organic pilot farms. The selection was made in order to depict the variation of farms. This can be seen in the variation of pilot farm size (Table 1) and in the variability of farming practices. In Spain there is a great variation in size due to the big farms with agroforestry systems for extensive livestock studied (dehesas).

Table 1. "Pilot farms assessed and size"

	Arable	Tomato	Vineyard	Fruits	Dairy	Beef	Sheep
Pilot Farms	6	6	7	1	6	5	1
Minimum size (ha UAA)	11	15	4		87	232	
Average size (ha UAA)	146	138	24		156	780	980
Maximum size (ha UAA)	400	230	130		230	1715	

The soil organic matter content of the pilot farms was mostly homogenous. Most of the pilot farms studied in Spain have a low soil organic matter content (see figure 1). Over all the pilot farms, the soil organic matter is stable in most cases, and there are about five pilot farms reporting an increase (see figure 2)



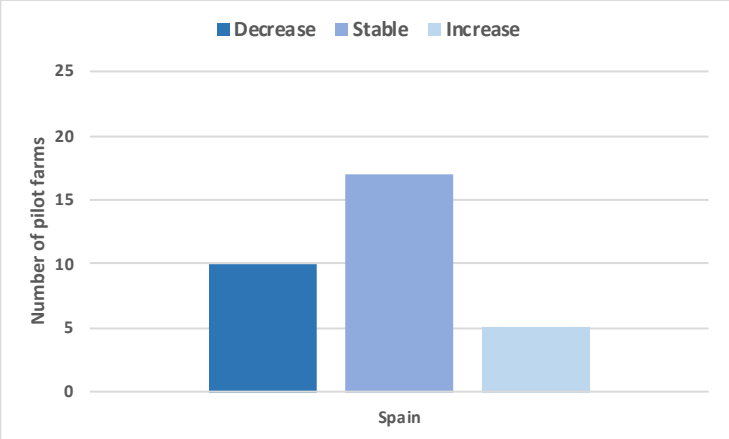


Fig. 1: Overview of the pilot farm soil organic matter content (left)
Fig. 2: Organic matter trend (right)

Soil water reserve in Spanish pilot farms is very low too, see figure 3

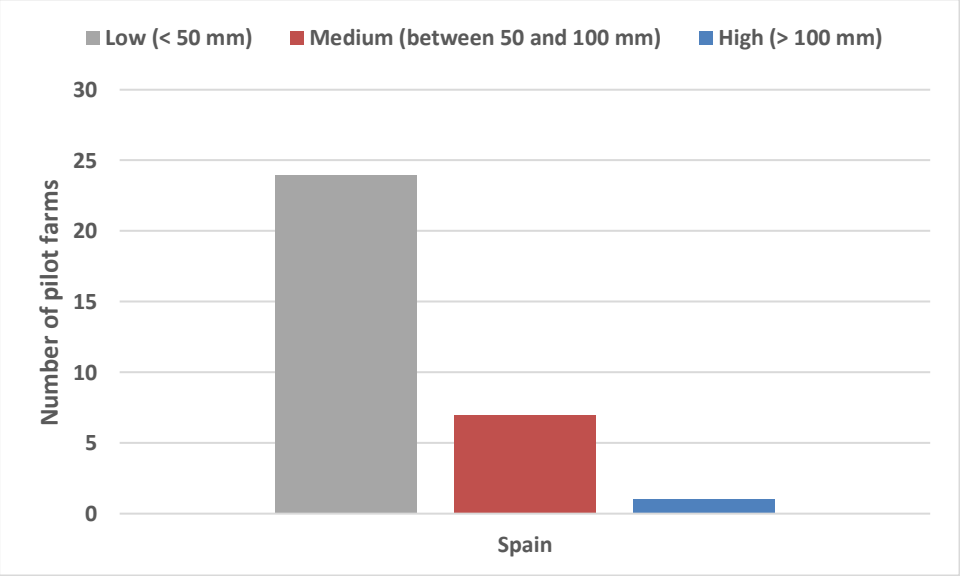


Fig. 3: Overview of the pilot farms soil water reserve

Regarding irrigation, 11 pilot farms are irrigated (see figure 4), and the water volume used for irrigation varies considerably depending on the crops and the areas (see figures 5 and 6)

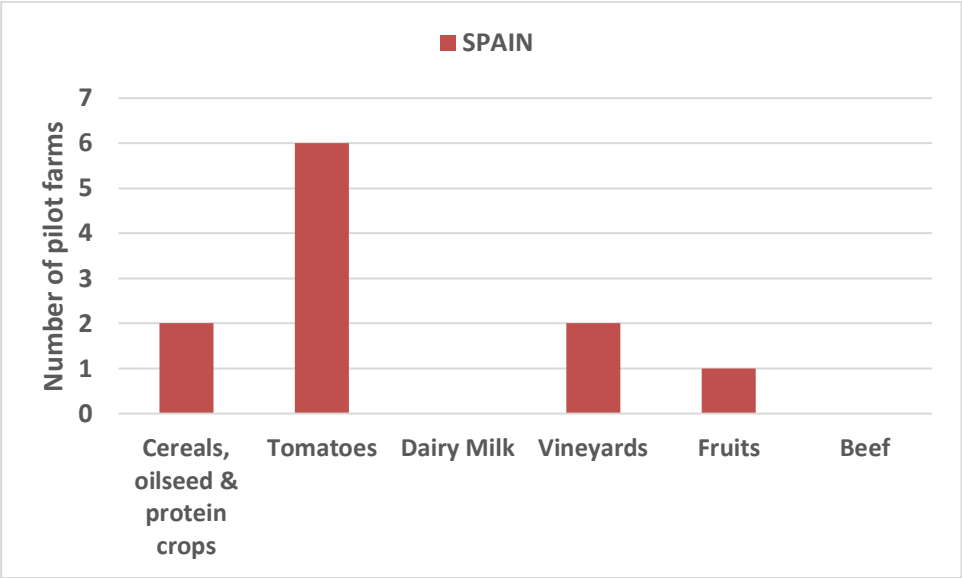
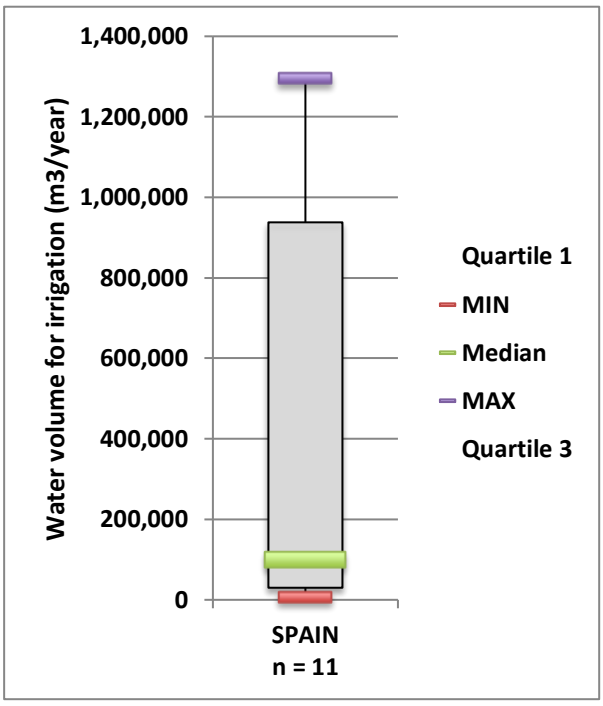


Fig. 4: Overview of pilot farms irrigated classified by agrarian systems



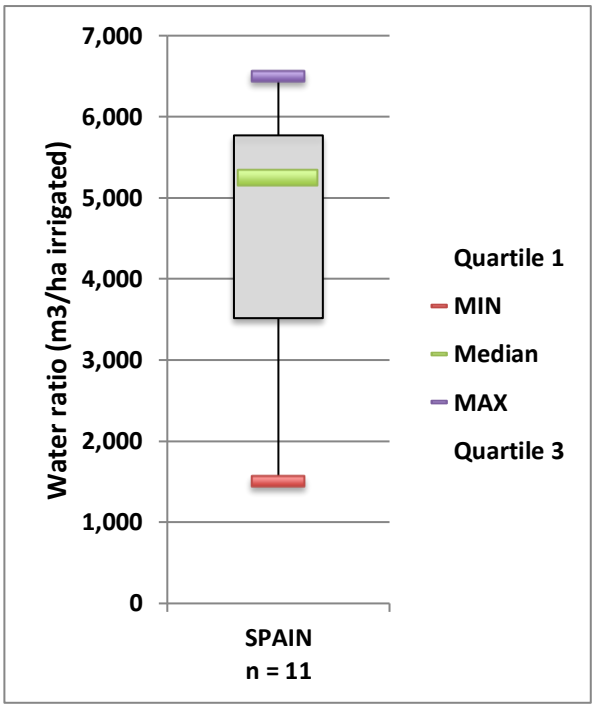


Fig. 5: Overview of the water used for irrigation on pilot farms (m3/year) (left)
Fig.6: Overview of water used (m3/ha irrigated) (right)

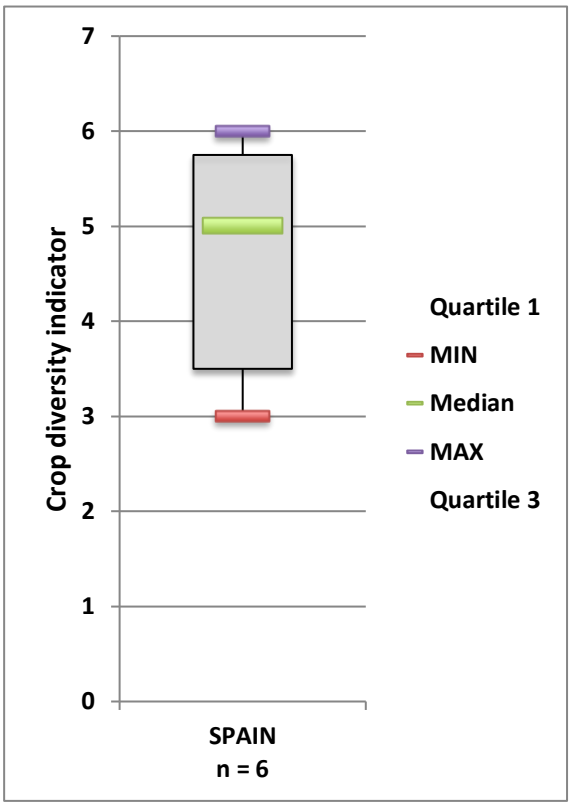
Arable pilot farms

Crop yield variability in Southern agrarian systems is very high, the frequency of occurrence of climatic stress (exposure) in % is very high, and even the extent of the consequences (impact). (See table 2)

Table 2: Crop yield variability for Spain (FAO, national level)

HARVEST		Barley FAO	Wheat FAO	Maize FAO	Sorghum FAO	Rapeseed FAO	Sunflower FAO	Peas, dry FAO	Lentils FAO	Chick peas FAO	Potatoes FAO
2000		33,7	31,0	92,2	47,0	15,8	11,0	14,1	9,0	7,0	25,9
2001		20,9	23,0	97,2	38,7	23,2	10,1	10,3	6,9	6,9	26,0
2002		27,0	28,3	95,1	38,0	15,8	10,2	12,6	7,6	7,9	27,9
2003		27,4	29,2	90,4	33,2	13,4	9,7	14,1	7,2	6,3	26,4
2004		33,5	32,6	100,7	34,4	15,9	10,9	14,7	8,3	7,3	27,2
2005		14,7	17,7	96,1	34,0	12,1	7,4	8,7	6,9	3,1	27,0
2006		25,4	28,8	97,4	37,9	14,5	10,6	12,7	6,6	7,8	28,8
2007		37,0	35,7	100,0	36,6	17,5	12,2	11,3	8,6	9,8	28,9
2008		32,5	32,5	99,1	32,8	19,1	11,9	13,5	7,6	9,8	26,2
2009		24,1	27,1	100,7	43,5	15,9	10,2	9,2	5,2	8,6	31,9
2010		28,3	30,5	105,6	51,2	18,1	12,7	12,5	7,7	9,8	29,4
2011		30,7	34,5	113,7	43,2	19,9	12,6	10,5	5,3	9,0	30,7
2012		22,1	23,7	109,2	35,6	18,6	8,5	7,9	4,1	5,9	30,4
2013		35,9	36,4	110,4	50,1	25,6	12,1	14,6	5,9	9,7	30,9
2014		25,0	29,8	114,1	65,4	24,1	12,2	10,2	6,1	7,6	33,5
2015		25,8	29,2	114,6	60,1	21,0	10,4	12,0	5,9	7,2	31,9
2016		28,5	31,0	115,6	53,3	20,4	10,9	11,6	5,8	8,0	32,7
Number of years		17,0	17,0	17,0	17,0	17,0	17,0	17,0	17,0	17,0	17,0
Yield	Minimum	14,7	17,7	90,4	32,8	12,1	7,4	7,9	4,1	3,1	25,9
	Average	27,8	29,5	103,1	43,2	18,3	10,8	11,8	6,7	7,8	29,2
	Maximum	37,0	36,4	115,6	65,4	25,6	12,7	14,7	9,0	9,8	33,5
Yield variation	Potentiel (%)	87%	69%	24%	66%	72%	53%	60%	74%	105%	25%
	Coefficient of variation (%)	21%	16%	8%	23%	21%	13%	18%	19%	22%	9%
Adverse wheather conditions	Frequency (%)	24%	18%	35%	47%	41%	18%	35%	35%	24%	41%
	Impact (%)	32%	31%	12%	30%	29%	24%	27%	28%	34%	14%

Arable pilot farms have a low crop diversity indicator in Spanish pilot farms, with an average of 4 crops per farm and a maximum of 6 crops (See figure 7: Overview of the pilot farm crop diversity indicator) regarding Genetic diversity, the average of ha per variety is 23 and the maximum is 68 ha/variety (See figure 8: Overview of the pilot farm genetic diversity)



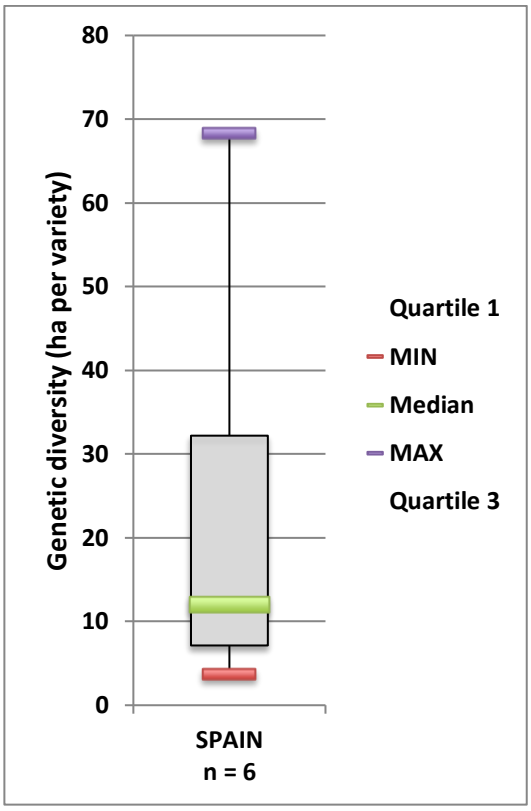
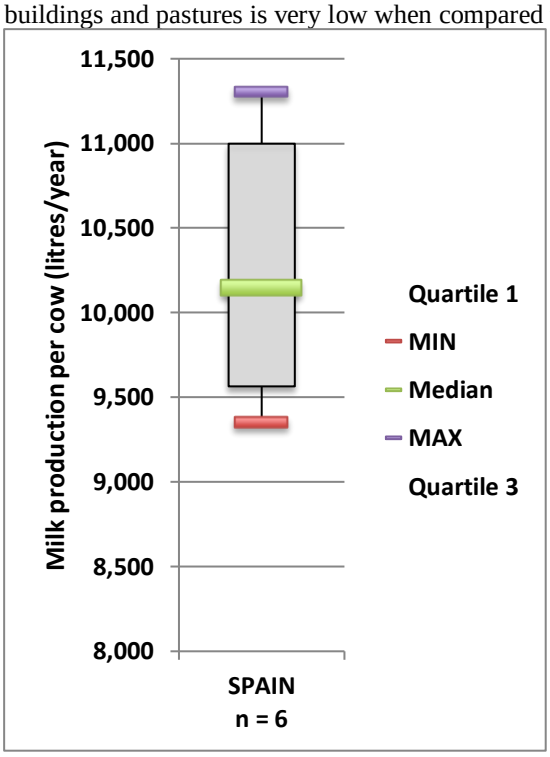


Fig. 7: Overview of the pilot farm crop diversity indicator (left)
Fig. 8: Overview of the pilot farm genetic diversity (right)

Livestock: dairy pilot farms. For the livestock farms, the vulnerability tool measures different indicators, the most representative is: Milk production/cow (litres per year). In the Spanish pilot farms, the average is very high (intensive farms) with an average of 10.266 litres/year (See figure 9). Fodder autonomy % is high: 87% but it could improve (see figure 10) and there is a high variability between the different farms. Thermal comfort in buildings and pastures is very low when compared to other European regions (See figure 11)



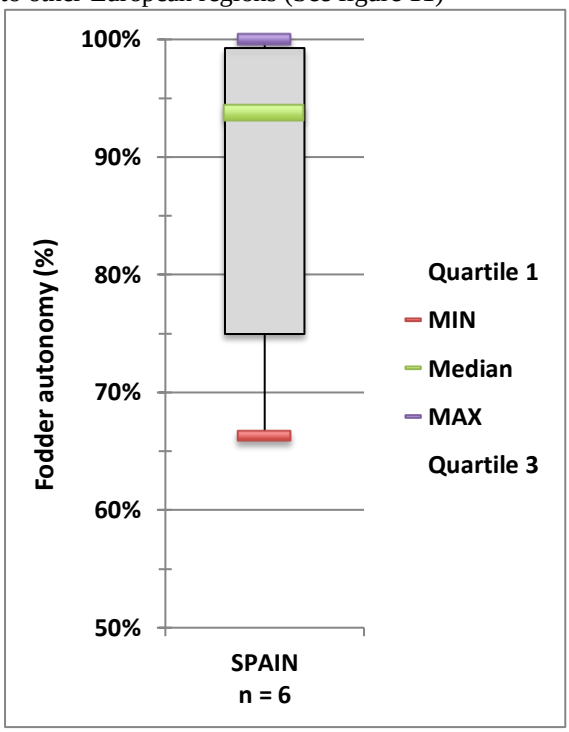


Fig. 9: Milk production/cow (liters/year) (left) and Fig. 10: Fodder autonomy (right)

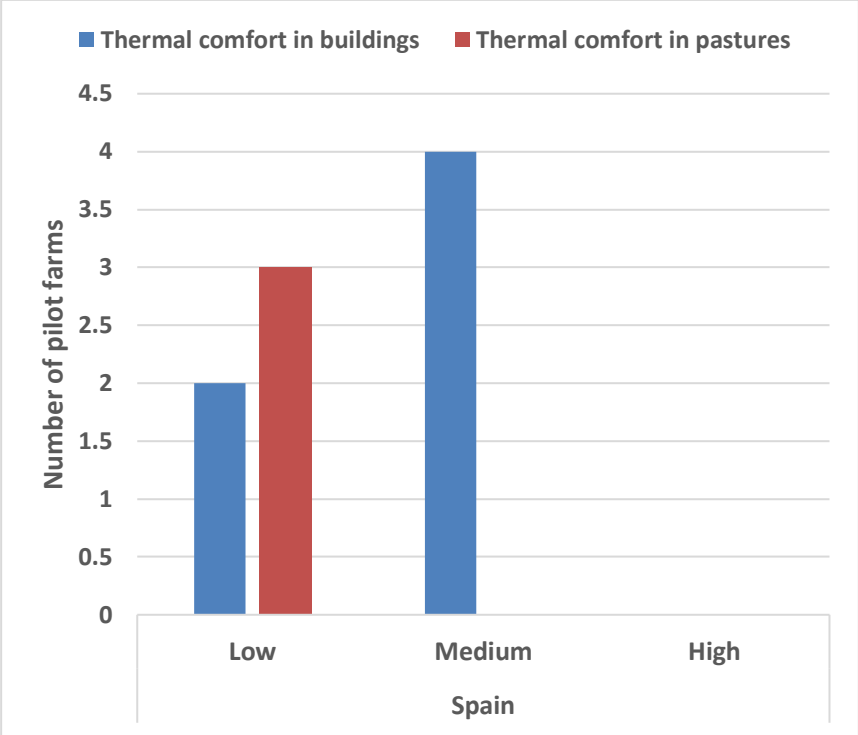
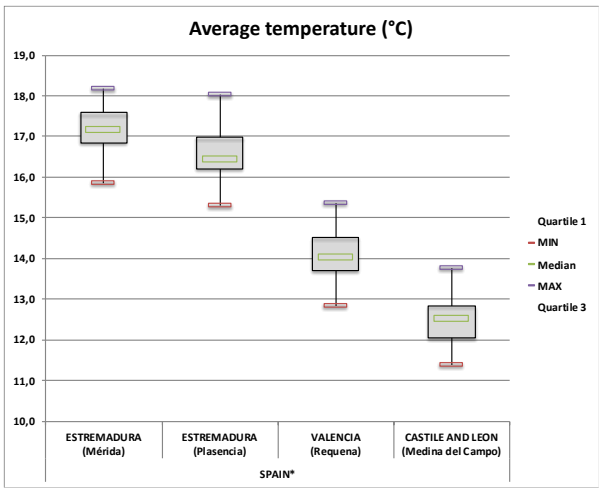


Fig. 11: Thermal confort in buildings and pastures

Climate observations

To illustrate the climate observations in the project countries of the different climate zones, representative points were taken: Mérida (Extremadura), Plasencia (Extremadura), Requena (Valencia) and Medina del Campo (Castilla y León. The data for the climate observations was taken, like the climate data for the vulnerability assessment, from the platform Agri4Cast.

The observed climate data taken is the data from the past 30 years (1987 – 2016). The average temperature decreases, as expected, from South to North (Figure 12). The same trend is seen with the number of days > 25°C (Figure 13).



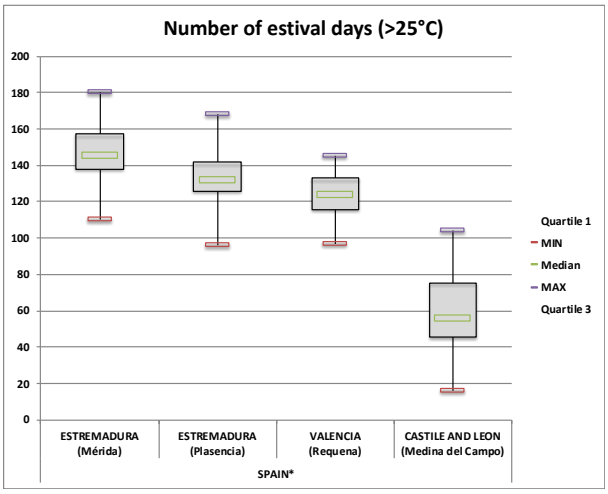
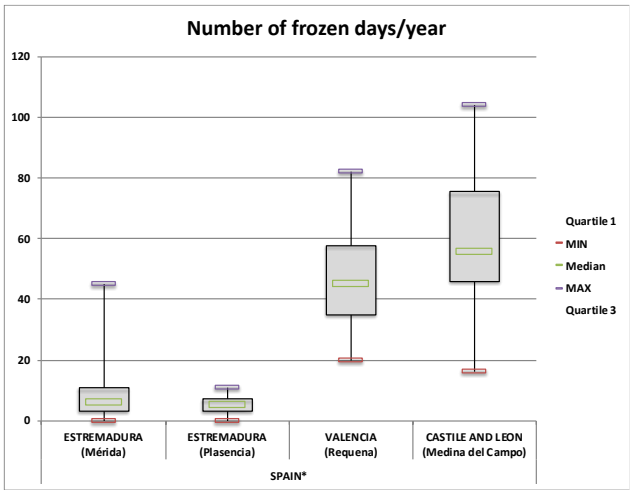


Fig. 12: Average temperature (ºC) (left). Fig. 13: Number of estival days > 25ºC (right)

The observed number of frost days/year increases from South to North of Spain, and in Castilla y Leon region there is a high variability between the different observed years (see figure 14). The annual evapotranspiration (ETP/year mm) decreases from South to North of Spain (see figure 15).



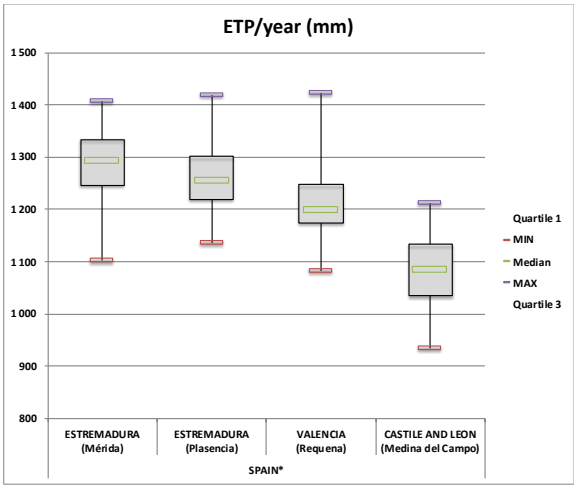


Fig. 14: Number of frozen days/year (left). Fig. 15: ETP/year (mm)

Climate events at farm level

The most relevant climate events for the pilot farms are: hail, intense/late frost, droughts, high temperatures and storms & intense rainfall. Hail is mainly problematic for permanent crop farms, in early spring and late summer. High temperatures are a problem for all pilot farms. Drought problems are increasing in frequency (See table 3)

Table 3: Frequency and impact of selected climate events on pilot farms

Climate event	Pilot farms in Spain
Hail	Regular for 75% of cereal farms, but impacts very variable (5%-50% yield reduction) Most problematic for permanent crops
Intense/late frost	Regular for 75% of the cereal farms, impacts very variable (30%-70%) Permanent crops: lower frequency - variable impact
Drought	More frequent and potential significant impacts (20-100%) Most limiting climate factor for permanent crops & dehesa
High temperatures	High frequency Significant impacts for animals, permanent crops and tomatoes
Storm & intense rainfall	Arable crops: storms in June and July, led to impacts between 5-30% Tomatoes: high precipitation in April and May a problem

Climate projections

For the assessment of vulnerability, climate projections are illustrated under several agroclimatic indicators (ACI) that show the changes for relevant agricultural indicators from the recent past (RP) to the near future (NF). The data for the climate projections was the same data that was used for the vulnerability assessment on the pilot farms (SRES scenario A1B). For the assessment, only one climate model (ETHZ-CLM-HadCM3Q0 model) was used in order to show the pilot farmers the impacts of climate change in a simplified way. Assuming the limitations of using only one climate model and considering that the model used is the warmest and driest out of the models available on Agri4Cast compared to the RCP scenarios, the projections still show a very moderate climate change which is useful for communication purposes (for not being very optimistic or pessimistic).

The following figures, 16 and 17, illustrate changes for relevant agricultural indicators from the recent past (RP) to the near future (NF)The RP being the years 1987 – 2016 and the NF the years 2017 – 2046. In order to compare the RP with the NF, the RP is not the observed climatic data, but modelled data with the same assumptions as the model for the NF. These ACI are used to show the pilot farmers the impacts of climate change in a simplified way. Two areas are shown in the following figures, Extremadura (Southwest of Spain) and Castilla y León (Northwest of Spain)

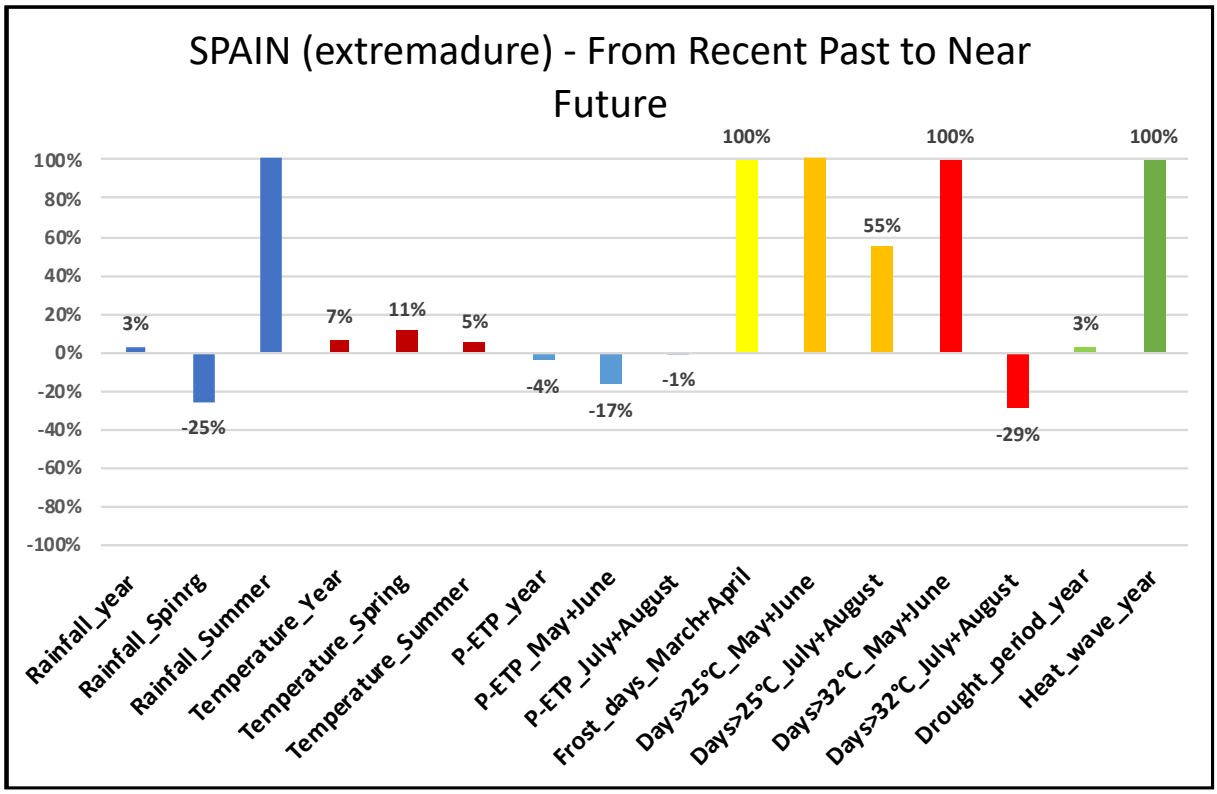


Fig. 16 Climate projections illustrated under several agroclimatic indicators (ACI) in Extremadura

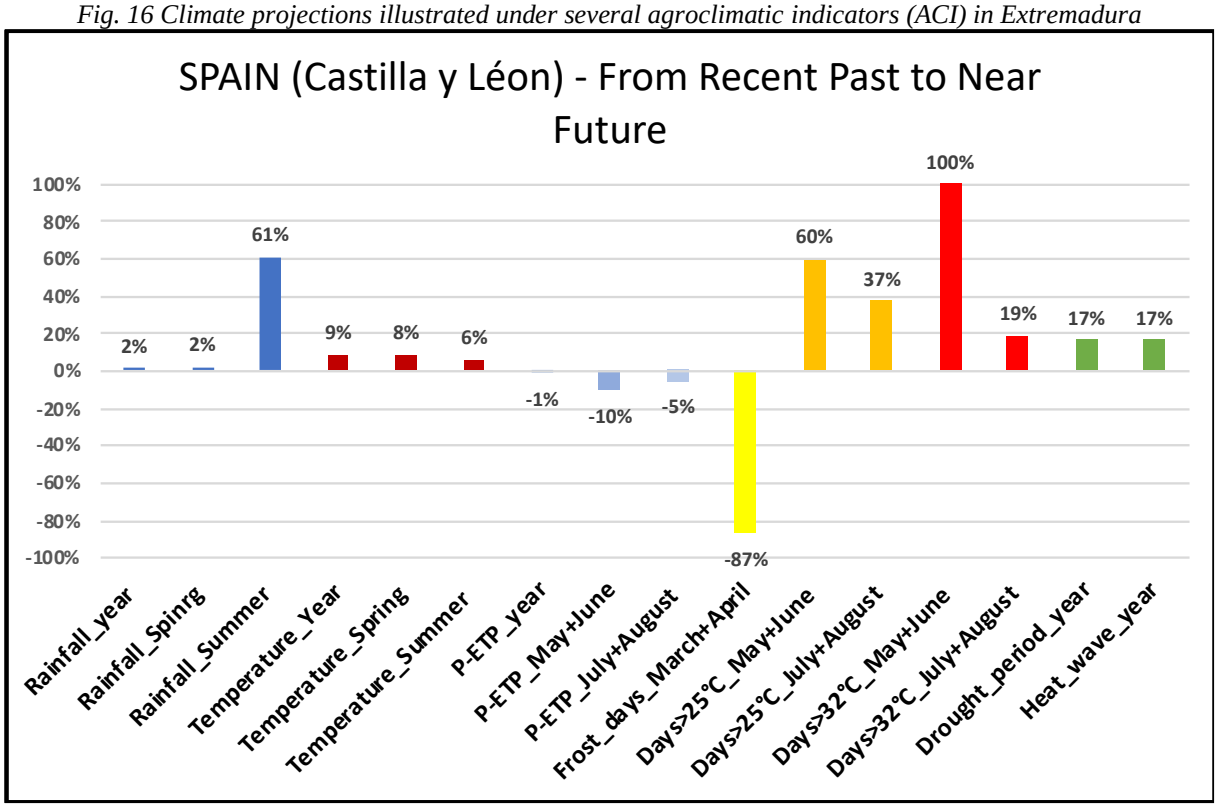


Fig. 17 Climate projections illustrated under several agroclimatic indicators (ACI) in Castilla y León

Arable crops: cereal crops

For Cereal Crops, the main ACI identified in the studied areas are:

- ACI-C1- Heat stress: nº of days with a Tª Max> 30ºC (15/04 – 15/07), that according to the model used will increase considerably in all the regions causing shriveling of the grain at the beginning of its development. See figure 18

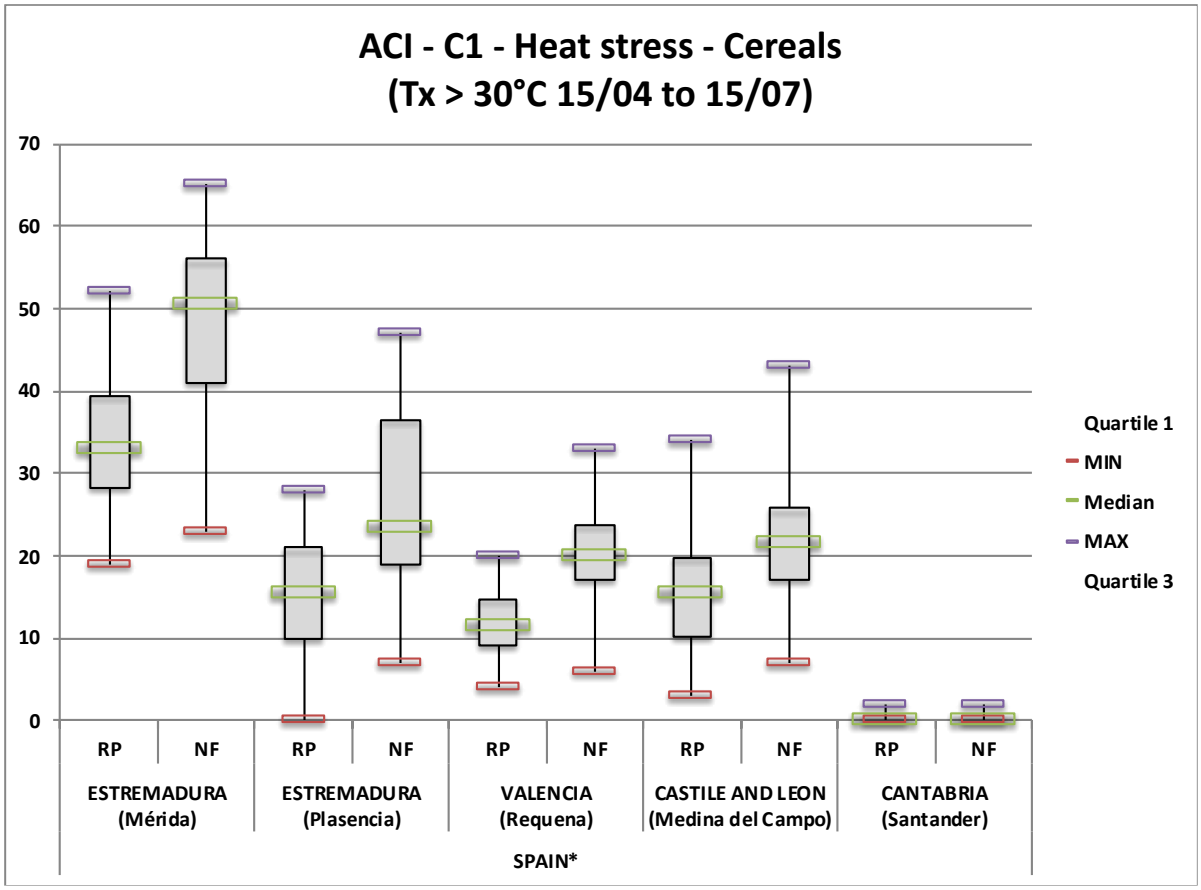


Fig. 18: ACI-C1- Heat stress – cereals (Tx > 30ºC 15/04 to 15/07)

- ACI–C3 Hydric deficit (May to June) ETP/mm from May to June that will decrease considerably in all the regions, except in Cantabria (North of Spain, Atlantic climate) under the studied model for the near future. (Considering that a hydric deficit in Spring-time under -300 mm in rainfed cereals is a critical threshold) See figure 19.

- ACI - C2 Frost stress (ear 1cm) – Cereals (Tn < -4ºC 20/02 to 10/04). This indicator will decrease in all the studied regions, but it's not expected that disappear in important regions for cereals crops in Spain, as Castilla y León. This is a very limiting matter for the introduction of new crops in the region (figure 20)

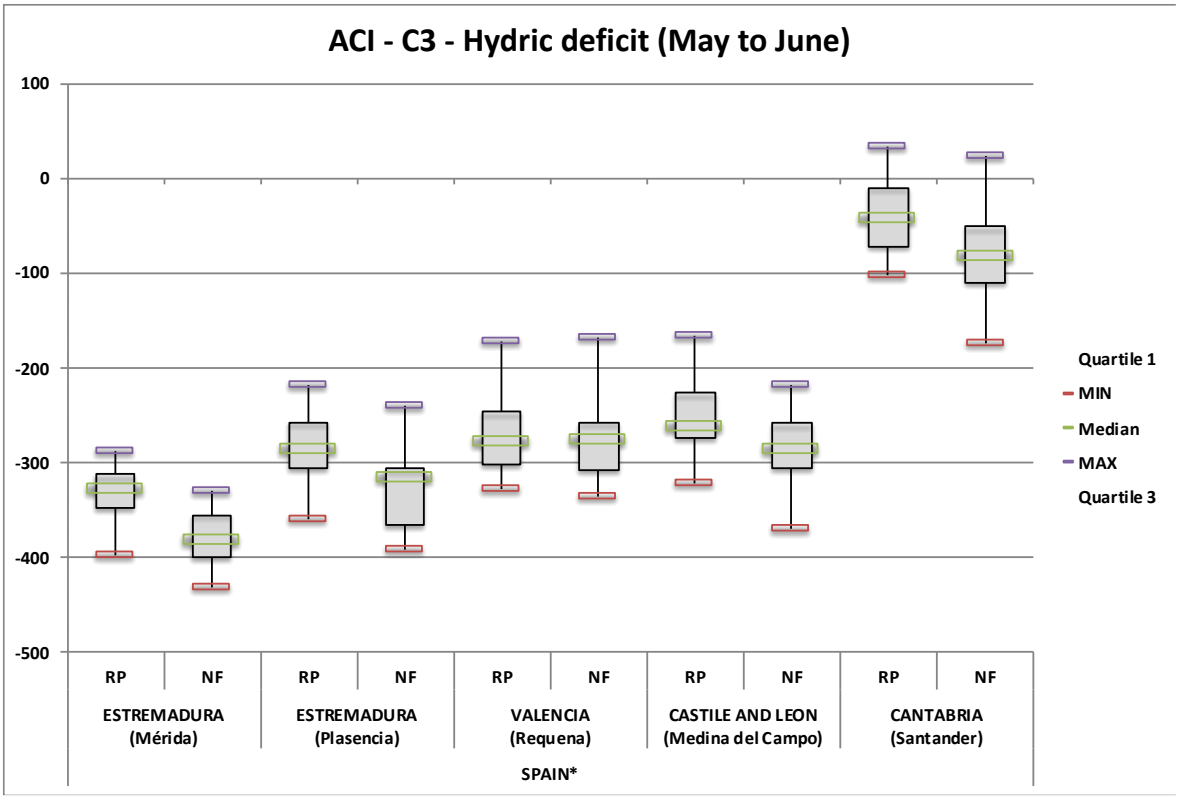


Fig. 19: ACI-C3- Hydric deficit (May to June)

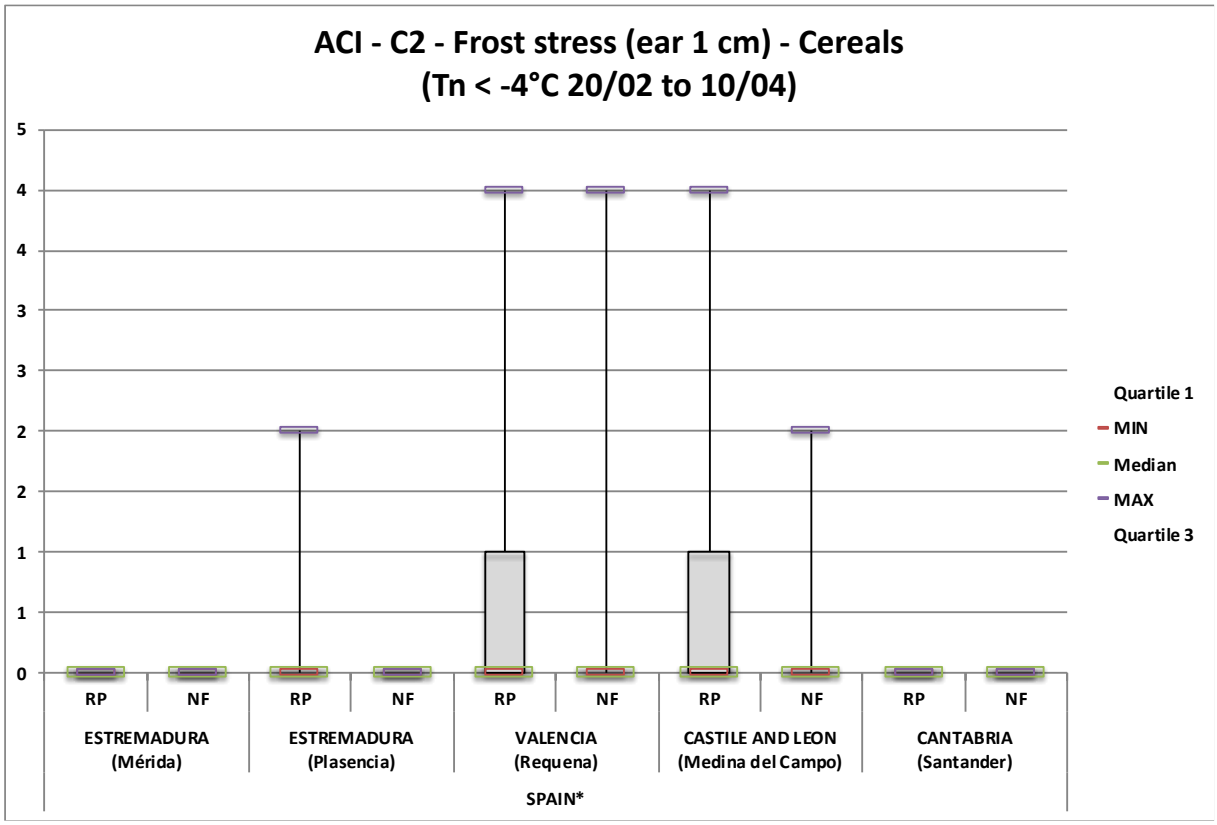


Fig. 20: ACI-C2- Frost stress (ear 1cm) – Cereals (Tn < -4ºC 20/02 to 10/04)

Arable crops: maize and sunflower

The main Agroclimatic indicators identified for maize and sunflower are:

- ACI-M1-Heat stress corns and sunflower maximum temperature > 32 ºC (01-06 to 30-09). Figure 21 shows a considerable increase of this indicator under the studied model in all the regions.

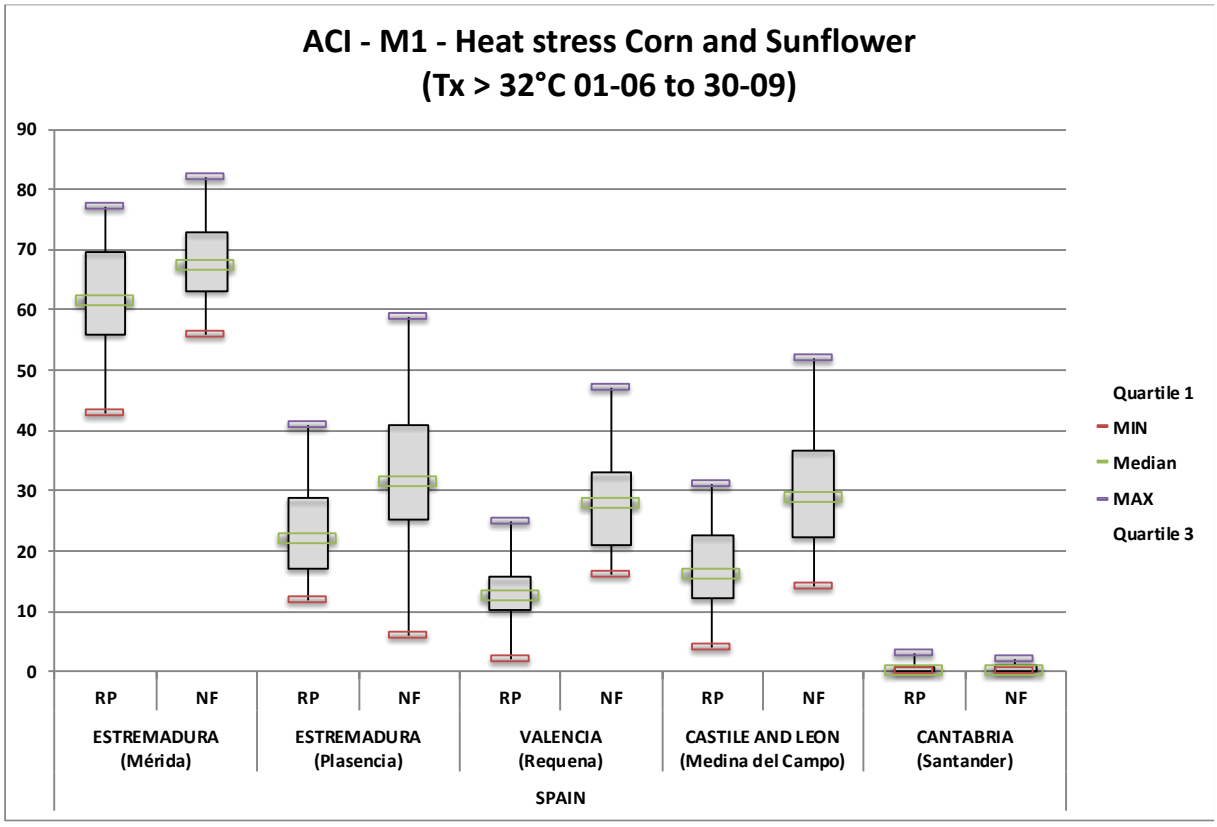


Fig 21. ACI-M1-Heat stress corns and sunflower. Tx > 32 ºC (01-06 to 30-09).

- ACI -M2 hydric deficit from May to August, that under the studied model will considerably decrease in all the regions from recent past to near future (figure 22)

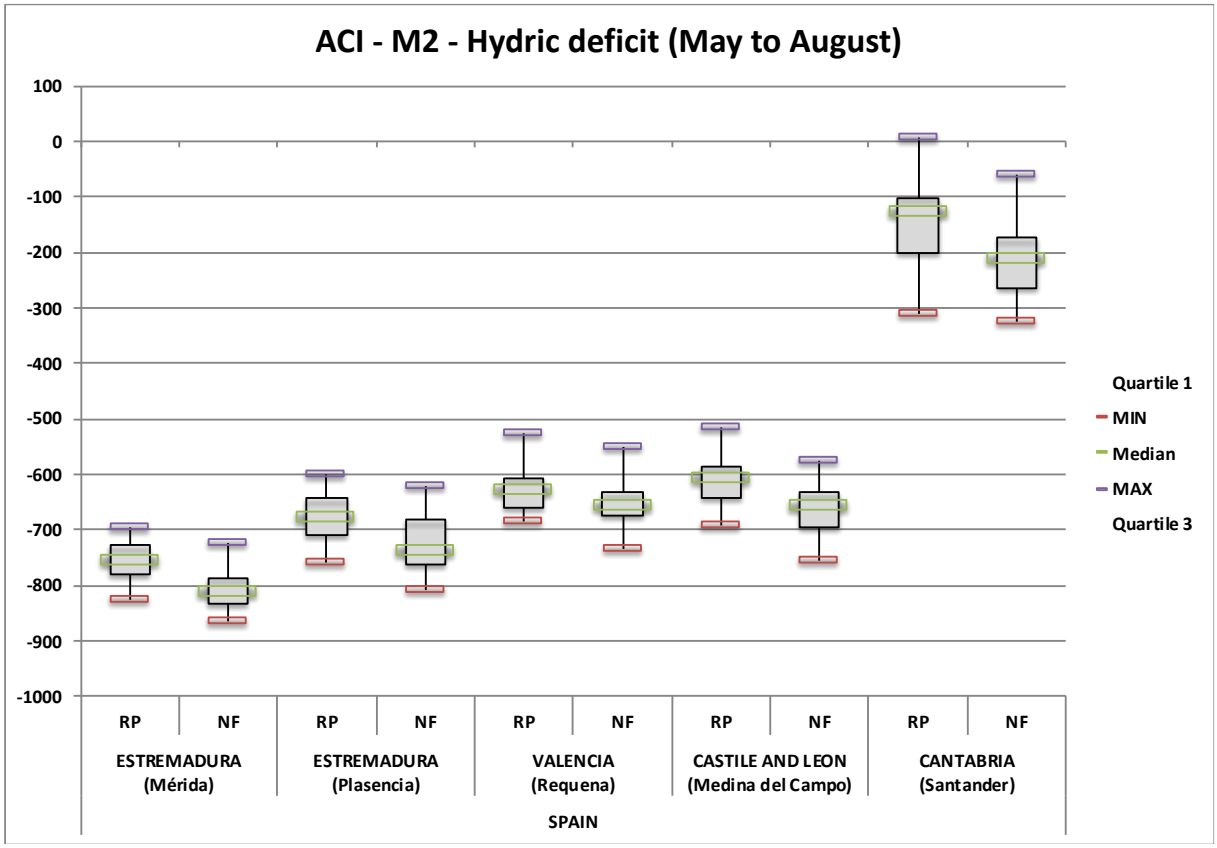


Fig. 22: ACI-M2- Hydric deficit (May to August)

<u>*Livestock farms*</u>

For livestock farms, a relevant indicator for cattle (both dairy and meat cows) is the Temperature-Humidity-Index (THI), which assesses the risk of heat stress. For the pilot farms with cattle, the amount of days with a stress factor of 73 – 80 (moderate to severe stress) was calculated. The figure 23 shows that stress for cattle will increase considerably in the Southern Region. With moderate to severe stress, the respiration and heart rate increase, there is a small reduction in milk production and fertility and the fodder consumption decreases.

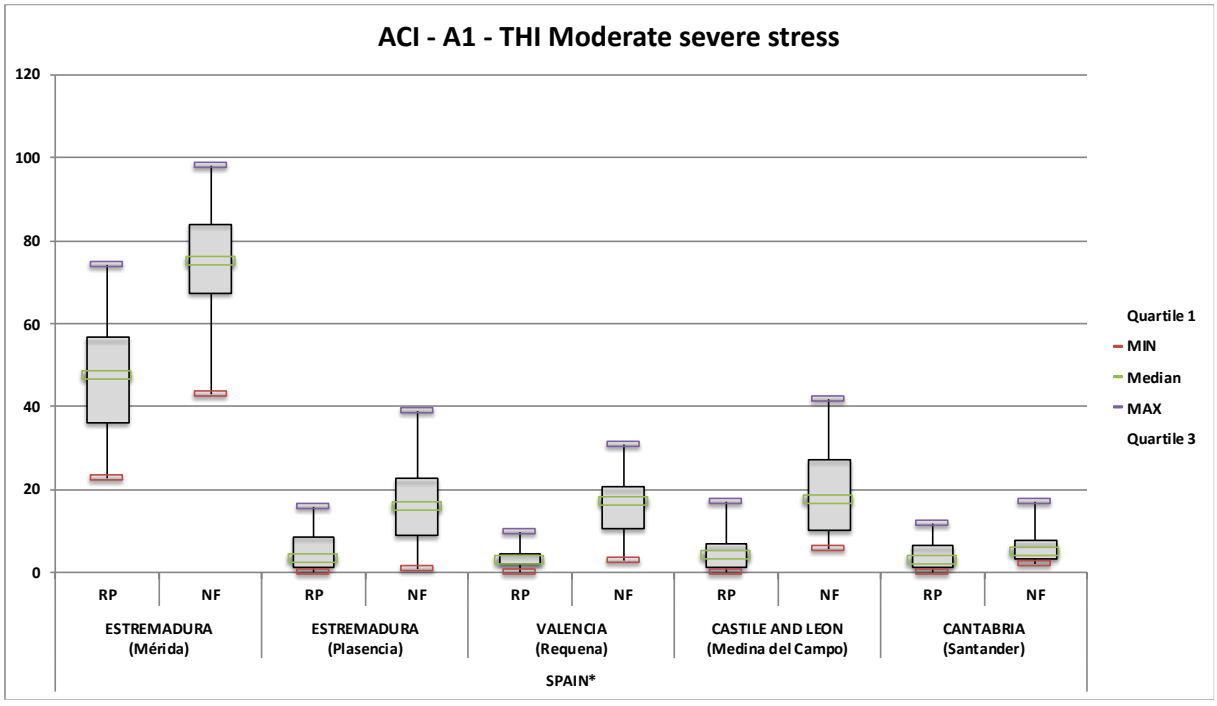


Fig. 23: ACI – A1- THI Moderate severe stress

In extensive livestock, the main Agroclimatic Indicators (ACI) are related to the forage or pastures needs. The main ACI identified that affect pastures growing are:

- ACI – F7 - Rainfall – Fall. Rainfall in autumn has a higher influence than the total year rainfall and the rainfall in spring in the year total production. Rainfall in autumn creates the greatest part of the pastures of each year and buffers the effect of spring rainfalls. Production in a good year is four times higher than that of a dry year, when supplementary feeding must be provided throughout the whole year. Under the studied model rainfall - fall will decrease in Extremadura and Valencia, and will increase in Cantabria (north of Spain). See figure 24.

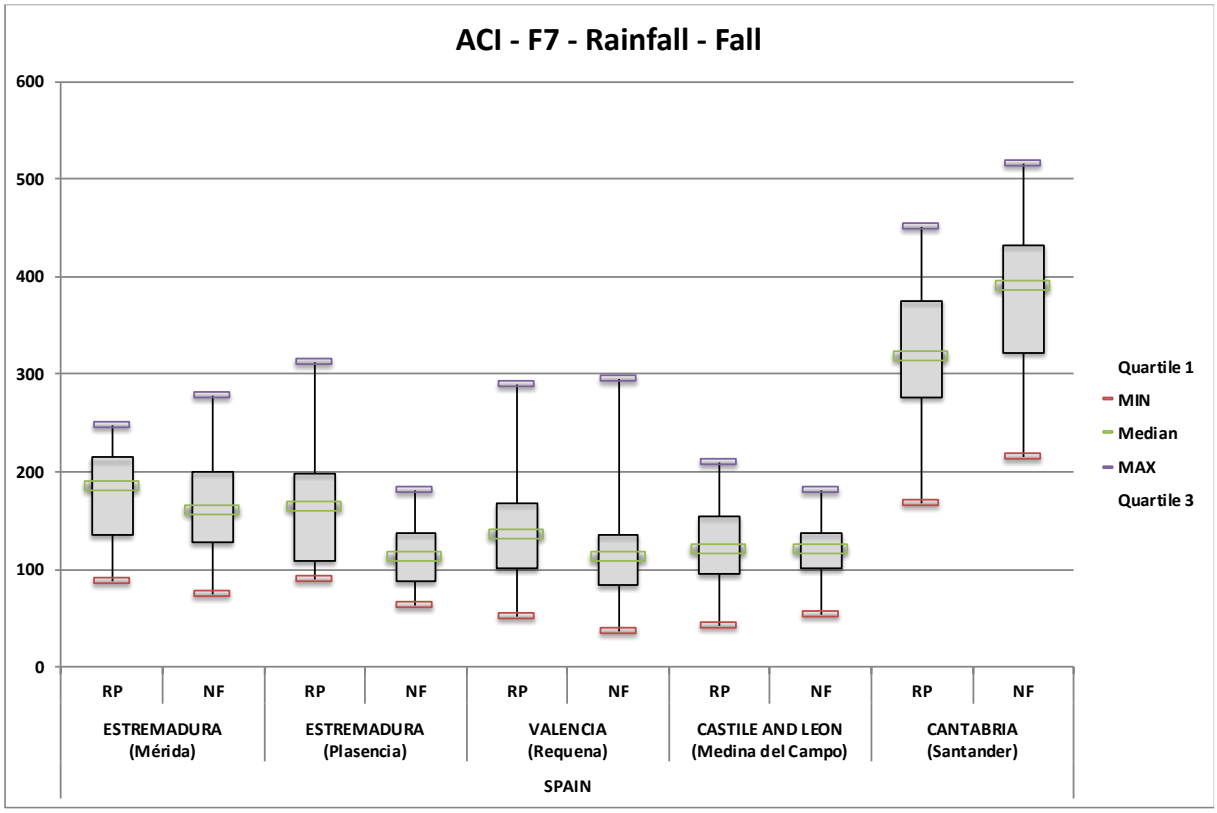


Fig. 24: ACI-F7- Rainfall – Fall

- ACI-F8 - Rainfall from April to June. Rainfall in spring is even important for the pastures production in spring. Within the used model, rainfall in spring will decrease in Extremadura and has a great variability for the near future in the other regions (figure 25).

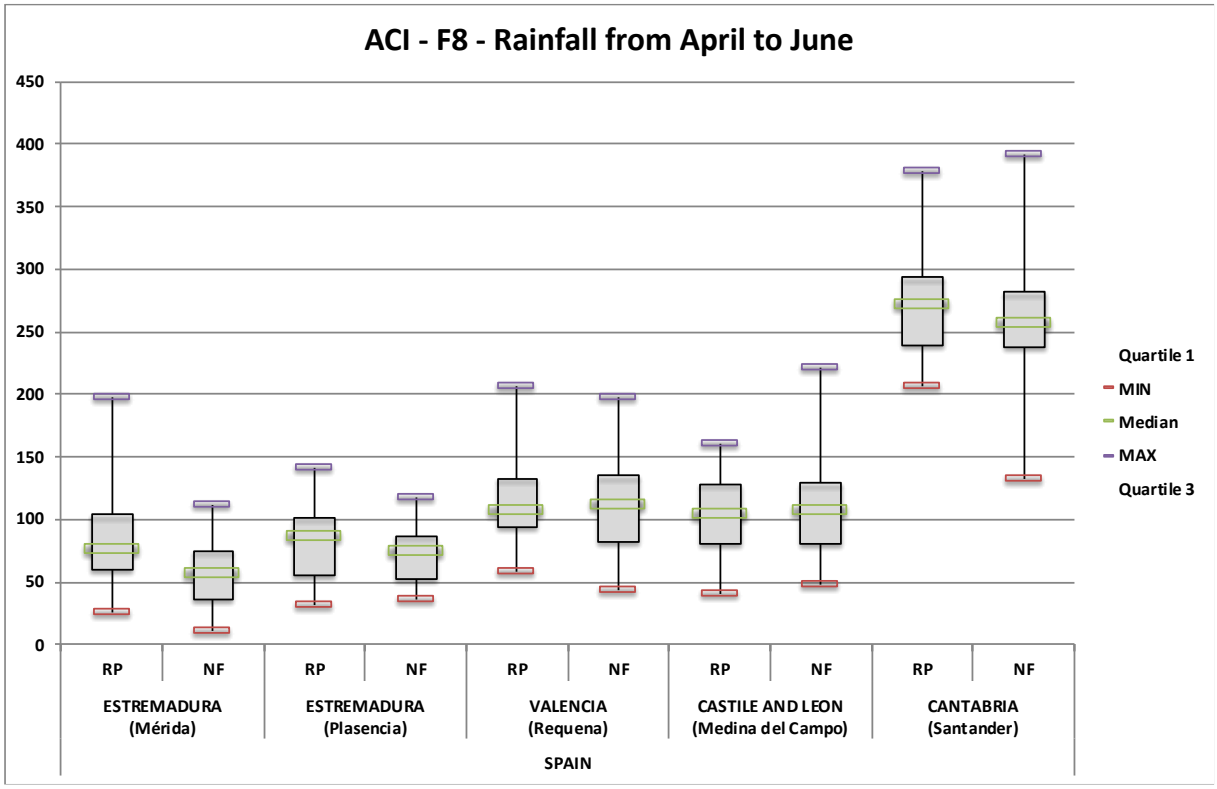


Fig 25: ACI – F8- Rainfall from April to June

<u>*Vineyards*</u>

For 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 develop a good quality of the wine. The ACI shows the development of the minimum night temperature in September (see figure 26). There is an increase of night temperatures in all regions, but especially in the Southern Zone of Europe. This may lead to the cultivation of other grapes varieties. Other classic indexes sued in viticulture (such as Huglin Index or Drought Index) illustrate how vineyards in Spain will suffer from more stress than in previous decades.

While extreme events related to frost tend to disappear, heat waves (spring but especially summer) and reduced rainfall (all year round but with almost no rain in spring and summer) will be more frequent in all the vineyards analyzed in Spain. This has proven in the past to have a significant impact on yields, but also leads to a decoupling of the technological ripening (sugar development) and phenolic maturity (aroma development), which leads to unbalanced wines. These two ACI are especially interesting because they highlight how climate change can have a quantitative (yield being the most comprehensible quantitative parameter for farmers) but also qualitative effect on crops (quality of the wine). Spring and summer hails are also responsible for dramatic losses in yields, but models cannot predict the probability of such events.

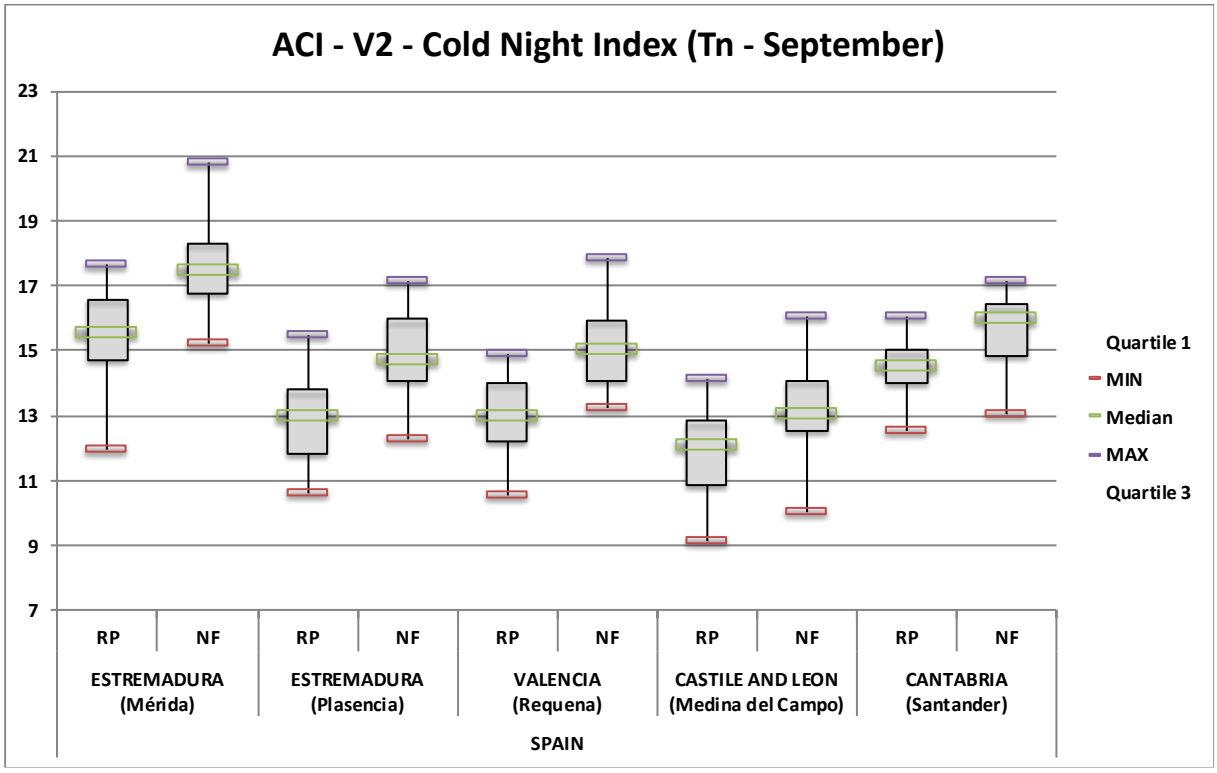


Fig. 26: ACI-V2- Cold Nighte Index (Tn – September)

Pilot Farms SWOT Analysis for Spain (Southern Zone of Europe)

Table 4: SWOT Analysis

Strengths	Weaknesses
• Agricultural insurance • Varieties well adapted to climate change • Farming systems with diverse crops, extensive agroforestry systems	• Increasing dependence on monocultures • Insufficient management of grasslands
Opportunities	**Threats**
• 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	• Increase in heat waves in spring & summer: increase in yield variations and heat stress for animals • Less rainfall in winter-spring • Increase of hydric deficit in spring and summer

Sustainable adaptation measures

With the help of this analysis, **sustainable adaptation options were** chosen and implemented at farm level.

For arable farming the focus of the sustainable adaptation options is on the improvement of soil structure and fertility. With improved soil fertility, water can be taken up more easily and stored for a longer period of time. Sustainable adaptation measures recommended are:

- Wider crop rotations (including legumes) and higher crop diversification
- Use of catch crops, cover crops and cover soil with straw or stubble, to reduce the amount of bare soil
- Cultivation of new crops for the region, and new varieties adapted to high temperatures and drought conditions.
- Efficient irrigation systems or substitution of irrigated crops
- Adapt date of sowing & variety precocity
- Mix of varieties within plots more sensitive to climate stress (cold, drought…)
- Reduced tillage and organic fertilizers

For permanent crops sustainable adaptation options recommended in all regions are:

- Improvement of soils through biodiverse ground covers
- Use of adapted varieties
- Focus on quality and not quantity (especially in wine production)
- Prune in green to balance leaf surface and number of bunches (Vineyards)

Sustainable adaptation options for livestock farms focus mainly on the reduction of heat stress:

- Appropriate density of animals in buildings
- Improved cooling systems (open barns with passive ventilation, installation of ventilators, shelter for animals outdoors, shading of barns)
- Increase fodder storing capacity
- Increase fodder autonomy and diversification
- High number of drinking troughs
- Grazing management plans to increase quantity and quality of pasture in extensive livestock systems

Conclusions

The most relevant climate events for the pilot farms are hail & frost days, hydric deficit and high temperatures. Hail is mainly problematic for permanent crop farms. High temperatures are a problem for all pilot farms, with drought increasing in frequency. In the near future, the days over 30°C in May-June will increase, as well as the number of days with heat stress for cattle and the minimum night temperature (affecting vineyards). Through our analysis on the pilot farms we have identified several sustainable adaptation measures that are applicable to farms in all climate risk regions and can make farms more resilient or less vulnerable to climate change. These are measures for reducing the amount of bare soil, improving soil structure and amount of organic matter, increasing the on-farm biodiversity by increasing the crop diversification and rotation and measures for increasing the thermal comfort of livestock.

References: LIFE AgriAdapt: www.agriadapt.eu