



# PIISA

Piloting Innovative Insurance  
Solutions for Adaptation

## D3.12 Pilots for Agriculture

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## Summary

The Spanish and Italian farmer surveys show very similar patterns: farmers in both countries face severe climate related risks—especially drought, heat and heavy rainfall—and most have already experienced losses that they expect to worsen. While farmers are actively adopting agronomic adaptation measures and some form of insurance, financial constraints, limited information and dissatisfaction with traditional insurance reduce their ability to manage risk. Insurance coverage often does not match the most important hazards. Overall, the surveys highlight a structural vulnerability both in Mediterranean and boreal agriculture: high climate exposure combined with an insurance protection gap. Farmers express low awareness yet strong potential interest in simple, transparent index-based insurance products.

A participatory co-design process with olive farmers in Andalusia (Spain) using the CoDepi tool, demonstrated how integrating farmer-defined thresholds and historical climate data can produce more credible and trusted parametric products. The experience with olive farmers shows that aligning index triggers with real on-farm impacts enhances both technical performance and farmer acceptance.

Successful implementation will depend on Spain's insurance framework and on the need to maintain actuarial sustainability. Designing viable index-based insurance requires balancing farmer expectations for frequent payouts with sound pricing and risk transfer mechanisms. Further work should assess the commercial feasibility of the co-designed product, explore its applicability to other regions and crops, and integrate complementary climate services.

Seasonal impact forecasting for Northern European agriculture remains limited by relatively low forecast skill and emphasis on general agro-climate indicators. To close these gaps, priority actions include improving data post-processing and multi-model ensembles, developing national and Nordic-wide, crop-specific indicators (including extremes), integrating forecasts with crop models, strengthening stakeholder engagement, and transitioning tested tools into sustainable national operational services.

In conclusion, strengthening climate service integration, tailoring insurance to local hazards and farmer needs, and increasing EU/national support, through incentives, clearer regulation and public guarantees, are seen as essential. A participatory, demand-driven approach linking farmers, insurers, climate services and public authorities is key to building climate resilience.

## Keywords

parametric insurance, index-based insurance, climate risk, agricultural insurance, olive cultivation, insurance protection gap, CoDepi tool, climate change adaptation, Mediterranean agriculture, Boreal agriculture, farmer perceptions

## Abbreviations and acronyms

| Acronym      | Description  |
|--------------|--|
| ASAJA        | Asociación Agraria de Jóvenes Agricultores (Agrarian Association of Young Farmers) |
| BSC          | Barcelona Supercomputing Centre  |
| CAP          | Common Agricultural Policy   |
| CAWI         | Computer Assisted Web Interview  |
| CEMS         | Copernicus Emergency Management Service  |
| CHIRPS       | Climate Hazards Group InfraRed Precipitation with Station data                     |
| C3S          | Copernicus Climate Change Service  |
| ECMWF        | European Centre for Medium-Range Weather Forecasts                                 |
| EFAS         | European Flood Awareness Systems   |
| EU           | European Union   |
| FMI          | Finnish Meteorological Institute   |
| GloFAS       | Global Flood Awareness Systems   |
| Ibl          | Index-based Insurance  |
| LocalTapiola | LocalTapiola Group   |
| NorCPM       | Norwegian Climate Prediction Model   |
| POLIMI       | Politecnico di Milano  |
| RCP          | Representative Concentrations Pathways   |
| UTC          | Coordinated Universal Time   |

## 1 Introduction

In Europe, considerable progress has been made in planning for climate adaptation and implementing related policies. However, the recent European Environment Agency review of national climate adaptation actions highlights that implementation of adaptation activities needs to be significantly strengthened (Leitner et al., 2024). Alongside the more recognised barriers to action, there is a need for new and alternative ways to design insurance policies, which could help stimulate climate adaptation activities while addressing affordability and risk-reduction objectives (Ceolotto et al., 2024).

PIISA (Piloting Innovative Insurance Solutions for Adaptation) is a Horizon Europe funded project working to reduce the climate adaptation gap (i.e. the difference between the recognised need for adaptation and the implemented adaptation activities) by developing and piloting new insurance and risk-sharing concepts to address mounting climate risks in Europe.

The PIISA project seeks to extend insurance from purely compensatory, post-damage mechanisms to proactive instruments that incentivise farmers, households, firms and public authorities to adopt climate adaptation measures.

Recognising that innovative insurance solutions and risk awareness raising have roles to play in helping EU Member States strengthen their climate adaptation efforts, PIISA has developed and tested a range of insurance related innovations that have been co-created to enable and stimulate farmers, households, firms and the public sector to manage climate risks and adapt.

The project has developed new innovative concepts, products and services through a piloting process that includes co-creation with stakeholders and potential users. PIISA pilots focus on three areas: (a) Cities and well-being; (b) Agriculture; and (c) Forests. This document summarises the development work and results of the Food and Agriculture pilot (Task 3.3).

This agricultural pilot case study is part of the PIISA, whose overall objective is to develop innovative insurance solutions that strengthen climate adaptation. Agriculture is a critical focus area because it is among the sectors most exposed to climate variability and extremes, while simultaneously exhibiting one of the largest insurance gaps, driven by high climate risk, affordability constraints, and the limited suitability of existing indemnity-based products. Within PIISA, piloting work also includes the development of related climate services, and the agricultural pilot contributes to this objective by assessing how climate services can facilitate the design and uptake of index-based insurance solutions.

The activities reported in this document include farmer surveys on climate risks, adaptation, and insurance gaps in three pilot locations; participatory workshops to elicit farmer-defined risk thresholds and needs; and the preliminary design of an index-based insurance (IbI) concept for olive cultivation in Andalucía, supported by seasonal forecasts of climate indicators and historical validation. Task 3.3 was connected to development work in PIISA WP2 “Innovations in adaptation and climate services for insurance” which was one of key sectors in climatic indices and services development. Results of climate services developed for pilots, including agriculture, are reported in Deliverable 2.3 “Climate Services on insurance options and adaptation alternatives for citizens” (Trentini et al. 2026). Together, these activities illustrate how the Food and Agriculture pilot translates project-level objectives and KPIs into concrete, sector-specific applications for climate resilience in agriculture.

This document summarises work and main results of several PIISA partners (BSC, FMI, POLIMI, LocalTapiola) in PIISA Task 3.3. Report is structured as follows:

- Section 2 presents result of and discusses the surveys on farmers' views on climate-related risks and insurances. Work focused in three countries: Spain, Italy and Finland.
- Section 3 articulates case study on olive tree farmers in Spain.
- Section 4 climate service development performed in Task 3.3 Food and Agriculture pilot.
- Section 5 contains main conclusions based on this report.

In the context of the whole PIISA project, this deliverable presents development work, analyses and results that are particularly relevant to the following PIISA Specific Objectives (SO):

- SO1 Collection of existing data, products, and best practices
- SO5 Localized piloting
- SO6 Activating Climate Resilience Dialogue

The work reported contributes to the following results listed in the PIISA GA:

- R4: Piloted concepts for employing risk indicators for drought, severe convection and heatwaves and impacts on agriculture and food
- R7: New impact information flows from e.g. insurance sector and citizen science to the governmental research and services organizations are tested
- R9: An early warning system for guiding the citizens about weather, seasonal and climate risks as regards their living area, possibilities to mitigate risks, possibilities to adapt will be developed incentivizing for insurance
- R11: Novel risk indicators and forecast services for the sectors and target audiences will be developed (e.g. regarding heatwaves, drought, severe convection), trend analyses, maps based on most recent climate scenarios will be produced and will support the whole Europe and especially the Atlantic, Boreal, Continental and Mediterranean areas
- R13: Five biogeographical regions (including several countries) will be engaged with different climatic risks presenting advice on adaptation and insurance gaps to be addressed by public budgets in regions. Guidance and Support will be provided regarding types of insurance products that would best address the region's climate risk. Topical state-of-the-art knowledge, best practices, and emerging innovations on insurance solutions will be shared to wider audience via the extensive network of PIISA
- R15: Policy frameworks will be reinforced on many levels, in EU and regional ministerial meetings, as this is part of the responsibilities of the partners in their other working roles beside the project

## 2 Surveys on farmers' views on climate-related risks and insurances

### 2.1 Motivation for farmer surveys

EU agriculture faces €28 billion annual average loss from extreme weather, projected to reach €40 billion by 2050, with most losses uninsured. Only 20-30% of climate-related losses are insured via public, private or mutual systems, including by Europe's Common Agricultural Policy (CAP). There are large differences in crop insurance protection across EU Member States, including several cases where protection is non-existent. This alarming information was compiled in report "Insurance and Risk Management Tools for Agriculture in the EU" commissioned by the European Commission and the European Investment Bank. (fi-compass 2025)

Several reasons have been identified why the penetration rate of insurance among farmers is low in the PIISA Project's D1.1 report (Ceolotto et al. 2024). The causes vary e.g. due to socio-economic context, supply systems, and regulation. To be able to develop insurance solutions acceptable for farmers, they need to be tailored to meet the needs and solvency of farmers. On the other hand, it is preferable to innovate insurance concepts that can be modified to other circumstances and contexts, too. Surveys were conducted to gauge farmers' views on obstacles and enablers to insuring their crops in three EU countries: Spain, Italy and Finland. In particular, farmers' perceptions and interest on parametric<sup>1</sup> insurance was examined.

In Finland, climate change and structural transformation in agriculture force farmers to improve their risk management. Farmers' income has decreased, even though farms' turnover has increased. Farms are facing the possibility of bankruptcy (Niskanen and Heikkilä 2015).

Stabilising farmers' incomes has become one of the CAP's objectives. However, instruments such as farming income insurance, mutual funds, and income stabilisation tools have remained marginal. The largest share of agricultural subsidies is paid on an area basis, and the rate has been flat for years. Counter-cyclical payments and premium subsidies for insurance are almost absent in the CAP. Furthermore, risk management under national agricultural policies in European countries has an ex-post (and ad-hoc) rather than ex-ante nature (Bielza Diaz-Caneja 2009). This cultural loading hampers the establishment of the insurance market for weather risks in the EU.

In Italy, agriculture plays a stabilizing and strategic role in the Italian economy, with 3.4% of employment and 2% of Italy's GDP. The climate change is increasing the vulnerability of the sector where climate risks are increasing. The floods that impacted Emilia Romagna in 2023 affected approximately 42% of the region's agricultural area and caused estimated damages of €1.5 billion. In this context, climate adaptation strategies, including insurance solutions, are becoming essential not only for ensuring environmental sustainability but also for safeguarding economic viability. A regionally targeted survey explored exposure to climate risks, farmers' perceptions, and approaches on risk management.

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<sup>1</sup> Parametric insurance and Index-based Insurance (IbI) have been used in this report interchangeably to describe a non-traditional insurance concept that utilise parameters or indices for a pre-defined, "triggered" payout structure.

The Spanish farmer survey was motivated by the need to inform the design of an index-based insurance solution based on farmers' lived experience of climate risk, rather than relying solely on externally defined indicators. As climate extremes increasingly affect olive production in southern Spain and traditional indemnity insurance is seen as costly, slow and often inadequate, the survey was used to capture farmers' perceptions of key climate risks, past losses, risk management practices, insurance use, and demand barriers, as well as their preferences for specific climate indicators, data sources, trigger thresholds and compensation structures. This demand-driven evidence is essential to assess the feasibility of parametric insurance, identify potential sources of basis risk and misalignment, and ensure that any proposed insurance solution reflects agronomic realities, thereby increasing relevance, a sense of ownership and potential uptake.

## 2.2 Methods and events in Spain

For the food and agriculture pilot, Spain was the key development region. Quantitative and qualitative methods, and participatory approach were used to assess climate risk and co-develop index-based insurance solution for the olive farmers. This included a structured farmer survey, an in-person farmer workshop, multiple virtual meetings with key stakeholders, as well as a webinar to get relevant feedback from the insurance sector. End of loop surveys were also conducted to understand the expectations of and gather the feedback from the project partners and stakeholders. The various events are summarised in the table below:

| Activity                  | Date(s)     | Aim   | Target Group(s)   | Scope                   | Number of participants |
|---------------------------|-------------|---|---|-------------------------|------------------------|
| Meetings with Agroseguros | Spring 2024 | To understand the Spanish context for Ibl from the insurance sector perspective and gauge the supply-side market interest             | The largest management entity of insurance companies in Spain | National; Spain         | 6                      |
| Meetings with ASAJA Jaen  | 2024-2025   | Multiple meetings throughout the co-development phase to inform co-design   | ASAJA Jaen  | Regional; Andalusia     | 4                      |
| Agriculture pilot webinar | March 2025  | Communication and dissemination, as well as feedback from key stakeholders  | Insurance companies, farmer associations                      | Multi-national; EU wide | 73                     |
| Farmer workshop           | April 2025  | Focus group discussion to deeply understand context, elicit farmer-defined thresholds for specific indicators, and validate bad years | Olive farmers   | Regional; Andalusia     | 12                     |

|                     |             |  |                                       |                          |                 |
|---------------------|-------------|--|---------------------------------------|--------------------------|-----------------|
| Field Visit         | April 2025  | Observe farm systems for contextualisation   | ASAJA Jaen                            | Regional; Jaen           | 5               |
| Farmer survey       | Spring 2025 | Assess climate risk perceptions, losses, insurance use and preferences for index-based insurance | All types of farmers                  | Regional; Southern Spain | 47              |
| End-of-loop surveys | 2024-2026   | Four rounds of surveys to know the expectations from and feedback for each pilot loop            | Project partners and key stakeholders | Multi-national; EU wide  | 20 <sup>2</sup> |

## 2.3 Survey of Finnish farmers

We conducted an extensive questionnaire aimed to evaluate Finnish farmers' interest in parametric weather insurance (Eerola et al 2024). Parametric weather insurance is not currently sold in Finland, which is why we study a hypothetical product. Currently, weather-induced yield variation, or yield risks, are insured with indemnity insurance. Indemnity insurance is based on insurance contracts, insurance claims, and claims inspection. In Finland, insurance contracts differ somewhat from those common in the United States or central Europe. In Finland, indemnity payments are typically paid only if the yield loss is total. Therefore, the farmer's deductible has commonly been very high, roughly 95%. Finnish farmers do not currently have access to partial or shallow loss yield insurance. Nor can they insure themselves against adverse weather events.

The data was collected using a questionnaire sent to farm customers of the insurance company LocalTapiola. The main format chosen for the survey was an opinion poll with a five-step Likert scale. The survey response rate was 5.4%. According to a LocalTapiola specialist, this response rate is very close to the normal response rate of customer satisfaction surveys. This indicates that the survey was "business as usual" in an insurance company context.

The K-means cluster analysis was used to find homogenous and recognisable farmer clusters. All 35 statements in the questionnaire were used for this task. The number of groups was determined based on their reliability and interpretative interest. Later the groups were described and named based on the farmers' average opinions within the clusters.

Based on farmers' opinions in Cluster 0, we entitled this cluster as *Non-insurers*. Farmers in this cluster think that crop variation does not matter much to them, and that they can manage crop variation through their own actions<sup>3</sup>. Farmers also do not believe that climate change will increase extreme weather events. On average, farmers in this cluster are older, and they farm slightly smaller farms (Table 1).

<sup>2</sup> End-of-Loop survey 3 replies are missing. The Loop 3 survey was still open at the time of writing this report.

<sup>3</sup> We do not have data on farmers' average yield performance. The previously defunct state-run CDC program favored low-yield farmers. Some low-yield farmers even specialized in applying for government crop damage compensation.



Farmers in Cluster 1, *potential parametric insurers*, are interested in parametric insurance. They also accept basis risk as a natural part of parametric insurance. They are unwilling to sacrifice the speed of the claims handling process to achieve a smaller basis risk. It was expected that production line would have effect on farmers having higher interest towards parametric weather insurance. However, that was not the case in our data. Grain farmers were just slightly overrepresented on this farmer cluster (Table 1).

Farmers in Cluster 2, *conventional insurers*, do not tolerate basis risk. They think that there must be a conventional yield loss on the farm to be eligible for yield insurance compensation. They are interested in parametric insurance, but they do not accept indemnity payments that are based on weather parameters alone.

Table 1 Farm and farmer characteristics by cluster.

|                                      | Hectares<br>own | Hectares<br>leased | %<br>grain farms | Age,<br>years | %<br>farmers | %<br>land |
|--------------------------------------|-----------------|--------------------|------------------|---------------|--------------|-----------|
| All                                  | 43.2            | 34.7               | 58               | 54.1          | 100          | 100       |
| <i>Non-insurers</i>                  | 38.3            | 26.4               | 58               | 56.5          | 33           | 30        |
| <i>Potential parametric insurers</i> | 47.5            | 36.8               | 60               | 52.0          | 35           | 38        |
| <i>Conventional insurers</i>         | 43.5            | 40.2               | 56               | 54.0          | 32           | 32        |



## 2.4 Survey and workshop with Italian farmers

### 2.4.1 Survey on Italian farmers

A better understanding of farmers' current exposure to climate risks, their perceptions, and the strategies they are adopting represents a necessary step for designing effective policies and tools aimed at fostering climate resilience in agriculture. To this end, a CAWI (Computer Assisted Web Interview) survey was conducted targeting farmers in four Italian agricultural regions (Lombardy, Emilia Romagna, Tuscany, and South Italy) chosen because of their differences in geography and agricultural practices. In total, 626 valid responses were collected with a sample mainly composed of small-scale farms (20 hectares or less).

The current exposure of Italian farmers to natural hazard-related risks is dominated by weather-related phenomena, particularly heavy rainfall and hailstorms, which affect 65% of the exposed farmers. Flood risk represents another relevant threat, reported by 35% of exposed farmers, especially among those whose farms are located in proximity to rivers or watercourses. Moreover, in the past five years, 82% of the farmers have experienced at least one natural hazard, and among these, 53% have suffered a related economic loss.

However, only 51% of farmers are concerned about the current climate change situation, signalling a lack of risk perception, which is a fundamental parameter in the climate adaptation measures, as evidence confirm that the more individuals perceive a risk, the more willing they are to implement climate adaptation measures including acquiring an insurance policy.

An interesting data that emerged from the analysis is represented from the adaptation actions that farmers are implementing in terms of ecological, social, and economic solutions. The results show that 89% of Italian farmers have already implemented climate adaptation measures, primarily relying on the changing of agricultural practices (48%) and investing in technologies (27%). However, although the percentage of farmers not adopting these measures is relatively small (11%), the evidence shows that the main barriers preventing a greater implementation of climate change adaptation measures are lack of awareness, and inadequate environment for implementation. This means that, apart from having adequate infrastructure for the implementation, spreading awareness, not only on climate risks but also on adaptation measures, is relevant.

The previous results provide a perfect introduction for insurance, an essential tool for supporting climate change adaptation among Italian farmers. Insurance solutions play a dual role: on the one hand, they protect farmers from the financial consequences of adverse events, on the other, they can act as incentives for risk reduction and adaptation.

Indeed, as illustrated in the PIISA Project's D1.1 report (Ceolotto et al. 2024), insurance incentivizes proactive risk management and supports the adoption of innovative, sustainable solutions that enhance resilience against the increasing impacts of climate change.

In this context, the general picture is positive with the majority of farmers (86%) that are insured against at least one natural hazard. However, a deeper analysis of insurance levels for specific climate risks reveals a more concerning scenario. The hazards most commonly insured are hail and fires, yet only half of the farmers have coverage for these risks. To understand this pattern, what is interesting to notice is that, by including a chi-square test, we were also able to show a significant relationship between the likelihood of purchasing a hazard-specific insurance policy and the level of perceived risk.

Farmers with higher risk perceptions are significantly more likely to buy insurance, reinforcing the idea that risk aversion drives insurance uptake, this is also consistent with the finding in previous studies.

The described situation shows an evident insurance gap related to special natural hazards. Among the principal barriers, that prevent higher insurance uptake, we can see that the primary obstacle is related to the characteristics of the insurance policies, with 31% of farmers reporting trust issues toward insurance companies, and approximately one-quarter concerned about the complexity and cost of these policies. This underlines how insurance symptoms, among others, a lack of awareness with respect to climate risks. At the same time, some innovative insurance instruments have been developed, such as parametric insurance: an insurance contract where the final payment or contract settlement is determined by a weather or geological observation or index, rather than on individual loss assessments. In this sense, parametric payouts are determined according to the measurement of a (highly correlated) index such as temperature, rainfall, windstorm.

Given its novelty, it is not surprising that knowledge among farmers about parametric insurance remains limited. Only 14% of farmers can accurately explain what parametric insurance policies are, 39% have merely heard about them, and approximately half of them (47%) have never heard of. As of today, only 8% of farmers, knowing what these new solutions are, are willing to change their current insurance policy in favour of parametric policies. To say, 84% do not outright reject this change opportunity, but declares that their decision largely depends on other factors, like the amount of compensation the parametric policy guarantees (52%) or the conditions of the insurance policy (35%).

The challenges to achieve climate resilience in agriculture remain substantial, and the PIISA project directly addresses them by preparing and planning for climate resilience. The evidence presented in this deliverable shows that action is required along two closely related dimensions. On the one hand, strengthening farmers' awareness and understanding of climate-related risks is essential, as risk perception clearly emerges as a key trigger for the adoption of adaptation measures, including insurance. On the other hand, looking ahead, there is the need to develop the parametric market, potentially overcoming current gaps related to trust, complexity and coverage. Parametric insurance could also play a strategic role by enabling a more proactive approach to risk management, shifting insurance from an ex-post compensation mechanism towards a preventive lever for climate adaptation. In line with PIISA objectives, wider penetration of agricultural insurance can be supported through improved access to risk data, targeted awareness initiatives, and incentives, ultimately contributing to accelerating transformations towards climate resilience.

### 2.4.2 Workshop with Italian farmers

In order to further validate and deepen the findings emerging from the CAWI survey, an in-presence workshop was organized in February 2026 in collaboration with Confagricoltura Bari–BAT, the main agricultural representative organization of the Metropolitan Area of Bari and the Province of Barletta-Andria-Trani.

The workshop involved 35 participants, including member farmers, owners of large agricultural enterprises, and sector technicians active in olive cultivation. The focus on olive cultivation was also considered to get comparable results with those obtained in the Spanish olive workshop. The area of Bari represents one of the most relevant agricultural districts in Southern Italy and was one of the four macro-areas included in the survey sample.

The workshop was structured in two phases. In the first phase, the main results of the survey were presented, with particular attention to insurance uptake, perceived barriers, and the potential role of parametric insurance solutions. In the second phase, an interactive discussion was facilitated to further explore the relationship between farmers and insurance companies, focusing on perceived barriers, incentives, and trust dynamics, especially in relation to innovative insurance products.

The discussion strongly confirmed the quantitative results of the survey and provided additional qualitative insights. 23 participants responded to the live survey.

### **Issues in the relationship with insurance companies**

Participants highlighted several recurring concerns in their interaction with insurance companies among which: high insurance costs (69%), lack of clarity in coverage definitions (38%), complexity in the calculation of compensation amounts (23%) and to a lesser extent the lengthy procedures and delays in claim settlement.

These elements confirm that barriers to insurance uptake are not only economic, but also structural and relational, reinforcing the trust gap identified in the survey results, where trust issues (31%), policy complexity (26%), high costs (25%) and lack of awareness (18%) were ranked in the first positions.

### **Conditions to increase insurance uptake**

When asked which conditions would make them more inclined to subscribe to additional policies or extended coverage, farmers mainly emphasized greater transparency and simplification of contract clauses (50%), but also lower costs (33%).

These responses suggest that increasing insurance penetration requires not only financial incentives, also seen in the survey results, but also product redesign and clearer communication strategies.

### **Trust in parametric insurance and data-driven solutions**

Interestingly, while at the beginning none of the participants were aware of parametric insurance or heard about, after our explanation, the majority of participants expressed openness towards insurance solutions based on new data sources provided that: measurement methodologies must be clearly communicated in advance, the insurance provider is reputable, and farmers have some flexibility in defining relevant thresholds. This pattern reflects survey results, where information access was one of the most relevant incentives (40%) influencing farmers to adopt parametric insurance.

As we can see from the three analyzed perspectives, overall, the workshop findings confirm and reinforce the survey results, highlighting that barriers to insurance uptake are not only economic, but also structural and relational. At the same time, the discussion indicates a growing openness towards innovative solutions such as parametric insurance.

These findings suggest that the role of insurance in agriculture is evolving from a purely compensatory tool to a more preventive instrument for climate risk management. However, strengthening climate resilience requires more than product innovation: it calls for improved communication, trust-building, and greater awareness of climate risks and adaptation options. Only through this integrated approach can insurance effectively support informed decision-making and long-term resilience in the agricultural sector.

## 2.5 Survey of and Workshop with Spanish farmers

Spain is the world's largest olive producer, with Andalucía accounting for approximately 75% of national output. Within Andalucía, Jaén is the principal olive-growing province, with roughly 588,000 ha dedicated to olive cultivation. As part of the Food and Agriculture pilot in the PIISA project, BSC collaborated with ASAJA-Jaén to assess the feasibility of parametric insurance tailored to the climatic conditions of olive production. ASAJA, the Agrarian Association of Young Farmers, is Spain's largest agricultural organisation, representing more than 350,000 members nationwide. ASAJA-Jaén plays a central role in supporting local producers, facilitating knowledge exchange and advocating for the region's olive sector. BSC used the farmer network of this association to conduct surveys and workshops to inform its research.

### 2.5.1 Farmer Survey

The survey was designed to assess how farmers in Southern Spain perceive climate risks, how these risks affect their agricultural activities, and how farmers engage with existing insurance tools, including both traditional indemnity-based products and index-based insurance (IbI). The questionnaire consisted of eight thematic sections covering demographic and farm-level characteristics, exposure and sensitivity to climatic hazards, historical losses, adaptation practices, insurance awareness and use, and preferences for the design of potential IbI products. The survey also incorporated a co-design component to elicit farmers' preferred triggers, thresholds, compensation structures, and tolerance for basis risk.

The survey was administered in spring 2025 using digital distribution channels provided by ASAJA Jaén, a major farmers' association in the region. This ensured broad dissemination among olive producers, who form the dominant agricultural group in the province. Responses were collected anonymously in full compliance with the EU General Data Protection Regulation (GDPR). A total of 47 complete responses were obtained, allowing for descriptive analysis of trends and patterns. While the sample is not statistically representative of all Spanish farmers, it captures a focused population highly exposed to climate hazards and provides valuable insights into the feasibility of parametric solutions in the Mediterranean context.

#### Sample characteristics

Most (66%) surveyed farmers fall between 45 and 65 years of age, indicating substantial agricultural experience. The sample has a higher proportion of male respondents (74.5%) compared to female respondents (25.5%), consistent with the gender distribution in the agricultural sector of Andalucía in which women represented 25.3% of total employment in 2019, while men accounted for the remaining 74.7% (Analistas Económicos de Andalucía, 2020). The majority report annual personal incomes above the Spanish national average of slightly over €15,000 (INE, 2023), with 51% earning between €25,000 and €40,000 or more, and with approximately 45% holding a university graduate degree.

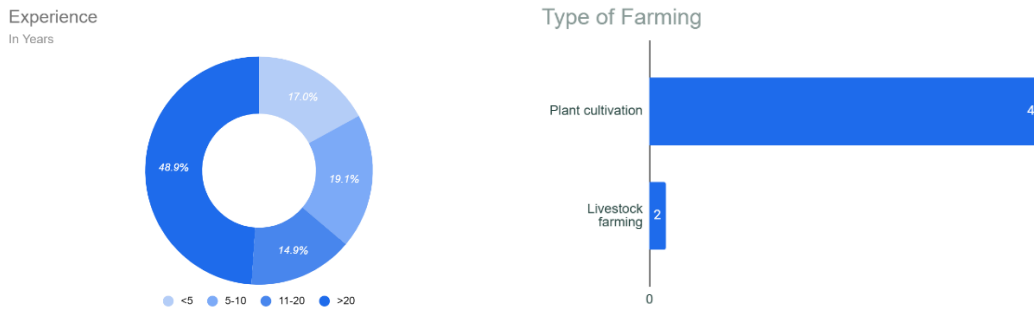


Figure 1 Farming experience and type.

Farming experience is high: nearly half the sample report more than 20 years of agricultural practice, while the remainder spans a balanced distribution of experience levels, with only 17% indicating less than 5 years of experience. In terms of type of farming, plant cultivation is overwhelmingly predominant, reported by all respondents, with only two also engaged in livestock farming (Figure 1). Farm ownership and management vary, with about half owning farms exclusively, around 19% managing farms without ownership, and roughly one-third both owning and managing farmland. The total number of farms owned or managed are reported to be 1 by nearly 64% of the farmers, with an additional 17% reporting 2 farms, and few responses in the rest of the categories. These statistics are represented in Figure 2 below.

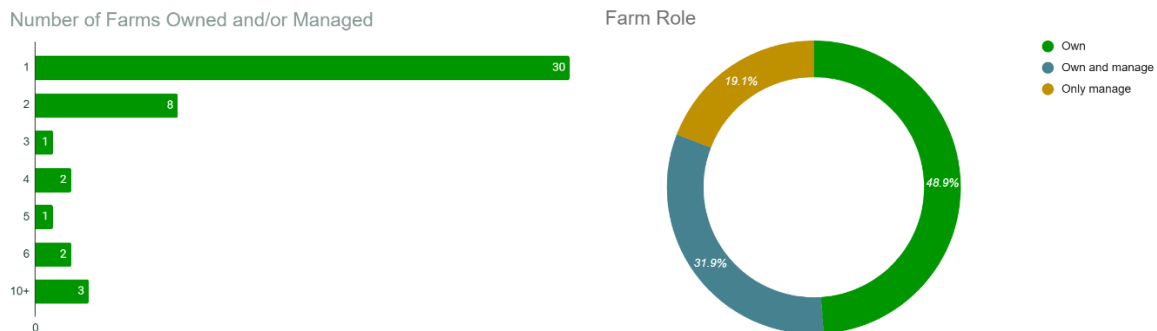


Figure 2 Farm characteristics.

Farm locations are concentrated in Andalucía, particularly Jaén, with some representation from Córdoba and Granada, as shown in Figure 3. This geographic focus reflects the sampling strategy through ASAJA Jaén. Figure 6 shows the crop production and total farm area under cultivation. In terms of crop production, olive cultivation dominates (98%), followed by limited cereal production (28%) and few other crops. Farm sizes vary widely, from less than 5 hectares (12%) to more than 100 hectares (21%), with the latter category typically associated with respondents managing or owning multiple farms. The largest group of respondents (34%) fall under 5-20 hectares of farm area.

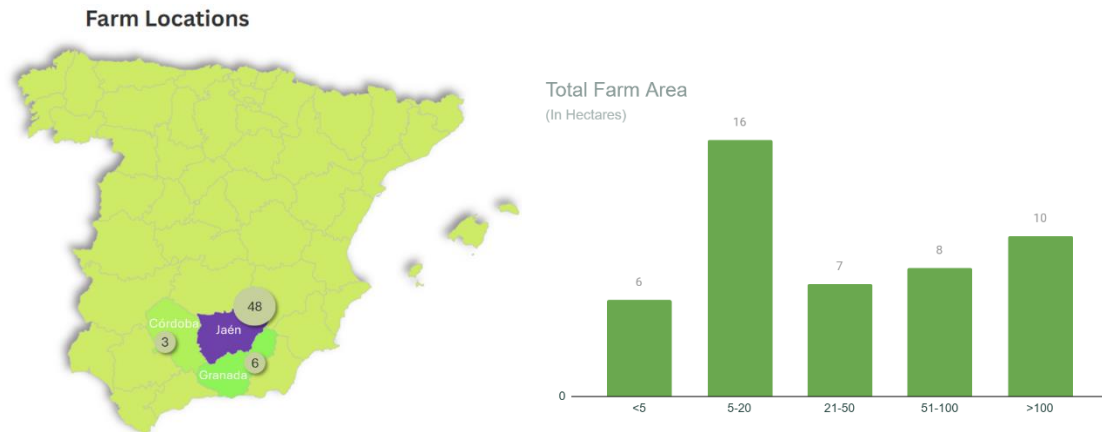


Figure 3 Farm locations and farm area.

### Climate sensitivity and risk

In Figure 4 below, farmers identify drought and heatwaves as the dominant climatic risks affecting their crops. Nearly all respondents regard drought as a primary threat, and many also highlight heatwaves. Less frequently mentioned hazards include landslides and strong winds, though these are considered more relevant for buildings than crops. Severity rankings reinforce this pattern: drought is overwhelmingly assessed as the most damaging risk, followed by heatwaves, with other hazards perceived as comparatively minor.

Farmers were asked to indicate which months of the year their crops are most sensitive to weather conditions. Responses show that crop, particularly olive, production is particularly vulnerable between April and September, with May standing out as the peak sensitivity period (reported by 55% of the farmers)). Conversely, winter months (November through February) are considered lower-risk periods. This aligns with the phenological cycle of olives and the seasonal timing of drought and heat events in Southern Spain.

### Climate Risk Severity Ranking

n = 47, 1 - Highest, 5 - Lowest

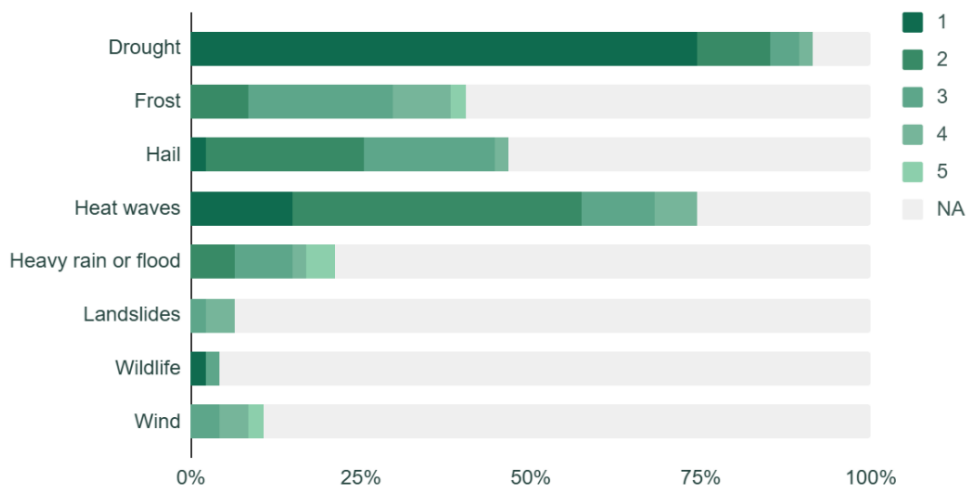


Figure 4 Ranking of the severity of climate risks.

In terms of weather impact, nearly 87% of farmers report moderate to severe weather-related impacts on crops within the past five years (Figure 5). Buildings, by contrast, show significantly less damage, with more than 40% of respondents reporting no weather impacts at all. This distinction supports the relevance of crop-focused rather than infrastructure-focused insurance solutions.

**Losses from climate risks**

Farmers provided accounts of past years in which they experienced losses from climate events. The results are shown in Figure 6. Drought appears as the most frequently cited (frequency > 38) cause of crop losses, particularly in 2022, 2023, 2024, and 2025. Several respondents note that drought affects both short-term yields and the medium-term health of olive trees, leading to cumulative multi-year impacts. Heatwaves also feature prominently (frequency = 11), especially when they coincide with flowering in May, causing severe flower burn and reduced fruit set. Frost-related losses are less common but notable, particularly where irrigation limitations exacerbated damage to young trees. Heavy rain and hail are mentioned occasionally, often with reference to specific timing that increases vulnerability, such as during fruit formation. Note that these are self-reported losses and have not been verified using independent data (e.g., weather observations, historical yield records, etc.).

**Weather Impact on Crops**

Last 5 Years

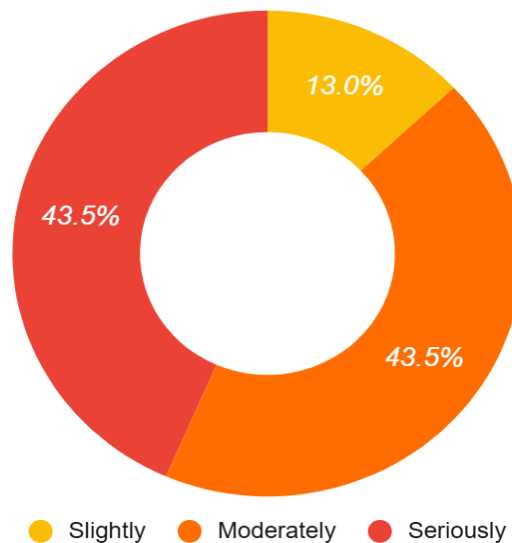


Figure 5 Weather impact on crops in the last 5 years.



### Highest Loss Events and Years

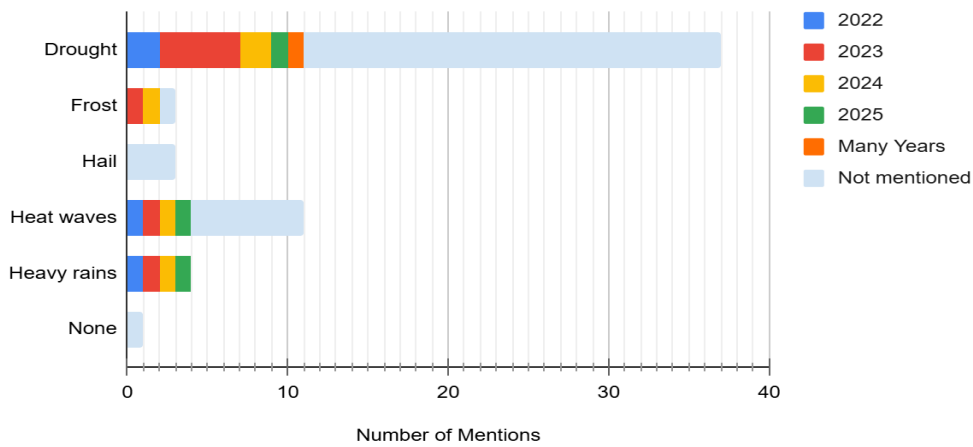


Figure 6 Highest loss events and associated years.

### Climate risk management

In this section, farmers were asked which climate risk management strategies, apart from insurance, do they employ at their farms. Additionally, they were asked to rate the effectiveness of these strategies. The list of climate adaptation strategies contains those relevant for olive farmers in Andalucía. As shown in Figure 7, out of the ones most frequently mentioned by the farmers are early harvest (79%), soil management (79%), selective pruning (81%), and soil conservation (79%). On the other hand, among the less frequently mentioned adaptive measures are protective structures (e.g. greenhouses) (40%), anti-icing sails (42%), humidity sensors (47%), and windbreaks (47%). Some respondents also chose “Others”, which included agricultural insurance; delayed (late) pruning, advance treatments and harvesting; drip; fertilizer in the irrigation, rather than on the surface, to facilitate absorption; and proper management of vegetation cover. Lastly, few farmers mention none.

### Agricultural Strategies for CRM

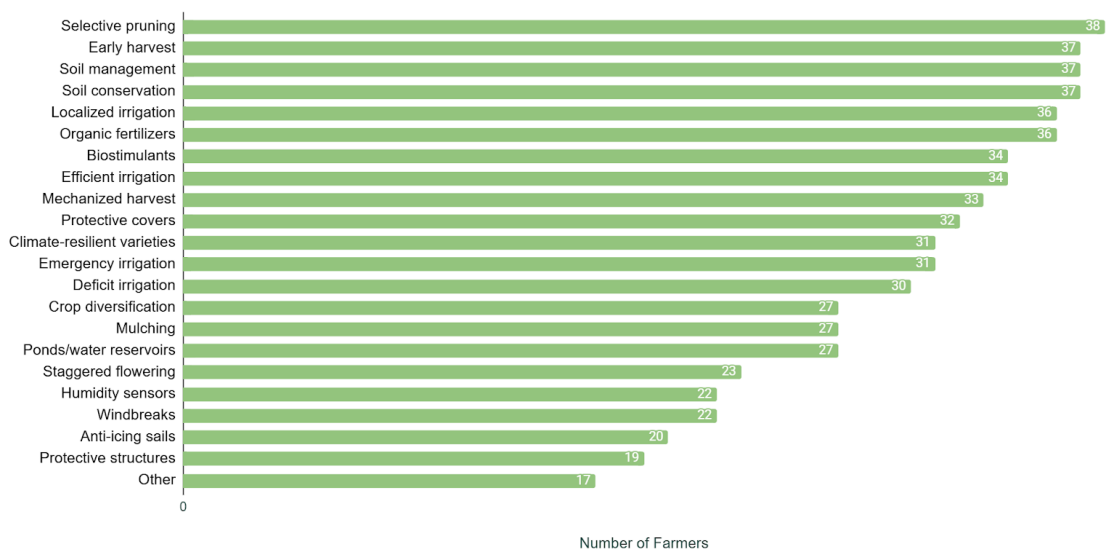


Figure 7 Agricultural strategies for climate risk management.

In Figure 8, farmers report the perceived effectiveness of different agricultural strategies in managing climate risk. They clearly see most climate-risk measures as useful, but with different degrees of confidence. Ponds/water reservoirs, emergency/localised and efficient irrigation, organic fertilizers and selective pruning stand out with very high shares of “4” and “5,” meaning they’re widely viewed as effective. More technical or context-specific practices like staggered flowering, windbreaks, humidity sensors, crop diversification and anti-icing sails show a more mixed distribution, with noticeable portions of “3” and lower scores, suggesting variability in suitability or familiarity. Mulching, mechanized harvest and soil management still rank strongly overall, but opinions are more dispersed. In short, farmers favour broad, proven agronomic strategies, while niche or highly technical measures receive more cautious assessments.

### Effectiveness of Agricultural Strategies for CRM

1 = not effective, 5 = very effective

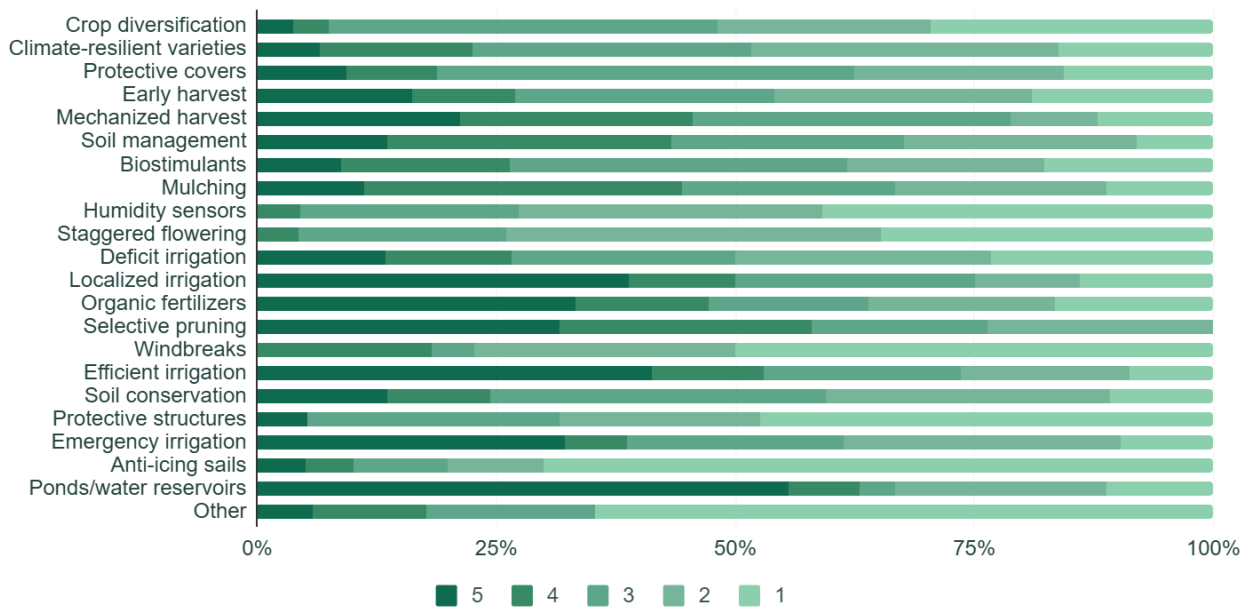


Figure 8 Effectiveness of agricultural strategies for climate risk management.

Figure 9 below shows that, apart from insurance, government grants are the main source of finance for climate-risk measures, used by over a third (35.7%) of respondents. Savings and emergency funds, along with loans or credit, each account for a quarter of responses, showing that many farmers (50%) rely on their own liquidity or borrowing capacity. Only small shares turn to cooperatives, Agroseguros<sup>4</sup>, or income from outside farming, and a similar share (5.4%) reports having no financing source at all. Overall, most farmers depend on public support or their own money rather than collective or market-based options.

<sup>4</sup> Agroseguro is responsible for the management of agricultural insurance in the name and on behalf of insurance companies that are part of the co-insurance pool. It is not, therefore, an insurance company, but a management entity.



**Finance Sources for CRM**

Excluding Insurance

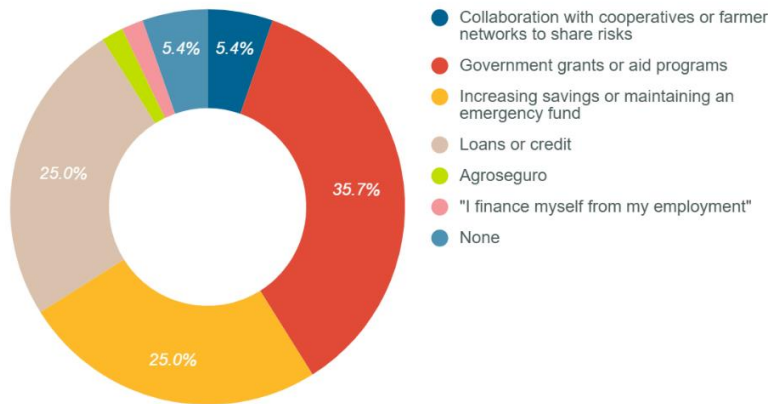


Figure 9 Finance sources for climate risk management.

**Use and perceptions of climate insurance**

Figure 10 presents the current awareness and experience of farmers with climate or weather insurance. Awareness of climate insurance is moderate. Nearly half of the farmers report only partial or no awareness (45.7%), while 54.3% report full understanding. Even so, a majority (49%) currently hold some form of coverage. Drought insurance is the most common (55%), followed by hail (34%), frost and building coverage (each 17%), and flood or heavy-rain coverage (13%). Satisfaction is generally high, with nearly 45% rating their experience highly, and only a small minority (17.2%) reporting dissatisfaction. Also note nearly 38% of the respondents give an average score of 3 for consumer satisfaction, which reflects a scope for improvement.

**Awareness of Climate Insurance**

Fully Aware Partially Aware Not Aware



**Current Use of Climate Insurance**

Yes No I don't know



Figure 10 Awareness and use of climate insurance.

Cost is the main barrier to wider uptake, cited by around 30% of the total respondents (Figure 11). Other obstacles include inadequate coverage for relevant risks (20%), lack of suitable products (20%), limited understanding of how insurance works (10%), and low trust in providers (6%). These barriers align closely with perceptions of Agroseguro. While many farmers use Agroseguro products, almost half are not satisfied with them. Only about one-fifth consider the system useful and trustworthy, and about 20% of the farmers do not use Agroseguro because they find the products unsuitable. Note that



while the satisfaction level from climate insurance is generally high among the users, only 10% of the total sample, including users and non-users, considers Agroseguro useful and trustworthy.

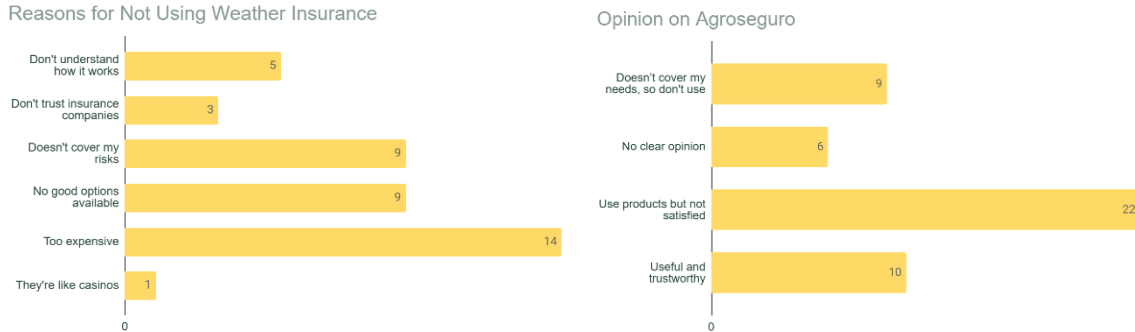


Figure 11 Reasons for not using weather insurance and opinion on Agroseguro - the current provider of weather insurance.

Overall, the results suggest that although farmers are willing to insure their crops and many already do so, concerns about affordability, coverage adequacy, and lack of available options continue to limit broader use of climate insurance.

### Index-based insurance

Figure 12 shows the farmers' awareness of index-based insurance products. Familiarity with index-based insurance is low. More than half of respondents indicate no knowledge of IBI, and only a small fraction (19%) feel confident in understanding how it works. Those who are aware of IBI typically learned about it through agricultural associations or directly from insurance agents/companies rather than through media channels or reports/articles.

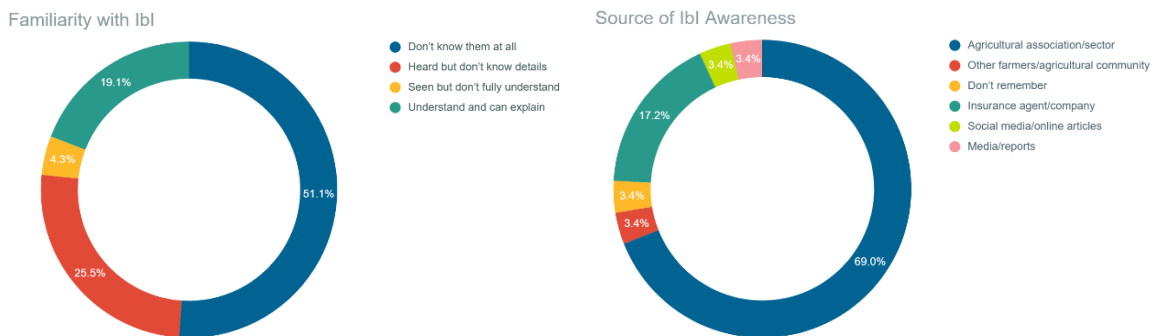


Figure 12 Familiarity with IBI and the source of awareness.

Moreover, more than 68% of the surveyed farmers have never purchased an index-based insurance policy, 26% had purchased such a product, and about 6% were unsure. This corresponds with the earlier finding that both awareness and understanding of IBI remain limited. Among those who have bought index-based insurance, drought is by far the most common hazard insured, reported by around 49% of the farmers. Heatwaves and hail appear with much lower frequency – 23% and 14% of farmers, respectively, and only 14% farmers reported IBI coverage for other risks such as heavy rain, frost or strong wind. Overall, the use of IBI remains modest and is concentrated mostly on drought protection.

Among farmers who have purchased index-based insurance, experiences are generally favourable (Figure 13). More than half of the farmers describe their experience as very positive or positive and a third as neutral, while only about 15% report negative or very negative experiences, indicating that dissatisfaction is present but limited. Interest in IBI is considerably higher than both awareness and past use. Nearly half of the farmers (about 49%) say they are somewhat interested, and a further 17% report strong interest. Around one-fifth are unsure, which reflects the low familiarity highlighted earlier. Only a small minority, roughly 15% combined, express little or no interest. Overall, the results suggest substantial openness to IBI, even though understanding remains limited.

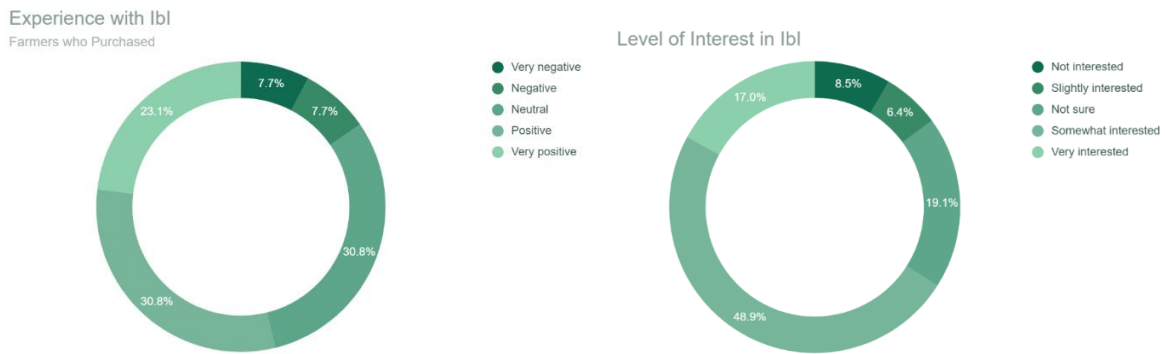


Figure 13 Experience with purchase of IBI and the level of interest.

Figure 14 shows the current barriers to the demand for IBI and the features that would make such a policy ideal for the users. Lack of awareness is the most significant barrier to adopting index-based insurance. Nearly half of the farmers identify this as their main obstacle. Cost is the second major hurdle, mentioned by about a quarter of respondents. Smaller groups point to the need for guidance in understanding how IBI works, as well as concerns about trust, complexity or compensation. A notable minority (15%) report no barriers at all, indicating openness to trying such products. When asked about their preferred features of an index-based policy, simple contracts with clear terms receive the strongest support (53%), followed by affordable and tailored premiums (44.7%). Many also value crop-specific coverage (36%), broader protection against multiple weather risks (30%) and fast, reliable payouts (32%). Clear communication is also important to a sizable group (25.5%), while only a few prioritise reducing bureaucracy (4%). Overall, farmers favour products that are easy to understand, reasonably priced and responsive when adverse years occur.

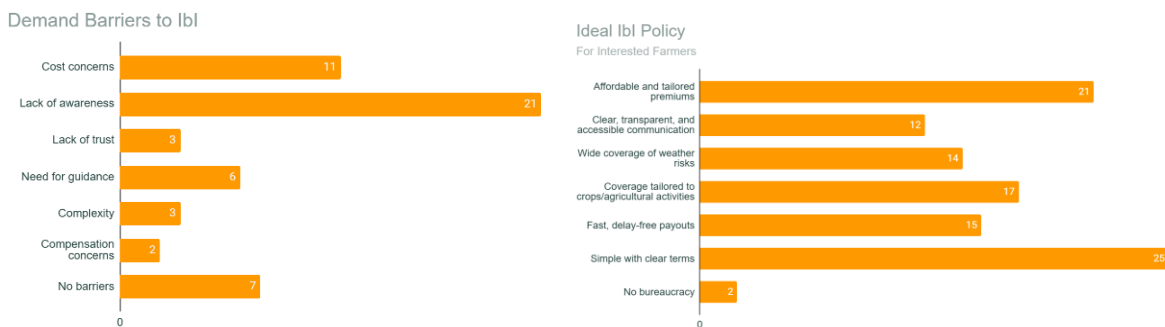


Figure 14 Barriers to the demand for IBI and defining an ideal policy.

**Co-design of IBI**

This section summarises the results most relevant for co-developing an index-based insurance product for olive farmers in southern Spain. Figure 15 shows the climate indicators to be monitored for IBI and the data sources for the same. In terms of climate risks, farmers prioritise the hazards that most affect their production, with drought identified by the largest share (37), followed by heatwaves (33). Hail (22) and frost (19) remain important, while heavy rain or floods (10), strong wind (9) and landslides (3) are secondary concerns. The pattern reflects the region’s dominant climate pressures. Farmers also express clear preferences for data sources to underpin an index. Local weather stations stand out as the preferred option (32), well ahead of alternatives such as satellite data (13), on-farm tools (11), or national weather data and remote sensing (10 each). Only a few favour model-based information or third-party services. Overall, farmers favour local, verifiable and easy-to-understand data for index design.

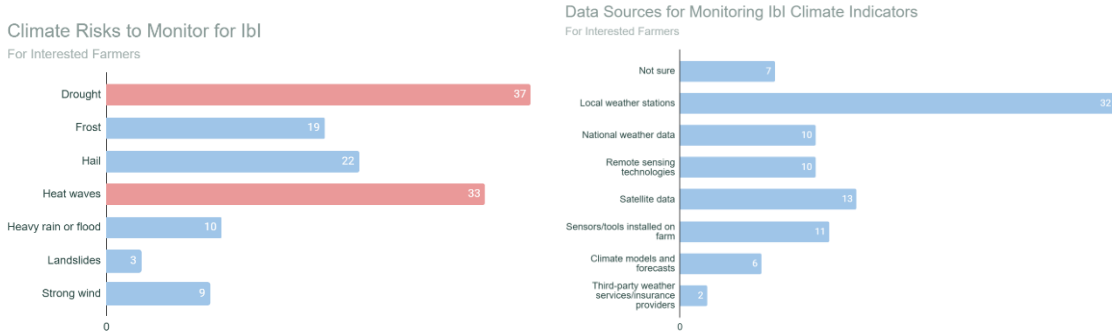


Figure 15 Climate indicators to monitor and the data sources to use.

Additionally, farmers show a clear preference for individual farm-level insurance (32), compared to collective (10) or regional (6) options, indicating demand for coverage reflecting farm-specific conditions. Compensation preferences focus on income stability, with income loss coverage most preferred (25), followed by full (16) and partial (14) index-based payouts. Coverage for input and operating costs is less prominent (9 each), with limited emphasis on recovery support (6). Overall, farmers expect individual-level income protection with clear, index-linked payouts.

In Figure 16 below, the results indicate quite limited tolerance for *spatial basis risk*, which is the biggest concern associated with IBI. Around one-quarter of farmers prefer no basis risk at all, and roughly one-third are comfortable only with low levels. A smaller group accepts moderate basis risk (17%), while about one-quarter are unsure. Overall, the majority prefer indices that closely match conditions on their own farms. Preferences regarding the distance to the weather station used for the index reflect the same pattern. Most farmers favour stations located within only a few kilometres of their farms, with around 41% selecting distances up to 0–5 km, with a high concentration at 5km (22%). Tolerance declines noticeably beyond 5–10km, and only a few farmers (19.5%) accept stations farther away. These responses highlight a strong preference for hyper-local data sources to minimise basis risk. However, note that maximum farmers (26.1%) report a tolerance up to 10km from their farm locations, which reflects the group willing/able to tolerate moderate risk.

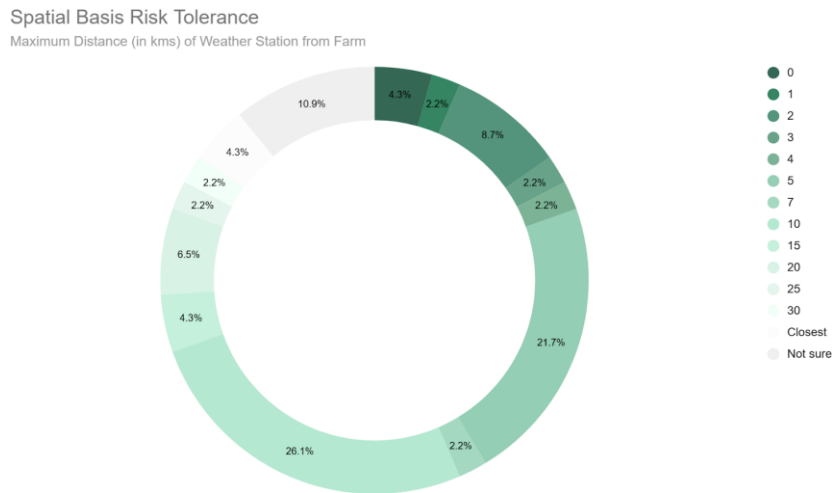


Figure 16 Spatial basis risk tolerance.

In Figure 17, willingness-to-pay responses suggest that farmers prefer flexibility rather than fixed premium levels. Only about one-fifth are willing to pay 1–3% of annual farm income, and a similar share would pay 3–5%. A smaller group (10%) is open to 5–10%, while a few prefer a flexible premium linked to yearly farm performance (5%). The largest group, however, remains unsure and requests concrete premium examples by farm size and crop type.

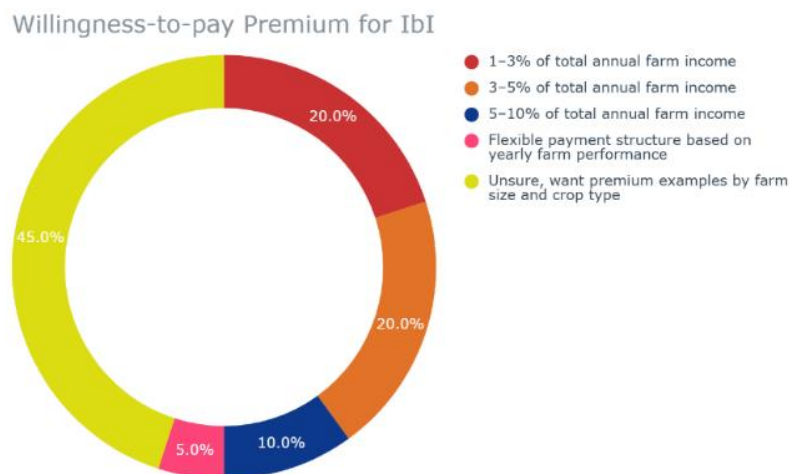


Figure 17 Willingness to pay.

Laslty, farmers report the practical on-farm indicators that they rely on when assessing the impacts of adverse weather. Lower yields are the most frequently cited effect (70%), followed by income losses (60%). Many also highlight visible crop damage (38%) and, to a lesser extent, higher production costs (25%). Only a few rely on climate indicators (6%) or market prices (2%). Overall, farmers evaluate weather impacts primarily through direct production and income outcomes rather than technical or market-based signals.



### 2.5.2 Farmer Workshop

A workshop with 12 olive farmers and agricultural technicians was held in Jaén on 8 April 2025 in collaboration with ASAJA-Jaén (Figure 18). The objective was to understand local agricultural practices and seasonal calendars, rank recent “bad years”, and elicit farmer-defined indicators and thresholds relevant for index design. Information was collected through a Mentimeter questionnaire, written responses and group discussion, providing qualitative evidence to complement the wider farmer survey conducted in southern Spain.



Figure 18 Photos taken during the farmers workshop in the office of ASAJA-Jaén.

Farmers outlined a clear seasonal cycle used to define vulnerability periods and contract windows (Figure 19). Winter (Jan–Mar) focuses on fertilisation and pruning, with pest control starting and intensifying into spring. Irrigation runs from March to October and dominates in summer. Autumn brings renewed fumigation and fertilisation, while harvesting occurs mainly from November to January (occasionally earlier). These patterns highlight spring as a critical period where climate conditions most strongly affect yields.



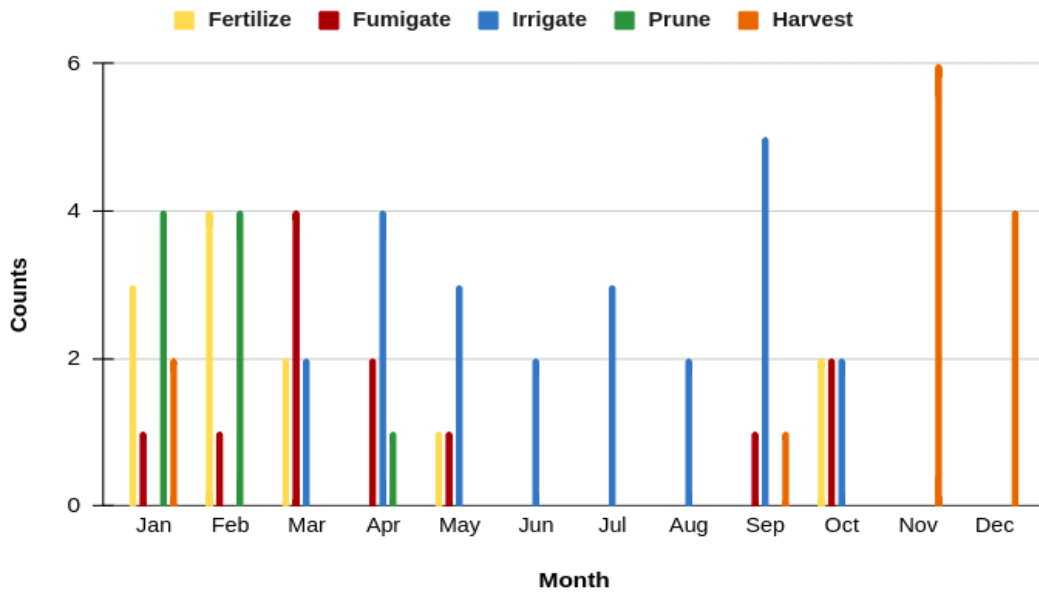


Figure 19 An overview of the main agricultural practices reported by the olive farmers, expressed as the number of times each were reported for a given month.

Farmers identified several years over the past three decades as particularly damaging for olive production, with almost all attributed to severe drought and, in some cases, compounded by ground frost or extreme heat. Farmers additionally highlighted that extreme high temperatures can negatively affect both crop yield and quality. Table 2 summarises the seven worst years reported for the period 1995–2024.

Table 2 The ranking of the worst seven years reported by the farmers for the period 1995 to 2024, with rank 1 indicating the worst.

| Rank | Year | Climatic reason                |
|------|------|--------------------------------|
| 1    | 1995 | Drought (worst year on record) |
| 2    | 2023 | Drought and ground frost       |
| 3    | 2022 | Drought                        |
| 4    | 2012 | Drought                        |
| 5    | 2014 | Drought                        |
| 6    | 2000 | Drought                        |
| 7    | 2005 | Drought and ground frost       |



The final part of the workshop focused on identifying key climatic thresholds in relation to the climate hazards that pose a threat to olive cultivation. Table 3 presents an overview of these thresholds that represent climate conditions beyond which damage or losses to the olive crop are expected and payouts should be triggered in Ibl.

Table 3 An overview of the climate thresholds defined by the farmers during the workshop.

| Climate variable    | Months              | Threshold              | Duration                  |        |
|---------------------|---------------------|------------------------|---------------------------|--------|
| Precipitation       | annual              | < 300 mm               | year                      |        |
|                     | Mar-Apr-May         | < 150 mm               | season                    |        |
|                     | March               | < 75 mm                | month                     |        |
|                     | Sept-Oct-Nov        | < 150 mm               | season                    |        |
|                     | September           | < 100 mm               | month                     |        |
|                     | October             | < 100 mm               | month                     |        |
|                     | November            | < 100 mm               | month                     |        |
|                     | Maximum temperature | April-May              | $\geq 35^{\circ}\text{C}$ | 3 days |
|                     |                     |                        | $\geq 40^{\circ}\text{C}$ | 2 days |
| Minimum temperature | Dec-Jan-Feb         | < $0^{\circ}\text{C}$  | 3 days                    |        |
|                     | Dec-Jan-Feb         | < $-8^{\circ}\text{C}$ | 1 day                     |        |



## 2.6 Comparison of surveys in the Mediterranean region

In terms of similarities between the Spanish and Italian farmer surveys, both reveal a high farmer exposure to climate-related risks, with drought, heat extremes and intense precipitation consistently identified as the most damaging risks, reflecting common Mediterranean climate issues. In both Italy and southern Spain, a large majority of farmers report having experienced climate impacts and economic losses in recent years, and most expect these risks to intensify in the future. Farmers in both contexts actively implement on-farm adaptation measures, primarily through changes in agricultural practices and investments in technology, yet these efforts are often constrained by financial and informational barriers. Insurance use is relatively widespread in both countries, but coverage remains uneven and poorly aligned with the most relevant climate risks. Dissatisfaction with traditional indemnity-based insurance emerges clearly in both surveys, driven by high costs, complexity, delays in compensation and limited trust in providers. Awareness and understanding of parametric insurance are low in both cases, but there is clear interest in such solutions when they are simple, transparent and perceived as fair and reliable with low basis-risk.

Taken together, the Italian and Spanish surveys point to structural patterns that can be generalised across Mediterranean agriculture: high climate vulnerability combined with a persistent insurance protection gap, despite strong willingness to adapt. Farmers across the region rely heavily on agronomic measures but lack complementary financial instruments that effectively address climate risk, particularly for drought and heat stress. The findings suggest that climate services and insurance need to be more closely integrated, with products designed around locally relevant hazards, seasonal timing and farmer-defined loss thresholds to reduce basis risk and improve trust. Given the specificity of farmer needs, highly tailored and contextualised insurance products can complement the existing traditional insurance. At the policy level, both surveys support the need for stronger EU and national involvement, including targeted incentives, premium support, clearer regulatory frameworks for parametric insurance and public guarantees to enhance credibility. More broadly, the results highlight that demand-driven, participatory approaches that link climate services, insurance sector, farmer communities, as well as the state are essential for climate resilience in the Mediterranean region.

## 3 Case study of olive farmers in Spain

### 3.1 Motivations and objectives of the pilot case study

This pilot case study examines the feasibility of parametric insurance for agriculture in the Mediterranean region of the Iberian Peninsula, focusing on olive cultivation in southern Spain, a sector identified by the IPCC as highly vulnerable to climate variability and extremes. Spain is the world's largest olive producer, with Andalucía accounting for about 75% of national output and Jaén as the main production province, with roughly 588,000 ha under olive cultivation. Despite the sector's importance, olive farmers remain insufficiently protected against key climate risks, particularly drought and heatwaves. Existing coverage is largely limited to traditional indemnity-based products administered through *Agroseguros*, which many farmers perceive as poorly aligned with their needs. Survey and workshop results indicate dissatisfaction with current insurance and interest in index-based solutions, pointing to a mismatch between farmer demand and available products, partly due to limited farmer involvement in past product design.

To ensure a demand-driven approach, the Barcelona Supercomputing Center (BSC) collaborated with ASAJA-Jaén to assess the feasibility of parametric insurance tailored to local climatic and agronomic conditions. ASAJA is Spain's largest agricultural organisation, representing more than 350,000 members nationwide, and its Jaén branch plays a central role in supporting olive producers and representing their interests. This collaboration enabled a grassroots assessment of climate risks and insurance needs grounded in farmers' experience.

The case study followed a three-step participatory process: identifying key climate hazards and vulnerable periods for olive production; collecting evidence on perceived risks, losses and barriers to insurance uptake; and co-developing a preliminary index-based insurance concept aligned with farmer-defined thresholds. The first two steps were implemented through a structured farmer survey across southern Spain and an in-person workshop in Jaén, forming the basis for the co-design of the parametric insurance concept.

### 3.2 Development cycles, methods, and loops

#### 3.2.1 CoDepi: A tool for co-designing index-based insurance

The Food and Agriculture pilot of the PIISA project aims to develop a co-design application that assists insurers in creating index-based insurance (IbI) products that are technically robust, commercially viable and aligned with farmers' needs. A central premise is that insured products must be demand-driven: they should reflect farmers' own perceptions of climate risks, their preferred thresholds and their past experiences with damaging years. Accordingly, CoDepi was developed following multiple rounds of engagement with ASAJA-Jaén and the participating olive farmers in the workshop, complementing the broader farmer survey.

CoDepi (Co-designing Parametric Insurance) is a participatory tool (logo in Figure 20) developed for olive farmers in southern Spain to collaboratively design a climate IbI that works for them. Built in alignment with the methodology developed by the International Research Institute for Climate and Society (IRI), CoDepi incorporates their best practices, particularly the "convergence of evidence" approach, iterative parameter adjustment, and participatory validation with end-users, in this case the

olive farmers of Jaén. The application enables the design of tailored Ibl products by aligning historical payouts with farmers' actual experiences, through adjustments in key model parameters. It also assists in setting appropriate premium prices and understanding trade-offs.



Figure 20 CoDepi logo. Source: BSC

The cornerstone of CoDepi's methodology is the *convergence of evidence* approach, a validation strategy that triangulates the performance of the proposed index across multiple, independent information sources to assess whether payouts would have occurred in years that farmers recognise as genuinely damaging. The process consists of several steps. First, historical index payouts are simulated using satellite-based datasets or local weather station records over a sufficiently long time period. These simulations are then compared with alternative climate information to ensure consistency in the representation of drought, heat or other hazards. In parallel, farmers' recollections of "bad years" are collected through structured participatory methods and aligned with the simulated payouts. Divergences between datasets, such as payouts triggered in years farmers do not consider harmful, or the absence of payouts in years they identify as severe, signal the need to adjust index parameters, including the contract window, thresholds or variable caps.

The aim of this process is to maximise agreement between scientific climate records and farmers' lived experience, thereby strengthening both the technical accuracy and perceived legitimacy of the index. Ensuring that payouts occur during years farmers identify as bad is fundamental not only for actuarial credibility but also for building trust and promoting uptake of the index-based insurance product.

### Base parameters

CoDepi uses a set of base parameters that define how climatic data is converted into insurance payouts. Each parameter plays a distinct role in shaping the sensitivity, reliability, and agronomic relevance of the contract (Figure 21). The parameters are described as:

- **Contract Windows:** These are defined periods within the agricultural calendar year when the crop is most vulnerable to climatic conditions, typically covering flowering and early fruit development in the case of olives. The window marks the start and end dates during which an index is measured for the purposes of triggering payouts. Currently, CoDepi allows for a single contract window, but can be extended to include multiple contract windows. Potentially, each window could be assigned a weight based on its relative importance to final yield.
- **Trigger and Exit Thresholds:** In index-based insurance, the trigger and exit thresholds define the boundaries of the payout function. These thresholds are not arbitrary values but are grounded in the farmers' self-reported threshold values as well as the historical distribution of the chosen climate index variable and calibrated to match actual loss conditions experienced by farmers.



- The trigger threshold is the point at which the index value becomes extreme enough to indicate the start of agronomic stress. In case of drought protection, for example, if the measured index (e.g., total rainfall during the contract window) remains above the trigger, the season is considered normal or non-damaging, and no payout is made. However, if the measured index falls below the pre-identified threshold value, then payout is automatically triggered.
- The exit threshold is the point at which the index value is so extreme that it reflects severe loss conditions. To take the previous example, when the rainfall index falls below this level, the insurance pays out 100% of the insured value. No more payout is made beyond this point, as the maximum payout value is reached.

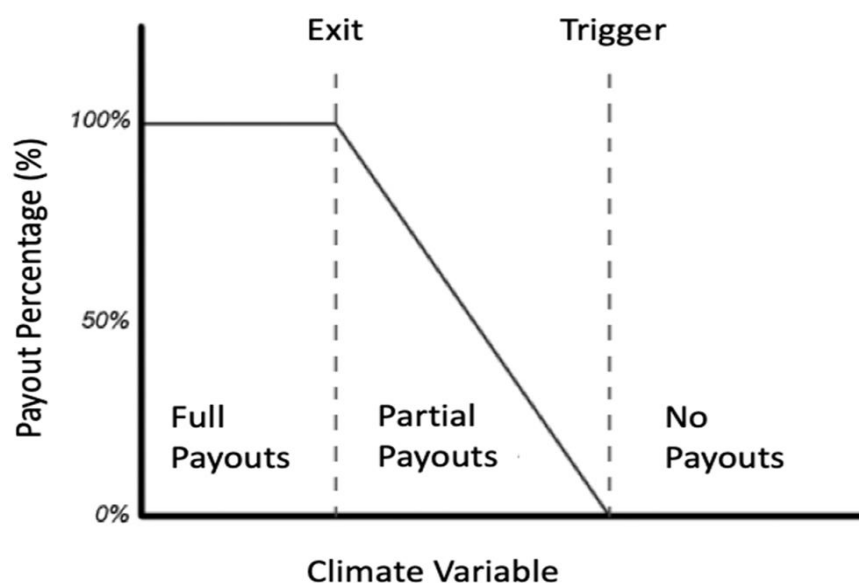


Figure 21 Trigger and exit thresholds, payout zone and slope for Ibl. Source: IRI

- **Payout Zone:** The range between the trigger and exit is called the payout zone. Within this zone, payouts increase as the gap between the trigger threshold and the index value increases. This relationship is typically modeled with a linear payout function, where each unit of the climate variable deficit or surplus corresponds to a proportional increase in payout.
- **Payout Slope:** This refers to the shape of the payout function between the trigger and exit thresholds. In CoDepi, a linear slope has been used. This function is standard in the literature and minimizes complexity. In advanced applications, non-linear functions can be explored.
- **Payout Frequency:** Payout frequency refers to how often an index insurance contract is expected to result in a payment to the insured party. This is not about how many times the contract allows payouts per season (e.g., monthly vs. seasonal), but rather how the design of the index influences the likelihood of payouts over time. It is a strategic decision that reflects the balance between offering protection against more frequent, moderate losses versus less frequent, severe ones.

If a contract is designed to trigger often, it will result in more frequent but typically smaller payouts. This can offer reassurance and continual engagement with the insurance product, but



it also increases the cost of the premium. On the other hand, setting the trigger lower will lead to less frequent payouts, only in very dry years, but allows for larger compensation amounts when they do occur and keeps premiums more affordable. Deciding the preferred payout frequency is a trade-off that must be considered carefully in consultation with farmers. Some prefer a product that acts more like a safety net for rare disasters, while others may want smaller but more consistent relief from regular climate stress. The frequency also influences how farmers perceive the value and fairness of the insurance over time.

- Caps:** To prevent distortions caused by extreme but ineffective climate events, a cap is applied to the amount of a climate variable measured, say rainfall, that can be counted per unit of time, say per day or per dekad (10-day period) in the index calculation over the contract period, say a month. For example, a cap of 30 mm/dekad ensures that any rainfall above that threshold is excluded from index measurement. This is especially useful in Mediterranean climates, where short, intense rainstorms may not contribute meaningfully to crop water needs. Applying a cap helps improve the agronomic relevance of the index by filtering out favourable climate events that do not actually benefit the crop.

### Historical payout validation

Once the index structure and base parameters are co-defined with farmers, CoDepi conducts back-testing simulations over the historical climate record, as illustrated in Figure 22. The resulting payout series is then compared with farmers’ recollections of “bad years” and with independent climate datasets to assess the consistency of the index. Payouts are plotted across the full timeline, and discrepancies are flagged. For example, if 2005 is widely reported as a severe drought year but the index yields no payout, the design parameters require reconsideration.

This evaluation forms the basis of an iterative convergence process, in which contract windows, trigger and exit thresholds, payout frequency and, where relevant, the underlying climate dataset are adjusted and re-tested until the index aligns more closely with both climate evidence and farmer experience. In addition to historical validation, CoDepi can also incorporate seasonal monitoring, enabling real-time assessment of risk exposure and index performance using field observations, crowd-sourced data, satellite products and meteorological information. This functionality supports the refinement of the Ibl product during its operational lifetime and enhances transparency for end users.

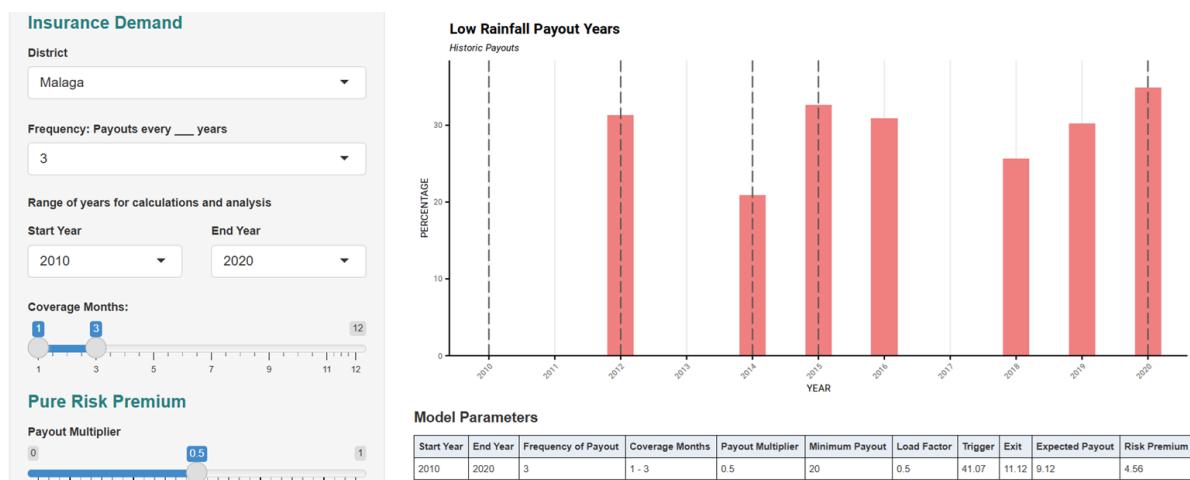


Figure 22 Historical payout validation for a location in Spain as displayed in CoDepi tool.

## Seasonal Forecasts

Seasonal climate forecasts provide **probabilistic** information on climate conditions at lead times of months to seasons. In the context of Ibl, they are not typically used to trigger payouts as they remain based on observed indices (e.g., station data, satellite products, or reanalysis) to avoid adverse selection and to maintain contractual clarity. However, seasonal forecasts can complement Ibl as an ancillary climate service, supporting (i) early warning and preparedness for farmers during phenologically sensitive windows, and (ii) portfolio monitoring and liquidity planning for insurers and cooperatives.

This is particularly relevant for olive production in Jaén, where both the survey and workshop indicate heightened sensitivity during spring (flowering and early fruit set) and strong concern about spring rainfall deficits and heat extremes. Farmer-defined thresholds (Section 4.1) include, for example, March–May precipitation below 150 mm and episodes of high temperatures in April–May.

To illustrate how seasonal climate information can be operationally delivered to stakeholders, we use seasonal forecasts from the ECMWF seasonal prediction system SEAS5.1, distributed through the Copernicus Climate Change Service (C3S). Forecasts are ensemble-based and are expressed as probabilities of relevant events (e.g., total precipitation below a user-defined threshold over a 3-month window). In this pilot, forecasts are bias adjusted following established post-processing approaches (e.g., Leung et al., 1999; Torralba et al., 2017). Figure 23a shows an example of a forecast product aligned with a farmer-defined drought threshold: the forecast probability that March–April–May 2025 total precipitation will be below 150 mm, initialised on 1 March 2025.

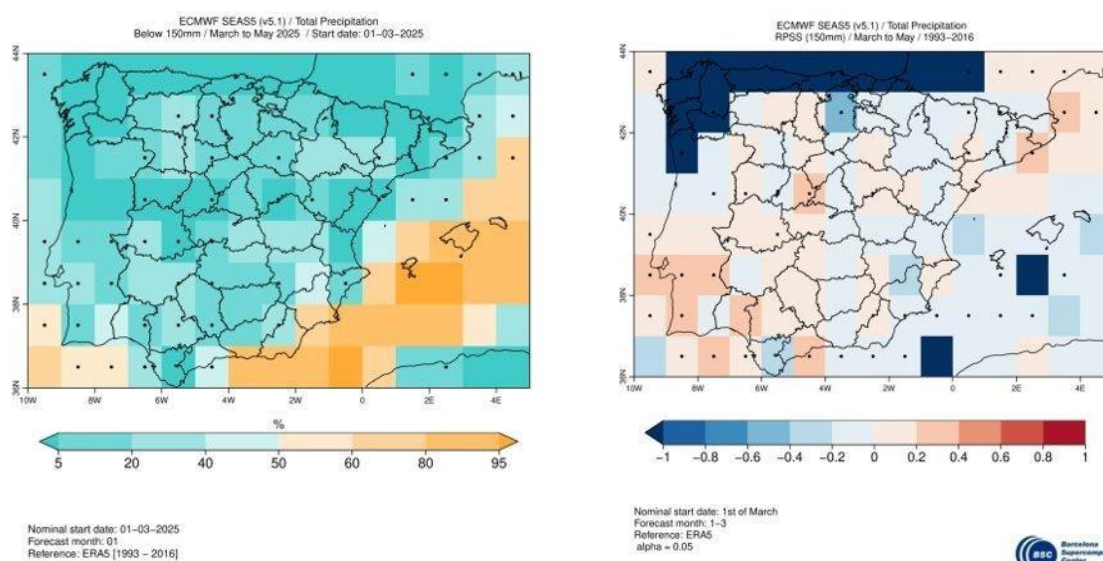


Figure 23 Left (a) bias-adjusted probability that March–April–May 2025 total precipitation will be below 150 mm, initialised 1 March 2025 (ECMWF SEAS5.1). (b) Hindcast skill for the same event definition, expressed as RPSS for 1993–2016.

Because seasonal forecasts are inherently uncertain and their reliability varies by region, season and variable, forecasts should be accompanied by an objective assessment of historical skill. We therefore evaluate forecast performance using hindcasts for 1993–2016 and compute the Ranked Probability Skill Score (RPSS) for variables and event definitions relevant to agro-climatic risk (Figure 23b and Figure 24). RPSS measures the improvement of probabilistic forecasts relative to a reference forecast

(typically climatology); positive values indicate improved performance, while negative values indicate worse performance than the reference.

The RPSS maps included indicate that skill varies substantially across Spain and by variable. In general, near-surface temperature exhibits more spatially coherent positive skill than precipitation, while precipitation skill is weaker and more heterogeneous (particularly for drought threshold events).

To support transparent access to forecast information and skill diagnostics, a prototype Shiny-App was developed for the PIISA case-study (Figure 25). The tool enables users to visualise bias-adjusted probabilistic forecasts for selected variables and thresholds and to inspect associated skill metrics. Presenting forecasts together with skill information is essential to reduce misinterpretation and to support informed use alongside Ibl products.

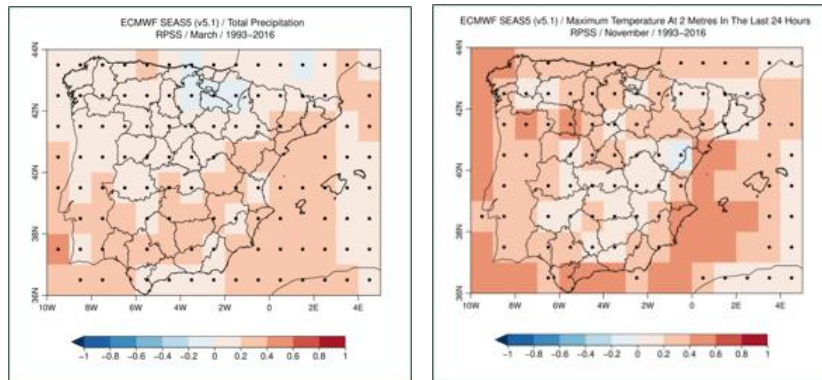


Figure 24 Ranked Probability Skill Score (RPSS) of bias-adjusted ECMWF SEASS.1 seasonal predictions over the Iberian Peninsula (hindcast period 1993–2016) for Total Precipitation (left) and Maximum temperature at 2m (right) relevant to agro-climatic risk. Positive RPSS values indicate improvement over climatology, while negative values indicate worse performance.

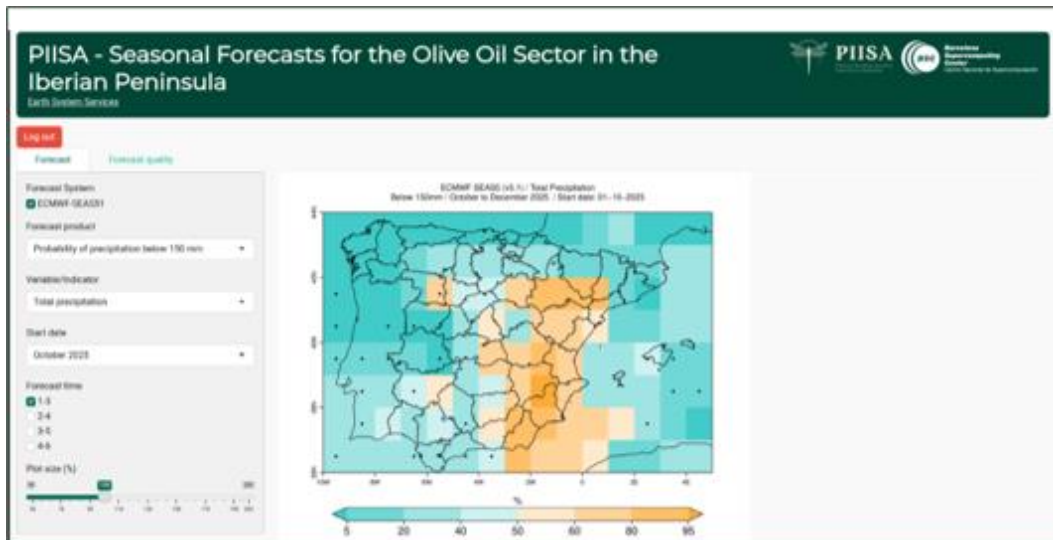


Figure 25 Prototype dashboard for seasonal forecasts for the olive sector in the Iberian Peninsula, providing probabilistic forecasts for user-defined thresholds and accompanying forecast-quality diagnostics.

Insurance companies increasingly rely on climate services to guide underwriting and portfolio management, drawing on platforms such as the World Climate Service, which aggregates major seasonal forecast models to assess evolving climate signals months in advance. These forecasts are used qualitatively when deciding whether to underwrite, renew, or adjust the capacity, especially

when large-scale drivers like ENSO or the IOD indicate elevated drought or rainfall risk. In such cases, insurers may recalibrate pricing, adjust deductibles, or reduce exposure if payout probabilities rise. One of the main criticisms of traditional insurance is that while it uses forecasts to decide whether to underwrite, renew, or adjust the capacity of the crop, they do not consider the current and past production of the crop itself. For established parametric programmes, underwriting decisions are normally made well before the risk season, limiting the possibility of bias. However, when products are distributed through cooperatives shortly before sowing, insurers must ensure the covered risk is not overly sensitive to farmers' late decisions to avoid anti-selection. Overall, climate forecasts help insurers determine their willingness to insure, the structure of contracts, and the level of capacity they allocate for agricultural portfolios, even though such use is less pronounced in temperate regions (AXA Climate).

The analysis also highlights the complementary role of climate services. Seasonal forecasts, early warning systems and related tools can improve decision-making and increase the value of Ibl by providing anticipatory information. Developing such integrated climate-risk tools, however, requires sustained public investment, regulatory clarity and coordinated engagement between public and private actors. Experiences from other contexts show that the early phases of Ibl development often rely on external funding, and market uptake may be constrained when product development costs are perceived as high relative to expected demand.

### 3.2.2 Conclusion and way forward

This case study examines the potential of index-based insurance to transfer climate-related risk in the Mediterranean agriculture sector. The evidence from Spain indicates that although many farmers already engage with insurance, concerns regarding cost, adequacy of coverage and product relevance persist. At the same time, there is a clear willingness to consider index-based insurance (Ibl) when products are transparent, tailored and supported by policy institutions. The results reflect that there is a disconnect between currently available instruments and the climate risks farmers face.

The participatory approach implemented with ASAJA Jaén, supported by the CoDepi tool, provides a structured method for addressing this gap. By integrating farmer-defined thresholds, historical climate information and iterative parameter adjustment, the co-design process strengthens both the agronomic validity and perceived fairness of parametric products. The case of olive farmers in Jaén illustrates that aligning index triggers with lived experience, rather than relying solely on externally defined parameters, can enhance technical performance and foster user trust. As the tool evolves, it offers a replicable pathway for developing Ibl concepts in regions facing different climatic and agricultural conditions.

Finally, the feasibility of implementing Ibl in Spain is shaped by structural features of the national insurance system, including the central role of Agroseguro and the need to ensure long-term actuarial sustainability. Previous experiences in the region show that products with high payout frequencies may be attractive to farmers but financially unsustainable for insurers. Designing viable Ibl therefore requires balancing farmer preferences with sound pricing and risk-transfer structures. Key potential areas of research include assessing the technical and commercial viability of the index insurance solution developed in consultation with insurance partners, the transferability of this approach to other crops and regions and integration of additional climate services.

## 4 Climate service development for agriculture

The European agricultural sector is facing significant challenges due to climate change. The EU is urged to improve risk management systems to mitigate these risks and expand farm insurance. Of the climate perils, drought is the worst, causing an annual averaged losses across the EU of almost EUR 10 billion (fi-compass 2025). Drought conditions are the largest peril both in Southern and in Northern Europe, where farming is commonly rain-fed. Currently operational climate services in the boreal region focus on monitoring and short-term (hours to two weeks) weather forecasting and the use of extended range forecasting is limited.

In this report, development of composite indices for planning of agricultural risk management of drought is described in the following section 4.1. Section 4.2 examines the current state of services, research and data systems related to seasonal impact predictions for food security in the Boreal & Arctic region and assesses their maturity and gaps. These sections complement and contrast the Mediterranean focus of pilot activities.

In PIISA, development of climate indices and services was performed in WP2 “Innovations in adaptation and climate services for insurance”. Deliverable D2.3 “Climate services on insurance options and adaptation alternatives for citizens” describes some other indices and services relevant for the agricultural sector (Trentini et al. 2026).

### 4.1 Agro-climatic drought and water stress indicators for risk management and adaptation

Climate change is placing increasing pressure on food production across Europe, although its impacts differ between semi-arid regions and regions that have historically experienced wetter climates. While water scarcity is intensifying in parts of southern Europe, rainfed agriculture in Central and Northern Europe may also become more vulnerable as precipitation patterns change and growing seasons shift. These developments highlight the need for indicators that better capture water-stress risks affecting crop productivity.

To explore potential extensions of climate services for agricultural risk assessment, two complementary indicators are considered: the Standardized Precipitation and Growth Index (SPGI) and potential crop yield loss under rainfed conditions. These indicators link precipitation variability, growing-season dynamics, and crop water demand to better represent drought-related risks to agricultural production.

Although these indicators are not currently part of the PIISA agricultural parametric insurance pilot, they provide a complementary and more process-based perspective on drought-related production risks and they are applied for multi-decadal projections. Both indicators are derived using EURO-CORDEX regional climate simulations, allowing an assessment of historical agro-climatic conditions and potential future changes under different climate scenarios.

#### **Standardized Precipitation and Growth Index (SPGI)**

The Standardized Precipitation and Growth Index (SPGI) is designed to evaluate drought conditions during the period most critical for vegetation and crop development. Unlike traditional precipitation-

based drought indices, SPGI accounts for the timing and duration of the growing season<sup>5</sup>, ensuring that precipitation anomalies are evaluated during the biologically relevant period for plant growth.

The index is calculated by standardizing precipitation accumulated during the growing season relative to its long-term climatology:

$$SPGI = \frac{P_{GS} - \mu_{GS}}{\sigma_{GS}}$$

$P_{GS}$  Represents precipitation accumulated during the growing season,

$\mu_{GS}$  is the long-term mean growing-season precipitation, and

$\sigma_{GS}$  is the standard deviation of growing-season precipitation.

Because the index is standardized, positive SPGI values indicate wetter-than-normal growing seasons, while negative values indicate increased drought risk during the crop growth period; values between -1 and 1 represent near-normal conditions, 1 to 2 moderately wet conditions, greater than 2 extremely wet conditions, -1 to -2 moderately dry conditions, and below -2 extremely dry conditions, which may correspond to severe drought impacts on crops and ecosystems.

### Crop yield loss under rainfed conditions

The second indicator estimates potential crop yield loss caused by water stress under rainfed conditions, assuming that irrigation is not available to compensate for precipitation deficits.

The approach follows the FAO crop water balance methodology (Allen et al., 1998; Doorenbos and Kassam, 1979). First, the reference evapotranspiration ( $ET_0$ ) is calculated using the FAO Penman–Monteith equation.

Crop evapotranspiration demand is then estimated using crop-specific coefficients:

$$ET_c = K_c \times ET_0$$

Actual evapotranspiration under rainfed conditions ( $ET_a$ ) depends on precipitation and soil water availability. When precipitation is insufficient,  $ET_a$  becomes smaller than  $ET_c$ , indicating water stress. The relationship between evapotranspiration deficit and crop yield reduction is described using the FAO yield response function:

$$1 - \frac{Y_a}{Y_m} = K_y \left( 1 - \frac{ET_a}{ET_c} \right)$$

where  $Y_a$  is the actual yield,  $Y_m$  is the potential yield, and  $K_y$  is the crop-specific yield response factor.

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<sup>5</sup> The thermal growing season is defined following Ruosteenoja et al. (2016) as the period when daily mean air temperature exceeds +5 °C. The start of the season is determined by the permanent exceedance of this threshold in spring (i.e., temperatures remain above +5 °C without subsequent drops below), and the end is defined by the permanent decline below +5 °C in autumn. The growing season length is calculated as the number of days between these two dates.

Both indicators were calculated using an ensemble of ten EURO-CORDEX regional climate simulations (Jacob et al., 2014), representing combinations of global climate models and regional climate models. The simulations used in this analysis were:

- ICHEC-EC-EARTH / CLMcom-CCLM4-8-17
- ICHEC-EC-EARTH / DMI-HIRHAM5
- ICHEC-EC-EARTH / KNMI-RACMO22E
- ICHEC-EC-EARTH / SMHI-RCA4
- IPSL-IPSL-CM5A-MR / IPSL-WRF381P
- MPI-M-MPI-ESM-LR / CLMcom-CCLM4-8-17
- MPI-M-MPI-ESM-LR / MPI-CSC-REMO2009
- MPI-M-MPI-ESM-LR / SMHI-RCA4
- NCC-NorESM1-M / DMI-HIRHAM5
- NCC-NorESM1-M / GERICS-REMO2015

The results shown represent the ensemble mean of these ten simulations.

### **SPGI projections across Europe**

To assess potential future changes in growing-season drought conditions, SPGI was calculated across Europe using the EURO-CORDEX ensemble. The maps show the difference relative to the historical baseline period (1971–2000) for two future periods: mid-century (2041–2070) and end-century (2071–2100) under RCP4.5 and RCP8.5 scenarios (Figure 26).

Across most simulations, a clear north–south gradient emerges. Northern Europe, particularly Scandinavia and parts of the Baltic region, shows positive SPGI anomalies that become stronger toward the end of the century and under the higher-emission scenario. This pattern is broadly consistent with projections of increasing precipitation and longer growing seasons in northern latitudes. On average, an increase of water availability during the growing season is projected, which suggest potential for increasing production. However, late spring and early summer droughts are projected to increase. The lengthening of growing season cannot compensate yield losses of rain-fed crops due to early summer water scarcity. In future, production uncertainties and yield variability continue to be challenging for farmers in high-latitude conditions. (Peltonen-Sainio et al. 2021).

In contrast, parts of southern Europe and the Mediterranean region display weaker or locally negative SPGI changes, particularly by the end of the century under RCP8.5. This likely reflects the combined influence of declining or more variable precipitation and increasing evaporative demand under warmer conditions, which may intensify drought stress during the growing season. Due to combination of large production and vulnerability, drought conditions affecting Spain, Italy and France would produce the largest absolute losses during extreme years in future (Pirjo et al., 2021).

Overall, these projections suggest that growing-season water availability may increase in northern Europe while water scarcity and drought risks may intensify in southern regions, although regional variability remains substantial.

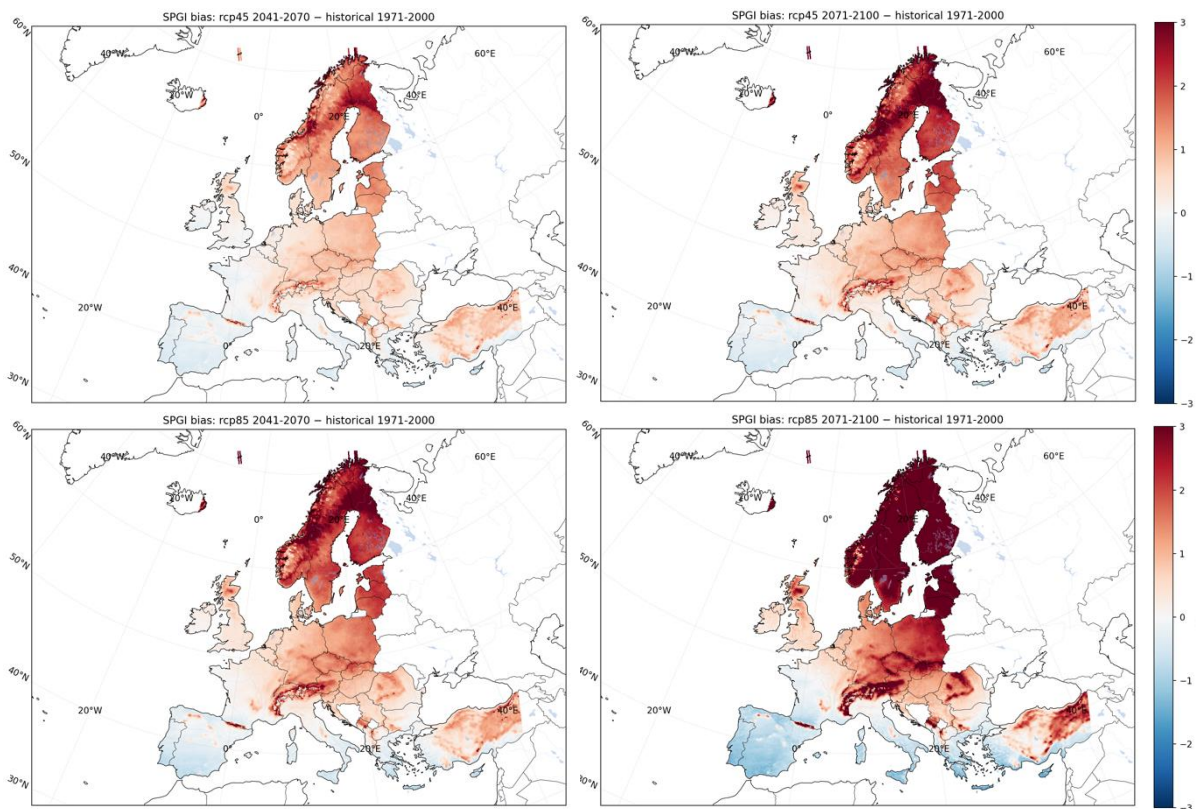


Figure 26 Projected changes in the Standardized Precipitation–Growing Index (SPGI) based on the ensemble mean of 10 EURO-CORDEX regional climate model simulations. Panels (a)–(b) show SPGI changes under RCP4.5 for mid-century and end-of-century, respectively, while panels (c)–(d) show SPGI changes under RCP8.5 for mid-century and end-of-century.

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Overall, these projections suggest that growing-season water availability may increase in northern Europe while water scarcity and drought risks may intensify in southern regions, although regional variability remains substantial.

### **Projected crop yield loss in Finland**

To examine the potential impacts of water stress on agricultural productivity, the crop yield loss indicator was applied to Finland using the same EURO-CORDEX ensemble. Results reveal that the ensemble mean of the ten simulations for the end-of-century period (2071–2100) under the RCP8.5 scenario, when large portion of fields have potential for growing maize in Finland.

For maize, projected yield losses are generally around 40–50% in Finland. This reflects the sensitivity of maize to water stress during the growing season and the increasing evaporative demand expected under warmer climatic conditions.

For wheat, the spatial pattern is more heterogeneous. Northern Finland shows relatively high yield losses, exceeding 50% in some areas, whereas southern Finland tends to exhibit lower losses, typically around 20–40%. This difference may reflect regional variations in precipitation patterns, growing-season length, and crop water demand.

An important factor contributing to the relatively high projected yield losses, particularly for maize, is the increase in evaporative demand associated with rising temperatures. Even in regions where precipitation is projected to increase, higher temperatures can substantially raise reference evapotranspiration and crop water requirements during the growing season. As a result, the balance between water supply (precipitation) and atmospheric water demand may still lead to water stress conditions for crops. This effect can be particularly pronounced for crops such as maize that have high water requirements and strong sensitivity to moisture deficits during key growth stages, which may explain the relatively large projected yield losses across Finland in the model simulations.

Overall, the results indicate that water availability during the growing season may remain an important limiting factor for crop production even in northern European regions, despite projected increases in precipitation. Rising temperatures are expected to increase evaporative demand and crop water requirements, which may offset potential gains from higher rainfall.

### **Future perspectives**

Although the SPGI and crop yield loss indicators are not currently included in the PIISA agricultural parametric insurance pilot, they illustrate how climate information can be translated into impact-relevant metrics for agricultural risk assessment and adaptation planning.

In the future, such indicators could support early-warning systems for drought during critical crop growth stages, inform climate-resilient agricultural management strategies, and potentially contribute to the development of next-generation parametric insurance indices that better capture the relationship between climate variability and agricultural impacts.

Further work would be required to integrate these indicators within operational climate services, including improved representation of crop management practices, soil characteristics, and irrigation strategies.

## 4.2 Maturity & Gaps study: Seasonal impact prediction for Boreal & Arctic agriculture and food systems

This section examines the current state of services, research and data systems related to seasonal impact predictions for food security in the Boreal & Arctic region, and identifies gaps, challenges and opportunities for improvement. The assessment evaluates the maturity across:

- data including quality evaluation,
- agro-climatic indices,
- crop growth modelling with emphasize on the integration of seasonal forecasts in crop growth models, and
- farmers engagement in using seasonal forecast products in decision making.

The study summarizes existing capability and knowledge gaps across the Nordic countries and reviews services and expertise available in other European regions, including their maturity level, and potential for upscaling these services to the Boreal and Arctic region. The geographical focus is Northern Europe and temporal scale considered is seasonal.

### 4.2.1 Status of data availability

A large set of **operational seasonal forecast data** is available for the target region. These sources offer the variables needed for agro-climate indicators.

- 1) Seasonal forecast data are operationally available from **C3S** (<https://climate.copernicus.eu/seasonal-forecasts>), including forecasts from 8 state-of-the-art models and the C3S multi-model ensemble. The forecasts are updated on 6th or the 10th at 12 UTC of each month, horizontal resolution 1°x1°. **Maturity level: operational**
- 2) **ECMWF SEAS5** model data available for member states through MARS. Compared to SEAS5 data available in C3S, this dataset has higher horizontal resolution (0.25°x0.25°) and longer reforecast dataset. **Maturity level: operational**

In addition, **operational hydrological seasonal forecast datasets** (EFAS and GloFAS) available in CEMS Early Warning Data Store provide hydrological variables that are useful for agriculture, such as soil wetness index, volumetric soil moisture and snow water equivalent.

- 1) **EFAS dataset:** Seasonal forecasts of river discharge and related data by the European Flood Awareness System: <https://ewds.climate.copernicus.eu/datasets/efas-seasonal?tab=overview>

Horizontal resolution: 1x1 arc-minute for version 5.0, 5x5km for version 4.0 and older ones  
Temporal coverage: 1 November 2020 to 1 September 2023 and 1 May 2024 to near real-time  
Forecasts are updated monthly, initialized the first of each month with lead time of 215 days.  
EFAS is using ECMWF SEAS5 as meteorological forcing. **Maturity level: operational**

- 2) **GloFAS dataset:** Seasonal forecasts of river discharge and related data by the Global Flood Awareness System: <https://ewds.climate.copernicus.eu/datasets/cems-glofas-seasonal?tab=overview>

Horizontal resolution: 0.05° x 0.05° for version 4.0, 0.1° x 0.1° for version 3.1 and older.

Temporal coverage: 1 December 2020 to near-real time for operational version for river discharge and various dates for legacy versions. 1 March 2024 to near-real time for operational version for soil wetness index and snow depth water equivalent.

Forecasts are updated on the 10<sup>th</sup> of each month initialized with lead time of 123 days. GloFAS is using ECMWF SEAS5 as meteorological forcing. **Maturity level: operational**

- 3) **Multi-model seasonal forecasts data of river discharge for Europe from January 2021 to present:** provides hydrological seasonal forecasts of monthly mean river discharge across Europe, available in C3S: <https://cds.climate.copernicus.eu/datasets/sis-hydrology-variables-derived-seasonal-forecast?tab=overview>

This dataset provides information only for river discharge that might be potentially used for impact studies. **Maturity level: operational**

- 4) **Norwegian Climate Prediction Model (NorCPM):** started producing seasonal-to-decadal predictions operationally in May 2022, with the goal of eventually becoming part of the C3S seasonal prediction models. The model is under development, datasets not made available yet. **Maturity level: under development**

## 4.2.2 Data quality assessment

Currently, there are only a limited number of studies that assess the quality of seasonal forecast model outputs in the Nordic region. Most existing research focuses on specific areas, such as Finland and Norway, while several broader studies address seasonal forecast quality across Europe. This review emphasizes studies targeting Nordic countries.

**Finland:** Skill assessment and post-processing of key monthly climate variables from ECMWF SEAS5 have been conducted for both the growing season and annual period. These variables include temperature, precipitation, snow cover and soil moisture (Vajda and Hyvärinen 2020, Hyvärinen et al. 2020, Vajda et al. 2021). The quality of all the studied variables was successfully increased through bias adjustment; however, the predictability of precipitation is found to be more limited over Finland. Temperature prediction is skilful during months LM0 and LM1, however skill is lower during summer. Soil moisture showed high skill scores and was useful for LM0 and LM1, skill was somewhat lower during the summer. Snow forecasts have strong skill over Finland during the first two lead times and proved to be useful also for the third lead month (Vajda and Hyvärinen 2020; Vajda et al. 2021; Hyvärinen et al. 2020).

Similar results were reported when for temperature quality across the Nordic and Baltic countries (Hyvärinen and Vajda 2025). We are currently working on post-processing and verifying precipitation, testing new post-processing techniques to improve forecast quality.

**Norway:** A probabilistic time-to-event forecast of the hard-freeze time was constructed and applied to seasonal temperature forecast (Roksvåg et al. 2022). This approach used a multi-model ensemble from the Copernicus CDS (ECMWF, CMCC, MétéoFrance and UKMO). Statistical postprocessing successfully corrected the systematic biases in the raw daily temperature forecasts, and the postprocessed forecasts consistently outperformed the climatology forecast at most study locations.

### 4.2.3 Agro-climate indicators and other tailored seasonal forecast products for Northern European agriculture and food system

Many tailored, agriculture-specific seasonal products have been developed and piloted in **Finland** (e.g. Vajda & Hyvärinen 2020; Hyvärinen et al. 2020) and **Norway** (Roksvåg et al. 2022, Vigna et al. 2024). In contrast, there is very limited or no published work on agriculture-specific seasonal forecast products in Sweden and Denmark, with references mainly appearing indirectly through broader European studies.

Overall, the current **maturity level** of the developed seasonal forecast product for agriculture remains at the **research or pre-operational stage**.

**Finland:** Seasonal products developed and tested include:

- Mean temperature
- Growing season development
- Growing degree days
- Cold spell occurrence
- Total precipitation
- Dry/rainy conditions
- Soil moisture

These products were **semi-automated**: forecast updates were generated automatically and combined manually into climate outlooks, which were distributed via email. **Production of these products stopped** after the research project ended due to resource limitations. According to **farmers feedback**, these tailored forecasts were useful and beneficial; total precipitation, growing season development, growing degree days and soil moisture were considered the most valuable.

**Norway:** As part of the general forecasts, MetNorway provides operational sub-seasonal forecasts for agricultural users, including daily temperature values and precipitation probabilities for three weeks ahead. However, tailored agro-climate indices are not provided. The **hard-freeze forecast** developed by Roksvåg et al. (2022) is still in the research phase.

**Nordic and Baltic Region:** Tailored seasonal forecast products for crop breeders are being developed as part of the NordForsk NordBalFoodSec project and will be tested with users in 2026. These indices focus on temperature and precipitation and are designed for breeding potatoes, barley and red clover.

**Sweden:** SMHI provides seasonal river-flow outlooks (seasonal lead) accompanied by ensemble temperature and precipitation outputs (ECMWF ensembles) processed through the HYPE chain ([Forecasts Data - HypeWeb](#)). Although these products are primarily hydrology-focused, they are routinely used by agricultural advisors and irrigating farmers in areas with limited water resources or soil moisture. These forecasts are currently **unavailable** (as December 2025).

Operational tools developed for agriculture and food productions that rely on short-range forecasts are available in the Nordic countries, for ex. VIPS and CropManager. However, none of these tools include sub-seasonal or seasonal forecasts.

**European context:** At the European level, Ceglar and Toretti (2021) assessed the potential value, skill, and reliability of seasonal climate forecasts in supporting the European winter wheat production sector. The indicators computed using the CLISAGRI package for R included:

- Hydrological Balance Indicators: SPEI for various growing phases of plants (drought, near normal and wet conditions)
- Excessive Wetness Indicators: number of days when daily rainfall exceeds a specific threshold
- Temperature Stress Indicators: number of days during specific growth stages when daily temperatures fall below or exceed predefined thresholds
- Wheat flowering dates

The skill of these indices was evaluated using SEAS5 forecasts from C3S with a 7-month lead time. They concluded that the predictability of climate events relevant to European wheat production is strongly dependent on the forecast initialization time, as well as on the nature of the event to be predicted. Drought events predictions were generally skillful and reliable, while flowering and excessive wetness predictions showed skill mainly in Central and Eastern Europe but limited or no skill elsewhere. Forecasts for cold and heat stress lacked reliability in Northern Europe. These indicators are **not issued to users on an operational basis**. For service developers open-source packages of agro-climate indicators are available from GitHub (see Appendix 2).

#### 4.2.4 User and farmer engagement and readiness

There is very limited research on user engagement in the co-creation of seasonal forecast services and products for agriculture and food production in Northern European countries. The available studies and their findings are summarized below.

**Finland:** Vajda et al. (2021) reported on Finnish users' engagement in the development and testing of agriculture-focused products. This study involved the Central Union of Agricultural Producers and Forest Owners (MTK) and over 200 farmers during two pilot seasons. However, there is no information on how many farmers regularly used the seasonal climate outlooks during the pilot. The usability of the seasonal forecast products was evaluated through co-evaluation using farmers feedback collected via questionnaires after each pilot season. Farmers found the tailored forecast useful and beneficial; total precipitation, development of growing season, growing degree days and soil moisture conditions were considered the most useful. Farmers expressed interest in using the products regularly in the future.

**Norway:** Oubrhou (2023) investigated the potential value of sub-seasonal to seasonal climate forecasts for Norwegian forage-based dairy farming using a dynamic, user-based system model parameterized for a specific farm in Vestland, Norway. Through system mapping workshops with farmers, the study identified the dynamic structure of decision-making in forage-based dairy farming. The findings indicated that utilizing S2S forecasts could measurably improve decision-making regarding harvest quantity and quality, profitability, and cost reduction.

MetNorway engaged with farmers using Serious Gaming as a participatory methodology to bridge the gap between climate service providers and agricultural users (i.e., forage-based dairy farmers) in Vestland, Norway, with focus on sub-seasonal and seasonal forecasts. The goal was to gather information on farmers' decision processes and information needs and to gain knowledge on how to effectively communicate uncertainties and probabilities (Vigna et al. 2024). The applied serious game, named Melkeværet, engaged effectively the participants and helped identify users' perceptions of S2S products: (1) there was a general lack of trust in the forecasted conditions for the third week of the 21-day product, (2) although the S2S forecast was not used as direct support for making decisions, it played a role in triggering the need for more detailed weather forecast information, (3) challenges

regarding use and long-term planning, (4) preference for descriptive content. In general, the maturity level of S2S forecast use was low.

This participatory approach could be applied elsewhere to effectively engage users in agriculture and other sectors.

#### 4.2.5 Goal and improvements needed to fill gaps

**Goal:** Improve the availability of seasonal impact forecasts for agriculture in Northern Europe, particularly in Finland, and advance the maturity of related services.

##### Gaps identified

1) Skill and data post-processing (bias adjustment)

Although a large amount of seasonal forecast data is openly available, the evaluation of key variables and their bias adjustment remain limited for many Northern European regions, especially Sweden, Denmark and partly Norway (except for the ongoing Nordforsk project work). Even after bias correction, the skill of some variables remains low, particularly during the summer season. Assessments of the predictability of extreme events are largely missing.

There is a lack of robust evaluation and communication of forecast skill and uncertainties across the Nordic region.

2) Gaps in geographical coverage of seasonal agro-climate products

Most of the tailored, agriculture-focused seasonal products have been developed and tested in Finland and a few in Norway. Other Nordic countries have very limited or no published work on seasonal agro-climate indicators.

3) Gaps in agro-climate indicators and products

Existing agro-climate products are primarily generic indices (e.g., growing season development, temperature, precipitation, soil moisture). There are no indicators of extreme conditions, such as frost after the start of the growing season or drought.

4) Lack of impact variables and integrated models

Studies linking the seasonal forecast products directly to crop growth, yield, disease risk or specific management operations are lacking. Cross-sector integration, including seasonal predictions in the agriculture and water sectors, is in its infancy or absent. Forecast products should also be tailored to different crops to support decision-making.

5) User uptake challenges

The uptake of available agro-climate indices by users remains low. Farmers and stakeholders must be engaged more effectively through various techniques in the co-creation of seasonal agro-climate indicators. Users require clear guidance on uncertainties and interpretation, as well as extended usability testing to build trust in and recognize the value and usability of tailored seasonal forecast products.

6) Operational and sustainability gaps

The maturity level of developed tailored seasonal agro-climate products is mostly pre-operational (e.g., semi-automated) or research-stage. Since most of these products were developed in research projects, their sustainability beyond pilot phases is uncertain, and ensuring their continuity remains a major challenge.

### **Improvements needed to fill the gaps**

The following practical steps correspond to the above-outlined gaps. Many of these actions require development at the national institutional level. However, this document highlights specific steps relevant to Finland as potential considerations for future development.

- ***Advancements in skill and data post-processing***

Conduct a comprehensive data quality assessment for essential variables and developed indicators related to agriculture and food production across the Nordic region. This implies testing new statistical methods and other techniques, such as machine-learning based techniques for postprocessing data. Create a multi-model ensemble for the Nordic region using available CDS seasonal forecast models and techniques to determine the most effective multi-model ensemble, as multi-model ensembles generally outperform single models (Slater et al., 2016). This approach, however, requires significant computational resources.

At FMI, the data post-processing has been performed on monthly data, this should be extended to daily data, as many hydrological and crop models require daily input data.

Additionally, we must account for forecast model updates (for ex. updates of ECMWF SEAS5 to SEAS6) which necessitate further data evaluation and post-processing.

- ***Development of agro-climate indicators and expansion of geographical coverage***

While additional agro-climate indicators for the Nordic regions are already in progress (see the Nordforsk NorBalFoodSec project), there is a need to create indicators that specifically target extreme events and are tailored to different crop types. Additionally, existing indicators should be extended to cover the entire Nordic region.

This will require cross-border collaboration among institutions and engagement with diverse user groups.

Several studies have demonstrated the development and the performance of agro-climate indicators for extreme events on a European scale (Ceglar and Toretti, 2021), for specific European sites (for drought see Lines and Werner, 2025; Brands et al. 2025; Turco et al. 2017; study in PIISA project) and for sites in the US (for drought see Kondal et al. 2024, Zamora et al. 2021). While the predictability of these events varies by region, the approaches and methodologies used in these studies can be adapted to the Nordic context.

- ***Development of integrated models combining seasonal forecasts and crop production models***

Enhancing the usability of seasonal forecasts for agricultural decision-making requires incorporating them with crop production models. Previous studies in Europe, particularly in the Mediterranean region, have used seasonal forecasts to quantify crop yield and water use risk (Capa-Morocho 2016). An operational tool has also been developed to successfully predict yield at the local, regional and national levels using seasonal forecasts (Dainelli et al. 2022). Similarly, seasonal forecasts have been

combined with land surface model and crop models to model crop production (Boas et al., 2023). Similar experiments should be conducted in Nordic countries to support risk assessment and food production. This integration requires close collaboration between climate experts and crop modeling specialists.

- ***Enhancement of user uptake through stronger collaboration***

Increasing user uptake of tailored seasonal forecast products requires strengthening collaboration between information providers, farmers, and other decision-makers. Improving users' perception and understanding of uncertainties in forecast products is a key priority. This can be achieved by applying diverse engagement approaches during the co-creation process to foster dialogue and the joint development of products and services. Examples include interactive methods such as serious games and participatory workshops. For instance, the Melkeværet game developed by MetNorway could be adapted for use with larger stakeholder groups.

Additionally, providing clear guidance materials and advisory services will help users more easily interpret and understand the forecasts. Close collaboration and knowledge sharing among experts in various fields, such as crop modeling, hydrological modeling, and climate science, are also essential. This interdisciplinary approach ensures an in-depth understanding of the background and information requirements for integrated models.

- ***Expansion of the available operational services***

The development of operational services should be prioritized at the national level. As an initial step, existing tested products should be transitioned into operational runs. Where feasible, these runs should be scaled up to the Nordic region.

Currently, several operational services and tools are available in Europe, offering tailored seasonal forecasts for drought management (e.g., the **RAINCAST** platform in Spain, **DIANA** platform in Belgium, Greece, Italy, Portugal, Romania, and Spain) or crop yield forecasts for Italy (Dainelli et al., 2022). Building on these examples and the available products can accelerate the implementation of robust, user-oriented services across the region.

## 5 Conclusions

Based on and guided by farmers surveys Agriculture and Food pilot addressed two key themes, innovative insurances and climate services for agriculture. Both have potential to improve agriculture's ability to manage natural hazards and adapt to the challenges of climate change. Implemented together in a coordinated manner, they have larger potential to enhance agriculture adaption and financial resilience than fragmental approaches.

PIISA surveys showed that farmers throughout Europe experience high exposure to climate-related risks. In Mediterranean regions a large majority of farmers report having experienced climate impacts and economic losses in recent years, and most expect these risks to intensify in the future. Both in Spain and Italy, there was dissatisfaction with traditional indemnity-based insurance emerges clearly in both surveys, driven by high costs, complexity, delays in compensation and limited trust in providers. Responses suggested that increasing insurance penetration requires not only financial incentives, but also product redesign and clearer communication. Both in Mediterranean and boreal region (Finland) surveys farmers expressed interest to index-based insurances. In contrast, several barriers were identified, too. PIISA Task 4.5 assessed barriers and opportunities for key results of Agriculture pilot too and produced a Replicability Roadmap. Roadmap describes pathways how the results and solutions generated in Agriculture pilot can be replicated, transferred, or adapted to other European contexts (Lameh 2026).

The participatory tool CoDepi (Co-designing Parametric Insurance) was developed for olive farmers in southern Spain to collaboratively design a climate index-based insurance (IbI). CoDepi incorporates "convergence of evidence" approach, iterative parameter adjustment, and participatory validation with end-users, which in pilot were the olive farmers of Jaén, Spain. The application enables the design of tailored IbI products by aligning historical payouts with farmers' actual experiences, through adjustments in key model parameters. It also assists in setting appropriate premium prices and understanding trade-offs.

Climate services for agriculture and agricultural insurers were developed and assessed in the pilot. For the olive farming case study, a prototype seasonal-forecast dashboard and a drought indicator was implemented in the dashboard. In addition, new drought indicators were developed and explored. The current state of services, research and data systems related to seasonal impact predictions for food security in the Boreal & Arctic region was assessed. Main gaps were identified and improvements needed identified. Data and model driven approach for advancements in skill and usability, and new services development could be achieved by integrating seasonal forecast and crop production models.

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## Appendix 1: Technical Readiness Level

Goals of Task 3.3 were complex and extensive: develop parametric and data-driven insurance solutions for the agricultural sector, integrating high-resolution climate data, stakeholder input, and European-scale modelling capacities, develop a web tool for co-designing index-based insurance (CoDepi) and demonstrate operational delivery of climate information (seasonal forecasts) to farmers.

The development of tool CoDepi was the key contribution of the pilot, therefore, TRL assessment was performed CoDepi. The tool visualizes how adapting key base index parameters such as the trigger thresholds, coverage, payout frequency, affect historical payouts and configures the parameters appropriately to match historical payouts to farmer-reported "bad years" to minimise basis risk, which is the key limitation of IBI. The purpose of the tool is to overcome this limitation to make an IBI solution feasible. CoDepi tool was designed for co-designing with farmers and insurers a tailored index-based insurance. It was tested in real-world context with aim to co-develop an index-based insurance concept tailored to olive tree farmers against drought in Andalusia, Spain.

In the beginning of the piloting, there existed the methodology developed by the International Research Institute for Climate and Society (IRI) using the "convergence of evidence" approach, iterative parameter adjustment, and participatory validation with end-users, for co-designing tailored insurance for farmers. This situation corresponds to TRL 3-4.

During Loops 2 and 3 the methodology was developed and programmed into a participatory tool which was used with olive farmers in southern Spain to collaboratively design a climate IBI that addresses their insurance protection gap. Tool was demonstrated in a relevant environment and demonstrated in an operational environment with end-users. During final months of PIISA project demonstration will be done for insurers. Tailored index-based climate insurance design service, enabling the co-development of parametric drought insurance products aligned with local crops and farmer-validated thresholds. CoDepi is an emerging product that has reached TRL level 6-7.



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## Appendix 2: Open-source packages available for agro-climate indicators

For the development of climate services, there are open-source packages available for agro-climate indicators in GitHub developer platform.

- CLISAGRI, package for R (Ceglar et al. 2020): <https://github.com/ec-jrc/Clisagri>

This package produces dynamic agro-climatic indicators that bring key information to crop producers during different stages of crop growth. It quantifies the occurrence of different climatic extremes such as drought, excessive wetness, heat stress and cold stress during sensitive stages of crop growth.

- CSIndicators, package for R (Pérez-Zanón et al. 2023): <https://gitlab.earth.bsc.es/es/csindicators>

The package is intended for sub-seasonal, seasonal and decadal climate predictions, computing a set of indices primary for agriculture and energy applications. 10 agri-climate indicators identified as critical indices for the three agricultural sectors - grape/wine, olive/olive oil and wheat/pasta - have been considered in this CSIndicators package. The wheat indicators can be used for Northern European agriculture.



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