H2020-SC5-01-2017

MED-GOLD

Turning climate-related information into added value for traditional **MED**iterranean **G**rape, **OL**ive and **D**urum wheat food systems

Deliverable 3.4

Assessment of the added value for the decision-making process for the wine sector.

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Document Status Sheet

Deliverable Title	**Report on the added value of the pilot service to the user**	
Brief Description	This deliverable aims to assess the added value of the Dashboard in Wine sector through an online workshop and interview.	
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1.1	13-09-2021	LEEDS UNI and BSC	49	Second Draft
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All partners involved in the production/implementation of the deliverable should comment and report (if needed) in the above table. The above table should support the decisions made for the specific deliverable to include the agreement of all involved parties for the final version of the document.

Finally, after the peer review process, the deliverable should be modified accordingly to the comments and the reflections to the comments should be reported in the above table.

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Executive Summary

The aim of Work Package3 (WP3) was to co-develop a climate service in the Grape and Wine sector working closely with SOGRAPE which is a Portuguese wine producing company. This WP consisted of four main tasks:

Task 3.1: Appraising needs and critical decisions

Task 3.2: Developing the tool

Task 3.3: Testing the tool

Task 3.4: Assessing the added value of the pilot service to the user

The climate information needs and decisions in SOGRAPE were assessed via a workshop that was held in 2018 (Task 3.1). Several interactions between the seasonal climate predictions provider (BSC) and the end-users (SOGRAPE) were taken in 2018 and 2019 to co-develop the tool which is called MED-GOLD Dashboard (Task 3.2). The tool was tested by SOGRAPE' end-users at two different times in 2019 and 2020 (Task 3.3).

The assessment of the added value of the pilot service (Task 3.4. and covered within this report) was pursued through two different analyses:

1. Assessment of the added value of the Dashboard with SOGRAPE end users to understand the extent in which the tool is usable and of potential value to them. The assessment of the tool started with a broad literature review to develop a conceptual framework underpinning this analysis. The assessment was conducted through an online workshop, and 15 semi-structured interviews which are explained in detail in the methodology section. The results show that most interviewees use weather forecasts in their day-to-day activities and for operational planning in operations such as spraying (type and dose of product to use and/or when to use it) and harvest planning. Apart from weather forecasts, historical climate information is also used by some participants at managerial level for cost justification, and long-term investment. Although seasonal forecasts and climate projections are hardly used by participants, they believe that using these types of timescales could add value to their medium-term planning (e.g., stock management, seasonal labour scheduling) and long-term planning (e.g., purchasing land/vineyard, vineyard installation). This assessment is described in section 6.
2. Characterise the probability thresholds that a wine manager could apply to trigger a decision based on tercile categories. The methodology was tested on a case study based on the application of a seasonal prediction product provided by the MED-GOLD climate service for the Spring total precipitation seasonal forecasts. This variable is a critical component in the wine producing workflow. While the results are case-specific, tailored to costs and benefits of the user under analysis, the methodology could be replicated for other decisions. This analysis is described in section 7.

1. Objectives

With this deliverable, the project has contributed to the achievement of the following objectives (DOA, PartB Table1.1):

Table 1-1 project objectives

No.	Objective	Yes
1	To co-design, co-develop, test, and assess the added value of proof-of-concept climate services for olive, grape, and durum wheat	X
2	To refine, validate, and upscale the three pilot services with the wider European and global user communities for olive, grape, and durum wheat	
3	To ensure replicability of MED-GOLD climate services in other crops/climates (e.g., coffee) and to establish links to policy making globally	
4	To implement a comprehensive communication and commercialization plan for MED-GOLD climate services to enhance market uptake	
5	To build better informed and connected end-user communities for the global olive oil, wine, and pasta food systems and related policy making	

2. Impact

This deliverable aims to assess the added value of the Dashboard in wine sector. The provision of climate services may not necessarily lead to the desired outcome of increased productivity due to a variety of reasons and obstacles and the assessment could help us to identify such obstacles. The assessment of the climate service in the sector was done through a semi-structured interview and this deliverable provides the result of the assessment.

Table 2-1: Expected impacts of the deliverable

No.	Expected impact	Yes
1	Providing added-value for the decision-making process addressed by the project, in terms of effectiveness, value creation, optimised opportunities and minimised risk	X
2	Enhancing the potential for market uptake of climate services demonstrated by addressing the added value	X
3	Ensuring the replicability of the methodological frameworks for value added climate services in potential end-user markets	
4	To implement a comprehensive communication and commercialization plan for MED-GOLD climate services to enhance market uptake	
5	To build better informed and connected end-user communities for the global olive oil, wine, and pasta food systems and related policy making	

3. Definitions

Concepts and terms used in this document and needing a definition are included in the following table:

Table 3-1 Definitions

Concept / Term	Definition
Climate service	Climate Services involve the (co-)production, transfer, and use of tailored climate information products to improve decision-making at different scales (Vaughan and Dessai, 2014).
Value	The word 'value' has been defined as the range of benefits (economic and/or non-economic) that can be gained from using climate information in decision-making (Bruno Soares et al., 2018).

4. Acronyms

Acronyms used in this document and needing a definition are included in the following table:

Table 4-1 Acronyms

Acronym	Definition
AN	Above normal
BaU	Business as usual
BN	Below normal
CNR	National Research Council
CS	Climate service
DSS	Decision Support System
MED-GOLD	Referring to the project entitled "Turning climate-related information into added value for traditional MEDiterranean Grape, OLive and Durum wheat food systems"
N	Normal
RD	Reference documents
TRC	Tercile
WP	Work Package

5. References

The following documents, although not part of this document, amplify or clarify its contents. Reference documents are those not applicable and referenced within this document.

Table 5-1 Reference Documents

Ref.	Title	Code	Version	Date
[RD.1]	Report on the two case studies at seasonal- and long-term timescales for the wine sector	D3.1		2018
[RD.2]	Report on the methodology followed to implement the wine pilot services	D3.2		2019
[RD.3]	First Feedback report from users on durum wheat pilot service development	D 3.6		2020
[RD.4]	Second Feedback report from users on durum wheat pilot service development	D 3.7		2020
[RD.5]	Bruno Soares M, Alexander M, Dessai S .2018. Sectoral use of climate information in Europe: a synoptic overview. Climate Service 9:5–20.			2018
[RD.6]	Lemos MC. 2008.What influences innovation adoption by water managers? Climate information use in Brazil and the United States. JAWRA J Am Water Resour Assoc 44(6):1388–1396.			2008
[RD.7]	Lemos, M. C., K. S. Wolske, L. V. Rasmussen, J. C. Arnott, M. Kalcic, and C. J. Kirchhoff, 2019: The Closer, the Better? Untangling Scientist–Practitioner Engagement, Interaction, and Knowledge Use. Weather. Climate Society., 11, 535–548, https://doi.org/10.1175/WCAS-D-18-0075.1.			2018
[RD.8]	McNie EC .2007. Reconciling the supply of scientific information with user demands: an analysis of the problem and review of the literature. Environment Science Policy 10(1):17–38. https://doi.org/10.1016/j.envsci.2006.10.004.			2007
[RD.9]	Robinson J, Tansey J .2006.Co-production, emergent properties and strong interactive social research: the Georgia Basin Futures Project. Sci Public Policy, 33(2):151–160.			2006
[RD.10]	Tall, A. Coulibaly, J.Y. Diop, M. 2018. Do climate services make a difference? A review of evaluation methodologies and practices to assess the value of climate information services for farmers:			2018

	Implications for Africa. Climate Services 11: 1–12. https://doi.org/10.1016/j.cliser.2018.06.001.			
[RD.11]	Tall, A., and Njinga, J. 2013. Developing a methodology to evaluate climate services for farmers in Africa and South Asia workshop report. Copenhagen, Denmark: CGIAR Program on Climate Change, Agriculture and Food Security. Retrieved from www. ccafs.cgiar.org.			2013
[RD.12]	VanderMolen, K. Meadow, A.M. Horangic, A. Wall, T.U. 2020. Typologizing Stakeholder Information Use to Better Understand the Impacts of Collaborative Climate Science. Environmental Management 65:178–189 https://doi.org/10.1007/s00267-019-01237-9.			2020
[RD.13]	Vincent, K., Daly, M., Scannell, C., Leathes, B., 2018. What can climate services learn from theory and practice of co-production? Clim. Serv. 12, 48–58.			2018
[RD.14]	Vincent, K., Conway, D., Dougill, A.J. Pardoe, J. Archer, E., Bhave, A.G., Henriksson, R., Mittal, N., Mkwambisi, D., Rouhaud, E., Nhleme, DT. Re-balancing climate services to inform climate-resilient planning – A conceptual framework and illustrations from sub-Saharan Africa. Climate Risk Management 29 (2020) 100242.			2020
[RD.15]	Vogel, J., Letson, D., Herrick, C. 2017. A framework for climate services evaluation and its application to the Caribbean Agrometeorological Initiative. Climate Services, 65–76.			2017

6. Assessing the added value of the Dashboard

6.1. Co-developing a climate service for the Grape and Wine sector

Work Package 3 (WP3) aim was to co-develop a climate service in the Grape and Wine sector through direct engagement with SOGRAPE, the leading wine company in Portugal. This Work package consists of four main tasks as follows:

Task 3.1: Assessing the needs and decisions of SOGRAPE

Four focus group were conducted with SOGRAPE managers in 2018 to assess their climate information needs. The result showed that they need:

- Seasonal forecasts, 6-month lead-time weekly forecasts of temperature and precipitation would be ideal, updated weekly, with a minimum reliability of 70%.
- Decadal forecasts, quarterly projections of average temperatures (maximum and minimum) and precipitation would be ideal with quarterly updates. The agreed minimum reliability for which they would consider using such forecasts would be 80%.

Results of this task and outputs can be found in Deliverable 3.1.

Task 3.2: Developing the tool

Several interactions between SOGRAPE and climate scientists were conducted to co-develop the Dashboard in 2018-2019. The MED-GOLD Dashboard is an easy-to-use visualisation tool which was co-developed with users in the wine sector. The link below demonstrates the final version of the Dashboard: https://www.youtube.com/watch?v=2Y5xgdXnPI8.

More details can be found in Deliverable 3.2.

Task 3.3: Testing the tools

First version of Dashboard was developed in 2019 and tested with SOGRAPE' end-users at two different times in 2019 and 2020. Detected bugs were corrected, visualization, ease of use and onscreen intuitive guidance were improved and fixed during the testing stage and then the final version of the tool was released in April 2021.

At the end of the co-development process, the Dashboard is accessed via a web platform and provides different types of climate data to its users including historical, seasonal forecasts and climate change projections. Currently the data can be visualised for the Douro Region (which is where approximately half of SOGRAPE's vineyards are located) as well as the Iberian Peninsula (SOGRAPE also owns wineries and vineyards in Spain). The data and information that can be visualised as well as downloaded from the Dashboard are summarised in the table below (Table 6.1.):

Table 6.1. Timescales and variables available in the Dashboard

<table>
<tr><th rowspan="2">Variables available in the Dashboard</th><th colspan="3">Timescales available in the Dashboard</th></tr>
<tr><th>Historical</th><th>Seasonal forecasts</th><th>Climate change projections</th></tr>
<tr><td>Climate variables</td><td colspan="3">• Monthly Precipitation
• Monthly Maximum Temperature
• Monthly Minimum Temperature
• Monthly Average Temperature</td></tr>
<tr><td rowspan="2">Bioclimatic indicators</td><td colspan="3">• Growing season average temperature (GST): average of daily average temperatures between April 1st and October 31st (Northern Hemisphere)
• Total rainfall during harvest season (HarvestR): Aug 21st to Oct 21st (Northern Hemisphere)
• Spring total precipitation (SprR): total rainfall from April 21st to June 21st (Northern Hemisphere)
• Number of heat stress days (SU35): annual count of days when daily maximum temperatures exceed 35°C,
Warm spell duration index (WSDI): annual count of days with at least 6 consecutive days when the daily maximum temperature exceeds its 90th percentile.</td></tr>
<tr><td colspan="2">N/A</td><td>• Growing degree days (GDD): sum of daily differences between daily temperature averages and 10°C (vegetative growth minimum temperature) between April 1st and October 31st (Northern Hemisphere)</td></tr>
<tr><td>Wine risk indicators</td><td colspan="2">Sanitary risk: The possible fungal disease (mildew and rot) risk in the Douro region during a growing season.
• Heat risk: The risk of temperatures that higher or lower than normal conditions to the crop yield and quality, consequently affecting wine production.</td><td>N/A</td></tr>
</table>

An info sheet for helping users navigate the Dashboard (e.g., timescales and variables available, geographical location, etc) was also developed and is available embedded in the Dashboard. See the info sheet here: https://www.med-gold.eu/wp-content/uploads/docs/MED-GOLD_infosheet08_dashboard_EN.pdf

More information on the outcomes of this task can be found in Deliverables 3.6 and 3.7.

Task 3.4: Assessing the value of the Dashboard

At this stage, the added value of the final version of Dashboard was assessed and is presented in section 6. The assessment helped understand the extent in which the tool meets users' specific needs and fits its purpose. The methods used to pursue this assessment are explained in section 6.2 followed by results in section 6.3. Finally, section 7 provides an example of application of one of the MED-GOLD seasonal forecasts, the Spring total precipitation (SprR). The case study was set by analysing users' characteristics and their decision-making process in section 7.1 followed by the methodology in section 7.2. The case study results are presented in section 7.3 while broader conclusions on the optimal application of climate predictions are reported in section 7.4.

6.2. Methodology used to assess the value of the Dashboard

The assessment of the added value and benefits of the Dashboard started with developing a conceptual framework. The literature review which sets the theoretical foundations of the conceptual framework is explained in Section 6.2.1. The methods to do the assessment are described in detail in section 6.2.2.

6.2.1. Conceptual framework for assessing the value of the Dashboard

Although some studies consider accessibility, and understandability as a way to define useful climate services (Tall and Njinga, 2013; Tall et al., 2018), this in itself has often not translated into use of climate information in decision-making (Lemos et al., 2012; Vincent et al., 2018). This means data availability is only a requirement of using data in decision-making and usability is beyond data availability (Vincent et al., 2020). Cash et al. (2003) have classified all usability factors into three main criteria that make information to be usable in decision-making which are credibility, saliency and legitimacy (Lemos 2008; McNie 2007, 2013; Lemos et al., 2012; Lemos et al., 2018; VanderMolen et al, 2020).

Saliency refers to timeliness, spatial scale, appropriate selection of variables, and understandable presentation format (visualisation). Saliency requires that the information be relevant to a decision maker's problem (Gettelman, Rood, 2016). For example, information that is timely and informs decision makers about problems that are on their agendas have high saliency and information that arrives at the wrong time in the evolution of an issue (too early, or too late), can fail to influence decision making for lack of saliency (Kingdon 1995; Cash et al., 2002).

Credibility is the degree to which the scientific information is seen as high quality as judged by the standards of the scientific community. It refers to accuracy, reliability and quality of data (VanderMolen et al., 2020). A high level of trust in the climate information by farmers is often associated with a high level of accuracy, which means that the forecast unfolds as predicted (Tall et al., 2018). Reliability as trustworthiness of how closely the forecast provided corresponds to observed frequencies (Weisheimer and Palmer, 2014).

Legitimacy comes from the process used to produce the information, which must be free from bias and perceived to be transparent by stakeholders (Cash et al. 2006; Lemos 2008; McNie 2007, 2013). Inclusion of users in the process of producing a service, two-way engagement between users and providers of information, can help building legitimacy and greater trust in its use (Jasanoff and Wynne, 1998; Robinson and Tansey, 2006; Vincent et al., 2018; Vincent et al., 2020). Therefore, legitimacy of the process of developing the knowledge (i.e., the extent to which stakeholders were involved in knowledge development (Cash et al. 2003; Evely et al. 2010; Fazey et al. 2014; Wall et al., 2017).

Based on the literature review, the adapted framework for the assessment is presented in Figure 6.1

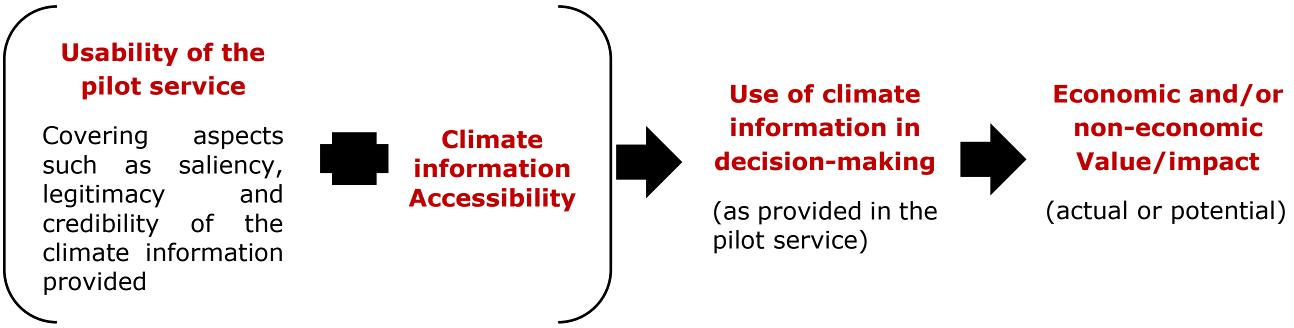

Figure 6.1 Adapted conceptual framework to assess the usability of the MED-GOLD pilot services

6.2.2 Methods

As figure 6.2 demonstrates, an online workshop, survey and semi-structured interview were applied to assess the values/benefits (actual or potential) of the Dashboard in the wine sector.

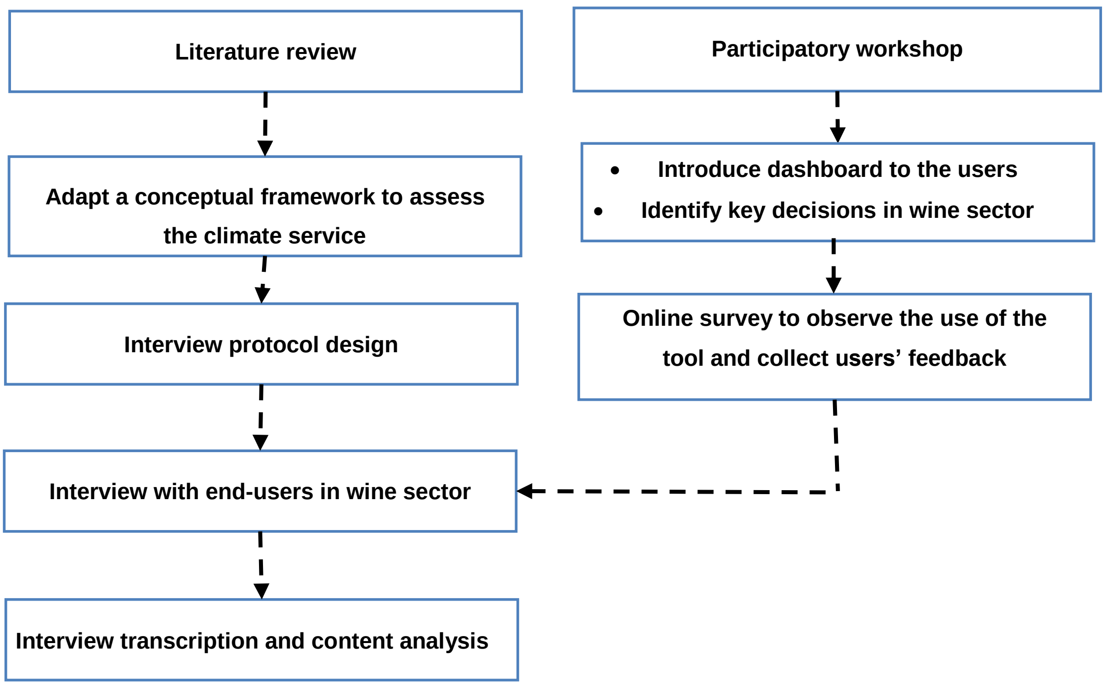

Figure 6.2. Methodology to assess the added value of the climate service in the wine sector

Participatory workshop: To conduct the assessment, it was vital to showcase the final version of the tool to SOGRAPE' end-users and give them access and interaction with the tool. Hence, the MED-GOLD project organised an online workshop in April 2021 to showcase the final version of the Dashboard to the SOGRAPE users. Nineteen members of SOGRAPE Company, who had been directly involved in the co-development process of climate service, attended the workshop. The participants were from various departments of SOGRAPE such as oenology, viticulture, R&D and senior management.

The workshop was divided into two sessions. The first session of workshop was held in English and aimed to introduce the final version of the tool. Hence, it started with an introduction of Dashboard using a video of the tool (https://www.youtube.com/watch?v=2Y5xgdXnPI8) and followed by descriptions of the climate information that users can access in three temporal scales, namely historical information, seasonal forecasts and long-term climate projections. The second session was run in Portuguese and aimed to set the procedure for the assessment of the tool's added value for decisions in the wine sector. Hence, during this session the users were asked to provide examples of key decisions in their area of expertise that are influenced by climate conditions throughout the year. The participants (potential interviewees) were also asked to interact with the tool for 6 weeks (from the 16th of April to 1st of June 2021) and check how usable the tool could be in their decision-making. Then after these 6 weeks, they were invited to a personal interview.

Online survey: To monitor users' feedbacks based on their weekly interactions with the Dashboard, an online survey was designed to observe the use of the tool and collect feedbacks during the test period.

Interview with end-users in wine sector: The test period was followed by a total of 15 semi-structured interviews with people working in SOGRAPE conducted in June 2021. As table 6.2 shows the interviewees in our sample held responsibility for different types of roles in the wine sector such as Vice president, Oenologist, Viticulturist, Energy director, researcher, system controller, and marketing manager.

Table 6.2 Type Interviewees by role in SOGRAPE

Role	Number of interviewees
Vice president	1
Oenologists	4 (2 heads)
Viticulturists	5 (1 COO, 1 head)
Quality, environment and safety director	1
Corporate brand and sustainability manager	1
R&D staff	2
Controlling	1
Total	**15**

The conceptual framework was further developed into questions and included in an interview protocol which was used in all interviews (see Annex 1). This protocol addressed the following themes:

1) The climate information currently used by interviewees to support their decision-making
2) Interactions with the Dashboard and the (actual or potential) benefits of using the Dashboard in their roles
3) The Dashboard usability
4) Recommendations to improve the Dashboard usability

All interviews were conducted in Portuguese by partner University of Leeds and recorded via MS Teams Microsoft, then translated and transcribed into English full verbatim. The transcriptions were then prepared and analysed using qualitative thematic analysis in line with the interview protocol questions and wider conceptual framework.

6.3 Results

6.3.1. Use of climate information

In this section, the interviewees were asked whether they currently use any weather and/or climate information in their roles. The results show that weather forecasts are the most frequently used data in our sample for day-to-day operational activities and planning (Figure 6.3). In this regards, three interviewees (20%) were not user of climate information in their role and twelve of them (80%) use weather or climate information (directly or indirectly) in their roles.

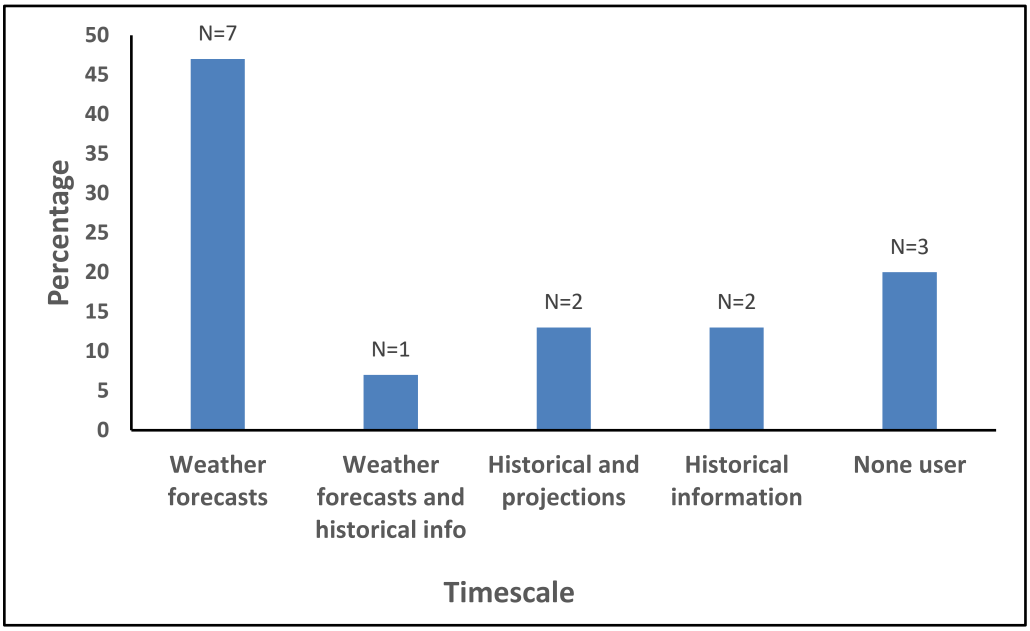

Figure 6.3 Various timescales currently used by interviewees in SOGRAPE

Seven interviewees (50%) were users of weather forecasts in their roles, as oenologist or viticulturist (Table 6.3). Based on the following quotes, they use weather forecasts for their short-term planning such as treatment, and harvest timing. In this regard, one of them from viticulture department said:

"I use climate information only during harvest every day, I check for the next day and also for the following week. Therefore, I use it for short and medium term, I don't use it during the year". [Interviewee 15]

One interviewee, head of oenology, who was responsible to decide on the harvest dates for the internal and external vineyards [1]confirmed:

"Climate information is essential for grape quality, and we need cold nights to have wine quality. I use climate information when it is closer to harvest times. At the end of maturation cycle, I start checking for the weather forecast to check if the weather conditions will be ideal, and if not, what is going to be happening. After the maturation cycle, at harvest time, I check the rain forecast regularly using the maps from Weatheronline.co.uk which provides me data with maps and are updated every 3 hours". [Interviewee 13]

Regarding the long-term decisions, two directors (13.3%), from managerial level, confirmed they use historical climate information and climate projections. One of them said:

"We use historical climate information and long-term projections for investments decisions, such as choosing regions for the purchase of vineyards, and plantations (for next twenty-five, thirty years)" [Interviewee 4].

[1] Internal vineyards are vineyards which are owned and managed by SOGRAPE. External vineyards are not owned by SOGRAPE but managed by the company.

Table 6.3 Various types of weather and climate data used in SOGRAPE according to interviewees' roles

Role	Type of use	Timescale of interest
R&D incentives and data technician	Non-user	Non-user
Quality, environment and safety director	Indirect user	Historical data
R&D Researcher	User	Weather forecasts and historical data
Agricultural technical manager	Indirect user	Historical climate data
Vice president	Indirect user	Historical data and climate projections
Oenologist (Chief Operations Officer)	User	Historical data and climate projections
Oenologist (Head of oenology Douro)	User	Weather forecasts
Oenologist (Chief of oenology Bairrada)	User	Weather forecasts
Oenologist (Winemaker)	User	Weather forecasts
Viticulturist (Vineyard manager QA)	User	Weather forecasts
Viticulturist (Vineyard manager HP)	User	Weather forecasts
Viticulturist (Head Douro)	User	Weather forecasts
Viticulturist (Head Other regions)	User	Weather forecasts
Corporate Brand and Sustainability manager	Non-user	Non-user
Controlling (Head)	Non-user	Non-user

6.3.2. Sources of weather and climate information

The interviewees were further questioned about their source of information they normally use. The data shows they rely on different sources of climate information to triangulate the data they need in their decision-making such as IberMeteo, IPMA, Windy app, AccuWeather or Weatheronline.co.uk. Based on figure 6.4, they mostly use IberMeteo which is the provider of customized weather forecasts based on data from the company's weather stations, however, they use other sources to triangulate the information. In this regard, one head of viticulture stated:

"I use IberMeteo, and many times I complement it by checking other sources because of the lack of reliability that I feel. this is what other colleagues do in my field. So, we check Accuweather, WindGuru, Windy, etc. to try to have some reliability" [Interviewee 13].

One viticulturist also pointed out:

"First, I use Windy app, then I compare the data with AccuWeather (cross-reference the information.), these two are the most accurate. I also use IberMeteo (the company that uses SOGRAPE weather stations to provide weather forecasts which is more detailed and contains bioclimatic indicators)" [Interviewee 14].

Some of interviewees who are not direct users of climate information, interviewees at managerial level, usually ask their technical team to provide them the information they need in their roles.

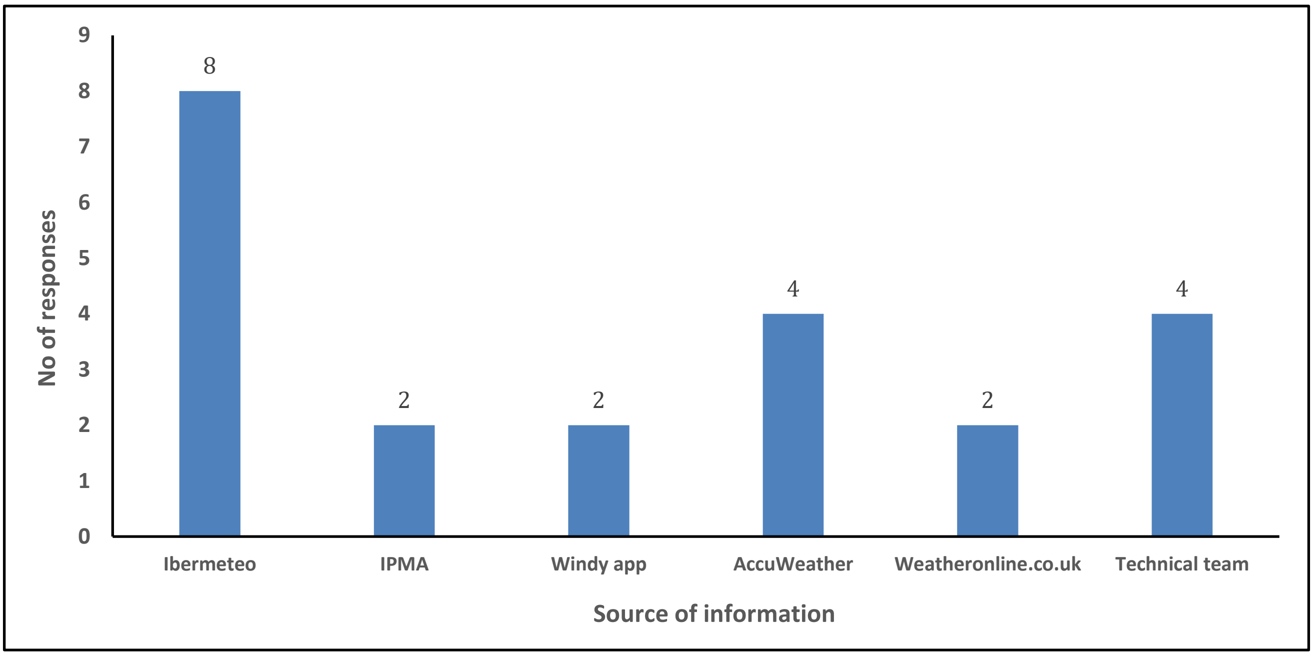

Figure 6.4 Sources of weather and climate information per type of data/information

Then, they were asked whether there is a willingness in their company to use seasonal or climate change projections. They all confirmed there is a need to use seasonal forecasts and climate projections in the Company. An oenologist said:

"We definitely need these types of data, but it depends on the department. Using this information is essential in Oenology and for grape harvest. In our department, we need to check the weather everyday (for next day and following week) during the harvest. However, there must be other departments that will have the need to see the forecasts during the year''.

One oenologist in senior management stated:

"Yes, SOGRAPE has always been a pioneer at using meteorological data. We have weather stations and the people in charge to receive meteorological information and provide weather forecasts based on what our weather stations see. Field managers, who oversee the farm, need climatic data to manage day to day activities

such as treatments and etc. We already use these indicators you have on the Dashboard, we now only calculate the GST, the number of days of drought, extreme temperatures, etc. This is data that we already analyse every year, and we do a statistical analysis for our farms help us to see how the year went, to be able to explain the wines, to be able to predict what you are going to do the following year, etc. However, for me it is more strategic, I need long-term information to make decision about acquiring plantations, choice of boxes of vine, orientation of the plantations. We also need this data for our viticulture decisions''[Interviewee 13].

6.3.3. Interactions with the Dashboard

As mentioned earlier, the interviewees were asked to interact with the tool before interview and check how they could apply it in their decision-making during the test period. In this section they were questioned about the extent in which the Dashboard could help them in their decision-makings.

Fourteen out of fifteen interviewees interacted with the Dashboard more than once during the test period **and all of them confirmed their interactions were only exploratory and they did not use the information in their decision-makings.** Their reasonings for not using the Dashboard in practice are summarised in Figure 6.5.

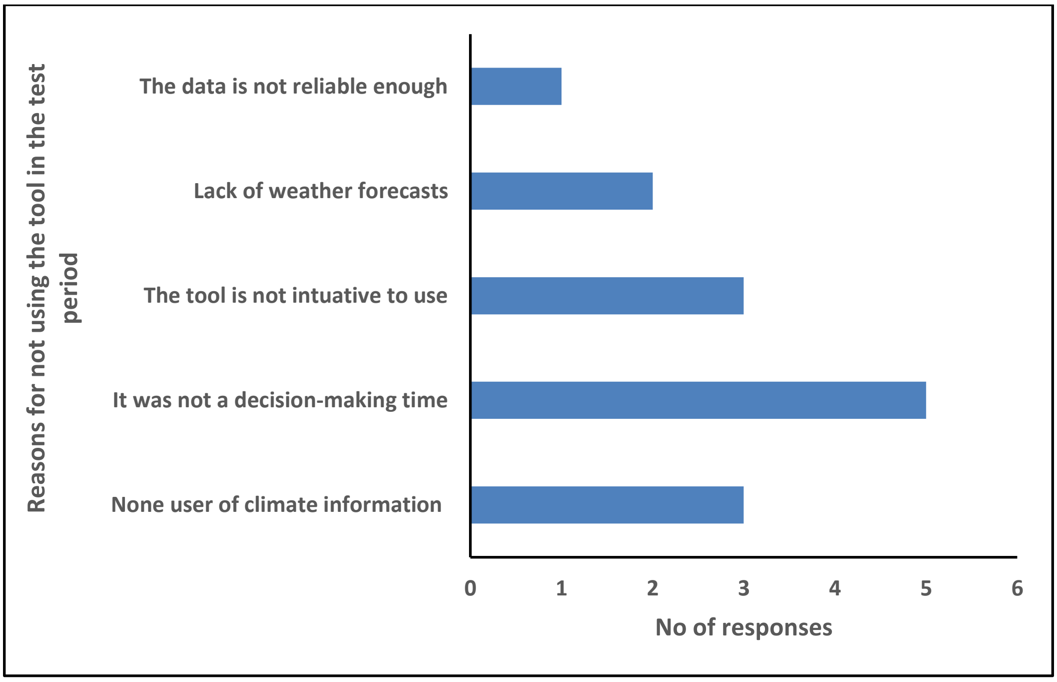

Figure 6.5 Reasons for not using the Dashboard in decision making during the test period

Three out of the 15 interviewees do not use climate information in their decision-making.

Five out of 15 interviewees mentioned that these 6 weeks (test period) were not the time to make decisions for them. However, three of them, from managerial level, confirmed the tool could help them in a possible long-term investment. One of them stated:

"I didn't use the tool and the information because I wasn't in a situation where I needed to make any decisions. I wasn't looking for new land or there wasn't a decision that I had to make. However, we were looking to acquire some lands last year and I asked my team to provide me with some climate information and they sent me some maps from Med-Gold Dashboard. The maps helped me to check how the climate would be in the future in our target regions, and we could compare it with what we know from other farms we have nearby, but 200m below in altitude''. [Interviewee 5]

Three interviewees claimed that the tool is not intuitive to use it in their roles. One vineyard manager claimed: *"I couldn't understand how it works and in there is not much information around Vidigueira where my farm is''.* [Interviewee 14]

Another expert mentioned:

"I wanted to check maximum temperatures and precipitation to understand how the end of the year will be (before October and harvest time), and whether we could be at risk of scalding. However, I could not use it because it's not very intuitive, and difficult to access''. [Interviewee 12]

Two interviewees stated that they use weather forecasts in their decision-making which is not available in the Dashboard. In this regard, one interviewee mentioning that:

"I need weather forecasts for the day-to-day decisions in the farm, I want to know whether it is going to rain next week. I could not use it as this information does not exist in the platform''. [Interviewee 6]

One interviewee intended to use the Dashboard to plan the harvest, however, he said he was not sure whether the data was reliable. He said:

"I looked for temperatures and precipitation to see if we would have a shorter harvest time or not, and if the temperatures would be higher. I compared them with the previous results, and they are not very reliable yet, they didn't get all right yet''. [Interviewee 8]

Since the interviewees have not used the climate information available on the Dashboard in their decision-makings, they were questioned about the potential benefits of using the information in practice (next section).

6.3.4. Potential benefits of using the Dashboard in decision-making

According to the interviewees' responses, historical climate information, seasonal forecasts and climate change projections available through the Dashboard could support their decisions in their medium and long-term activities and planning. These are summarised in table 6.4. below.

Table 6.4 Potential benefits of using the information available in the Dashboard

Historical climate information	Seasonal forecasts	Climate change projections
• Planning harvest times • Help with cost justification • Support validation of decision-making	• Better stock management • Plant protection • Planning harvest times • Schedule seasonal labour • Improve water management and irrigation • Scheduling fermentation and maintenance	• Help identify and support decision for purchasing land/vineyard • Inform conditions for installation of vineyards • Selection of suitable grape varieties • Understanding future needs for irrigation (e.g. setting up of irrigation systems) • Support validation of decision-making

The following quotes explains how the climate information on Dashboard could support SOGRAPE's end-users in their medium and long-term activities and planning.

Historical climate information

According to the interviewees' responses, historical climate information could help them with better harvest planning and cost justification. Regarding the harvest planning, one head expert said:

"We normally use weather forecasts to make a decision about harvest time in the short term, like a week, or make decisions about the beginning of the harvest. What I need to know is whether we need to start the harvest on a Tuesday, Wednesday, or when we start. Historical climate information on the Dashboard could help me to understand how the year in terms of climate was, what we have the prediction for the next harvest. With historical information, I understand a little bit the characteristics of the year, which will help me when the next harvest time comes.". [Interviewee 2]

One expert from Controlling, said that historical climate information could also help them validate or justify yearly costs in SOGRAPE:

"Historical climate information helps our department to justify and validate some costs that have been made by other sections. We receive some explanations from the operational areas of viticulture, for example, they tell us when the agriculture year was bad because there was little precipitation. With the Dashboard, we will be able to validate this information and have a faster visualization of these costs". [Interviewee 12]

Seasonal forecasts information

One manager, who was responsible for organizing and planning the vineyards explained how seasonal forecasts could help them with **plant protection and stock management**. He stated:

"The seasonal forecast helps me to plan my treatments and stock management. For example, the maximum temperature can be useful because I can anticipate purchases of Kaolin (a lime-based product that is used to prevent scalds) or if I'm going to have to do one, two, three treatments". [Interviewee 12]

One head of oenology, who is responsible for **harvest planning,** and which involves, amongst other functions, deciding the harvest dates for internal and external vineyards of grapes in different locations, said:

"If I can get information about the temperature and precipitation six months ahead, comparing to the historical information this would be very useful for me. At this moment I am about to schedule the harvesting. Therefore, I could plan which day would be best to start the harvesting in different regions". [Interviewee 13]. He also mentioned that he looks "(…)*for temperatures and precipitation to see if we have a shorter or early harvest time or not, and also if the temperatures would be higher".* [Interviewee 13].

One expert from the viticulture department confirmed that seasonal forecasts could support them in their **seasonal labour scheduling**. He said:

"With seasonal forecasts we can understand what kind of harvest we are going to have (early or late start). if we are sure that the harvest is going to start earlier, then we can coordinate with the whole team to see if the seasonal employees should come earlier or not. Or if we have rain forecast for the third week for example, we could maybe try to concentrate on harvesting more in the first and second week and know if we need to hire more people". [Interviewee 8]

The amount of water that grapevines need depends on several factors, such as climate, heat, soil, etc. In this regard, one expert from the viticulture Department asserted that:

"Temperature seasonal forecast will help me with the water management, and the irrigation. knowing that the summer forecast is very hot, I will have to increase the watering hours, because there will be more evapotranspiration, so I will have to compensate the plants somehow". [Interviewee 14]

One chief of oenology at SOGRAPE also explained how seasonal forecast could help them with **fermentations and scheduling maintenance.** He stated:

"I have to perform fermentations outside the harvest period at the lowest cost, but with the best interest for SOGRAPE. For fermenting outside, I would really like to know what the trend is for next winter. If I have to use cryophilic yeast or not! If I have too much, if I have all the cold winters, then I have to prepare in my outdoor fermentation system with heating – or rather, the other way around: I will have to furnish my fermentation capacity with more refrigeration capacity. It's a little bit the trend, "...everything is plus or minus 10%.", so let's keep everything as it is and let's just combine the plus or minus 10% with my growth. Now, look: if I grow 20% a year and if I still have to add 10% or 20% energy capacity, it's much worse. I'm going to have to predict my scenarios". [Interviewee 6]

Climate change projections

Interviewees claimed that long-term climate change projections can support their long-term decisions such as purchasing land and/or vineyard for the type of wines that the company aims to produce in the next decades, establish vineyards, choose adequate grape varieties, and determine [2]row-orientation or need for irrigation. In this context, one senior manager explained how this type of projections can help them in **purchasing future land**:

"We are now trying to make investments and purchase 40 hectares of land, and obviously we could validate this decision with the help of the Dashboard". [Interviewee 15]

During a **vineyard installation** and planting process, there are several decisions to be made including row direction which is a permanent and thus critical decision. In this regard, one senior manager said:

[2] Row orientation refers to **the direction in which rows of vines are planted**, possible options are NS, EW, NE-SW, and NW-SE. Depending on the orientation of the row, the angle of incidence of the sun may affect light and temperature profiles in the rows, as well as inside the canopies.

"In my role, long-term climate information on the Dashboard will serve as input for strategic investment decisions, namely when entering wine growing regions and whenever there are replanting of grapevines – it will help us with how to plant". [Interviewee 4]

Choosing proper grape varieties depends on the temperature as optimum temperature varies depending on grape variety (Cardell et al., 2019). Long term climate change projections help managers to choose what kind of varieties is worth investing based on the future climatic conditions. In this regard, one head of viticulture, stated:

"(…) compared to the 1960s, we had certain conditions, and those conditions did not accelerate the physiological process. [For example] Tinta Amarela was the dominant grape variety in the Douro region. It was a grape variety that was harvested at the correct time (September or October), but nowadays we are harvesting it in the end of August (given a faster ripening process due to dehydration). As a result, the shorter physiological cycle of this grape variety is becoming less adequate for the climatic conditions expected in the region. As such, varieties with longer-cycles (e.g. Touriga Franca) and which require higher heat content for their ripening process will be more suitable in the future. " [Interviewee 15]

One interviewee at senior managerial level confirmed that the long-term climate change projections could help him understand and **validate decisions** made by other managers in SOGRAPE. He said:

"It helps me to understand some decisions that are already made. For example, when a viticulture manager makes decisions or asks for certain permissions to make some kinds of investment, this tool helps me to confirm those decisions or investments "[Interviewee 4].

6.3.5. Feedback on the overall Dashboard

In this section the interviewees were questioned whether they found the Dashboard easy to work with and use. Seven interviewees (47%) stated that the tool and map are intuitive and easy to understand (noting that 3 out of these seven interviewees do not use climate information in their role). Five interviewees (33%) believed the Dashboard is not an intuitive tool (Figure 6.6 below).

Most of the interviewees agreed that it is difficult for them to find the parcels/vineyards, they are responsible for in the map. One oenologist suggested that for them the Dashboard "(…) *"it is not intuitive because, the first thing is, I can't locate where I am. It is very difficult to position myself or find a farm"*[Interviewee 6].

One viticulturist also mentioned that *"It took me a while to find a farm, but I did it. I added the latitude and longitude there and it worked but I couldn't just zoom in on the map"* [Interviewee 12].

Some interviewees had difficulty understanding the climate data available in the Dashboard such as the bioclimatic indices. In this regard, one of the heads of viticulture, mentioned that: *"The information that is available is quite complex, there is a complexity to understand the risk indexes there, but map is easy to read and then you eventually get familiar with it, you understand it well".* [Interviewee 7]

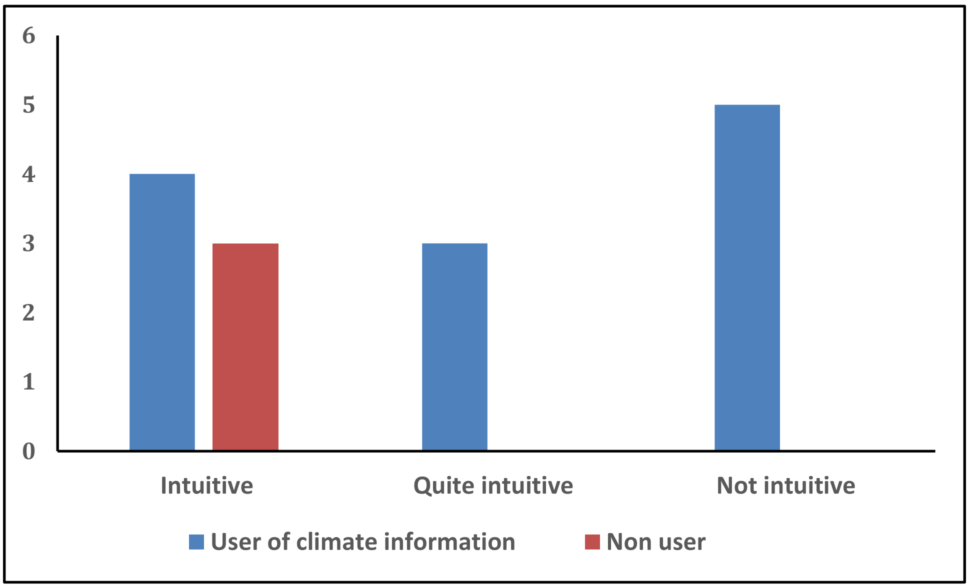

Figure 6.6 Interviewees responses to the tool and data understandability

Most interviewees believed that the tool provides the timescales – historical climate, seasonal forecasts and climate change projections - they need to support the activities and decisions in their role within SOGRAPE. However, four interviewees commented that they also need weather forecasts to support and inform their day-to-day activities and decision-making. One viticulture manager mentioned that *"What is missing is weather forecasts, which is what I use in my day-to day operational decisions."* [Interviewee 12].

When interviewees were asked about what variables they need available in the Dashboard, most of them confirmed that precipitation and temperature are the most frequently used climate variables in the wine sector. They all agreed that the Dashboard contain the type of climate variables (precipitation and temperature) they need in their roles.

With regards to the adequacy of the spatial resolution provided in the Dashboard, 80% of the interviewees (12) agreed that it is sufficient for what they need in their activities and support their decisions. 20% interviewees (3) were of the opinion that more detail was required.

Interviewees were questioned about data reliability (i.e. how closely the forecast provided corresponds to observed frequencies) and all interviewees perceived the data on the Dashboard as reliable. One interviewee claimed that: *"I checked the bioclimatic indicators, I've noticed it shows days above 30 degrees. I believe data is reliable and the information there is correct. I see these are well done and I see value there. However, when I looked at the historical data, it was not as accurate as bioclimatic indicators."* [Interviewee 14].

According to the conceptual framework, the data must be legitimate and lack of bias. Inclusion of users in the process of producing a climate service, and two-way engagement between users and providers could build the data legitimacy. Therefore, in this assessment we asked the interviewees whether they have been involved in the co-development of the Dashboard and nearly 50% of interviewees have been involved in the process from early stage of the project. Those who had not been involved in the co-development confirmed that the data looks legitimate to them.

6.3.6. Recommendations to increase the Dashboard usability

Finally, the interviewees were asked about recommendations and suggestions to increase the usability of the Dashboard in order to better support their role, activities and decisions. Their comments were analysed and aggregated into different categories. These are further described below.

Simplifying the Dashboard

As mentioned previously, some interviewees stated that the Dashboard was not intuitive enough for them and suggested the need for simplifying the tool to increase data understandability. For example, one participant suggested to "(…) *make this more intuitive and easier to access [and] be able to consult information on the cell phone."* [Interviewee 12] whilst another suggested that *"The graphics here are a little bit confusing to me, but from the moment it's explained to me, it's easy to work with."* [Interviewee 14]

Include clear and concise tutorials

Some interviewees claimed that they needed previous training or tutorial to work with the tool. They also mentioned that they had to ask help from the MED-GOLD coordinators in SOGRAPE to work with the Dashboard. One expert suggested that:

"This is a very technical tool and maybe having a video explaining how we can do things. This would be helpful. I deal with several platforms and when they are not so intuitive, I always prefer those that have a video, to remind me how to work with it." [Interviewee 3].

Avoid confusion in labelling

Some interviewees suggested further clarity on how the information is labelled in the Dashboard through the use of meaningful terms. For example, explaining exactly what is meant by the terciles categories of normal, below normal and above normal was asked by three of the interviewees; adding additional numerical information to the terciles categories; or by providing more succinct and clear labels in the Dashboard.

''(…) Above normal, is an indicator, but maybe having a description of what "above normal" is. It is an indicator that potentially will be above, but how much above? Which is the percentage that would present risk?''

'' My comment is about the normal values as a label on the tool. Usually, the results are presented based on the normal value, above normal or below normal and what I think is: some people may have a great climatic memory and have some idea what the weather has been like for the last thirty years, twenty years. In my case, I have no idea. So when I'm told it's above normal or normal is below normal, without having a number, it doesn't give me any information''. [Interviewee 1].

''The bioclimatic indexes, they could be written in a more succinct, more direct way, (it would also be a good improvement) because from my experience dealing with the public, I know that people want to get the most information in the least time possible and if they can get that by reading three lines instead of reading a full text, it is better."[Interviewee 3].

Including weather forecasts on the Dashboard

Weather forecasts is currently the most used data by interviewees and a few of them expected to have weather forecasts in the Dashboard for their day-to-day operational decision-making. In this regard, one interviewee said:

"I think the expectations about this platform failed a little bit because it doesn't have a weather forecast option (The next days and the next weeks). We need better short-term forecasts, and my colleagues use other sources for information but they want to improve this information. "It said it was going to rain and it didn't rain."[Interviewee 6]

Cover more geographical areas

One senior manager who is responsible for long-term decision-making, believed extending the geographical areas represented in the Dashboard within and beyond Portugal could help them find future suitable vineyards by better understanding how the climate is going to evolve in the coming years/decades. He stated that *"The most important improvement would be extending this kind of information, level of detail to other* *region like Iberian Peninsula. We will be able to better define which is the geographical area we should look for land to plant a vineyard.".* [Interviewee 4]

Including more crops in the Dashboard

Some interviewees suggested the potential benefits of using this kind of information in other crops. One head of viticulture, suggested:

"I think this tool is great for viticulture, and extremely qualified. I would even say that even other agricultural crops can take advantage of it, for example the almond, can also take information from the Dashboard, or other crops that work in the same space, in the same territory will be able to take advantage. For example, 35 degrees, the bioclimatic index, will be useful for many crops in agriculture sector." [Interviewee 15]

Using the Dashboard in the future

When asked about using the Dashboard in the future, all interviewees agreed with the usefulness of the tool in their specific roles and activities within SOGRAPE as well as within the wider wine sector. One interviewee mentioned that they would *"(…) definitely use it to predict, not looking to the historical data anymore, but to predict what will happen in the months of May, June and July, or April, May and June so I know when I should apply the products."* [Interviewee 10].

However, some emphasized that their use would be dependent on the improvements and recommendations made (see above) for the continued use of the tool. For example, one head of viticulture commented that:

"They would use it if the tool be simplified and becomes more intuitive." [Interviewee 12]; whilst one of the oenologists stated that "*If the results are more accurate, I [will] use the predictions."* [Interviewee 8].

6.4. Conclusions

The web-based climate service tool developed within the MED-GOLD project known as the Dashboard was assessed in terms of its potential use and value to end-users in the SOGRAPE. This was pursued through close engagement and semi-structured interviews with 15 participants in order to:

1) Assess the tool usability based on the conceptual framework developed;

2) Provide recommendations to increase the tool usability and the potential value to end-users.

We found that weather forecasts are currently the most frequently used climate data for day-to-day activities and operational planning in SOGRAPE. Most users of weather forecasts are oenologists and viticulturists and they use this type of forecasts for informing short term planning activities such as spraying (e.g., type and dose of product to use or when to use it) and harvest timing. Apart from weather forecasts, historical climate information is used by some of the interviewees to help them with costs justification, and long-term investment particularly those with managerial roles. Although seasonal forecasts and climate change projections are currently hardly used by participants, they believe that using these timescales could add value and additional benefits to their medium-term planning and activities (e.g., improve stock management, effective scheduling seasonal labour) as well as long-term (e.g., purchasing land/vineyard, vineyard installation). The potential value and benefits of using the Dashboard within SOGRAPE activities and decision-making processes have been summarised in table 6.3.

Generally, the interviewees were very positive about the usability of the tool in SOGRAPE as well as its applicability in the wider wine sector. Some even consider that such tool could also be useful and usable in other crops (e.g., almond) and even some believe a similar tool must be developed for other crops such as apple and orange. They perceived the data provided in the Dashboard as reliable and legitimate. However, the saliency of the Dashboard was questioned as nearly half of the participants stated that the tool was not intuitive enough and there were several issues of the labelling and need for simplification. In terms of the timescale of the information they require in their roles, some participants mentioned the importance of, and expected to have available in the dashboard, weather forecasts to support their short-term decision-making. Some more constructive suggestions and recommendations were provided by the end-users to increase the tool saliency in the wine sector. Although participants recognised that the Douro Valley region was the case study area for the MED-GOLD project, they suggested extending the geographical scope of the tool to other areas such as the Iberian Peninsula as global warming has already shifted the geographical distribution of suitable wine regions and would be necessary for them to use the tool for long-term planning and investment in the future.

7. Achieving decision-triggering thresholds for the application of seasonal forecasts in vineyard management

Seasonal predictions based on tercile categories have gained attention among farmers as a possible support tool in tackling climate risks. At the same time, a gap has been identified between understanding and using this climate information. Collaborations with farmers have revealed the interest in understanding how to best integrate climate information in their risk management practices. This section presents a case study for the evaluation of seasonal forecasts in the wine sector to identify when and how they can be successfully used. Although the results are case-specific the approach proposed can be extended to other users and decisions.

7.1. Case study

In the MED-GOLD climate service co-development phase one vineyard manager reported the detection of a rising uncertainty in spring rain patterns that could severely affect its yields. In fact, high rainfall, especially in springtime, raises the sanitary risks because it favours the development of dangerous fungal diseases in the vineyard such as the downy mildew (*Plasmopara viticola*).

Data to perform this analysis has been gathered through the wine producing company (SOGRAPE), which has provided estimates of costs and associated yields based on internal data records. More specifically, the purchasing department provided cost data on plant protection products and labour whereas the vineyard manager combined this information with canopy management operation needs and yields (according to tercile scenarios).

7.2. Method

a) Spring Total Precipitation (SprR)

The Spring Total Precipitation (SprR) is a bioclimatic indicator that has been defined according to the wine producers' need to adapt to the impacts of spring rain variability (Fontes et al. 2016). More specifically, SprR is the total precipitation from 21st April to 21st June (for the Northern Hemisphere). The wetness of spring represented by this indicator affects the level of vigour associated with fungal disease and hence, the amount of costs linked to protective treatments and operations. The SprR indicator is defined as follows,

$$Total\ precipitation = \sum_{start\ date}^{end\ date} prlr$$

where prlr is the daily sum of precipitation in mm. The start (end) date is the first (last) day of the period considered for the specific index, in this case 21st April to 21st June, corresponding with the spring period in the Northern Hemisphere.

Dry springs delay vegetative growth and reduce vigour and leaf area total surface. In this scenario fungal disease pressure is often lower and, therefore, there is less need for protective and/or curative treatments (translating into lower costs). Conversely, wet springs promote greater vigour, increase the risk of fungal disease and disrupt vineyard operations, as the emergence of mud sometimes prevents machinery from entering the vineyard.

b) Decisions linked with SprR

From users' viewpoint, knowledge of the spring rainfall months ahead (i.e. by looking at seasonal predictions of SprR) would allow them to optimize their decision-making in two areas: plant protection and canopy management. In the following paragraphs we will describe an illustration of what impact could have this anticipated information in the current user decision workflow in both areas.

Plant protection

Each year in January the purchasing department issues an order for a fixed amount of plant protection products (sprays). The sprays are needed basically to protect the vineyard from fungal diseases. These thrive in humid conditions and, therefore, abundant rain requires the application of extra spraying. Whenever this situation arises, the department tries to correct it by buying more spraying products, but at a risk of higher prices than in January. Actually, in case of heavy rains all over the country demand may become so high that, in extreme cases, suppliers can run out of stock. Thus, late purchase causes higher costs and also exposes the user to the risk of unavailability of spray with potentially nefarious consequences on the diffusion of fungal diseases and disruption of yields. On the other hand, in case of dry season, less spraying is needed, allowing for savings and less impact to the environment surrounding vineyards.

In such circumstances, if the information of the seasonal predictions of SprR was available well in advance, the purchasing department could optimize the quantity of sprays to order for the upcoming spring. However, to do so the user has to be confident enough that using the seasonal predictions will bring a solid benefit because, otherwise, misestimating the amount of spray to purchase would also cause extra costs. Indeed, spare spray cannot be re-used the following year because it loses its effectiveness, so purchasing more than needed is a waste. On the contrary, if too little amount is purchased, the risk of running out of stock could materialize.

Canopy management

Turning to canopy management, if there is a lot of rain, plants grow more, and leaf removal becomes necessary. In fact, too many leaves expose the grapevine to higher sanitary risks and, simultaneously, the application of the spraying products is less effective (more difficult to penetrate and reach grapes). This requires extra labour that should be contracted at the earliest to be ahead of widespread demand for it. If the season turns out to be dry, though, cutting leaves is dangerous because there will be little or no regrowth before summer and, hence, there is a real risk of scalding berries and leaves in the grapevine during the hottest months. Consequently, miscalculation of the rainfall can lead to mistakes in canopy management practices as well as to unnecessary labour costs.

c) Decision workflow: Business as Usual vs. seasonal forecasts

In the framework of seasonal climate predictions, the vineyard manager's decisions depend on the probability of different situations to occur. However, it is important to consider that changes in decision processes as well as deviations from the plan often entail non-negligible costs. Therefore, a change in decision led by an unfulfilled prediction (or incorrect interpretation) can potentially cause higher damages than passively suffering the seasonal variability. Therefore, identifying the probability thresholds to safely trigger a decision is critical for every decision and user.

To analyse the optimal use of the SprR indicator we rely on decision theory (Rubas et al. 2006). The climate service (CS) user must decide with the goal of maximising an objective (Payoff = ∏). Here we consider the value of the CS to be the difference between payoffs of the decision taken with and without using the CS, as defined below.

$$\text{CS' Value} = \prod \text{wcs} - \prod \text{wocs}$$

Being ∏wocs, payoffs from decision made without CS; and ∏wcs, payoffs from decision with CS. If the CS' value is positive, using the CS benefits the decision-maker. Reversely, a negative value indicates that the information provided by the CS had a negative economic impact for the user. This may be driven by different reasons depending on the relationship between users' decisions and prediction characteristics.

To define the payoffs, there is a need to identify the costs and benefits of the vineyard management actions related to spring rain. Costs are represented by purchase of plant protection products and labour hiring (for canopy management) and vary according to the combination of the strategy adopted and the observed rainfall. The benefits are represented by the yields and their monetary value is measured considering the market price of the wine produced with a kilogram of the type of grape of the vineyard under analysis. For the vineyard under analysis the average price for a kg of yield (Y) is 0,5 euro.

$$1 \text{ kg } Y = 0{,}5\ €$$

Regarding the payoff, it is represented by the value of the benefits minus the costs.

$$\text{Payoff}(\prod) = €Y - Cpp - Ccm$$

Where Y corresponds to benefits from yield; Cpp corresponds to the costs of plant protection; and Ccm are the costs relative to canopy management.

Although yields value and costs vary substantially across companies (e.g., with different sizes and purchasing power) and even across vineyards of the same company (depending on the location, the dimension and the type of wine produced), the process for identifying the optimal threshold is always the same. Particularly, though, for this study we have selected a slope vineyard of 70 hectares located in the Douro region.

Business as Usual strategy (BaU)

The first step involves the description of the current baseline strategy. That is, to define the possible payoffs without using the climate service. In the case under analysis, the vineyard manager adopts the same strategy every year independently of the expected climate conditions. We define this strategy, not using climate information, as Business as Usual (BaU). The BaU strategy is summarised in **Errore. L'origine riferimento non è stata trovata.**.

In January, the vineyard managers communicate to the purchasing department the standard amount of protection products that is needed under usual climate conditions to treat the hectares of the field. Given the specific characteristics of the field under analysis, the costs per hectare of purchased protection products were estimated at 316 €, an average of 6 years (2014-19). Similarly, the vineyard manager plans canopy management assuming usual climate conditions. These costs include the labour force and amount to 495,77€ per hectare. If everything goes as planned, 3 997kg / ha of grapes should be harvested - being this the expected yield, E(Y). If SprR turns out to be on normal levels (N, i.e., within climatological normal values), the grape production target will be achieved (assuming no other shocks before the harvesting) at the cost envisaged at the beginning of the year.

However, if the spring rain deviates from the expectations there can be serious consequences. One possibility is the spring being rainier than expected (Above Normal, AN). In this case, the vineyard manager needs to purchase additional spray for protecting the grapes from the increasing sanitary pressure and contract more labour force for canopy management. If the rain affects a substantial share of the country the price of spray and labour is likely to increase until there is no more supply available. This can cause huge damages to the vineyard, including the total disruption of the yield. In this exercise, based on the consultations with the vineyard manager, we assume an intermediate scenario where a supply shock occurs. This means the vineyard manager cannot purchase extra resources (the costs remain invariant), but there is a loss of 30% of the yield (Figure 6.7)

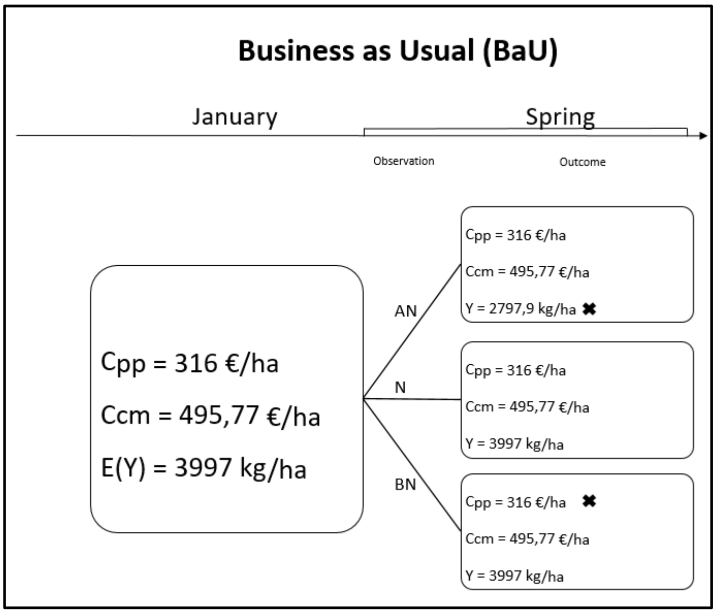

Figure 6.7 Business as Usual scenarios

In January the Business as Usual strategy is applied and the outcome obtained in spring depends on the rainfall during that period. Cpp and Ccm are, respectively, the plant protection and canopy management costs. E(Y) is the expected yield in January, while Y is the final yield. AN, N and BN indicate the three possible scenarios (Above Normal, Normal and Below Normal). In case the AN scenario materializes there is a loss of yields (signalled with a cross in the figure). If the BN scenario occurs, there is a waste of plant protection products because there is no need to use the whole amount purchased (signalled with a cross in the figure).

In the eventuality of a dry spring (Below Normal, BN) **Errore. L'origine riferimento non è stata trovata.**. may suggest that nothing occurs, because costs and yields are equal to the N case. However, this is not the optimal solution for the vineyard manager because it could have benefited from a reduction of plant protection costs (less spraying was needed).

Climate prediction strategy

When introducing seasonal predictions based on probabilistic tercile categories, the vineyard manager can take three different actions. This implies nine possible outcomes depending on the combinations of three possible actions and three possible options of observed spring rain.

If the seasonal predicted SprR indicator suggests normal levels of spring rain (N), the actions taken by the vineyard manager, and subsequent payoffs, correspond to the BaU scenario. But if the predicted SprR suggests higher or lower rain than normal, different actions might be taken. Figure 6.8 summarizes the possible scenarios with their relative outcomes and payoffs.

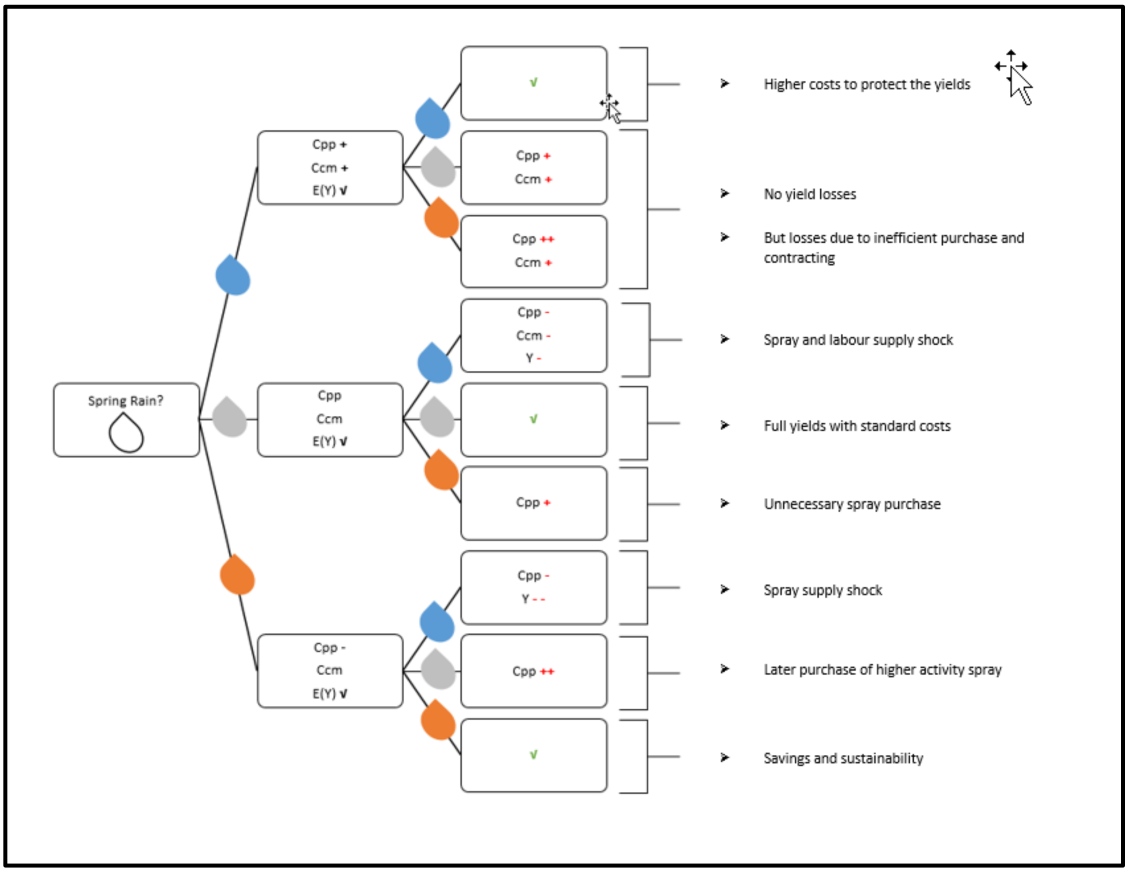

Figure 6.8 Two-levels decision tree representing all possible scenarios when using tercile seasonal predictions of SprR in January planning.

The first level represents the possible predicted categories in January (AN, N or BN, corresponding to blue, grey and orange drops), and the expected impacts in each field (Cpp, Ccm and E(Y)). The green tick indicates a hit (black tick is expected hit), whereas the red + (-) indicates more (less) of the associated item (black + and - signs indicated expectations). The second level of the tree shows the three possible outcomes we can encounter for each of the three initial predictions, followed by a brief description of them (to the right of the figure). These depend on the observed SprR (AN, N or BN, also represented by blue, grey and orange drops).

Based on the most likely predicted SprR signal, the vineyard manager can decide to protect the vines from high expected rain by purchasing additional protection products and contracting extra labour force (blue drop on the first decision branch of Figure 6.8). Then, if the observed rain matches the expectations (blue drop of the second decision branch of Figure 6.8) the yields will be almost entirely preserved from the downy mildew and the maximum payoff possible will be achieved (under these climate conditions). Nevertheless, if the spring turns out to be normal (blue drop of first branch followed by grey drop of the second decision branch of Figure 6.8), although there will be no impact of the decision taken on yield value, the vineyard manager would have extra costs when compared to its BaU expenses. More specifically, it would have wasted an additional 24,79€/ha in canopy management (see Table 6.4: AN;AN scenario Ccm 520,56 €/ha - N;AN

(=BaU) Ccm 495,77 €/ha) and 94,8€/ha in plant protection (Table 6.4: AN;AN scenario Cpp 410,8 €/ha - N;AN (=BaU) Cpp 316 €/ha). Similarly, if the spring turns out to be dry (orange drop on the second decision branch of Figure 6.8), there are no impacts on yield benefits but the plant protection toll represents an even higher cost compared to the optimal purchase in case of a dry spring prediction (189.6 €/ha; obtained from Table 6.4 difference between AN;BN scenario Cpp 410,8€/ha minus Bn;BN scenario Cpp 221,2€/ha).

Table 6.4: Outcomes by scenario measured in euro per hectare (AN–above normal, N–normal, BN–below normal).

Scenario (Action; Observation)	Cpp (€/ha)	Ccm (€/ha)	Yield value (€/ha)	∏wcs (€/ha)
AN;AN	410,8	520,56	1998,5	1067,14
AN;N	410,8	520,56	1998,5	1067,14
AN;BN	410,8	520,56	1998,5	1067,14
N;AN (=BaU)	316	495,77	1398,5	587,18
N;N (=BaU)	316	495,77	1998,5	1186,73
N;BN (=BaU)	316	495,77	1998,5	1186,73
BN;AN	221,2	495,77	999,25	282,28
BN;N	537,2	495,77	1998,5	965,53
BN;BN	221,2	495,77	1998,5	1281,53

For each scenario reported in the first column (possible combination of prediction and observation) the associated costs and yield value are described (columns two to four). The last column presents the payoffs for each scenario calculated as the difference between yields (column four) and the aggregated costs (columns two and three).

In fact, according to the assumptions set for BN conditions (Figure 6.7), the yield is not affected by a less rainy than normal spring and, additionally, less plant protection products are needed due to the unfavourable climate conditions for the development of fungal diseases. As a result, in the BN category prediction 221,2€/ha (Table 6.4 BN;BN scenario) of spray would be enough to guarantee the safety of the yield. Knowing this in January would allow for timely communication to the purchasing department and 94,8€/ha of savings compared to BaU (see Table 6.4: BN;AN scenario Cpp 221,2 €/ha minus N;BN (=BaU) scenario - Cpp 316 €/ha). On top of that, the application of less protection products is beneficial for the environment (however, this positive externality is not taken into account in the impacts for the vineyard manager). On the other hand, savings on plant protection purchases exposes the vineyard to a huge risk in case the predicted SprR turns out to be different than expected. If a normal rain scenario arises (orange drop of first decision branch and grey drop on the second decision branch of Figure 6.8), additional plant protection has to be purchased at the last minute at a higher price (getting to a total expenditure for Cpp of +537,2€/ha, Table 6.4 BN;N scenario) to ensure no crop disruption is faced. Even worse would be if the above rain scenario materialises (orange drop of first decision branch and blue drop on the second decision branch of

Figure 6.8) causing the loss of 30% of the yield, being too late to purchase any extra spray (see Table 6.4: BN;AN scenario Yield value).

7.3. Main results

a) Climate service value

In this section, we estimate the value of the climate service to support predicted SprR-related decisions. As explained in section 1.1.3 this value can be computed as the difference in payoffs between the decision taken using the forecasts (∏wcs) and without using any climate information (∏BaU). The following table shows the payoffs and CS value for each scenario already defined in Table 6.4.

Table 6.5. Climate service value by scenario.

Scenario	∏wcs (€/ha)	∏BaU (€/ha)	Climate Service Value ∏ wcs -∏ BaU (€/ha)
AN;AN	1067,14	587,18	**479,96**
AN;N	1067,14	1186,73	**-119,59**
AN;BN	1067,14	1186,73	**-119,59**
N;AN (=BaU)	587,18	587,18	**0**
N;N (=BaU)	1186,73	1186,73	**0**
N;BN (=BaU)	1186,73	1186,73	**0**
BN;AN	282,28	587,18	**-304,9**
BN;N	965,53	1186,73	**-221,2**
BN;BN	1281,53	1186,73	**94,8**

For each scenario reported in the first column (possible combination of prediction and observation) the payoffs of using the climate service (∏wcs) and the BaU (∏BaU) are computed in €/ha. In the fourth column the climate service value is obtained as the difference between payoffs.

Changes in decisions based on seasonal predictions of above or below normal rain generate benefits whenever prediction and observation match (as shown in Table 6.5 and 'hits' in Figure 6.9). However, it is also clear that a shift from BaU generates losses in those cases when the observation turns out to be different from the expectations. From Figure 6.9, we can also infer that the benefits of a match ('hit' in Figure 6.9) are much larger in case of correctly predicted high rainfall (when yields can be preserved), compared to the benefits given by plant protection savings in case of a well-predicted drought. Contrarily, the costs associated with a decisional mistake are high in case of drought, and relatively low in case of rainy spring (if compared to the potential benefits).

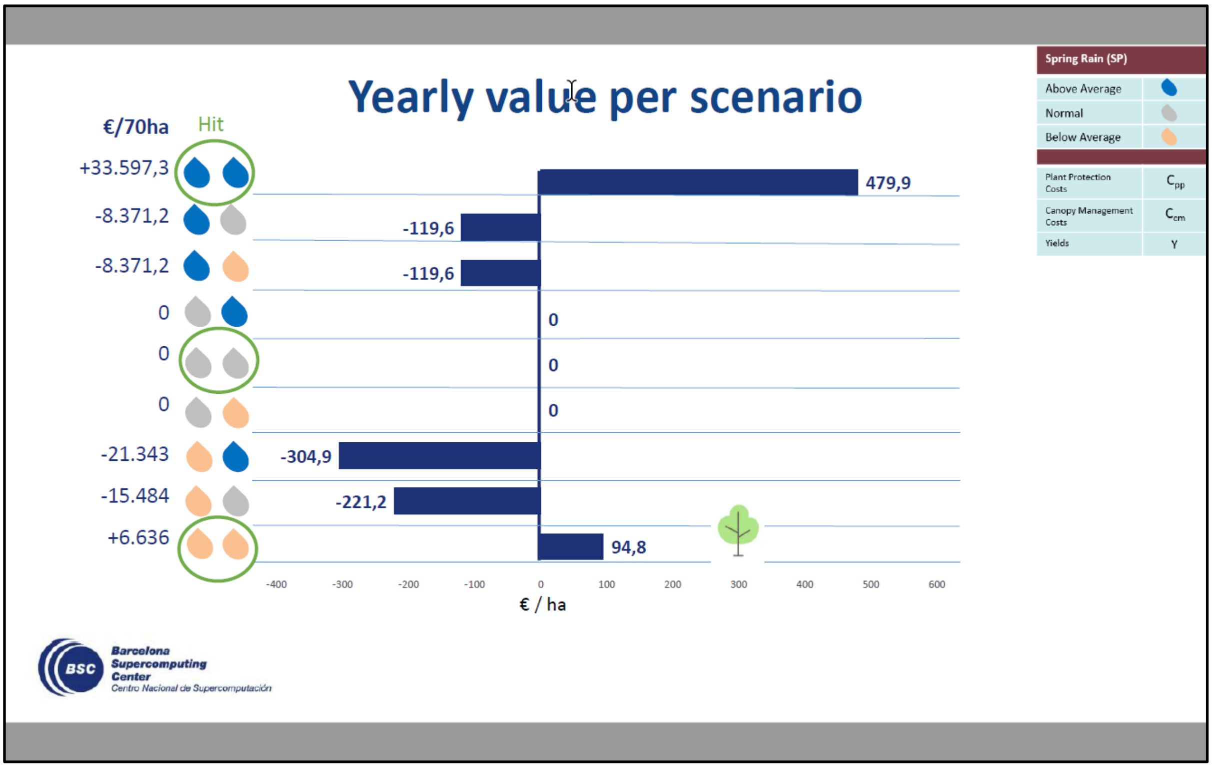

Figure 6.9 Summary of the seasonal climate service value per year and scenario.

Each possibility is represented by pairs of drops (first drop prediction and second drop observation). The bars show the benefits / losses generated per hectare. The value for the entire vineyard (70ha) is reported at the left of the figure. The green circle (hit) identifies when prediction and observation match.

b) Computation of the decision-triggering thresholds

In the climate service field, we define the predictions to be of enough quality when the users can rely on the benefits of including them in their decision workflows. Thus, once the CS annual value per hectare has been established (third column of Table 6.7), we can focus on linking CS-based decisions and the probability threshold that could safely trigger them. In our case, considering we have three tercile categories in which the user could be interested in: above normal (AN), normal (NN) and below normal (BN), there are 3 groups of 3 possible value scenarios each (depending on the possible combinations of prediction-observation, Table 6.7 second column).

Based on this information, we can develop a general approach on how to perform the computation of the decision-triggering thresholds for each scenario. It is worth noting we consider each potential decision to be tercile category independent there are no decisions that simultaneously depend on the prediction of two categories, for instance, AN and BN. This is the reason why our search for the probability thresholds is independent for every tercile category. Table 6.6 shows the needed information for this calculation.

Table 6.7: Triggering decisions thresholds

Fraction (%)	Scenario	CS Value ∏ wcs -∏ BaU
D1	TRC;AN	x
D2	TRC;N	y
D3	TRC;BN	z

The first column (Fraction, %) refers to the percentage of times each scenario has been observed (D1, D2 and D3) from the total number of times TRC has been predicted. The second column (Scenario) shows the prediction (TRC) followed by the actual observation (AN, NN or BN). Finally, the third column (CS Value, ∏ wcs -∏ BaU) is the economic impact of using the CS in each of these scenarios compared to BaU (x, y and z).

For obtaining the thresholds there are two conditions to fulfil:

(i) the sum of all the fractions is equal to 100 (eq. 1), because D1, D2 and D3 are, respectively, the fraction of times that AN, NN and BN categories have been observed out of the total of times TRC has been predicted;

$$D_1x + D_2y + D_3z \geq 0 \rightarrow D_1 \geq -\frac{D_2y + D_3z}{x}$$

$$D_1 + D_2 + D_3 = 100$$

(ii) the sum of the products obtained from multiplying each fraction by the corresponding CS value is equal or higher than zero (eq. 2) because we would like to avoid that the user has losses after applying the CS.

$$D_1x + D_2y + D_3z \geq 0 \rightarrow D_1 \geq -\frac{D_2y + D_3z}{x}$$

$$D_1 + D_2 + D_3 = 100$$

These two equations link CS annual value per hectare and the historical counts for each prediction-observation pair, independently of the category considered. As we can see, we have three degrees of freedom (D1, D2 and D3) for two equations and, hence, not only will we have multiple possible solutions, but we would need specific boundary conditions to be able to solve them.

These constraints could be either inferred from the magnitude of each CS value scenario or directly stated by the user. In the case of Table 6.6, if we suppose we are mostly interested in D1 (when the prediction-observation pairs match, also known as 'hits') we could look at the minimum number of hits needed to achieve a positive outcome:

$$D_1x + D_2y + D_3z = 0 \rightarrow D_1 = -\frac{D_2y + D_3z}{x}$$

$$D_1x + D_2y + D_3z = 0 \rightarrow D_1 = -\frac{D_2y + D_3z}{x}$$

And constrain D2 and D3 to obtain the percentage of hits needed in each situation. Hereafter we will proceed to compute these thresholds with the data gathered in Table 6.5 and for every tercile prediction.

Probability threshold for AN predicted conditions

In this category,

$$y = z = -119.59 \text{ €/ha}$$

And hence:

$$D_1x + D_2y + D_3z = 0 \rightarrow D_1 = -\frac{D_2y + D_3z}{x}$$

Becomes,

$$D_1 = -\frac{y}{x} \cdot (D_2 + D_3)$$

If we develop it further (taking advantage that y = z),

$$D_1 = -\frac{-119.59}{479.96} \cdot \underbrace{(D_2 + D_3)}_{D_2 + D_3 = 100 - D_1} \simeq 0.25 \cdot (100 - D_1)$$

Now we can work out the minimum value of D1 needed to safely trigger decisions dependent on the AN category.

$$D_1 = \frac{25}{1.25} = 20\,\% \rightarrow D_1 \geq 20\,\%$$

$$D_1 = \frac{25}{1.25} = 20\,\% \rightarrow D_1 \geq 20\,\%$$

Therefore, whenever the probability for AN prediction lies equal or above 20%, the user will be safer by adopting the corresponding action.

Probability threshold for N predicted conditions

In this case, since the N conditions are assumed to be what drive the BaU, there is no benefit in using them (see Table 6.5).

$$x = y = z = 0$$

Probability threshold for BN predicted conditions

In the BN category, if we need to work with hits, we would need to isolate D3 (see Table 6.5 and 3).

$$D_3 = -\frac{D_1 x + D_2 y}{z}$$

$$D_3 = -\frac{(-304.9\,D_1 - 221.2\,D_2)}{94.8} = 3.22\,D_1 + 2.33\,D_2$$

In this case even though we use,

$$D_1 x + D_2 y + D_3 z \geq 0 \rightarrow D_1 \geq -\frac{D_2 y + D_3 z}{x}$$

$$D_1 + D_2 + D_3 = 100$$

We still have two equations for three variables, so we will need a constraint. To do so we can explore the 'best' and 'worst' settings. The 'best' would be when D1 = 0, so we would only have D2 and D1 events (every time the model 'fails' causes the lower prejudice). In that situation,

$$D_2 = \frac{1}{2.33} D_3$$

So,

$$D_3 = \frac{100}{1.43} \simeq 70\,\%$$

$$D_3 \geq 70\,\%$$

It is important to note there would be a 'theoretical' better scenario if the model was perfect (so D1 and D2 were 0). In that case whenever the model predicted any category it would signal it with 100% probability and always would be right. However, this would convert our prediction into deterministic and, consequently, it would make any probabilistic analysis unnecessary.

Conversely, the worse scenario would be when D2 = 0 (every time the model 'fails' causes the maximum prejudice). In that case,

$$D_1 = \frac{1}{3.22} D_3$$

And,

$$D_3 = \frac{100}{1.31} \simeq 76.3\,\%$$

$$D_3 \geq 76.3\,\%$$

In a real working scenario, neither D1 or D2 will be 0. One option to achieve a more proper threshold would be to apply the mean on both. However, although D1 and D2 are climatologically equivalent, their relative impact is not,

$$\frac{x}{y} \simeq 1.38$$

Thus, to achieve the probability threshold in this case we need to use a weighted mean.

$$D_3 \geq \frac{1.38 \cdot 76.3 + 70}{2.38} = 73.7\,\%$$

In these three examples we have seen the probability thresholds that can reassure the user on its actions are deeply dependent on the predicted categories and their link with the cost / loss / benefits compared to BaU strategy. More specifically, we have obtained the following thresholds:

- AN: 20%
- NN: it is the assumed BaU (no gain possible)
- BN: 73.7%

In the BN prediction, for example, we need a very confident model to be able to see any benefit from anticipated actions (probabilities above 73.7%). This is logical, because of the negative consequences on the yield when purchasing less plant protection than needed.

The AN case, on the other hand, is interesting because the percentage is quite low (20%). This means that even the straightforward SprR climatology (~33% probability for each category, AN, N and BN) would offer value to the user even if always applying the AN actions. If we look at the expected CS value in the event, we always assumed the AN scenario (having 33% of 'climate' hits), we will see that we have 79.47 €/ha of benefits (see Table 6.8). It seems that always purchasing extra plant protection and contracting extra labour force implies less costs than allowing any damages caused by potential yield losses.

Table 6.8: Aggregated climate service value using climatological probabilities (in the AN prediction scenario).

Scenario	Climate Service Value Π wcs -Π BaU (€/ha)	Climate probability (observed)	Weighted Climate service Value (€/ha)	Aggregated Climate Service Value (€/ha)
AN;AN	**479,96**	0,33	158.39	79.47
AN;N	**-119,59**	0,33	-39.46	
AN;BN	**-119,59**	0,33	-39.46	

7.4. Conclusions

In this section we have illustrated a methodological approach to characterise the probability thresholds that a vineyard manager could apply to safely trigger a decision based on tercile categories (seasonal prediction product offered in the MED-GOLD wine climate service). The case study proposed has been based on spring rainfall, a critical component in the wine producing workflow.

In a co-production approach with SOGRAPE, we have firstly identified the bioclimatic indicator that could account for the spring variable, SprR. Afterwards, we have economically characterised different decisions that could be adopted in each tercile scenario, as well as the BaU to compare with. Finally, we have put forward a methodology to consider the minimum probability for having positive results when including costs, losses and benefits in each decision scenario.

The results obtained point towards the adoption of AN as a better BaU for this specific user. Actually, the expected payoffs suggest that acting to prevent above normal rainfall is the best default strategy because a forecasted probability of 20% of above normal rain is already sufficient to take action against the risk and see benefits. On the other hand, a high probability, 73.62%, of dry conditions should be signalled by the forecasts for the user to act accordingly. However, in the real world the user is not subject to a single decision and climate is not the only variable affecting them. It is out of the scope of this section to investigate more in-depth how the inner company variables shaped the BaU scenario, which is a needed step before making a robust recommendation based on these results.

The method followed in this case-study, though, can be easily applied to different cases as long as it is tailored to the user's costs and benefits. It’s worth noting, the thresholds elicited in this case study are only for methodological purposes, because different users and decisions may require other threshold values.

A potential caveat of this approach, and a topic for future work, is that we have assumed perfect reliability of the climate models. That is to say, the forecasted probabilities are the ones that would be observed climatologically if we had enough predictions with the same forecast probability to do the computation. This seldom happens with climate models and so one further step needed to be able to bridge the gap between seasonal forecast climate services and users’ up-take, is to include that uncertainty in the computation of any probability thresholds aimed to work as ‘decision-triggers’.

Annex 1: Interview protocol

Section A: About you and your organisation

1. What is your role in SOGRAPE?
2. Do you currently use any weather and/or climate information in your role? If so, what information and for what purpose?
3. Is there a willingness in your company to use seasonal or climate change projections? If so, why do you think that is?

Section B: Your interactions with the MED-GOLD Dashboard

4. Have you interacted with the MED-GOLD Dashboard in the last few weeks?
   If not: Why haven't you interacted with the Dashboard?
   If yes:
   - How many have you interacted?
   - Did you had an idea/objective in mind when you interacted with the tool? E.g., looking for particular information to help you in an activity?
   - Did you use the information to inform and/or support your decisions in SOGRAPE?
     - **<u>If yes</u>**: What kind of decisions did the Dashboard help or support your decisions during last six weeks?
     - Please describe how the information provided by Dashboard helped you in the decisions you mentioned in the previous question (e.g., which information/indices helped you to make which decisions)?
     - What other kind of decisions do you think the Dashboard could help you throughout the year?
     - What other potential benefits do you think you could experience by using Dashboard on your activities and decision-making?
     - Would you use Dashboard in the future to help you in your decision-making?

     - **<u>If no</u>:** why didn't you use the information provided by Dashboard?
     - What potential decisions and benefits do you think the Dashboard could give you by using the information available?
     - Would you use Dashboard in the future to help you in your decision-making?

Section C: Feedback on the MED-GOLD Dashboard

5. Is the climate information available in the Dashboard understandable for you?
6. Is the map on Dashboard easy to understand?
7. Is the export data format easy to understand (user-familiar format)?

8. Does the Dashboard provide the information you need at the right time to support your decisions?
9. Does the Dashboard provide information at the right timescale (i.e. Historical, seasonal and projections) to support your decisions?
10. What about the spatial resolution?
11. Do you think the data available in the Dashboard is reliable (i.e. the information is trustworthy)?
12. Do you think the technical knowledge and development of the tool is robust and reliable (trustworthy technically)?
13. Have you been involved in the development of this tool/Dashboard? If yes, how?

Section D: Recommendations to improve the Dashboard usability,

14. What changes would you make to improve the Dashboard?
15. Is there any climate information that you think is missing from the Dashboard?
16. Does Dashboard address the indices that wine sector' users need in their activities and decisions?

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