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Assessing the usability and value of a climate service in the wine sector

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ABSTRACT

Climate change can significantly affect and influence, both positively and negatively, the wine sector. In this context, the adoption of timely, cost-effective adaptation strategies may contribute to reduce such risks, maximise opportunities, and enhancing the sector's resilience to changing climatic conditions. Climate services involve the production and use of climate information to support decision-makers adapting to climate variability and change. Assessing the value and benefits of using climate services constitutes a critical area of research and can help climate service providers identify any barriers in their development, uptake, and use. The climate service developed in this research benefitted from a co-production approach with a Portuguese Wine company – SOGRAPE. In this paper, we aim to assess the usability and value of the climate service co-developed with SOGRAPE and identify possible barriers that limited the tool's usability and value. Engagement with SOGRAPE users was pursued based on mixed methods approach throughout the various stages of co-development and testing of the tool. The results show that the data provided in the Dashboard was perceived as reliable and legitimate. However, the saliency of the Dashboard was questioned, and some recommendations proposed to increase its saliency and overall usability. More importantly, SOGRAPE users were not able to use the climate information provided in the tool due to a number of barriers which are also reported in this study. The findings and recommendations from this study will help inform the design, development and usability of other climate services within and beyond the wine sector.

Practical implications

Wine production is climate dependent and highly sensitive to weather variability. Therefore, access to useful and usable climate information allows decision makers in the sector such as oenologists, and viticulturists to increase their adaptation and resilience to current and future climate conditions. In this regard, climate services can help towards their adaptation to climate change and reducing climate risk. This is mainly because it is often argued that what climate information providers produce is not exactly what users can use in their decision-making processes. This gap can challenge users in applying the climate information in practice due to a lack of saliency, credibility and/or legitimacy of the information. Hence, climate services are produced to reduce this gap by tailoring climate information.

Development of a climate service for a sector needs collaboration between climate information providers and users of climate information to produce usable climate information. Therefore, this research project benefitted from one of the Mediterranean wine producers, SOGRAPE Company, as the user of climate information to understand what climate information the users in the wine sector need, in order to adapt to climate change with focus on seasonal forecasts and climate change projections. The climate service developed in the wine sector based on a co-production process, is an online web-based tool known as the Dashboard. The Dashboard provides a range of long-term climate information, including historical climate information, seasonal forecasts, climate change projections, bioclimatic indicators, and risk indices, for decision-makers in the wine sector to reduce climate risks.

This research aims to assess the usability and values of the Dashboard as well as to identify possible barriers that limits the tool's usability. Here, we engaged with 15 users in the SOGRAPE Company who were directly (or indirectly) involved in the co-development of the climate service to understand the benefits of using the Dashboard in their decision-making. Engagement was

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conducted through an online workshop to showcase the Dashboard, and through semi-structured interviews to assess in more detail the usability and value of the Dashboard to the users of climate information.

The assessment shows that using timescales on the Dashboard could add value and additional benefits to the wine sector's medium-term (e.g., improve stock management, effective scheduling seasonal labour) as well as long-term (e.g., purchasing land/ vineyard, vineyard installation) planning. However, they recommended some feedbacks to increase the tool usability e.g., half of the participants stated that the tool was not intuitive enough, labelling is not clear and needs clarification. In terms of the timescale, some participants mentioned the importance of weather forecasts and expected to have it available in the Dashboard to support their short-term decision-making. Although participants recognised that the Douro Valley region was the research case study area, they suggested extending the geographical scope of the tool to other areas such as the Iberian Peninsula. It is mainly because 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.

1. Introduction

The importance of viticulture and winemaking in Europe is well recognised and Europe is known as the largest vineyard area in the world (Fraga et al., 2013). However, the production of grapes and wine is heavily influenced by weather and climate conditions (Mihailescu and Bruno Soares, 2020). While climate change impacts might be detrimental for viticulture in some regions by challenging the ability for adequate grape cultivation and wine production, in other regions, it can be beneficial by opening new areas for cultivation and given allowing earlier fruit maturity (Santos et al., 2020a). The expected changes in climate variability and change over the next years/decades may reshape the geographical distribution of wine regions (Santos et al., 2020b). In this context, access to useful and usable climate information can support decision-making processes and better inform adaptation measures for wine production such as relocation, row orientation, variety selection, dry farming, and crop diversification (Babin et al., 2022). In this regard, climate services can help by providing information to support climate change adaptation and reduce climate risks and impacts (Adams et al., 2015; Buontempo et al., 2018; Vaughan et al., 2018; Williams et al., 2020).

Different conceptualisations of climate services exist but these tend to include the production, translation, and provision of climate information that support users' needs (Hewitt et al., 2013; Bruno Soares and Buontempo, 2019). It is often argued that there is a gap between what producers of climate information perceive as useful climate information and what users can use in their decision-making processes (Lemos et al., 2012). This gap can lead to challenges in using the climate information in practice often due to a lack of saliency, credibility and/or legitimacy of the information (Bruno Soares et al., 2018a).

Although some studies consider availability, 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 a pre-requirement for using data in decision-making but does not necessarily lead to its use in practice (Vincent et al., 2020). The world Meteorological Organisation (WMO) suggest criteria to define the usability of a climate services such as: availability, timeliness, usable, credible, authentic and flexible (WMO (World Meteorological Organization), 2011; Tall et al., 2018). 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; VanderMolen et al., 2020). This latter framework is used in this study to assess the usability and value of climate service co-developed within the wine sector (Fig. 1). Hence, the factors are described here:

Saliency refers to timeliness, spatial scale, appropriate selection of variables, and understandable presentation format (visualisation). Salience requires that the information is relevant to a decision maker's problem (Gettelman and Rood, 2016). For example, information that is timely and informs decisions about users' problems have high salience whilst information that arrives at the wrong time in the decision-making process (too early or too late), can fail to influence for lack of salience (Kingdon, 1995; Cash et al., 2003).

Credibility is the degree to which the scientific information is perceived as of high quality as judged by the standards of the scientific community. It refers to levels of accuracy, reliability and quality of the data (VanderMolen et al., 2020). A high level of trust in the climate information is often associated with a high level of accuracy (cf. Tall et al., 2018). Reliability can also be used as criteria of trust in relation to the climate information provided as it demonstrates how closely the forecast probabilities align with observed frequencies (Weisheimer and Palmer, 2014).

Legitimacy comes from the processes used to produce the information, which must be free from bias and perceived to be transparent to stakeholders (Cash et al., 2006; Lemos, 2008; McNie, 2007; 2013). The inclusion of the users of the information in the process of producing a service (also known as co-production) as a two-way engagement between users and providers of information, can help building legitimacy and greater trust in its use (Robinson and Tansey, 2006; Vincent et al., 2018; Vincent et al., 2020). Therefore, legitimacy of the process of developing climate information and knowledge is often linked to the quality of stakeholders' engagement and ownership in that development process (Cash et al., 2003; Evely et al., 2010; Fazey et al., 2014; Wall et al., 2017).

To ensure the usability of climate services – in terms of their saliency, credibility and legitimacy – these should be produced through new modes of knowledge creation such as co-production processes (Lemos et al., 2012; Vincent et al., 2020).

Assessing the value and benefits that can be realised from using climate services is a critical area in this field of research (Bruno Soares et al., 2018b) as it helps to understand the extent to which climate information meet users' needs and support their decision-making in real life (Zeng et al., 2019). The word 'value' in climate services has been defined as the range of (potential) benefits – either economic, social and/or environmental – that can be generated from using climate information in decision-making processes (Nicolls, 1996; Bruno Soares et al., 2018a). These include both benefits that can be quantifiable as well as those more qualitative in nature (Anderson et al., 2015; Bruno Soares et al., 2018a).

A number of methodological approaches can be used to assess the value and benefits that can be realised from using climate information and services in decision-making (see e.g., Bruno Soares et al., 2018a). While ex-ante approaches assess the potential value of climate information (independently of its practical use), ex-post empirical assessments aim to capture the value realised from using such climate information in practice (Bruno Soares et al., 2018a; Tall et al., 2018; Vaughan et al., 2019). Ex-post analyses tend to use qualitative methods to assess the benefits of climate information to users which often require more time and resources. In addition, this type of assessment can only be pursued if the climate information is used in practice and the value and benefits are realised by such use (Bruno Soares et al., 2018a).

This paper aims to assess the usability and value of the climate service developed with the end-users who were directly (or indirectly) involved in the development of the climate service as well as to identify possible barriers that limited the tool's usability and value. To do this, Section 2 describes the various stages of the climate service development for the wine sector and the methodology used to assess the usability and

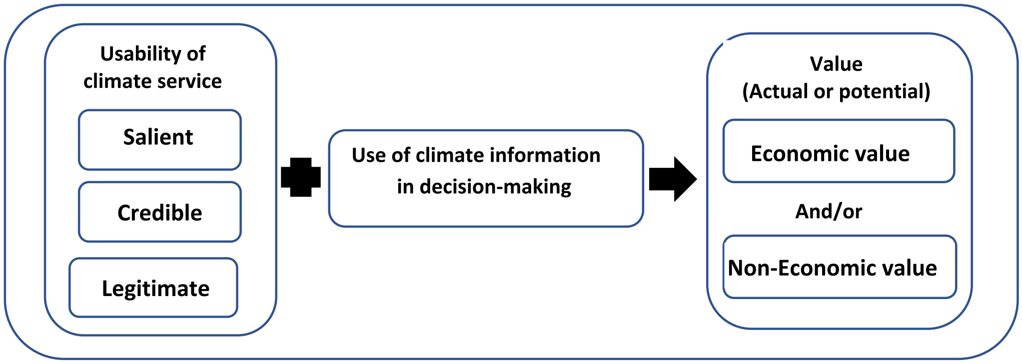

Fig. 1. Conceptual framework used to assess the usability and value of the climate service.

value of the climate service. Section 3 shows the research findings. Section 4 provides a discussion of our research findings and overall conclusions are presented in section 5.

2. Developing the climate service for the wine sector

The Douro Wine Region in Northern Portugal was selected as the case study area for developing the climate service for the wine sector. This was deemed as the ideal laboratory for developing it as Portugal is the 11th largest wine producer and the 9th biggest wine exporter worldwide (OIV, 2018; Santos et al., 2020) and the wine sector is one of its major socio-economic activities (Tavares and de Azevedo, 2010). Amongst the Portuguese wine producing regions, the Douro demarcated region is one of the oldest wine regions in the world, famous for its port wine and other high-quality wines (Fraga and Santos, 2017).

Developing a fit-for-purpose climate service for a sector demanded a strong collaboration between climate scientists and end-users to produce usable climate information. Therefore, one of the Mediterranean wine producers, SOGRAPE Company, was considered the end- user of climate information. The Company is the biggest wine company in Portugal, with annual revenue around US$250 million (Wine spectator, 2019). The climate service in the wine sector was developed using the following steps described below.

2.1. Assessing climate information needs and key decisions in SOGRAPE

Assessment of climate information needs is an important step for providing useful climate services (Khosravi et al., 2021). As a result, we started this assessment by pursuing four separate focus groups discussions with SOGRAPE participants in May 2018 to assess their climate information needs. Table 1 below lists the main focus groups' themes (based on main area of expertise of the participants and their area of agency in the company), the main types of decisions they are involved, and which are influenced by weather and climate conditions and type of climate information that was deemed most useful to better inform those decisions.

Table 1
Focus group themes, type of decisions and climate data needs in the SOGRAPE.

Focus group theme	Type of decision	Type of climate information
Strategy	• Site selection for new vineyardsChoice of grapes varieties for planting	• Climate change projections
Viticulture management	• Choice of grapevine's rootstock and clone for planting • Definition of training and pruning system • Cropping operations' planning • Management of agricultural machinery according to operational planning	• Seasonal forecasts
Oenological management	• Maturation control planningSetting harvest dates	• Seasonal forecasts
Stocks Management	• Stock Management (products and consumables for viticulture and winemaking)	• Seasonal forecasts

Source: Adapted from Teixeira et al., 2018,

This initial assessment showed that SOGRAPE participants were interested in accessing seasonal forecasts for helping them in decisions related to planting, plant protection, and harvest planning. In particular, the information requested were seasonal forecasts of temperature and precipitation with a 6-month lead-time and updated weekly.

Participants were also interested in climate projections of temperature and precipitation with quarterly updates for making long term decisions such as identifying opportunities for purchasing new vineyards in different geographical locations (Teixeira et al., 2018).

Visualization options (e.g., maps, graphics and colour bars) were also presented and discussed with SOGRAPE participants during the focus groups and they were asked to choose their preferred way to receive information on the climate variables of interest. Their preferred choice was using maps along with tercile /percentile plots and explanatory text available ideally through a web-based application for ease of access (e.g., through their mobile phones) (ibid).

2.2. Developing and testing the tool

Based on the initial assessment of user needs, the climate service tool was co-developed between the project team and SOGRAPE participants through several interactions between 2018 and 2020.

The Alpha version of the tool was developed based on essential climate variables and six bioclimatic indicators that were identified as critical to key issues in the wine sector including vine growth, yields and best harvesting dates for grapes (Marcos-Matamoros et al., 2020a). The bioclimatic indicators were identified based on the climate information needs of SOGRAPE users and an initial assessment of the level of uncertainty and skill in seasonal forecasts and climate change projections in Europe (see Met Office, 2019). These included: spring total precipitation (SprR), harvest total precipitation (HarvestR), growing season average temperature (GST), growing degree days (GDD), warm spell duration index (WSDI) and number of heat stress days (SU35) (See Marcos-Matamoros et al., 2020a; Dell'Aquila et al., 2021b). Two wine-specific risk indices were also developed – Sanitary risk and Heat risk – in order to provide holistic information on risks that can occur as a result of interdependent factors such as higher number of infestations or the quality and/or quantity of grape loss due to heat stress (See Marcos-Matamoros et al., 2020a; Dell'Aquila et al., 2021a).

A first participatory workshop was organised in May 2019 in SOGRAPE's headquarters in Portugal and involved 12 participants from SOGRAPE working in different areas and departments in the company (e.g., Viticulture, Oenology, Innovation, Human Resources) (Bruno Soares et al., 2019). The aim of the workshop was to present, discuss and gather feedback on progress made in relation to the wine climate service tool also known as the Dashboard. As some of the participants had not been initially involved in the project (i.e., through the focus groups described above), the workshop started by introducing the project and some of the key concepts used e.g., seasonal forecasts, essential climate variables, terciles. The workshop then proceeded by discussing with participants a) their preferences regarding visualisations of seasonal forecasts and climate change projections, b) the usefulness and potential usability of the climate variables and indicators in the Dashboard and c) any additional information required to best support their decision-making (ibid). The findings from the participatory workshop were used to further improve the climate information provided in the Dashboard (see Dell'Aquila et al., 2021a). These included (Marcos-Matamoros et al., 2020b):

- Preference for visualising climate information through maps alongside tercile/percentile plots and accompanying explanatory text;
- Blue-red gradient was selected as preferred colour scheme to be used to represent temperature whilst green–brown gradient for temperature;
- Progressive disclosure of information (i.e., option to access more detailed information in a gradual manner),
- Minimum 70 % hit-rate probability in seasonal forecasts for SOGRAPE users to trigger/support their decision-making,
- Interest in relative increase and/or decrease of climate variables in terms of long-term climate change projections.

Based on the feedback received it was decided by the project team that the Dashboard should be a web-based application[1] in order to allow for an easy way to visualise and interact with the climate information available in the Dashboard and as requested by users (Marcos-Matamoros et al., 2020b). The Beta version of the Dashboard as an online application was further developed and discussed with SOGRAPE[2] throughout the first few months of 2020 through fortnightly meetings to discuss progress achieved and discuss next steps (ibid).

In addition, a users' manual on how to use the Dashboard was also developed to support stakeholders and other practitioners when using the tool (Dell'Aquila et al., 2021b).

The original plan was to present the Beta version of the Dashboard to SOGRAPE users through another participatory workshop. However, with the surge of COVID-19 in early 2020 it was decided that the best option would be to postpone the workshop and gather online feedback with SOGRAPE users instead. As a result, online feedback sessions were organised to allow users to test and use the Dashboard and provide feedback on a number of topics, including: the structure and interface of the tool, content of information provided, presentation and visualisation of information (for more see Marcos-Matamoros et al., 2020b). A total of 9 online feedback sessions with 11 SOGRAPE participants were pursued in May 2020 and significant feedback and recommendations to improve the dashboard were collected (ibid). Following from the feedback received, additional detected bugs were corrected in the Dashboard, visualizations were improved, and ease of use and onscreen intuitive guidance were developed. The final version of the Dashboard was released in April 2021[3] and provided information on different timescales and covering a range of climate variables, bioclimatic indicators, and wine risk indicators (Table 2).

Table 2
Timescales and climate variables available in the Dashboard.

Variables available in the Dashboard	Timescales available in the Dashboard		
	Historical information	Seasonal forecasts	Climate change projections
Climate variables	• Monthly Precipitation • Monthly Maximum Temperature • Monthly Minimum Temperature • Monthly Average Temperature		
Bioclimatic indicators	• **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 35oC, • **Warm spell duration index (WSDI):** annual count of days with at least 6 consecutive days when the daily maximum temperature exceeds its 90th percentile.		
	Not applicable		• **Growing degree days (GDD):** sum of daily differences between daily temperature averages and 10oC (vegetative growth minimum temperature) between April 1st and October 31st (Northern Hemisphere)
Wine risk indicators	• **Sanitary risk:** The risk of pressure of fungal disease in grapes. • **Heat risk:** The risk of temperatures that are higher or lower than normal conditions to the crop yield and quality, consequently affecting wine production.		Not applicable

Source: Adapted from Teixeira et al. (2018) and Marcos-Matamoros et al. (2020).

The link below demonstrates the final version of Dashboard: https://www.youtube.com/watch?v=2Y5xgdXnPI8.

2.3. Assessing the usability and value of the tool

The usability and value and of using the climate information provided in the Dashboard in their decision-making was assessed with SOGRAPE users. This assessment was pursued using a mixed methods participatory approach including an online workshop and semi-structured interviews.

The online workshop was held in mid-April 2021 and 15 SOGRAPE participants from various departments of the company such as oenology, viticulture, R&D, production, marketing, agricultural technicians, and logistics attended.

The workshop was structured around two key sessions:

- Present the final version of the Dashboard;
- Set up the ongoing assessment of the usability and value of the Dashboard with SOGRAPE users.

The first session (which was run in English given the diversity of nationalities in the project team) showcased the Dashboard Videeo followed by a live demonstration of the climate information available in terms of historical data, seasonal forecasts and climate change projections and finishing with a Q&A session.

The second workshop session (which was run in Portuguese to help facilitate understanding) aimed at setting the procedure in the assessment of the usability and value of the Dashboard to SOGRAPE

[1] This web-based Dashboard would also allow the access to bioclimatic indicators and information to others sectors being studies in the MED-GOLD project such as the olives/olive oil sector.

[2] SOGRAPE's involvement during this stage was primarily through the involvement of SOGRAPE colleagues directly involved in the MED-GOLD project.

[3] Delays to the development of the Dashboard were experienced due to the impacts of the COVID-19 pandemic in the project team.

participants. The assessment involved three separate but intertwined stages:

a) Identifying participants' key decisions in coming weeks – This stage was pursued during the workshop. Participants were asked to reflect and take notes of key decisions that they would have to make in subsequent weeks and that were influenced by climate conditions. This exercise aimed at helping participants by using those key decisions as a starting point for interacting and using the information available in the Dashboard.
b) Interaction and use of the Dashboard by participants – this stage took place between mid-April and mid-June 2021. Although the original plan was to test the Dashboard with participants earlier in the year (in order to provide them with relevant bioclimatic indicators and indices in early Spring/Summer to help inform critical decisions regarding) this was not possible due to delays in the development of the Dashboard following the COVID19 pandemic. Participants were asked to interact with the Dashboard at least once a week and provide feedback through a short online survey (which included questions on accessing and using the information in their activities and decision-making). Participants were offered technical support from SOGRAPE colleagues directly involved in the MED-GOLD project during the testing period.
c) Individual interviews – conducted between mid-June and July 2021. A semi-structured interview protocol was developed to conduct the interviews and covered themes based on the conceptual framework, including current use of climate information in decision-making; use of the dashboard during testing period and benefits to their decision-making; usability of the dashboard and recommendations for improving it. All 15 interviews were conducted in Portuguese and recorded via MS Teams Microsoft. These were then translated and transcribed into English verbatim. The transcriptions were prepared and analysed using qualitative thematic and deductive coding in line with the interview protocol questions and wider conceptual framework.

3. Results

3.1. Current use of (weather and) climate information

Findings from the interviews showed that of the 15 interviewees, 12 of them were (direct or indirect) users of climate information in their roles whilst three interviewees did not use this type of information. Participants were asked about their current use of climate information and, although a few reported using historical climate information and climate change projections, the most used type of data in SOGRAPE were weather forecasts which are currently used to help support their day-to-day operational activities and short-term planning (Fig. 2). In particular, oenologists and viticulturists (n = 7) tend to use this type of forecasts for short-term planning of their activities such as disease treatment and harvest timing. One of the interviewees from the viticulture department stated: *"I use climate information only during harvest every day, I check for the next day and for the following week. Therefore, I use it for short-term planning, I don't use it during the year"*.

The head of the oenology department, and responsible for deciding on harvesting dates for SOGRAPE's internal and external[4] vineyards 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 the weather forecast to see if the weather conditions will be ideal, and if not, what is going to be happening. After mutation cycle, in 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 h"*.

Regarding long-term decisions, two directors, from managerial level, confirmed their use of historical climate information and climate change projections. One of them said: *"We use historical climate information and projections for investments decisions, such as choosing regions for the purchase of vineyards, and plantations (for the next twenty-five, thirty years)."*

The interviewees were also asked about the sources of weather and climate information they normally use. The data shows they currently rely on different sources of information to inform their decision-making processes such as IberMeteo, Portuguese Institute of Meteorology and Atmosphere (IPMA), Windy app, AccuWeather or Weatheronline.co.uk. Although interviewees mostly use IberMeteo they also use other sources to help them triangulate the information. In this regard, one viticulture director stated: *"I use IberMeteo, and 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"*.

3.2. The Dashboard usability: Saliency, credibility and legitimacy

Seven out of 15 interviewees stated that the tool and map were intuitive and easy to understand (noting that 3 out of seven interviewees did not use climate information in their role). Five interviewees were of the opinion that the Dashboard was not an intuitive tool. For example, one expert from Viticulture department claimed: *"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* ".

Most of the interviewees agreed that it was difficult for them to find their land 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"*.

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"*.

Some interviewees had difficulty understanding the climate data available in the Dashboard such as the bioclimatic indices. In this regard, one of the directors 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"*.

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 needed weather forecasts to be included in the Dashboard in order to help them in 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."*

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 tool 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, 12 of the interviewees agreed that it is sufficient for what they need in their activities and support their decisions. Three interviewees believed more detail was required.

Interviewees were asked about data credibility and reliability (i.e., how closely the forecast probabilities of an event correspond to the actual chance of observing the event) 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*

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

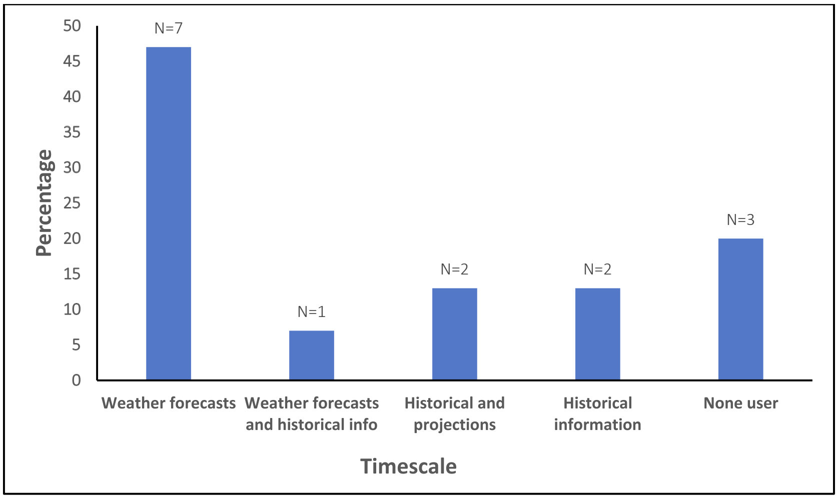

Fig. 2. Timescales of data currently used by SOGRAPE participants (N = 15).

are well done and I see value there. However, when I looked at the historical data, it was not as accurate as bioclimatic indicators."

According to the conceptual framework, the data must be legitimate and lack of bias which is built by including users in the process of co-production, two-way engagement between users and providers of information. 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 had been involved in the process from the outset of the project. Those who had not been involved in the co-development confirmed that the data appeared legitimate to them.

3.3. Using the Dashboard and perceived benefits of using it in decision-making

As described in the previous section, interviewees were asked to interact and use the Dashboard during the testing period so they could explore how to apply the climate information provided in their decision-making prior to the interview. During the interview, they were then asked about the extent in which the Dashboard had helped them in their decision-making during the testing period. Fourteen out of fifteen interviewees interacted with the Dashboard more than once during the testing period with a few interacting 3 and 4 times during that period. However, all interviewees confirmed that their interactions with the tool had been largely exploratory and that they did not actively used the climate information provided in their decision-making. The main reason for not using the information was that the testing period was short and not the right time for their decision-making. This was mainly due to delay in the development of the Dashboard following the COVID19 pandemic (Fig. 3).

However, three interviewees operating at managerial level, confirmed that the tool had helped them in a potential long-term investment. One of them stated: *"I didn't use the tool during the test period as I wasn't in a situation where I needed to make any decisions. However, we were looking to purchase 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 200 m below in altitude"*.

Since interviewees faced some challenges in using the climate information available on the Dashboard, we were not able to assess the actual value and benefits that could have been realised from such use. Instead, the interviewees were asked about the potential benefits of using that climate information in their activities and decision-making processes in the future. According to interviewees historical climate information, seasonal forecasts, and climate change projections available in the Dashboard could help inform and support their medium and long-term planning. The potential benefits of using the Dashboard information identified by the interviewees have been summarised in

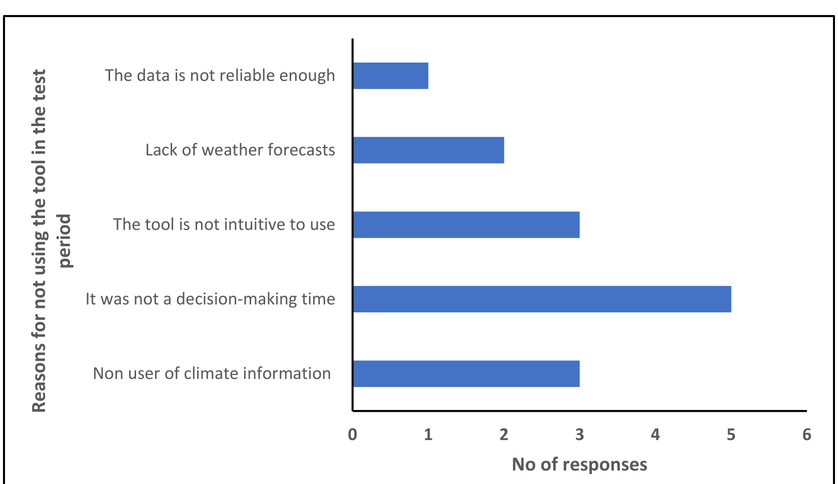

Fig. 3. Reasons for not using the Dashboard in decision making during the test period.

Table 3
Perceived benefits of using the information available in the Dashboard.

Historical 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

Table 3 and further described below.

- **Historical climate information**

According to interviewees, historical climate information could help them with better harvest planning and cost justification. Regarding the harvest planning, one director said: *"We normally use weather forecasts to make a decision about harvest time in the short term, like a week. Historical climate information on the Dashboard could help me to understand a little bit the characteristics of the year, which will help me when the next harvest time comes"*.

One expert said that historical climate information could also help them validate or justify yearly costs in SOGRAPE. She stated: *"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 that the agriculture year was bad due to little precipitation. With the Dashboard, we will be able to validate this information"*.

- **Seasonal forecasts**

One manager, who was responsible for 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.* E.g.*, the maximum temperature can be useful to anticipate the amount of calinos purchase or whether I'm going to do one, two, three treatments"*.

One director, who was responsible for harvest planning and 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, this would be very useful for me. I could plan which day would be best to start the harvesting in different regions"*. He also mentioned that *"(…) information help me to see if we have a shorter or early harvest time or not"*.

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"*.

- **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 row-orientation.[5] 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 ha of land, and obviously we validate this decision with the help of the Dashboard"*. This is extremely important as areas suitable for viticulturers are likely to shift into higher altitudes where mean temperatures are suitable for grape cultivation (Arias et al., 2022).

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: *"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"*. Literature confirmed how climate change projections can help managers to choose what kind of varieties is worth investing based on the future climatic conditions as choosing proper grape varieties depends on the temperature as optimum temperature varies depending on grape variety (Cardell et al., 2019).

3.4. Recommendations to improve the Dashboard

Finally, the interviewees were asked about recommendations to increase the usability of the Dashboard in order to better support participants' roles and decisions and, ultimately, increase the benefits that can be realised when using the climate information. Their comments were analysed and aggregated into different categories which are further described below.

- **Simplifying the Dashboard**

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."* 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."*.

- **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 project team in SOGRAPE to work with the Dashboard. One expert suggested that: *"This is a very technical tool and maybe having a videeo explaining how we can do things. This would be helpful. l deal with several platforms and when they are not so intuitive, I always prefer those that have a videeo, to remind me how to work with it."*

- **Avoid confusion in labelling**

Some interviewees suggested further clarity on how the information is labelled in the Dashboard by using 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?''*.

[5] Row orientation refers to the direction in which rows of vines are planted. 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.

''The bioclimatic indexes, they could be written in a more succinct, more direct way, because from my experience I know that people want to get the most information in the least possible time''.

- **Including weather forecasts on the Dashboard**

Weather forecasts are 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"*.

4. Assessing the usability and value of the Dashboard: Barriers and considerations

Throughout the assessment of the usability and value of the Dashboard, several barriers emerged which limited SOGRAPE users' ability to apply the climate information provided in the Dashboard and, consequently, limited our ability to assess the real value of using the climate information provided in the Dashboard. For example, some participants were not able to apply the climate information provided in their decision-making during the test period due to the timescales of the climate information which were seasonal forecasts and long-term projections. In this context the users explained that the test period was not set at the right time and the duration was not sufficient for them to apply the information available in the Dashboard. They would need at least one full growing season to be able to fully test the usability of seasonal climate information provided in the Dashboard. This emphasised the importance of planning and pursuing the assessment of the value of a climate service in a period of convenience for the users e.g., selecting a time of key decisions to be made (Bruno Soares et al., 2018b). Allowing sufficient time to test the tool also helps to better understand the full range of decisions that can be supported within a company such as SOGRAPE as well as help participants to gain trust in the information provided were also emphasised by the participants (Buontempo et al., 2018; Bruno Soares, 2017; Lemos et al., 2012).

The resources available to adequately test climate services with end-users are often constrained by existing funding structures which can limit how this type of assessments is conducted and ultimately influence the level of learning from the study (cf. Bruno Soares and Buontempo, 2019; Ranasinghe et al., 2021). In our case, the impacts of COVID-19 in the project led to delays in the co-development stages of the Dashboard (both in the technical work as well as in opportunities for more effective engagement e.g., through participatory workshops with SOGRAPE participants) and reduced the time originally planned for the testing phase of the Dashboard. Tus, research projects need to be flexible (both in terms of resources but also methodologies) to be able to adapt to unforeseen event such as covid19 (Bruno Soares and Buontempo, 2019).

A second group of barriers identified during this assessment was associated to the technical aspects of the climate information provided on the tool such as saliency which hindered the ability to use the information in practice. These types of barriers have been mentioned by other scholars (Lemos et al., 2012, Cash et al., 2003, Bruno Soares et al., 2018b; Tall et al., 2018). The technical barriers, were mostly related to the saliency of the tool and the climate information provided, as demonstrated in Fig. 3. In the context of climate services, saliency of climate information often refers to the suitability of the climate information to the users such as the format in which it is provided (e.g., type of visualisation), the timing of the information, and how it is communicated to users (Tall et al., 2018; Lemos et al., 2012; Bruno Soares et al., 2018b). From our study, it became clear that the current version of the Dashboard was not salient enough to all SOGRAPE participants as some had difficulties in understanding the climate data (e.g., bioclimatic indicators) and required technical support to help them understand the information available on the tool during the testing phase.

Despite comprehensive engagement with SOGRAPE participants throughout the development of the Dashboard, the saliency of the tool was still perceived as low by some participants. This may have been due to the fact that different SOGRAPE participants were involved at different stages in the co-development process. Since participants came from different departments/areas of work within the company their understanding and expertise of climate as well as its influence in their area of activities varied. This was something we could not control within the project as SOGRAPE was interested in exploring how the tool could be of potential use across their range of departments. However, similar future studies should perhaps focus the co-development of this type of tailored climate services on key users (within a company such as SOGRAPE) whose decisions may be more directly impacted by climate change before trying to engage with other potential users in the same organisation (Williams et al., 2020).

In addition, the lack of clear labelling accompanying the bioclimatic indices and difficulties in understanding the meaning of terciles categories of normal, below normal, and above normal were also highlighted as aspects affecting the saliency of the Dashboard. This mismatch shows that there was not enough communication to set out labelling by the project team and the users during the tool development process. Such mismatch has been experienced in other practices (Haines, 2019).

Although weather forecasts were not in the original scope of the research project, participants also wanted access to weather forecasts to be made directly through the Dashboard to help support all of their decisions including those related to short-term operational tasks, planning activities and long-term strategic investments. This would allow them access to legitimate weather and climate information across different temporal timescales in one single tool (rather than having separate tools covering different timescales of information). Such desire for tools that provide information at various timescales to support the range of activities and decisions which the end-users in the agricultural sector has also been highlighted in other studies (e.g., White et al., 2017; Mihailescu and Bruno Soares, 2020; Bessembinder et al., 2019; Falloon et al., 2018). In fact, this trend towards more seamless approaches to the development and provision of information across weather and climate has been the subject of research efforts over the last few years (see e.g., Ruti et al., 2020; Kushnir et al., 2019; Hewitt and Lowe, 2018).

Due to the barriers mentioned above, it was not possible to assess the actual value of using the climate information provided to SOGRAPE participants. Instead, they were asked about the potential value of using the tool in their company and the wine sector in general. The responses emphasise how seasonal forecasts and climate change projections could support their medium and long-term decisions. Seasonal forecasts could help them to reduce some costs, such as better anticipation of the amount of disease treatment to purchase (stock management), scheduling disease treatments, seasonal labouring, and harvest planning. This has been confirmed by existing literature (Santos et al., 2020; Ceglar and Toreti, 2021). Interviewees from senior level of management at SOGRAPE confirmed this, commenting that the long-term climate projections can replace historical data they currently use to support their long-term decisions such as establishing vineyards, choosing adequate grape varieties, and determining row-orientation. In fact, it should also be noted that, although the information provided in the Dashboard did not lead to concrete changes in the decisions to be made by SOGRAPE participants during the testing period, there was an instance where information from climate change projections provided in the tool helped inform and validate the discussions being held at the senior management level regarding the acquisition of potential new plots of land for SOGRAPE.

These findings support the wider literature on how using climate projections assist long-term decisions around viticulture investments, new vineyard purchase, and setting irrigation systems (Dunn et al., 2015; Nesbitt et al., 2022).

Participants' recommendations on how to improve the Dashboard were largely related to saliency aspects of the tool, simplifying the Dashboard and including concise tutorials to help users learn the tool. These are confirmed by literature as Vincent et al (2020) suggest increasing saliency, one option would be to train users to interpret scientific presentations of information. Another option would be to visualize the information in ways that may be more easily understood. These are in line with Brown and Bachelet (2017) who suggested that climate services' terminology should be clearly explained, and training opportunities provided for managers to understand how to use them. Thus, a videeo (https://www.youtube.com/watch?v=2Y5xgdXnPI8) was added to the tool which shows the tool's application step by step. Adding a tutorial or a toolkit tour were seen in other online decision support tools for climate decision-making (e.g., NOAA's resilience tool kit—https://toolkit.climate.gov/) (Lemos et al., 2019). Moreover, some additional numerical information was added to the terciles categories to avoid confusion. These recommendations could help improving the design of the Dashboard and its usability, as well as inform the design of other climate service co-production process beyond the wine sector.

5. Conclusions

Wine production is highly sensitive to weather and climate variability and change (Dunn et al., 2019; Martins et al., 2021). While the interannual variability has important impacts on production of high-quality wines by affecting the wine acidity and berry sugar content (Santos et al., 2020b), long-term change in climatic conditions can have profound effects such as reshaping wine regions and their geographical distribution (Santos et al., 2020a). As a result, knowing future climate conditions can help vulnerable economic sectors, such as the wine sector, better adapt to climate change, and a climate service can provide the tailored and usable data that decision-makers will need to prepare towards climate adaptation (Tall and Njinga, 2013).

Under the auspices of the MED-GOLD project, the Dashboard was co-developed with users in SOGRAPE, a large wine company based in Northern Portugal. The usability and value of the Dashboard was assessed by engaging with 15 decision-makers in the wine sector through an online workshop to showcase the Dashboard, and semi-structured interviews.

We found that weather forecasts are the most frequently used data for day-to-day activities and operational planning in the wine sector. Although, weather forecasts were outside of the scope of the research, users of weather forecasts, oenologists, and viticulturists, asked for this timescale to be included in the dashboard as they currently use other sources of data for weather forecasts. Thus, having a more seamless approach to the development and provision of all needed timescales in one single tool makes it more attractive for the users in the wine sector.

Our assessment shows that using the data on the Dashboard (seasonal forecasts and climate change projections) could certainly be of some use and add value to the wine sector's medium-term and long-term planning. However, several barriers hindered assessing the actual value of using the tool during the test period. Firstly, the participants would need at least one growing season to be able to test the seasonal forecasts' data usability in practice which this challenge must be considered in future research proposal's timeline. Secondly, there was a mismatch between some aspects of the tool's saliency and decision-makers' preferences. The saliency of the Dashboard was questioned by half of the participants as stated that the tool was not intuitive enough for them to use. E.g., labelling need additional numerical information to avoid confusion. This shows that some aspects of saliency especially visualisation such as labelling, and terminologies have not been agreed during the co-development process. This means the key to the development process of a successful climate service is the co-development process which discusses all aspects of a usable climate service. In addition, assessing the quality of climate services must be an important step of the co-development process before being communicated and disseminated to the wider community.

It must be noted that following the recommendations provided by the interviewed decision-makers in the wine company, further changes made by the MED-GOLD team such as simplifying the labels and adding a toolkit (https://www.youtube.com/watch?v=2Y5xgdXnPI8) to the online version prior to its dissemination to the wider community of users. Further assessment is required to assess the usability of the tool through engaging with wider community in the wine sector after tool's upscaling to complement this assessment.

CRediT authorship contribution statement

Fatemeh Khosravi: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Marta Bruno Soares:** Conceptualization, Investigation, Supervision, Writing – review & editing, Funding acquisition. **Marta Teixeira:** Project administration, Resources. **Natacha Fontes:** Project administration. **Antonio Graca:** Project administration, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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