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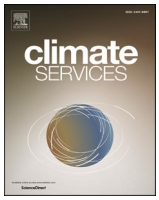

Editorial

Turning climate-related information into added value for traditional Mediterranean grape, olive, and durum wheat food systems☆

The MED-GOLD project (https://doi.org/10.3030/776467) exceeded expectations significantly. As a research and innovation project, MED-GOLD was expected to co-develop climate services at proof-of-concept (i.e., prototype) rather than real market level. By contrast, not only was MED-GOLD able to demonstrate the added value of the pilot climate services, but it also addressed the replicability and marketability side of the services to the point that major European and international institutions showed interest in the MED-GOLD climate services and ICT platform, creating real business opportunities during the project lifecycle and beyond the duration of the project.

MED-GOLD was a 54-month research and innovation project with the initial goal of demonstrating the proof-of-concept for climate services in agriculture using three hallmarks of the Mediterranean food system: grape and wine, olive and olive oil, and durum wheat and pasta. The project sought to prototype climate services by developing case studies for these three major Mediterranean traditional systems.

This MED-GOLD Special Issue provides evidence of the added value resulting from the co-development of pilot climate services in agriculture, using case studies co-developed with Sogrape (https://sogrape.com/en) for grape and wine in the Douro region of Portugal, with DCOOP (https://www.dcoop.es/) for olive and olive oil in the Andalusia region of Spain, and with Barilla G. e R. Fratelli S.p.A. (https://www.barilla.com/en-us) for durum wheat and pasta in Italy.

The MED-GOLD project

Climate services, defined as the transformation of climate-related data and information into customized projections, forecasts, and analyses for supporting decision-making at all levels, have the potential to become the informed basis for a climate-resilient, low-carbon society (EC, 2015). This is critical as agriculture is the economic sector most vulnerable to climate variability and change (Schmidhuber and Tubiello, 2007; Rosenzweig et al., 2014; Challinor et al., 2014; IPCC, 2022). Further, the Mediterranean region is under immediate threat of shifting climatic patterns and associated ecological, economic, and social effects that could disrupt agriculture. Hence, developing a capacity to turn increasingly big climate-related data into climate services that can inform decision-making in agriculture is a key priority at the Mediterranean, European, and global levels (Vaughan et al., 2016; Bruno Soares et al., 2018; Buontempo et al., 2020; Born et al., 2021).

The long-term goal of the project was to make European agriculture and food systems more resilient to climate change, using climate services to minimize risks/costs and seize opportunities for added value. Specifically, MED-GOLD aimed to develop climate services for the crop systems that are the basis for producing olive oil, wine, and pasta. These crop systems have utmost climatic, ecological, economic, and cultural relevance to the Mediterranean region and the world, as they are not only hallmarks of the world heritage of the Mediterranean diet, but also food commodities with a global market (Ponti et al., 2016). Moreover, the Mediterranean food system has a demonstrated potential for contrasting the increasing homogeneity in global food supplies (Khoury et al., 2014), resulting in increased food security and significant health benefits (Guasch-Ferré and Willett, 2021), for enhancing and conserving biodiversity (Bagella et al., 2014, 2016; Rey et al., 2019; Paiola et al., 2020; Aguilera et al., 2020), and for reducing the ecological footprint of the global food system (Capone et al., 2013; Galli et al., 2017). Hence, the potential for developing climate services with high added value to society is immense. To address added value directly, MED-GOLD co-designed pilot climate services involving both suppliers and users (Alford, 2014; Bruno Soares and Buontempo, 2019). The project reviewed the operational decision-making of major industrial European users Sogrape, DCOOP, and Barilla G. e R. Fratelli S.p.A. to identify key decisions and/or introduce new actions that can benefit from climate-related information at timescales from months to decades. Online surveys and participatory workshops in five languages assessed the usability and upscaling potential of the services with a wider community of users not involved in the development of the services.

Prototype climate services were co-produced, tested, and validated using MED-GOLD linked methods for user engagement and cloud-based processing/visualization of data (i.e., the ICT[1] platform) implemented as a Web application programming interface (Web API) that enables different computer programs to communicate with each other over the internet. This enabled unprecedented replicability and scalability across regions, sectors, and users, as tested in Colombia for the world's top agricultural commodity, coffee (Cure et al., 2020, 2022; Rivas González et al., 2022). Colombian coffee provided a case study for testing the replicability of MED-GOLD climate services, showing high potential benefits in terms of informing regional crop management and

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[1] Information and communication technology.

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policymaking.

The ICT platform[2] (see infographics https://doi.org/10.5281/zenodo.7928703) was developed as a scalable, modular, cloud computing system enabling the following functionality:

- running heritage crop system models;
- providing custom visualization dashboards;
- connecting existing decision support tools and simulation models to cutting-edge climate data sources such as the Copernicus Climate Data Store (a single point of access to a wide range of quality-assured climate datasets provided by Copernicus, the European Union's Earth Observation Programme, see https://cds.climate.copernicus.eu/); and
- processing seasonal climate forecast data with on-the-fly bias correction.

The ICT platform was released as open-source code (see https://github.com/medgold-ict-platform).

Analysis of the EU market for climate services and development of a business plan provided a solid ground for the commercialization of the prototype services, by describing the value creation and service delivery processes.

The project built better informed and connected end-user and policymaking communities for the global olive oil, wine, and pasta food systems by presenting at 50+ international events, organizing 12 including eight participatory workshops, two online training events, four webinars, and publishing info sheets, user guides, infographics, videos, a policy brief, and a glossary in six languages (English, Greek, Spanish, Portuguese, French, and Italian). Added to multimedia and multi-language communication implemented throughout the project, 25 published scientific papers plus this project's Special Issue in the Climate Services journal accrued.

The COVID-19 pandemic impacted the project significantly. Substantial effort was devoted to converting the planned face-to-face activities to online engagement. A major result was the MED-GOLD final showcase event with 300+ registered contacts from across the world and speakers from industry, NGOs, international institutions, and the policymaking community. Industry users from the MED-GOLD consortium shared success stories, and enabled participants to share and exchange ideas regarding the potential to apply and use the MED-GOLD pilot services in their own cross-sectional decision-making. Key dissemination material produced by the project is available through the MED-GOLD Horizon 2020 Project community on Zenodo (https://zenodo.org/communities/med-gold/).

The co-design and co-development work revealed the incredible diversity of users and needs that challenge climate services in agriculture.

The following are critical production decisions identified where climate services can provide added value.

- Grape: siting, choice of scion variety and rootstock, control of pathogens and abiotic stress, and management of wine style.
- Olive: pest management, fertilization, irrigation, pruning, harvesting, and design of new orchards.
- Durum wheat: variety selection, purchase/selling of commodities, supply chain planning, breeding, and siting.

The added value generated by the project ranges from agricultural management to policymaking at the Mediterranean, European, and global levels.

The entire value chain for climate services in agriculture was represented in the project consortium, and the potential market for the services developed is global, with most service consumers currently located in the Mediterranean region. Engagement of potential users and development of a sound business model made MED-GOLD climate services attractive in commercial settings, as demonstrated by ongoing business development.

Overview of the special issue

This Special Issue includes twelve papers that cover a wide range of topics related to climate services for Mediterranean grape, olive, and durum wheat food systems. The papers address the co-production, usability, and value of climate services, monitoring and management of climate-related risks and opportunities, advanced seasonal predictions, and long-term impact assessment of climate change on crops and pests. The following is a brief overview of the papers included in the Special Issue.

Terrado et al. (2023) present the co-production pathway of the end-to-end MED-GOLD climate service for improved decision-making in the wine sector. The co-production process involved collaboration between scientists and users to raise awareness, exchange knowledge, and co-develop customized climate services. The MED-GOLD dashboard is the most tangible outcome of this collaboration, but the joint learning process, shared sense of ownership, and co-creation of new knowledge between scientists and stakeholders were also important outcomes. The MED-GOLD Dashboard, an interactive tool displaying detailed historical climate data, seasonal predictions, and climate projections, was co-designed with users to ensure their needs were met. Repeated interaction between scientists and users was found to be critical for better framing research questions and ensuring that the climate service could inform decision-making needs. The paper concludes that further research is needed to understand how the knowledge co-produced with a single user can be scaled up to users with other profiles and requirements.

Dell'Aquila et al. (2023) present a pilot service that monitors climate-related risks and opportunities in the Douro Wine Region in northern Portugal, co-developed with industrial partner Sogrape. The study identified key user needs, selected relevant bioclimatic indicators, and developed compound risk indices as a combination of these indicators. The methodological work was validated against empirical climate characterization for the region using "bad" and "good" years chosen by users.

Nam et al. (2023) examine the value of climate services for viticulturists in mitigating the climate impact on fungal diseases and sunburn. Using seasonal forecasts derived from the Copernicus Climate Data Store, the study performed a cost-benefit analysis for micro grape growers in the Douro wine region of Portugal to determine an annual service fee to access bio-climatic forecasts on the MED-GOLD project's Dashboard. Results showed that climate services are financially beneficial and sustainable for the sector, despite an early-season accuracy of forecasts ranging from 54 to 60 %, given that expected accuracy using climatology would be 33 % when forecasting above-normal, normal, or below-normal bioclimatic indices (i.e., tercile forecasting).

Vigo et al. (2023) propose a methodology for using seasonal forecasts to establish probability thresholds to trigger disease management decisions in the wine industry focusing on the potential impact of spring precipitation on plant protection and canopy management based on different scenarios. The methodology engaged users in tailoring the analysis to their needs. This interaction created trust and allowed user risk profile analysis.

Khosravi et al. (2023) assess the usability and value of a climate service co-developed with the Portuguese wine company Sogrape, and identified potential barriers to the adoption of the climate service. The study found that the climate service was perceived as reliable and legitimate, with additional recommendations proposed to increase its saliency and usability. Limitations on Sogrape user ability to use the climate information provided are reported in the study. The results can

[2] See the MED-GOLD ICT platform on the Horizon 2020 results portal at https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-results-platform/32534.

inform the design, development, and usability of other climate services within and beyond the wine sector.

Ceglar et al. (2023) extend climate indicators developed in the MED-GOLD case study areas for grape (Douro wine region of Portugal) and olive (Andalusia region of Spain) to the entire European region where these crops are grown, and use these indicators to assess climate change impacts. The results show an increase in extreme high temperature events and frequency of compound events, such as combined dry spring and hot growing season, particularly in the Mediterranean region during future time 2020 to 2080. The results highlighted the need for a dedicated decision-making approach that can address the increased levels of future climate variability.

Chou et al. (2023a) examine the potential increase in value of seasonal forecasts for the wine sector by blending observations and forecasts for six important bioclimatic indicators over the Iberian Peninsula. The approach was evaluated using Pearson's correlation coefficient and Fair Ranked Probability Skill Score, and showed a marked improvement in forecasting skill during the growing season. This approach can provide users with greater confidence in their decisions and facilitate the uptake of seasonal forecasting in management.

Further, Chou et al. (2023b) evaluate the effectiveness of five seasonal forecasting strategies on bioclimatic indicators important for managing olive orchards. The results show that combining seasonal predictions or climatology with observations enhanced forecasting the tercile category for all indicators compared to using climatology or seasonal predictions alone. The combination of observations and seasonal forecasts were found to be particularly effective for Spring Maximum Temperature and Growing Season Temperature indicators.

Gratsea et al. (2022) investigate the long-term effects of climate change on olive crops in Andalusia, Spain, using climate indices and return period analysis. Results show increasing changes in the near and distant future with a robust increase in threshold-based indices in central and northern Andalusia. Bad year occurrences with return periods below 2 years may increase by ~20 % by 2060 due to future decreased precipitation. The range of the olive fly is expected to decrease in the northern areas of Andalusia.

Ponti et al. (2023) use physiologically based demographic modeling (PBDM), implemented on the MED-GOLD ICT platform as a Web application programming interface (API), to investigate the impact of climate change on interacting olive and olive fly in Andalusia. Results suggest that chilling required for olive blooming will decrease due to climate change, and that blooming will occur earlier in the season. Olive fruit yield is expected to increase or remain stable under climate change, while olive fly infestation will decrease, especially in the top-producing provinces of Andalusia. The study recommends adapting to decreased precipitation by leveraging increased water use efficiency due to increased CO_2 concentration in mostly rainfed Andalusian olive crop systems, and targeting the spring generation of the olive fly to reduce season long infestations through preventive pest management strategies.

Dainelli et al. (2022) explore the effectiveness of coupling seasonal climate predictions with crop models to provide durum wheat yield forecasts in Italy. Using a participatory approach, the study evaluated output from the Delphi crop model when fed with raw and bias-adjusted seasonal climate forecast data or with a historical climate scenario, using observed yield data as benchmark. The study found that the Delphi model performed better when forced with raw seasonal forecasts than with the historical scenario, but performed best when driven by bias-adjusted seasonal forecasts.

Zampieri et al. (2023) assessed the accuracy of the Copernicus Climate Change Service in predicting rain onset in Africa to aid in early warning and action for food security. Using hindcasts from 1993 to 2016, the study computes the skill of the forecast system in predicting normal, early, and late onset of the rainy season. Slightly positive skills are found in some African agricultural regions, and the study recommends improvements in the algorithm and participatory co-development with users to provide a useful climate service for the African agricultural sector.

Final remarks

In addition to the above scientific results, it is noteworthy that in the specific case of the wine pilot climate service, the resulting data and tools of the MED-GOLD dashboard were integrated into strategic planning for climate adaptation in the Douro region by family-owned wine company Sogrape that identified areas where in the future specific grape varieties will not be able to produce fine wines (Graça, 2023). These insights are also being used to inform policymakers about the need for re-evaluating geographical indications in the context of a changing climate (Graça et al., 2022), namely to accept introduction of foreign grape varieties (van Leeuwen et al., 2019; Wiatrak, 2020) or relocate geographical indication boundaries, as necessary.

For the olive sector, several bioclimatic indices have been co-developed. The olive sector usually operates on a very short timescale (weather forecasts and sub-seasonal forecasts), and MED-GOLD provided support for decision-making on longer timescales. Close collaboration between climate scientists and the olive cooperative DCOOP resulted in the development of bioclimatic indices based not only on climate parameters but also on olive phenology, including requirements of the crop at different phenological stages. Bioclimatic indices were evaluated using both seasonal predictions (Chou et al., 2023b) and long-term climate projections (Gratsea et al., 2022) with the goal of building trust required to expand climate services in olive production.

The co-developed pilot climate service for durum wheat and pasta tailored bioclimatic indices and improved climate data inputs for two existing software packages used to forecast durum wheat yields and manage crops. Indices were developed for seasonal predictions, forecasting crop conditions and yields up to six months in advance, and for long-term projections of future yields and suitable cultivation areas around the world. Climate services were developed through close interaction between climate scientists and the family-owned durum wheat/pasta company Barilla G. e R. Fratelli S.p.A.

CRediT authorship contribution statement

Luigi Ponti: Conceptualization, Funding acquisition, Writing – original draft, Writing – review & editing. **Alessandro Dell'Aquila:** Conceptualization, Funding acquisition, Writing – review & editing. **Matteo De Felice:** Conceptualization, Funding acquisition, Writing – review & editing. **Paolo Ruti:** Writing – review & editing. **Bruno Basso:** Writing – review & editing. **Andrew Paul Gutierrez:** Conceptualization, Writing – review & editing. **Sandro Calmanti:** Conceptualization, Funding acquisition, Writing – review & editing. **Antonio Graça:** Conceptualization, Funding acquisition, Writing – review & editing. **Javier López Nevado:** Conceptualization, Funding acquisition, Writing – review & editing. **Chiara Monotti:** Conceptualization, Funding acquisition, Writing – review & editing.

Supplementary information

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.

References

Aguilera, E., Díaz-Gaona, C., García-Laureano, R., Reyes-Palomo, C., Guzmán, G.I., Ortolani, L., Sánchez-Rodríguez, M., Rodríguez-Estévez, V., 2020. Agroecology for adaptation to climate change and resource depletion in the Mediterranean region. A review. Agr. Syst. 181 https://doi.org/10.1016/j.agsy.2020.102809.

Alford, J., 2014. The multiple facets of co-production: building on the work of Elinor Ostrom. Public Manage. Rev. 16, 299–316. https://doi.org/10.1080/14719037.2013.806578.

Bagella, S., Filigheddu, R., Caria, M.C., Girlanda, M., Roggero, P.P., 2014. Contrasting land uses in Mediterranean agro-silvo-pastoral systems generated patchy diversity patterns of vascular plants and below-ground microorganisms. C. R. Biol. 337, 717–724. https://doi.org/10.1016/j.crvi.2014.09.005.

Bagella, S., Caria, M.C., Farris, E., Rossetti, I., Filigheddu, R., 2016. Traditional land uses enhanced plant biodiversity in a Mediterranean agro-silvo-pastoral system. Plant Biosystems - An Int. J. Dealing All Aspects Plant Biol. 150, 201–207. https://doi.org/10.1080/11263504.2014.943319.

Born, L., Prager, S., Ramirez-Villegas, J., Imbach, P., 2021. A global meta-analysis of climate services and decision-making in agriculture. Clim. Serv. 22 https://doi.org/10.1016/j.cliser.2021.100231.

Bruno Soares, M., Alexander, M., Dessai, S., 2018. Sectoral use of climate information in Europe: a synoptic overview. Clim. Serv. Climate Serv. Pract.: What We Learnt EUPORIAS 9, 5–20. https://doi.org/10.1016/j.cliser.2017.06.001.

Bruno Soares, M., Buontempo, C., 2019. Challenges to the sustainability of climate services in Europe. WIREs Clim. Change 10, e587.

Buontempo, C., Hutjes, R., Beavis, P., Berckmans, J., Cagnazzo, C., Vamborg, F., Thépaut, J.-N., Bergeron, C., Almond, S., Amici, A., Ramasamy, S., Dee, D., 2020. Fostering the development of climate services through Copernicus Climate Change Service (C3S) for agriculture applications. Weather Clim. Extremes 27. https://doi.org/10.1016/j.wace.2019.100226.

Capone, R., Iannetta, M., El Bilali, H., Colonna, N., Debs, P., Dernini, S., Maiani, G., Intorre, F., Polito, A., Turrini, A., et al., 2013. A preliminary assessment of the environmental sustainability of the current italian dietary pattern: water footprint related to food consumption. J. Food Nutr. Res. 1, 59–67.

Ceglar, A., Yang, C., Toreti, A., Santos, J.A., Pasqui, M., Ponti, L., Dell'Aquila, A., Graça, A., 2023. Co-designed agro-climate indicators identify different future climate effects and adaptation strategies for grape and olive across Europe. Climate Services, under review.

Challinor, A.J., Watson, J., Lobell, D.B., Howden, S.M., Smith, D.R., Chhetri, N., 2014. A meta-analysis of crop yield under climate change and adaptation. Nature Clim. Change 4, 287–291. https://doi.org/10.1038/nclimate2153.

Chou, C., Marcos-Matamoros, R., Garcia, L.P., Pérez-Zanón, N., Teixeira, M., Silva, S., Fontes, N., Graça, A., Dell'Aquila, A., Calmanti, S., González-Reviriego, N., 2023a. Advanced seasonal predictions for vine management based on bioclimatic indicators tailored to the wine sector. Clim. Serv. 30 https://doi.org/10.1016/j.cliser.2023.100343.

Chou, C., Marcos-Matamoros, R., López-Nevado, J., López-Feria, S., González-Reviriego, N., 2023b. Comparison of five strategies for seasonal prediction of bioclimatic indicators in the olive sector. Clim. Serv. 30 https://doi.org/10.1016/j.cliser.2023.100345.

Cure, J.R., Rodríguez, D., Gutierrez, A.P., Ponti, L., 2020. The coffee agroecosystem: bioeconomic analysis of coffee berry borer control (Hypothenemus hampei). Sci. Rep. 10, 12262. https://doi.org/10.1038/s41598-020-68989-x.

Cure, J.R., Rodríguez, D., Pérez, M.M., Gutiérrez, A.P., Ponti, L., Riaño, D., 2022. Variabilidad climática en los agroecosistemas cafeteros Colombianos. Zenodo. https://doi.org/10.5281/zenodo.7432718.

Dainelli, R., Calmanti, S., Pasqui, M., Rocchi, L., Di Giuseppe, E., Monotti, C., Quaresima, S., Matese, A., Di Gennaro, S.F., Toscano, P., 2022. Moving climate seasonal forecasts information from useful to usable for early within-season predictions of durum wheat yield. Clim. Serv. 28 https://doi.org/10.1016/j.cliser.2022.100324.

Dell'Aquila, A., Graça, A., Teixeira, M., Fontes, N., Gonzalez-Reviriego, N., Marcos-Matamoros, R., Chou, C., Terrado, M., Giannakopoulos, C., Varotsos, K.V., Caboni, F., Locci, R., Nanu, M., Porru, S., Argiolas, G., Bruno Soares, M., Sanderson, M., 2023. Monitoring climate related risk and opportunities for the wine sector: the MED-GOLD pilot service. Clim. Serv. 30, 100346 https://doi.org/10.1016/j.cliser.2023.100346.

EC, European Commission, 2015. A European research and innovation roadmap for climate services. Publications Office of the European Union, Luxembourg. https://doi.org/10.2777/702151.

Galli, A., Iha, K., Halle, M., El Bilali, H., Grunewald, N., Eaton, D., Capone, R., Debs, P., Bottalico, F., 2017. Mediterranean countries' food consumption and sourcing patterns: an ecological footprint viewpoint. Sci. Total Environ. 578, 383–391. https://doi.org/10.1016/j.scitotenv.2016.10.191.

Graça, A., Teixeira, M., Silva, S., Antunes, J., Vigo, I., Marcos-Matamoros, R., Varotsos, K.V., Giannakopoulos, C., Santos, J.A., Fontes, N., Dell'Aquila, A., 2022. Is wine terroir a valid concept under a changing climate? Terclim 2022. In: Proceedings of the 14th International Terroir congress and 2nd ClimWine symposium, July 3-8, 2022, Bordeaux, France. https://ives-openscience.eu/13250/.

Graça, A., 2023. Who moved my wine? Adventures in oenological climatology. Presentation to the MetOffice Climate Services Network, March 13th, 2023. Avaliable from https://tinyurl.com/3enmdhfd.

Gratsea, M., Varotsos, K.V., López-Nevado, J., López-Feria, S., Giannakopoulos, C., 2022. Assessing the long-term impact of climate change on olive crops and olive fly in Andalusia, Spain, through climate indices and return period analysis. Clim. Serv. 28, 100325 https://doi.org/10.1016/j.cliser.2022.100325.

Guasch-Ferré, M., Willett, W.C., 2021. The Mediterranean diet and health: a comprehensive overview. J. Intern. Med. 290, 549–566. https://doi.org/10.1111/joim.13333.

IPCC, Intergovernmental Panel on Climate Change Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 2022 Cambridge University Press Cambridge, UK and New York, NY, USA https://doi.org/10.1017/9781009325844.

Khosravi, F., Bruno Soares, M., Teixeira, M., Fontes, N., Graça, A., 2023. Assessing the usability and value of a climate service in the wine sector. Clim. Serv., under review.

Khoury, C.K., Bjorkman, A.D., Dempewolf, H., Ramirez-Villegas, J., Guarino, L., Jarvis, A., Rieseberg, L.H., Struik, P.C., 2014. Increasing homogeneity in global food supplies and the implications for food security. PNAS 111, 4001–4006. https://doi.org/10.1073/pnas.1313490111.

Nam, C., Massano, L.T., Graça, A., Cotroneo, R., Dell'Aquila, A., Caboni, F., 2023. Valuation of climate services for viticulturists: tackling fungal diseases. Clim. Serv., under review.

Paiola, A., Assandri, G., Brambilla, M., Zottini, M., Pedrini, P., Nascimbene, J., 2020. Exploring the potential of vineyards for biodiversity conservation and delivery of biodiversity-mediated ecosystem services: a global-scale systematic review. Sci. Total Environ. 706, 135839 https://doi.org/10.1016/j.scitotenv.2019.135839.

Ponti, L., Gutierrez, A.P., Giannakopoulos, C., Varotsos, K., López Nevado, J., López Feria, S., Rivas González, F.W., Caboni, F., Stocchino, F., Rosati, A., Marchionni, D., Cure, J.R., Rodríguez, D., Terrado, M., Bruno Soares, M., De Felice, M., Dell'Aquila, A., Calmanti, S., Arjona, R., Sanderson, M., 2023. Prospective regional analysis of interacting olive and olive fly in Andalusia under climate change: a geospatial, physiologically based demographic modeling approach powered by cloud computing. Clim. Serv., under review.

Ponti, L., Gutierrez, A.P., Altieri, M.A., 2016. Preserving the Mediterranean diet through holistic strategies for the conservation of traditional farming systems. In: Agnoletti, M., Emanueli, F. (Eds.), Biocultural Diversity in Europe, Environmental History. Springer, Cham, Switzerland, pp. 453–469. https://doi.org/10.1007/978-3-319-26315-1_24.

Rey, P.J., Manzaneda, A.J., Valera, F., Alcántara, J.M., Tarifa, R., Isla, J., Molina-Pardo, J.L., Calvo, G., Salido, T., Gutiérrez, J.E., Ruiz, C., 2019. Landscape-moderated biodiversity effects of ground herb cover in olive groves: implications for regional biodiversity conservation. Agr. Ecosyst. Environ. 277, 61–73. https://doi.org/10.1016/j.agee.2019.03.007.

Rivas González, F.W., Ortuño, J., de la Fuente, D., Perez, P., Cure, J.R., Sanderson, M., Terrado, M., López Nevado, J., Toscano, P., Texeira, M., 2022. Climate service replicability report. Deliverable 6.9, H2020-SC5-01-2017 project MED-GOLD. Grant agreement No 776467. https://doi.org/10.5281/zenodo.6670573.

Rosenzweig, C., Elliott, J., Deryng, D., Ruane, A.C., Müller, C., Arneth, A., Boote, K.J., Folberth, C., Glotter, M., Khabarov, N., Neumann, K., Piontek, F., Pugh, T.A.M., Schmid, E., Stehfest, E., Yang, H., Jones, J.W., 2014. Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison. PNAS 111, 3268–3273. https://doi.org/10.1073/pnas.1222463110.

Schmidhuber, J., Tubiello, F.N., 2007. Global food security under climate change. Proc. Natl. Acad. Sci. 104, 19703–19708. https://doi.org/10.1073/pnas.0701976104.

Terrado, M., Marcos, R., González-Reviriego, N., Vigo, I., Nicodemou, A., Graça, A., Teixeira, M., Fontes, N., Silva, S., Dell'Aquila, A., Ponti, L., Calmanti, S., Bruno Soares, M., Khosravi, M., Caboni, F., 2023. Co-production pathway of an end-to-end climate service for improved decision-making in the wine sector. Clim. Serv. 30, 100347 https://doi.org/10.1016/j.cliser.2023.100347.

van Leeuwen, C., Destrac-Irvine, A., Dubernet, M., Duchêne, E., Gowdy, M., Marguerit, E., Pieri, P., Parker, A., de Rességuier, L., Ollat, N., 2019. An update on the impact of climate change in viticulture and potential adaptations. Agronomy 9, 514. https://doi.org/10.3390/agronomy9090514.

Vaughan, C., Buja, L., Kruczkiewicz, A., Goddard, L., 2016. Identifying research priorities to advance climate services. Clim. Serv. 4, 65–74. https://doi.org/10.1016/j.cliser.2016.11.004.

Vigo, I., Marcos-Matamoros, R., Terrado, M., González-Reviriego, N., Soret, A., Teixeira, M., Fontes, N., Graça, A., 2023. Managing spring rain risks in vineyards: a user-centred approach to identify climate decision triggers in seasonal forecasts. Clim. Serv., under review.

Wiatrak, B., 2020. Indigenous grapes: our past, our future? GuildSomm.

Zampieri, M., Toreti, A., Meroni, M., Bojovic, D., Octenjak, S., Marcos-Matamoros, R., Materia, S., Chang'a, L., Merchades, M., del Mar Chaves Montero, M., Rembold, F., Troccoli, A., 2023. FOCUS-Africa project and recommendations for future co-development of climate services in the agricultural sector. Clim. Serv., under review.

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