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Managing viticultural ecosystems using functional biodiversity indicators and agroecology approaches for sustainable production and consumer engagement – the case of SOGRAPE in Portugal and Spain

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Abstract: The 2022 Kunming-Montreal agreement for the United Nations Convention for Biological Diversity (CBD) saw unprecedented support and participation from global businesses that pushed governments for higher ambition in setting the Global Biodiversity Framework post-2020 (GBF). Sogrape actively participated in this landmark drive for a nature-positive world joining more than 700 global businesses from all sectors. This commitment stemmed from our pioneering adoption of IOBC-based integrated production for all Sogrape vineyards in Portugal for more than 20 years, dedicated sustainable viticulture work across five countries and the stern realization that natural resources underpinning Sogrape's wine business are threatened by the lack of efficient public governance for protection of ecosystems in wine regions. Owning more than 1100 hectares of vineyards in Iberia, Sogrape launched a wide project for nature-positive winegrowing integrated in its «Seed the Future» global sustainability program. Surveys were conducted to combine data on climate, soil pedology, crop vegetation, biodiversity and ecosystem for ecosystem management and agroecology indicators. In this work, we present data in Portugal and Spain to drive value from biodiversity and ecosystem-management into wine brand equity and engagement with consumers and citizens.

Key words: functional biodiversity, ecosystem services, agroecology, resilience, sustainability

Introduction

In 1974, the IOBC setup its Working Group Integrated Protection (IP) in Viticulture. Soon after, group and subgroup work developed leading to the publication of Guidelines for Integrated Production of Grapes (Böller et al., 2006; Bathon, 2010). Now, on its fifth edition the guidelines include strict rules and recommendations meant for organizations wishing to design and operate an IP scheme (Malavolta and Duso, 2020). In Portugal, IP guidelines were first regulated in 1985 (Decreto-Lei 180/95 de 26 de julho). In 2009, Decreto-Lei 256/2009 established a framework for practicing IP as well as technical standards and rules for recognition of approved technicians for advisory. A national law (Lei 26/2013 de 11 de abril) transposed European Directive 2009/128/CE on sustainable use of pesticides and adopted integrated protection guidelines as a legal requirement for farming. IP remained optional but, together with organic production, was promoted by the State as advanced sustainable farming (DGADR, https://www.dgadr.gov.pt/producao-integrada). A new document (Castiço and Cardoso, 2023) recently established IP principles, orientations and technical standards and acknowledged IOBC's contribution.

In December 2022, the United Nations (UN) Convention for Biological Diversity drafted and approved the Kunming-Montreal Global Biodiversity Framework (KM-GBF, CBD/COP/DEC/15/4) consisting of 4 goals and 23 targets. The whole framework promotes the theory of change and envisions, by 2050, a world living in harmony with nature where biodiversity is valued. The mission of the framework is a nature-positive world by 2030. In coherence with the framework, the EU is advancing a Nature Restoration Law (COM/2022/304). The UN 2030 Agenda for Sustainable Development 17 Sustainable Development Goals (SDGs) called for urgent collaborative action. Among them, SDG 12 targets sustainable patterns of resource use and responsible consumption behavior.

Sogrape is a family-owned wine company with an 81-year successful track record of producing and marketing wines, across more than 120 countries. It currently owns more than 1100 hectares across Portugal and Spain. Vineyard acreage is farmed under certified IP guidelines since 2002 in Portugal. In 2023, Sogrape started «Seed the Future», a sustainability program aiming to catalyze positive social change, while respecting the limits of nature.

For this work, spanning several years, we hypothesized that the creation of integrated datasets from applying precision viticulture concepts and tools to grape production under a certified IP approach would provide valuable insights for integrated management of the vineyard within its ecosystem. We wanted to check if synergies from resulting integrated datasets could support a more wholistic management of the whole value chain, from farming sustainably to promoting responsible consumption values near consumers and contribute to SDG 12.

This paper describes how the long and continued commitment towards IP production of grapes for wines contributed to deploy science-based, data-driven, nature-positive farming in both Iberian countries, while activating brands and exercising advocacy at all levels to bring awareness of nature's value to all stakeholders.

Materials and methods

Figure 1 shows the location of all vineyards farmed by Sogrape in Iberian wine regions. Since 2011, 21 automated weather stations were setup in the company's vineyards across all regions of Portugal. Stations comprise sensors (Campbell Scientific, Logan UT, USA) for 2-meter air temperature, relative humidity, wind speed and direction, solar radiation, precipitation and leaf wetness.

Data were recorded on a local logger every 15 minutes and remotely downloaded every six hours to a central server. Sensors, logger and modem are powered by a local photovoltaic (PV) unit integrating PV-cells and a battery. Data quality was analysed monthly using unsupervised and supervised routines. Sensor integrity, accuracy and maintenance routines were performed 4 times per year. Data availability exceeded 99 % of theoretical value. In Spain, weather stations were installed in respective vineyards reporting local values and, when needed, values from nearby public stations (Meteogalicia As Eiras, AEMET Rueda and SIAR Logroño) were also used. Microzoning surveys were conducted in order to define basic terroir units (BTU), from the perspective of interactions between elements of the soil-grapevine-wine system (Morlat, 2001; Courtin et al., 2004). An average of one sample per hectare was evaluated on texture, depth, drainage and geological type. Combining these data, soil pits were dug for all soil types and soil profile, horizon organization, aptitudes and constraints for agriculture were assessed. Data were aggregated and analyzed to produce maps converted to vector or raster geospatial files (QGIS Geographic Information System. QGIS Association. http://www.qgis.org). Biodiversity inventories were made after field visits in different moments of the year, through systematic identification, catalogation and quantification of fauna and flora species to establish a baseline. Considering wine regions in southern Iberia are more at risk from climate change forcing, the work followed a south-to-north priority. Soil occupation analysis identified crop, semi-natural and artificial areas and respective classes (i. e., vineyards, ecological corridors, woods, etc.). Each class was characterized for flora, habitats, soil cover, state of conservation and presence of species of conservation concern (Keller and Bollmann, 2004; Mota et al., 2021).

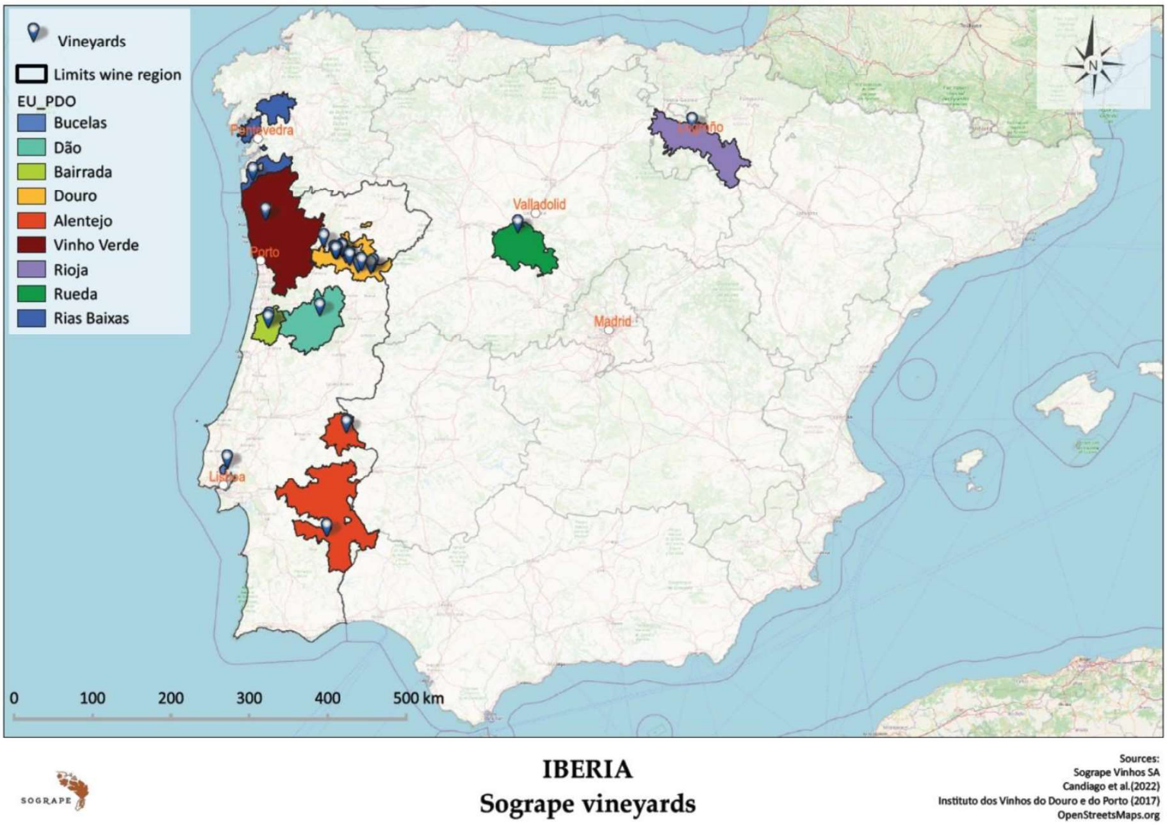

Figure 1. Location of SOGRAPE vineyards in Iberia.

Maps were produced as vector files and analyzed using QGIS. Catalogs of plants, invertebrates (butterflies, dragonflies and other arthropods) and vertebrates (birds, amphibians, reptiles and mammals) were established. A qualitative evaluation of the ecosystem status was made considering conservation value, presence of exotic and invasive species and overall biodiversity level. Ecological risk level was evaluated using a categorical quantitative assessment for indicators on water, biodiversity, climate adaptation and soil functions. Annual high-resolution crop health assessment in vineyards at veraison (BBCH 85; Eichhorn and Lorenz, 1977) was performed using unmanned aerial vehicle-based remote detection (UAV). Surveys in vineyards in Portugal and Spain were made using very high-resolution (5-10 cm/pixel) multi-spectral imaging gathered at low altitude (typically < 120 m above-ground level), using micro-UAV platforms and COTS cameras, of which details were published in prior work (Araújo et al., 2023). Data acquired since 2014 in Portugal and 2022 in Spain represent data indices from pure vegetation pixels - NDVI, NDRE and plant gap information – and derived information: average per block, block variability, index percentiles, statistically smoothed or segmented data. A proprietary software application was developed by the IT department of Sogrape to harness, aggregate, analyze and visualize operational culture and farming data (WiCo – Wine Connection, OutSystems, Linda-a-Velha, Portugal). Sogrape used wine brands to raise consumer awareness of the natural environment where winegrapes are produced both through commercial products (wine, olive oil, jams and sauces) and local experiences (tastings, biodiversity trails, educational activities).

Results and discussion

IP complements ecological knowledge with precision technologies (Castiço and Cardoso, 2023). Risk assessment, monitoring and scientifically-sound approaches are essential to define interventions and strategies which should always be adapted to local conditions (Malavolta and Duso, 2020). Baseline work to characterize climate, soils, crop and ecosystem is currently ongoing and should eventually cover the whole Iberian acreage of the company. On-site monitoring of climatic variables allows for understanding the meteorological and climatic drivers of crop development and ecosystem balances. Annual and monthly variations of temperature minima, maxima and amplitudes provide a basic picture of both the phenology of grapevine and the provision of ecosystem services according to the phenology of other species (Celette et al., 2008; Weiskopf et al., 2020; Naulleau et al., 2021). In Figure 2, we provide a comparison between 3 wine regions, showing significant differences in temperature patterns. This information, together with local rainfall patterns was used in planning for establishing hedges, ecological corridors and cover crops in different regions. For example, in Rueda, species *Lavandula angustifolia, Salvia rosmarinus, Santolina chamaecyparissus and Thymus vulgaris* were identified to be placed at the top of vineyard rows, whereas in Douro, because of more important annual and monthly temperature amplitudes endemic species were preferred: *Centaurea paniculata* subsp. *rothmalerana, Herniaria lusitanica, Asphodelus lusitanicus* var. *lusitanicus, Dianthus cintranus* subsp. *cintranus*.

Climate drift monitoring using ETCCDI indicators (Karl et al., 1999; Peterson et al., 2001) has allowed to monitor extreme conditions being experienced by the ecosystems in each wine region. Table 1 shows an example allowing for different annual management decisions (cover cropping, tillage, canopy management, insect control strategies, irrigation) to be pondered differently for each region as a function of its own risk types and levels.

Table 1. Climate change drift: comparison of 2022 heatwave days with average of 10 years for 3 wine regions. A heatwave is defined as the annual count of days with at least 6 consecutive days when maximum daily temperature exceeds the 90th percentile of the historical climate series).

Heatwaves	Vinho Verde	Dão	Alentejo
2022 heatwave days	12.0	24.0	36.0
2011-2021 avg. heatwave days	18.6	23.6	33.7

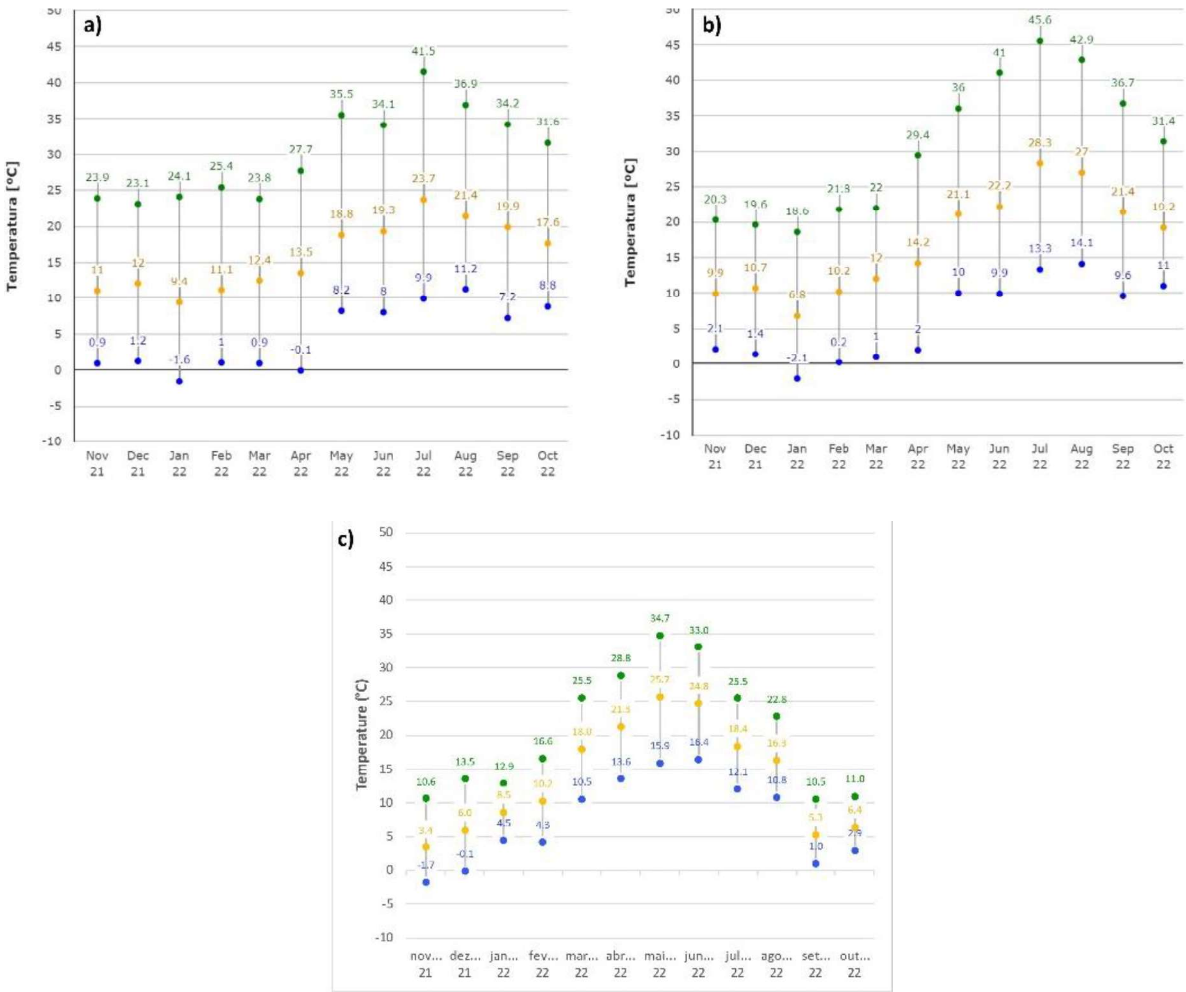

Figure 2. 2021-22 temperature amplitudes in (a) Vinho Verde, (b) Douro and (c) Rueda.

Soil surveys and precise mapping of basic terroir units provided important understanding of soil functioning and grapevine physiological behaviour as regards root system development and overall nutrition (Courtin et al., 2004). Derived indices such as the maximum usable water reserve (Figure 3) informed on the spatial variation of water availability and drainage conditions allowing for defining the correct strategy for cover cropping, in terms of species and management. BTU mapping and detailed characterization led to the development of a specific strategy of mineral nutrition to be applied according to their spatial boundaries. It further informed on the adaptability of grapevine rootstocks for optimal plant – soil exchanges.

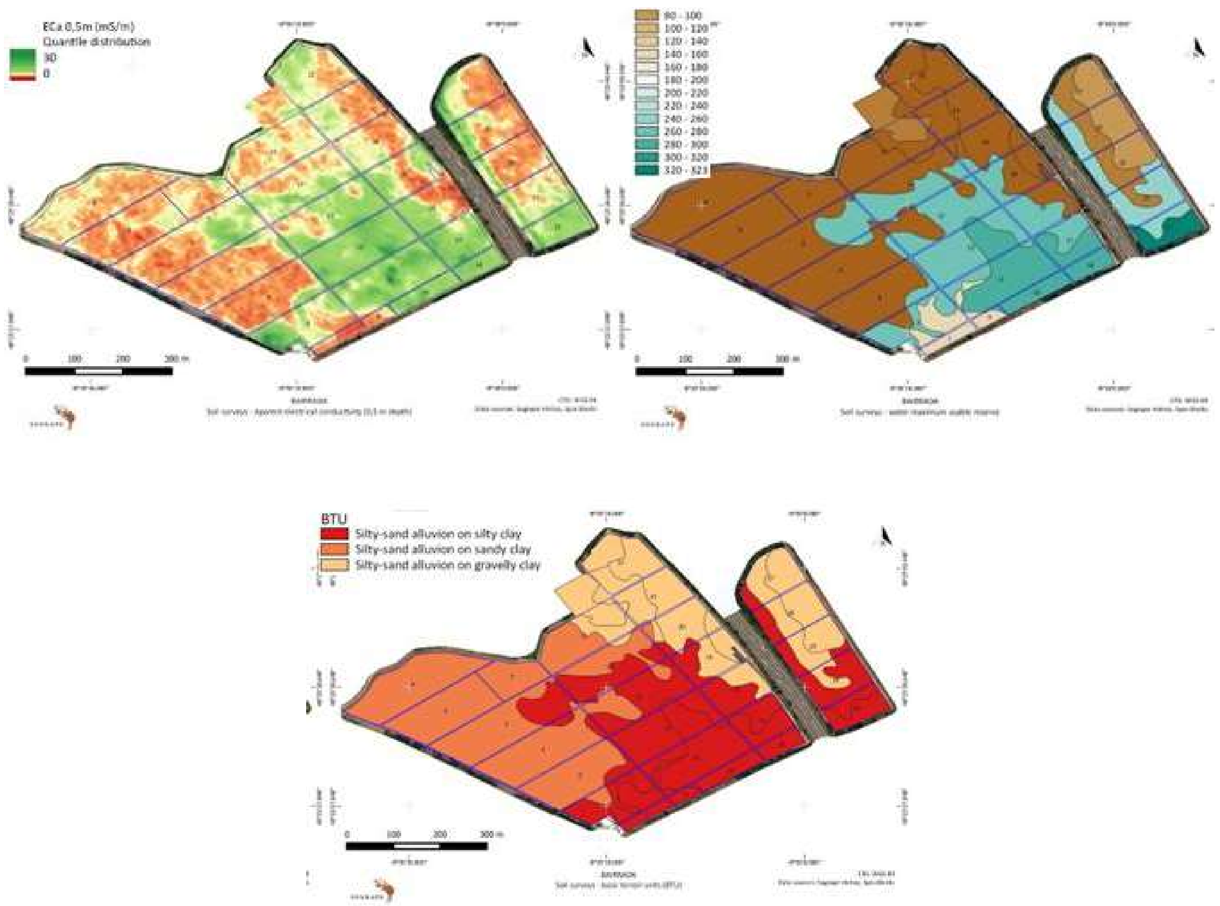

Figure 3. Soil spatial variability of a Bairrada vineyard. Left to right: apparent electrical conductivity at 0,5 m depth ($mS.m^{-1}$), maximum usable reserve of water (mm) and BTUs.

Considering that plants themselves provide reliable integration of environmental conditions (Yu et al., 2021; Pañitrur-De La Fuente et al., 2020), annual analysis of crop health using high-resolution data served two purposes: (i) mapping the structure of spatial distribution of vegetation which is conditioned by more stable components such as soil structure and climate and (ii) identifying areas where plant health was compromised for further investigation. Raw NDVI data (Figure 4 a) in areas of high-vegetation such as Vinho Verde and Rias Baixas regions provided oversaturated data requiring statistical treatment to reveal the underlying variation patterns (Figure 4 b). NDRE values (Figure 4 c) were less susceptible to saturation providing better statistical distribution of data. Combined NDVI / NDRE analysis allowed for identifying problematic areas (red areas in Figure 4 b-c) requiring local supervised analysis. When combined with soil and climate information they allowed a high-level of understanding of the multifunctional interactions at play in the vineyard ecosystem, improving decision making and management outcomes.

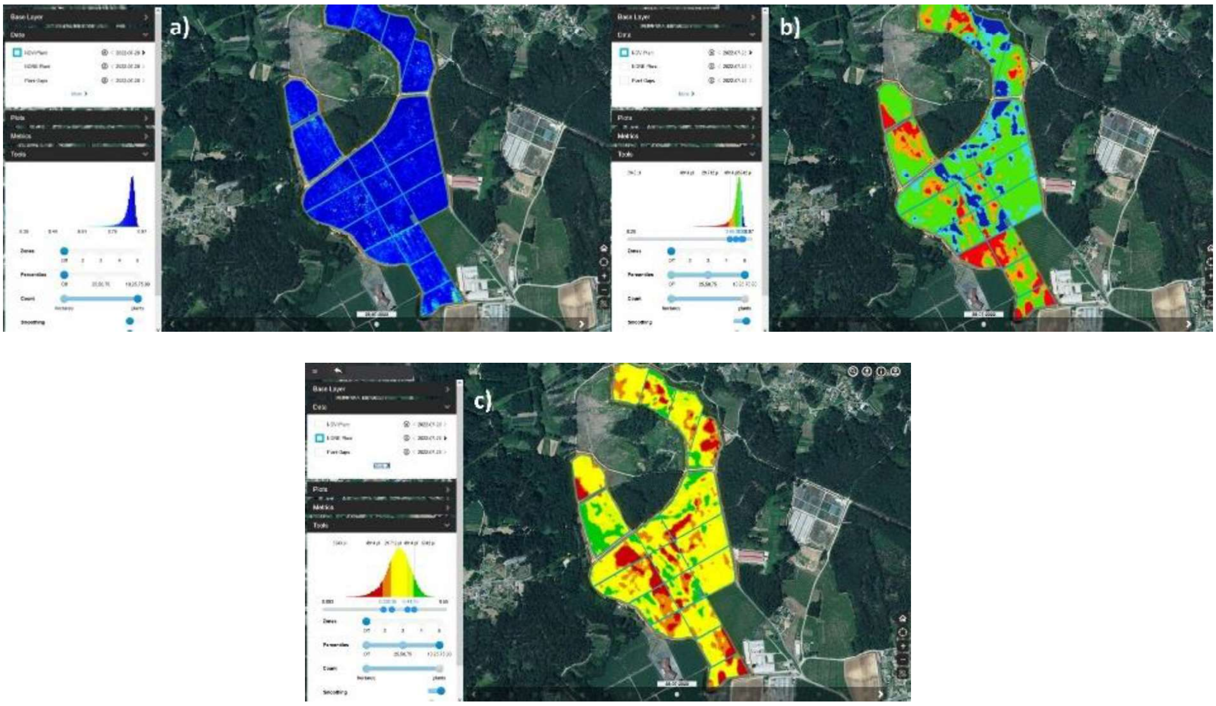

Figure 4. 2022 crop health spatial distribution in a Rias Baixas vineyard. Raw Normalized Differential Vegetation Index (NDVI) data (a) were smoothed and coloured by percentiles (red – 10^{th} / orange – 25^{th} / green – 75^{th} / blue – 90^{th}) to compensate saturation from high vegetation levels and reveal real vigour differences (b), to be compared to similarly computed Normalized Differential Red Edge (NDRE) data (c) correlated to chlorophyll levels in vegetation (red – lowest, green – highest). In each map, an histogram showed statistical distribution, offset index values and the number of plants between percentiles.

Coupling all above layers of data with biodiversity inventories in each vineyard supplied comprehensive analyses of surrounding ecosystems resulting in mapping land use and vegetal biomass of both crop and non-crop areas. Critical support areas for biodiversity services were identified together with areas where endemic and conservation concern species were found. In Alentejo, ecological risk was considered overall average with soil functions, pest and disease regulation showing low ecological risk. Soil occupation classes (Figure 5 a) with lower risk were ridges and wild brush areas. Those being spatially interspersed with crop areas provided high-level of beneficial ecosystem services. Inversely, a high-risk was found for crop areas and water bodies, requiring management. Plans for ecosystem, agroecology and landscape management were deployed as 5 action types addressing different areas: (i) cover cropping in vineyard and fallow areas, (ii) conservation of ridges and dense wild brush, restoration of waterways, open wild brush and wetlands, (iii) functional hedges in trails and fallow areas inside vineyards, (iv) shelters for bats near vineyards and birds of prey in seminatural zones and (v) repurposing of hedge olive groves and annual crop areas. Biomass distribution (Figure 5 b) analysis from NDVI provided insights on potential carbon sequestration potential (Ponce-Hernandez, 2004; Brunori et al., 2016; Caruso et al., 2019): higher in vineyards (Fig. 5 c, representing the biomass of individual grapevine plants) and olive groves when compared to annual crops, fallow or open wild brush areas.

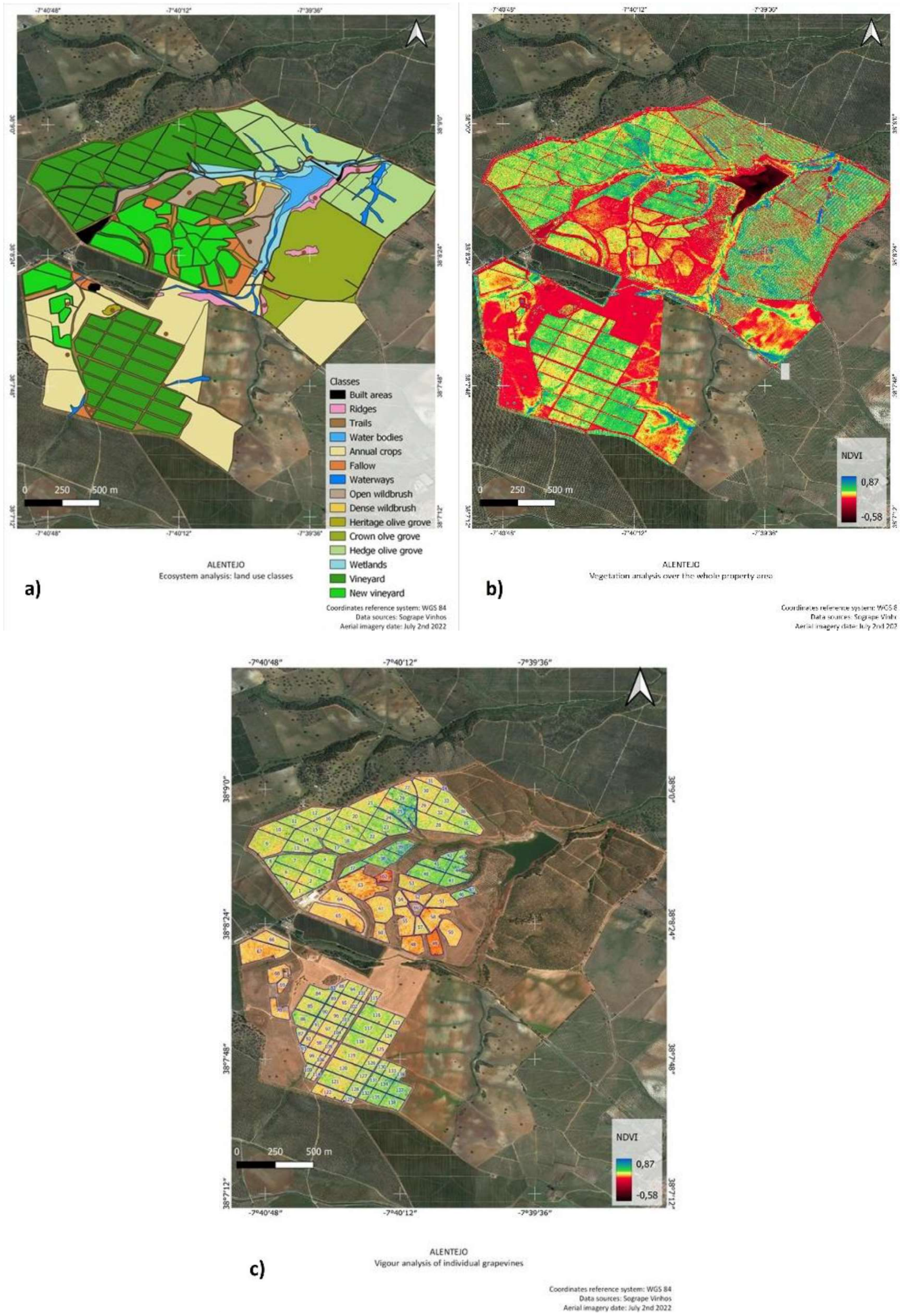

Figure 5. Analysis of the ecosystem of an Alentejo vineyard. In semi-arid regions, an inventory and mapping of land use classes (a) and respective comparison with above ground biomass (b) allowed to establish which uses provide higher level of biodiversity and carbon sequestration. Vineyards (c), once established, perform better than annual crops, fallow and open wild brush areas. Inversely, ridges, dense wild brush and waterways demonstrated higher performance.

Elements of biodiversity (plants – *Cistus ladanifer*, animals – *Otis tarda* and *Sus scrofa mediterraneus*) and landscape features, such as terraces, plateaux or plains were included in brand imagery and names (Figure 6). Nature trails near Sogrape's vineyards (Sendero de El Cortijo in Rioja or Quinta do Seixo Biodiversity Trail in Douro) engaged citizens directly providing emotional benefits from landscape and biodiversity (van Zanten et al., 2016; Graça et al., 2023). A partnership with national spanish organization (ZERYHTHIA, www.asociacion-zerynthia.org/oasis) led to establish a visitable butterfly oasis inside the riparian area of Viña Lanciano (Rioja) on the bank of river Ebro using 14 different plant species, attracting pollinators, pest antagonists and other ecosystem service providing species.

Figure 6. Strategies to engage consumers and the wider society in sustainable production and responsible consumption. Branding wine with biodiversity (a and b) and offering ecosystem-immersive experiences in vineyards (c and d) raises awareness of the role of nature, biodiversity and healthy ecosystems in food production, generates perception and emotion and promotes stewardship.

Conclusions

The wine sector possesses intrinsic and well-demonstrated expertise in consumer communication, wine-tourism recently extending its reach to audiences beyond consumers (Ingrassia et al., 2018; Joy et al., 2018; Sigala and Robinson, 2019; Fountain et al., 2021). A nexus between environmental protection, biodiversity conservation and human happiness is becoming well-established (Majeed and Mumtaz, 2017; Bonasia et al., 2022) and has been proposed as an essential tool for public environmental policies, biodiversity narratives tapping onto collective imagination, emotion and cultural heritage more than climate ones (Bjærke, 2019). A sound IP strategy relies on local knowledge and data to inform decisions (Malavolta and Duso, 2020). Increasing information detail (granularity) in both temporal and spatial dimensions provides managers a greater level of understanding of dynamics in vineyard ecosystems, respective biodiversity and services. In return, they can make better informed, customized and timely decisions, balancing efficiency with resilience. However, today that is not enough for a sustainable agrifood business. Social and market trends facing producers require matching value with responsibility and transparence, not just in their direct activity but also along the value chain they depend on (EEA, 2020). Communication of sustainable practices is therefore a key component of business development, but requires science-based information to drive trust in citizens making consumption choices. Critically, trustworthy communication has the potential to bridge the widening rural-urban gap and restore eroded farming and food production knowledge due to growing urbanisation (Tefft et al., 2017). Credibility of this communication lies with clear and actionable information for target audiences. The above reported advances in commercial vineyard ecosystem management for Iberian wine regions match those requirements and can be used as role-model for similar approaches in other agrifood sectors, securing contributions of global agriculture for the UN 2030 SDGs and nature-positive targets of KM-GBF.

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