

Research Paper

Web-based multicriteria spatial decision support system (MC-SDSS) for land suitability evaluation in olive groves. A case study in Calabria region, southern Italy

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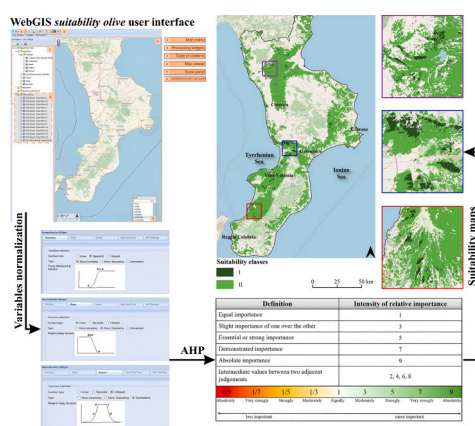
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HIGHLIGHTS

- A Webplatform designed to deal land suitability evaluation for olive growing.
- Weighted linear combination was implemented using several geospatial data.
- The proposed platform provides web tools for performing multicriteria analysis.
- The final map identifies the most suitable areas for sustainable olive growing.

GRAPHICAL ABSTRACT



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ABSTRACT

CONTEXT: Effective and sustainable agricultural land management is essential for developing agriculture and food production. Olive trees are among the most significant cultivated plants in the Mediterranean region. Yet, they are especially vulnerable to climatic and socioeconomic changes rapidly transforming agroecosystems at a regional and global scale.

Abbreviations: LSE, Land suitability evaluation; RS, remote sensing; GISs, geographic information systems; DSS, decision support systems; IT, Information Technologies; SDSS, spatial decision support systems; SDI, Spatial Data Infrastructure; MC-SDSSs, multi-criteria spatial decision support systems; MCDA, multicriteria decision analysis; SOA, Service Oriented Architecture; OGC, Open Geospatial Consortium; WPS, Web Processing Service; WLC, weighted linear combination; AHP, analytical hierarchy process; LU/LC, land use/land cover.

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Free open-source software for geospatial (FOSS4G)
 Web processing services (WPSs)
 Precision agriculture

OBJECTIVES: This study presents the outcomes of implementing a web-based multi-criteria spatial decision support system (MC-SDSS) designed explicitly for evaluating land suitability for olive cultivation. The aim is to identify areas that are most suitable for sustainable olive growing.

METHODS: This system relies on free and open-source geospatial software (FOSS4G). The implemented web platform (WebGIS Suitability Olive) was tested by performing an LSE for olive growing in the Calabria region (Southern Italy). The platform is designed to manage users with different levels of access (i.e., user's privileges): Guest (data visualization), Expert (making evaluations), and Decision-Maker (making final decisions). The decision-maker collects the results produced by each expert, aggregating all the intermediate results through a geometric mean and generating the final Suitability Map, which represents the synthesis of all the evaluations provided by the experts.

RESULTS AND CONCLUSIONS: The final suitability assessment identifies the most appropriate areas for sustainable olive cultivation. The results indicate that the total area suitable for sustainable olive growing in Calabria is 109,595.10 ha, of which olive groves already occupy 46,912.17 ha.

SIGNIFICANCE: This tool is designed to support more complex planning processes that require multi-temporal and multi-actor approaches. These approaches are essential for evaluating different alternatives and proposing various sustainable solutions from environmental and landscape perspectives.

1. Introduction

For sustainable agricultural development and food production, robust and efficient management of agricultural land management is required. Defining the relationship between soil characteristics and crop needs should be the first step in planning future agricultural land uses (Montgomery et al., 2016). Land suitability evaluation (LSE) refers to the degree to which land characteristics are suitable for supporting a particular land use. LSE is widely used for agricultural land suitability assessment, which is essential for sustainable farm production and development. LSE can be carried out on land plots and at regional scales (Collins et al., 2001; Mendas and Delali, 2012). From a regional perspective, agricultural suitability assessment plays a significant role in managing and creating a sustainable agricultural system (Kazemi et al., 2016). In the last decade, the recent advancements concerning remote sensing (RS), geographic information systems (GISs), decision support systems (DSS), and Information Technologies (IT) have improved and eased the LSE (Akpoti et al., 2019). These advancements have led to the development of spatial decision support systems (SDSS), defined by Lamelas et al. (2008) as “interactive, computer-based systems designed to support a user or group of users in achieving a higher effectiveness of decision-making while solving a semi-structured spatial decision problem” (Lazoglou and Angelides, 2020).

A well-established IT methodology for creating SDSS is to develop a Spatial Data Infrastructure (SDI) (Guarino et al., 2023; Lanucara et al., 2024; Modica et al., 2020). SDI can be defined as a platform for managing, sharing, and processing geospatial data and metadata. Multi-criteria spatial decision support systems (MC-SDSSs) represent an effective tool for achieving LSE in an agricultural framework. MC-SDSSs allow for spatial decision-making and help reach consensus by combining SDSS and multicriteria decision analysis (MCDA) capabilities (AbuSada and Thawaba, 2011; Malczewski, 1999, 2006; Modica et al., 2014). MCDA, being able to consider multiple sector experts' points of view, allows the management of the decision-making processes in agriculture, also providing fundamental information on the suitability of agricultural areas based on topographic, climatic, and soil characteristics, previous land uses, etc. (Lombardi et al., 2017). MCDA, by considering different aspects of complex situations, can provide priority rankings in terms of both qualitative/quantitative decision criteria and alternative scenarios (Greco et al., 2005).

In conjunction with MCDA, geospatial techniques integrate and transform geographic data (input map criteria) and value judgments (preferences and uncertainties) to provide an overall assessment for choosing between alternative actions (objectives), hypotheses, and locations (Borouhaki and Malczewski, 2008). In particular, MC-SDSSs allow sector experts to express their preferences concerning decision criteria and/or alternative scenarios using IT-based procedures that provide visual feedback and maps representing indices useful to

planners to optimize conditions (Jankowski et al., 2001; Romano et al., 2015; Silva et al., 2014). There are examples in the literature of Web-based MC-SDSS platforms implemented to deal with environmental issues. Silva et al. (2014) worked on assessing the environmental sustainability of dairy farms in Portugal, proposing using the Web MC-SDSS interface named ELECTRE TRI in ArcGIS. Rao et al. (2007) proposed a prototype Web-based SDSS based on the ArcIMS platform integrating a mapping component (Automated Feature Information Retrieval System) and a modeling component (Soil and Water Assessment Tool) to aid in the Conservation Reserve Program decision-making process. Paul and Bussemaker (2020) proposed a Web-based SDSS tool for the strategic decisions of municipal solid waste supply chain aimed at re-using municipal solid waste concerning opportunities in the market, locations for new waste conversion technologies, seasonal and spatial availability of waste streams, and promotion of collaborations toward a more circular economy. Other web applications can be implemented for irrigation water management, as explained by Maina et al. (2014), for watershed management (Zhang et al., 2015) and precision agriculture (Lanucara et al., 2024).

This study shows the research results of implementing a web-based MC-SDSS specifically designed to address an LSE for olive cultivation, entirely based on free and open-source geospatial software (FOSS4G). From the earliest stages of its development, the proposed platform was conceived and designed as an open and spatially explicit tool for sustainable landscape planning. This tool aims to support more complex planning processes that involve multi-temporal and multi-actor approaches, and different alternatives may also need to be evaluated while proposing various sustainable solutions from an environmental and landscape perspective. In this study, we present the results obtained through the web platform (here called WebGIS Suitability Olive), performing an LSE for olive growing in the Calabria region (Southern Italy). The olive tree is one of the Mediterranean basin's most important cultivated plants (Messina and Modica, 2022a). An inhabitant of ecological niches, *Olea europaea* L. is subject to a peculiar susceptibility to the climatic and socioeconomic transformations that are rapidly reshaping regional and global agroecosystems (Grandi et al., 2023). In Italy, about 80% of olive production is spread across the southern and island regions, with Puglia, Calabria, and Sicily being the most productive regions, covering over 70 % of the national output (ISTAT, 2023). Considering the high socio-economic importance of olive cultivation, especially regarding its best-known product, extra-virgin olive oil (Di Fazio and Modica, 2018; Rallo et al., 2016; Solano et al., 2019), it embodies both traditions and, to a large extent, the future of agriculture in many regions of the Mediterranean Basin (Messina and Modica, 2022b). Since the Calabria region is naturally suited for olive cultivation and stands as one of Italy's leading olive oil producers, higher quality olive oils have recently been obtained (Mafra et al., 2021). Given this context, implementing the Web-based MC-SDSS platform is essential to

identify the areas most suitable for sustainable olive cultivation. Although olive trees can thrive in a wide variety of conditions (Fraga et al., 2020), it is advisable for economically viable olive groves to select locations where constraints are minimal, allowing olive trees to be competitive in both production and management.

The structure of the article is as follows: the section on materials and methods discusses the operation of the web-based MC-SDSS Suitability Olive platform, which was tested for the Calabria region by consulting 15 experts. The third and fourth sections present the results obtained from the experts' responses, displayed as maps of the distribution of olive groves; the final section includes conclusions and potential improvements that can be implemented in the platform.

2. Materials and methods

2.1. Study area

The proposed web-based MC-SDSS was tested for the Calabria region territory (Fig. 1). Two seas wash Calabria, the Ionian Sea to the east and the Tyrrhenian Sea to the west. The morphology of territory is heterogeneous, varying from mountainous areas (Aspromonte and Pollino, in the south and north of the region, respectively) to plateaus (Sila and Sibari Plateau) and flat areas (Gioia Tauro Valley and Sant'Eufemia Valley, in the south of the region). The average width of the region is about 300 km and 50 km in the north-south and west-east directions, respectively (Avolio et al., 2012). The area's climatic and soil conditions have favored the spread of as many as 33 cultivars out of more than 500 of Italy's olive varietal heritage (Piscopo et al., 2016). With approximately 184,000 ha of olive-growing, Calabria covers almost 16 % of the Italian olive-growing area (ISTAT, 2024).

2.2. Multi-criteria spatial decision support system (MC-SDSSs) platform functioning

We implemented the web-based MC-SDSS by developing the SDI within a FOSS4G environment using a Service Oriented Architecture (SOA) approach. The implementation of applications in the FOSS4G environment is facilitated by free and open-source software and packages, which enable the management of the resulting maps and data through customizable web interfaces (Lanucara et al., 2024). Regarding the SOA approach, the implemented SDI consists of three layers with distinct functions arranged in a multi-tier architecture: a) a data repository for storing data and metadata within a geospatial database; b) a

server stratum for managing and processing stored data and metadata while enabling their publication on the Web; c) a client front-end stratum for user interaction with the system. The front end can exploit the Open Geospatial Consortium (OGC) international standards for sharing and processing data and services. The Web Processing Service (WPS) (<https://apic.casaccia.enea.it/suitability-olivo/BaseApp.html>) OGC standard implements the processing capabilities. The WPS allows the client to submit a processing task to a server for execution and publication of the results. These tasks can involve algorithms or models that work with spatially referenced data. WPS services can handle tasks in either synchronous or asynchronous modes. In synchronous mode, the client application waits for the server to complete the task. In asynchronous mode, the client can proceed with other tasks without waiting for the server to finish. In both cases, the results can be stored on the server and accessed via a URL or sent directly to the client. The SDI architecture is implemented in a virtual environment based on the Ubuntu operating system and run by a VMware®vCenter server. Further details on SDI are described in Modica et al. (2016).

Multi-criteria analysis in a geographic environment requires the consideration of several defined alternatives and a series of evaluation criteria represented by geospatial data. The main goal is to combine the criteria based on the values attributed to the criteria themselves and the experts' preferences, using a specific decision rule (Triantaphyllou, 2000). The MC-SDSS platform aggregates data using a weighted linear combination (WLC), where attributes are weighted based on their relevance, with weights derived from expert judgments. According to the established mathematical framework, the decision rule used to calculate the land suitability index (LSI) for the j -th area can be expressed through the following formula (Eq. 1) (Modica et al., 2014):

$$LSI_j = \left(\sum_{i=1}^n w_{ji} \bullet x_i \right) \bullet \prod_{k=1}^m c_{jk}$$

Where, n represents the number of factors x_i ; w_i represents the weight of the i -th factor; m is the number of constraints; c_{jk} are the k constraints in the j -th area (raster cell).

The results consist of multi-attribute geospatial features with final scores: the higher the score, the more suitable the area is. From a practical point of view, each factor constitutes a map (or GIS layer), and the application of GIS overlay techniques (geoprocessing or Map Algebra) allows for the integration of variables through an appropriate weighting system, typically provided by one or more experts. In this regard, for the present case study, 15 experts and evaluators were

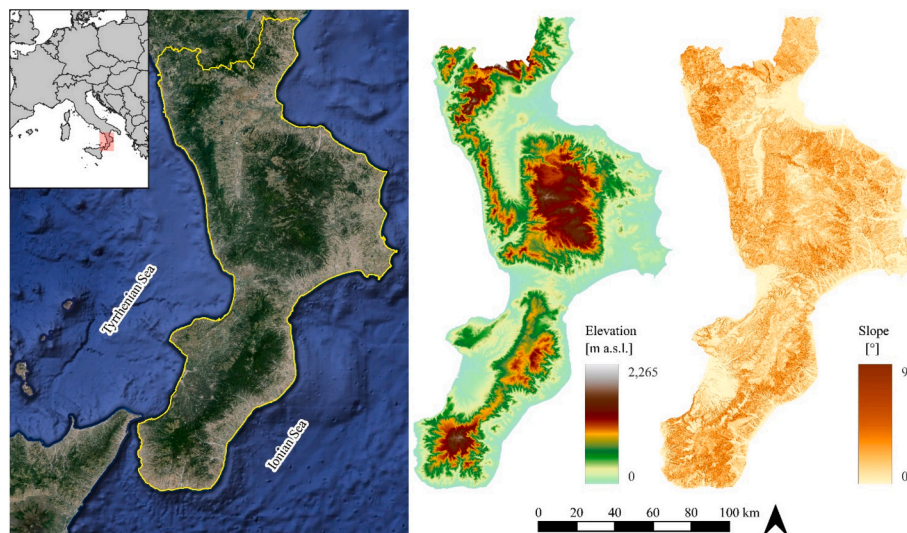


Fig. 1. Geolocation of the study area. On the left is a map of the Calabria region, while maps of elevation and slope are shown on the right. (For the interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article)

consulted, including selected olive growers and other experts from the academic and practical fields of agricultural sciences. This group includes two agronomy experts, two agricultural machinery specialists, two arboriculture specialists (olive growing), two rural landscape planners, and two soil science experts.

Relative criteria weights were derived by utilizing the analytical hierarchy process (AHP) proposed by Saaty (1980, 1977), a practical approach that is widely applied to evaluate land suitability. The AHP is founded on the pairwise comparison technique, where all the weights are considered two at a time. Pairwise comparisons are based on a scale of scores from 1 to 9, expressing the relative importance of the first variable compared to the second (Fig. 4): the values range from 1 (“equal importance”) to 9 (“extremely more important”); the following intermediate values are used to express intermediate judgments between two values: 2, 4, 6, and 8. The scores are arranged in a pairwise comparison matrix to facilitate comparisons of all possible pairs of variables, with evaluation criteria considered as factors. This method was applied in assessing multi-heterogeneous factors related to strategically important crops in specific territories, as demonstrated in past research (Chavez et al., 2012; Mandere et al., 2010). Specifically, the factors represent the measured decision variables, based on which the suitability of an area for a specific use can be evaluated. Further details on the implemented approach and its mathematical foundation are provided by Modica et al. (2016).

The WLC technique was implemented within the MC-SDSS using several geospatial data that describe the territorial features of the study area. Different suitability levels can be expressed and normalized for each one within a range of 0 to 1. Furthermore, a weighting process can be carried out by assigning distinct weights to each variable considered. The results of this process are geospatial data and relative maps (i.e., land suitability maps) indicating the most suitable areas for the analyzed crop related to the investigated variable. Each land suitability map is accompanied by a legend highlighting, in different colors, the following suitability classes: not suitable, very low suitable, low suitable, medium suitable, high suitable, and very high suitable.

Once logged in, each type of user will see an initial visualization related to the study area. The available view functions include basic options for panning and zooming, enabling users to adjust the map’s scale and identify geospatial data within the application. The table of contents panel displays information related to factors (or criteria) such as elevation, slope, aspect, land use/land cover (LULC) (Table 1), and pedology data that can be selected with a check mark (Fig. 2). The latter

includes the following sub-factors: texture, salinity, depth, available water content (AWC), and carbonates (Fig. 2). These factors were selected for their relevance according to existing literature (Akpoti et al., 2019) and mapped based on the data availability for the analyzed area.

The input geospatial layers were acquired from public data repositories provided by Calabrian Region public entities: the digital elevation model (ground sample distance, GSD of 5 m, reference year 2008) and the land Use Land Cover (reference year 2012) from the Geoportal of Calabria Region (<https://geoportale.regione.calabria.it/en>, last access 15 December 2024); the pedology map with a nominal scale of 1:250,000 from the Regional Agency for the Development of Calabrian Agriculture (ARSAC) (<https://www.arsacweb.it/sitac-sistema-informativo-territoriale-agricolo-della-calabria>, last access 15 December 2024). All these layers were acquired and homogenized in raster format and resampled with a GSD of 10 m, a spatial resolution with reasonable detail for a regional analysis.

To better manage the trade-off between evaluation factors, in the WebGIS interface of the MC-SDSS, the processing tool “Normalization Widget” was devoted to normalizing the following factors: elevation, slope, and aspect. In this phase, for each investigated variable, following a fuzzy approach (Yager, 1988), the expert can define a range of values highlighting different thresholds to indicate unsuitability and various degrees of suitability. For each of the three factors, the “function type” should be selected that best describes the trend in factor values from less favorable to more favorable (or vice versa) conditions for sustainable olive growing: sigmoidal, linear, or j-shaped function (as shown in Fig. 3). The trend of the function can be categorized as: “mono increasing” if the transition trend increases monotonically (Fig. 3a), “mono decreasing” if decreases monotonically (Fig. 3b), or “symmetrical” (Fig. 3c). The numerical parameters to be entered under each panel vary depending on the factor. In the elevation factor panel, experts must input values expressed in meters, while values in degrees should be used for both the slope and aspect factors. Fig. 3 shows three examples on the use of the Normalization Widget window. The function trend in Fig. 3a and the entered numerical values indicate that the expert deemed elevation values above 200 m optimal for sustainable olive growing, while values below this threshold show decreasing suitability. The function trend in Fig. 3b and the numerical values suggest that the expert considered slope values not exceeding 10 degrees optimal for sustainable olive cultivation. Values between 10 and 17 indicate a decrease in suitability, while values greater than 17 are regarded as unsuitable. The function trend in Fig. 3c and the entered numerical values demonstrate that the expert assessed the ideal aspect as being between southeast and southwest.

In the fourth panel of the Normalization Widget, which focuses on the LU/LC factor, relative importance intensity can be indicated using the provided slider, with selectable importance values ranging from 0 (very low importance) to 1 (very high importance). The “Reclassify” function enables the generation of the normalized LU/LC layer based on the parameters entered for individual classes (Fig. 4). Through assessment and reclassification of LU/LC, areas unsuitable for olive cultivation (i.e., urbanized areas, protected natural areas, areas subject to constraints, forests, and water bodies) are excluded.

In the last panel of the Normalization Widget, “AHP Pedology” the user (Expert level) can establish a pairwise comparison of the five sub-factors that characterize the pedology layer (i.e., texture, salinity, depth, AWC, and carbonate content) in accordance with the AHP procedure. According to Saaty’s scale (Fig. 5), the pairwise comparison reflects the importance of the first variable relative to the second variable or vice versa. If the two variables under comparison are deemed equally important, a value of 1 should be assigned. Otherwise, values ranging from 2 to 9 are available, indicating a spectrum from slight to absolute importance. Values for each factor pair should be entered in the “Weighted Linear Combination” box (Fig. 5). The box below displays a matrix with the scores for each factor organized according to a positive reciprocal matrix that shows the respective weights of the criteria

Table 1

Factors considered in the implementation of the land suitability evaluation (LSE) in olive groves and how they affect crop’s suitability.

Factors	Effects on suitability	References
Land Use/ Land Cover (LU/LC)	Information on the current LU gives indications on the availability of land. LU/LC data help to determine the potential productivity of an area for a specified cropping system. Determines micro-climate variations having an effect on crop health and production	(Liu et al., 2008)
Elevation	Determines the feasibility of cultivation operations requiring the use of machinery and other issues linked to hydrogeological risk	(Yi and Wang, 2013)
Slope	Determines the amount of solar radiation reaching crop and soil surface	(Yi and Wang, 2013)
Aspect	Determines the physical and chemical characteristics of the soil influencing crop management	(Akinci et al., 2013)
Pedology		(Bandyopadhyay et al., 2009; Benke and Pelizaro, 2010; Feng et al., 2017; Ismail et al., 2012; Zolekar and Bhagat, 2015)

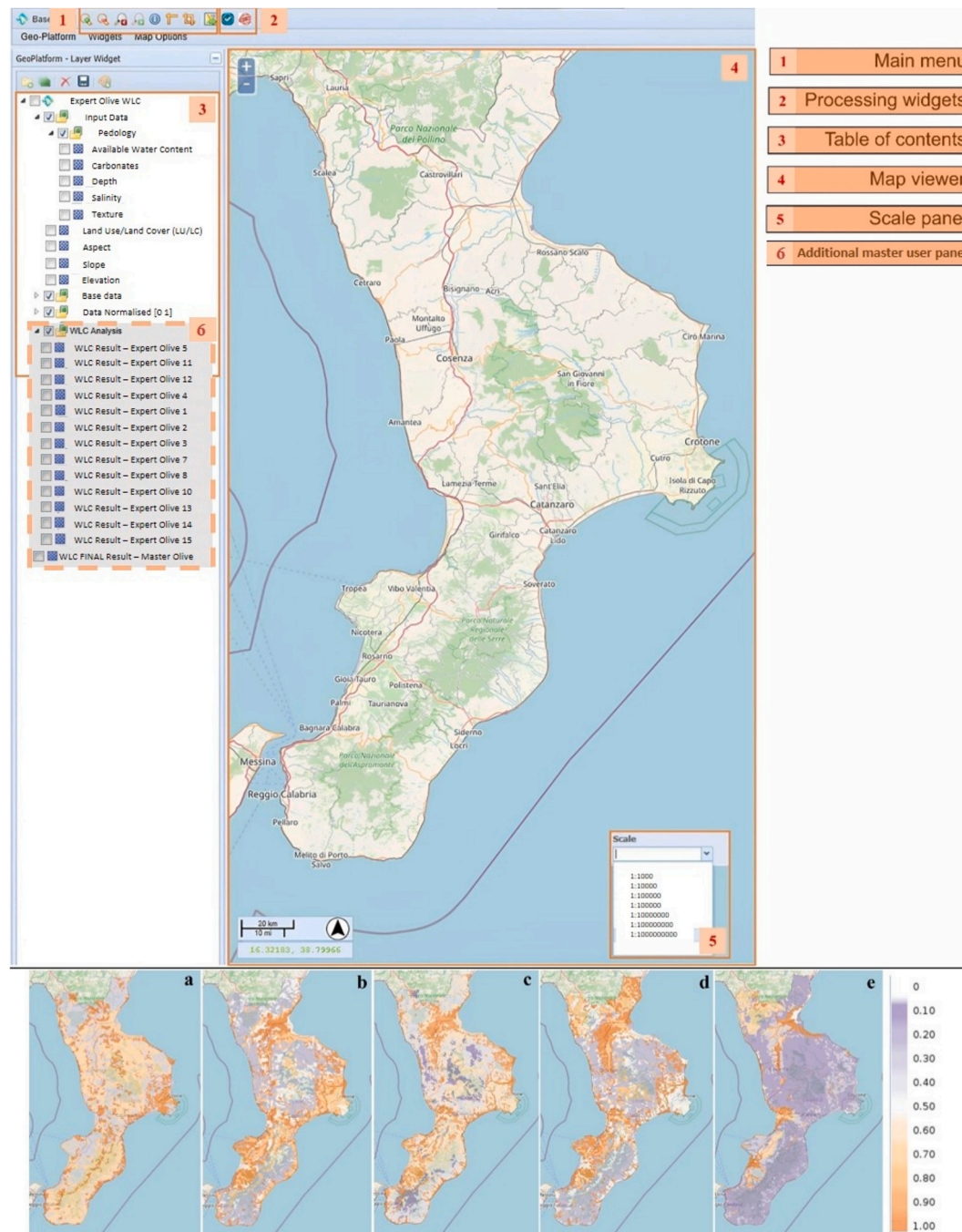


Fig. 2. Screenshot of WebGIS *Suitability Olive* / MC-SDSS platform's layout showing: 1) main menu; 2) the two processing widgets “AHP Widget” (blue icon) and “Normalization Widget” (red icon); 3) table of contents with the list of the informative base layers; 4) map view; 5) the option to change the display scale and 6) additional master user panel (only available to the master user) showing the results of individual expert evaluations. On the bottom, five screenshots showing the informative base layers concerning pedologic sub-factors (with values normalized 0–1): a) texture; b) salinity; c) depth; d) available water content (AWC); and e) carbonates. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

considered. The results obtained after the Weighted Linear Combination procedures are evaluated by means of the resultant consistency ratio (CR) that assesses the congruence in the judgments made by the experts (Pant et al., 2022; Saaty, 1977). AHP results are valid only for $CR \leq 0.1$. A pop-up warning alerts the user if this threshold is exceeded. The output will be generated by calculating WLC for the normalized pedology layer.

Then, a different widget (AHP Widget) enables us to conduct an AHP process by assigning weights to the five considered factors (i.e., elevation, slope, aspect, LU/LC, and pedology) using the pairwise comparison

technique. For this purpose, a rating must be entered in the ‘Weighted Linear Combination (WLC) Settings’ box for each possible pair by entering one of the values provided in Saaty’s scale (Fig. 6). The second panel of the widget is dedicated to evaluating the CR of the pairwise comparison matrix (acceptable only for values below 0.10). Once the choice of importance values is made, clicking on ‘Execute WLC’ performs the WLC calculation is performed according to the selected parameters. This procedure is repeated for each expert who accesses the platform using a specific username and password.

Once the parameters are set according to the procedure described

The figure displays three sequential screenshots of the 'Normalization Widget' in the WebGIS Suitability Olive / MC-SDSS platform. Each screenshot corresponds to a different factor: Elevation, Slope, and Aspect.

- Elevation Screenshot:** The 'Function selection' panel shows 'Sigmoidal' as the selected function type. The 'Type' is 'Mono.Increasing'. The 'Graphic fuzzy function' shows a sigmoidal curve with points 'a' at the start and 'b,c,d' at the plateau. The 'Function parameter' section has 'Parameter A' set to 0 and 'Parameter B=C=D' set to 200.
- Slope Screenshot:** The 'Function selection' panel shows 'Linear' as the selected function type. The 'Type' is 'Mono.Decreasing'. The 'Graphic fuzzy function' shows a linear decreasing line with points 'a,b,c' at the start and 'd' at the end. The 'Function parameter' section has 'Parameter A' set to 10 and 'Parameter D' set to 17.
- Aspect Screenshot:** The 'Function selection' panel shows 'J-shaped' as the selected function type. The 'Type' is 'Symmetrical'. The 'Graphic fuzzy function' shows a bell-shaped curve with points 'a' at the start, 'b' at the peak, 'c' at the end of the peak, and 'd' at the end. The 'Function parameter' section has 'Parameter A' set to 0, 'Parameter B' set to 135, 'Parameter C' set to 270, and 'Parameter D' set to 360.

Fig. 3. Screenshot of the WebGIS Suitability Olive / MC-SDSS platform showing factor normalization through fuzzy logic related to elevation (a), slope (b), and aspect (c). The functions selected are sigmoidal (a), linear (b), and j-shaped (c). The transition trends increase monotonically in screenshot (a), decrease monotonically in (b), and are symmetrical in (c). The function trend in (a) and the entered numerical values indicate that the expert deemed elevation values above 200 m optimal for sustainable olive growing, while values below this threshold show decreasing suitability. The function trend in (b) and the numerical values suggest that the expert considered slope values not exceeding 10 degrees optimal for sustainable olive cultivation. Values between 10 and 17 indicate a decrease in suitability, while values greater than 17 are regarded as unsuitable. The function trend in (c) and the entered numerical values demonstrate that the expert assessed the ideal aspect as being between south-east and southwest.

above and as a result of the WLC, the corresponding data (i.e., the Suitability Map) are generated as output and automatically made available within the WebGIS view of each expert. Additionally, each map can be exported in several formats: KML, PDF, TIFF, Shp-Zip, GML, GeoTiff, CSV, GeoJSON, and RSS. Subsequently, the decision-maker user

(i.e., master user) collects the results produced by each expert, aggregating all the intermediate results through a geometric mean and generating the final Suitability Map, which represents the synthesis of all the evaluations provided by the experts.

The final Suitability Map can be exported as geospatial data in GeoTiff file format. To identify the most suitable areas for olive growing, a map was generated containing the two highest suitability classes (i.e., II – High suitable and I – Very high suitable), with ranges of 75–85 % and 85–100 %, respectively. Pixel groups whose summed area did not exceed at least 2 ha were removed from the map. This process results in a map of Calabria's most suitable areas for sustainable olive growing. Finally, this map was exported, processed in a GIS environment, and intersected with the most recent LU/LC map available (2018) to quantify and analyze these selected most suitable areas (e.g., how many hectares fall in the best classes, how many of these are already cultivated with olive groves, etc.).

3. Results

Following the procedure outlined above, each of the 15 experts produced a suitability map for the Calabria region. In this context, all the experts are well-acquainted with the territory, climate, plant biological cycle, needs, and the olive-growing sector in both Calabria and Italy. The first factor that the experts needed to address in the Normalization Widget's panel was elevation. Of the fifteen responses provided regarding the type of function, six experts selected the linear function, while seven opted for the sigmoidal function (two of which were j-shaped). Concerning the function trend, ten experts chose a symmetrical function with two elevation values at which the optimum conditions for the sustainability of olive cultivation were maximized. Four experts selected an increasing function, and only one chose a decreasing function. The range of elevation values entered spans from 0 to 1000 m. The second factor the experts had to address was slope. Of the fifteen responses provided regarding the type of function, six experts selected the linear function, seven chose the sigmoidal function, and twelve users opted for the decreasing function trend. The range of slope degree values entered is between 0 and 35.

The third factor the experts had to address was aspect. Among all the responses regarding the type of function, seven experts or evaluators selected the sigmoidal function, while seven opted for the linear function (Supplementary material). Additionally, fourteen experts chose the symmetrical trend. The aspect values (expressed in degrees) that maximized the optimal conditions for sustainable olive growing range from 90° to 270° (east and west, respectively), indicating a south-facing aspect.

Regarding the panel on the reclassification of LU/LC, the summarized results of the responses can be found in the Supplementary material. Permanently irrigated arable areas (LU/LC code 212) were assessed as very highly suitable by ten out of fifteen experts. Similar evaluations were made for the reclassification of vineyards (LU/LC code 221), fruit trees (LU/LC code 222), citrus groves (LU/LC code 223), and lands consisting of olive groves and mixed olive groves (LU/LC codes 224 and 245, respectively). In relation to woody crop plantations (LU/LC code 226), only four experts assigned a high importance rating. Seven out of fifteen experts gave a very high rating for the reclassification of olive groves with complex cultivation patterns and agricultural lands that include areas of natural vegetation (LU/LC codes 242 and 243, respectively). Similar ratings were recorded for areas covered by natural grassland (LU/LC code 321), bushes and shrubs (LU/LC code 322), and sclerophyllous vegetation (LU/LC code 323).

In the pairwise comparison of the five pedology sub-factors (AHP Pedology panel) (i.e., texture, salinity, depth, AWC, and carbonate content), seven experts deemed texture to be more important and considered it equally important to AWC according to three respondents. The same sub-factor was rated as more critical than the carbonate sub-factor in eight responses. Ten experts indicated that texture is more

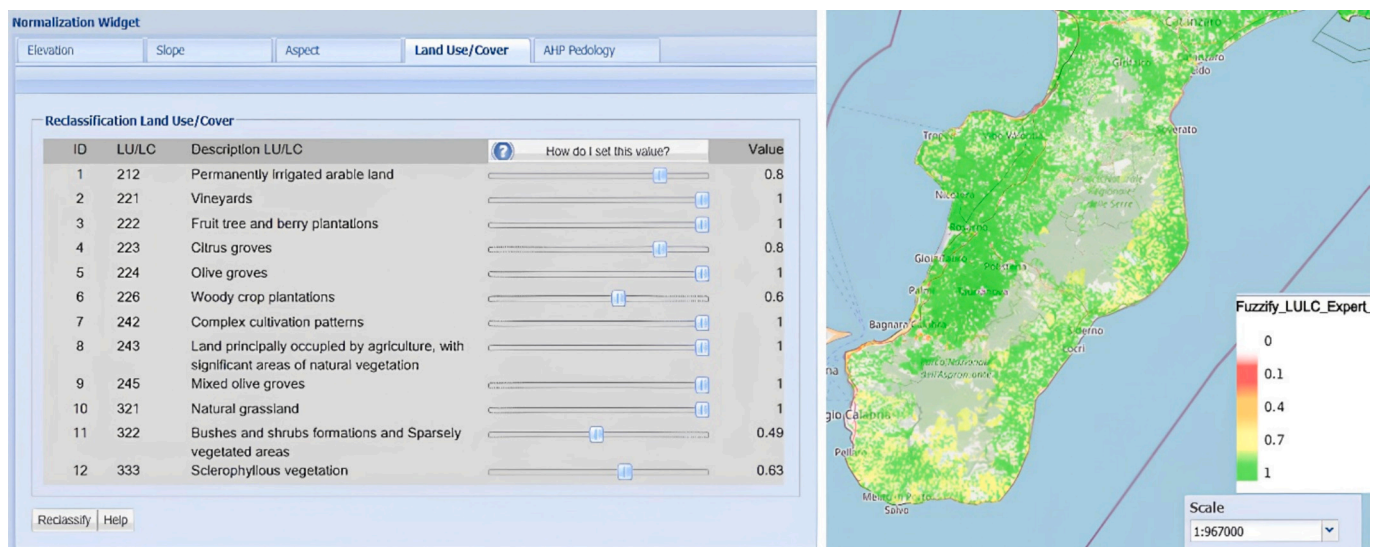


Fig. 4. Screenshots of WebGIS *Suitability Olive* / MC-SDSS's platform are showing on the left Normalization Widget panel for Land Use / Land Cover (LU/LC), and on the right, the normalized layer according to the entered parameters. The legend in the right figure indicates a suitability range from 0 (white, very low importance) to 1 (green, very high importance). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

important than salinity, while eight stated that texture is more significant than depth. Most experts regarded AWC as more important than carbonates, salinity, and depth. Nine experts asserted that carbonates are more critical than salinity. An equal number of experts (seven) assigned greater importance to carbonates and depth. Finally, nine experts identified salinity as a sub-factor that is more important than depth.

The pairwise comparison in the AHP Widget panel concerns five factors (i.e., elevation, slope, aspect, LU/LC, and pedology). All AHP procedures were deemed to be valid, as they achieved a CR ≤ 0.1 . The CRs obtained are listed in the supplementary material.

The slope was considered more important than elevation (in eight responses), aspect (in eleven responses), LU/LC (in eleven responses), and pedology (in eight responses). Elevation was found to be more important than aspect (in ten responses), LU/LC (in eight responses), and pedology (in nine responses). Nine and eight experts, respectively, recognized pedology as more important than aspect and LU/LC. Finally, in the pairwise comparison between the sub-factors of aspect and LU/LC, six experts considered aspect to be more important than LU/LC, while seven held the opposite view (two responses indicated equal importance). The experts' differing answers are also evidenced by significant differences in the presence (or absence) and the greater or lesser distribution of suitability classes, as shown in Fig. 7 a-b-c. The final Suitability Map, displayed in Fig. 7d, aggregates all the evaluations provided by the 15 experts.

When considering only the two classes of highest suitability for sustainable olive cultivation- namely, "high suitable" (class II) and "very high suitable" (class I), which correspond to ranges of 75–85 and greater than 85, respectively- the most suitable areas for olive growing in Calabria cover a total of 109,595.10 ha. Of this area, 99,863.18 ha fall into the high suitable class, while 9731.92 ha are classified as very high suitable (see Fig. 8). In the highly suitable class, 40,302.23 ha (40.36 %) are already planted with olive groves. In the very highly suitable class, 6609.94 ha (67.92 %) are also dedicated to olive groves. For the areas classified with a suitability of 75–85 % that are not currently occupied by olive groves and are therefore available for improving Calabrian olive cultivation, a total of 59,565.53 ha is available. According to the LULC classes outlined in the methodology, this area consists of 1659.80 ha of anthropized land, 22,878.31 ha of arable land, 8046.89 ha of vineyards and fruit orchards, and 24,192.60 ha allocated for other agricultural uses. Other natural surfaces occupy 2751.01 ha, while 36.92 ha is

allocated to streams. In areas classified as having over 85 % suitability that is not used for olive groves, which amounts to 3122.62 ha, the breakdown is as follows: 228.73 ha are anthropized areas, 793.47 ha are arable land, 143.33 ha are dedicated to vineyards and fruit orchards, and 1856.06 ha are used for other agricultural purposes. Additionally, other natural surfaces account for 101.03 ha. In contrast, the analysis of the least suitable classes (i.e., V - very low suitable, IV - low suitable, and III - medium suitable) revealed that there are 123,721.34 ha of olive groves in these areas.

4. Discussion

The differences produced by the experts' answers have resulted in varying degrees of differences in the areas designated for sustainable olive growing in the Calabria region. The diverse backgrounds of each expert- encompassing skills, knowledge, and experience in olive cultivation- inevitably influenced the outcomes of the questions posed by the platform in the individual panels and the generated output layers. Additionally, this variability is related to the factors associated with the questions. For instance, regarding elevation, the responses exhibited a wide range of values. In contrast, concerning aspect, the experts' responses aligned in the same direction. Observing the results for elevation, it was agreed that there are two extremes- lower and upper- below and above which olive cultivation cannot achieve optimal production levels, taking various climatic conditions into account. Although not explicitly stated, temperature was understood to be a crucial factor related to elevation that likely guided the experts' choices. In the future, climate variability may lead to significant changes in the geographical distribution of more sensitive natural species and the timing of different phenological phases (Fraga et al., 2020). Almost half of the experts considered an elevation between 200 and 400 m optimal, while another half considered higher values (700–800 m) optimal, considering both the olive's adaptability and its historical presence at all altitudes up to 1000 m (Loumou and Giourga, 2003).

Concerning the slope, the responses also varied due to the wide range of possible answers; however, the consensus among most experts is that the optimal slope should not exceed 11°. The terrain slope should not be steeper than 11–14° (20–25 %) to facilitate good machine circulation when using track tractors and light headers. Nonetheless, flat or gently sloping areas are preferred. While machinery is generally favored for slopes up to about 3° (5 %), where work can be done in any direction,

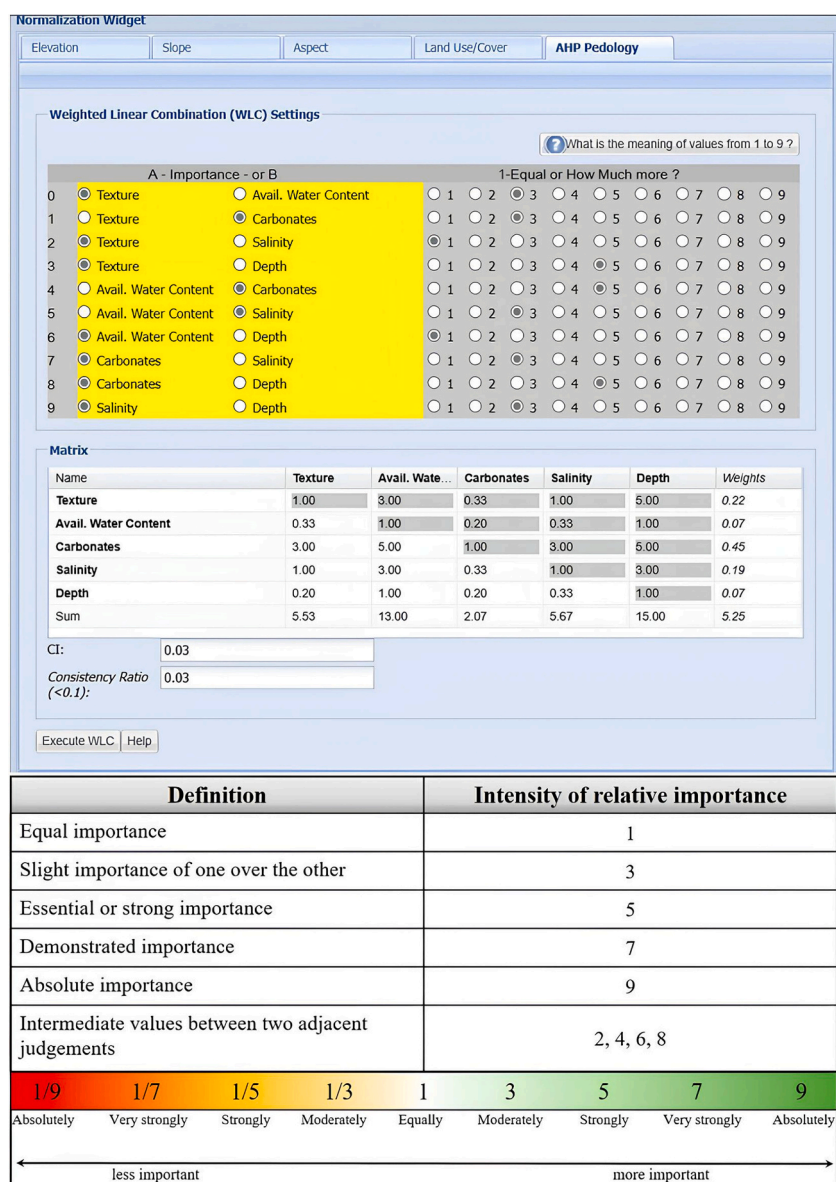


Fig. 5. A screenshot of the WebGIS Suitability Olive / MC-SDSS platform displaying the Weighted Linear Combination box at the top. The matrix box containing the scores for each factor is at the bottom, and the obtained consistency ratio is also shown. Saaty's scale for pairwise comparison is presented below. (For the interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article)

steeper inclinations (6°, or 10 %) necessitate management measures to protect the soil (Messina and Modica, 2022a). When slopes exceed 17° (i.e., 30–40 %), terracing should be employed, with increased costs and difficulties in mechanization justifiable only in exceptional cases, such as the production of olive oils in renowned regions that can command very high prices or the necessity to consolidate slopes (Modica et al., 2017; Rallo et al., 2013). Reasons that consider the difficulties of managing all the cultivation operations in the olive grove on steep slopes likely justify the optimal slope values indicated in the responses of no more than 10°. The opposite would inevitably result in a greater need for labor to compensate for the inability to mechanize certain operations and/or a greater expenditure of time to complete them, leading to more significant expenses for the farmer (Bernardi et al., 2018, 2021; Metzidakis et al., 2008).

Regarding the aspect of the area where the olive grove is located, within a range of 90° to 270°, although with minor variations, the experts unanimously preferred an optimal southward aspect for olive groves. The findings indicate that southern, western, and eastern

exposures are the best, ensuring good yields in both quantity and quality. In contrast, northern exposure is often unsuitable due to significantly reduced light availability, lower thermal levels, and an increased risk of pest attacks (International Olive Council, 2007).

Regarding the reclassification of LU/LC, permanently irrigated arable areas (LU/LC code 212) received significant consideration for olive cultivation, given the growing importance of irrigation (Mairech et al., 2021; Xiloyannis et al., 2012). Considerations were also made regarding the reclassification of lands occupied by vineyards (LU/LC 221), fruit orchards (LU/LC code 222), and citrus groves (LU/LC code 223), excluding the regional vocation in the production of various tree crops. Concerning the reclassification of woody crop plantations (LU/LC code 226), complex cultivation patterns, lands used for agriculture with areas of natural vegetation (LU/LC code 242 and 243, respectively), natural grassland (LU/LC code 321), bushes and shrubs (LU/LC code 322), and sclerophyllous vegetation (LU/LC code 323), the varied responses from experts, due to the breadth and diversity of expertise, are likely attributable to a lack of complete knowledge and familiarity with

AHP OLIVE Consistency calculation

Weighted Linear Combination (WLC) Settings

What is the meaning of values from 1 to 9 ?

A - Importance - or B

1-Equal or How Much more ?

1 2 3 4 5 6 7 8 9

1 ☐ Elevation ☒ Slope ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☒ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

2 ☒ Elevation ☐ Aspect ☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

3 ☐ Elevation ☐ Land Use/Land Cover(LU/LC) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

4 ☒ Elevation ☐ Pedology ☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

5 ☒ Slope ☐ Aspect ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☒ 7 ☐ 8 ☐ 9

6 ☒ Slope ☐ Land Use/Land Cover(LU/LC) ☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

7 ☒ Slope ☐ Pedology ☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

8 ☐ Aspect ☒ Land Use/Land Cover(LU/LC) ☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

9 ☐ Aspect ☐ Pedology ☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

10 ☐ Land Use/Land Cover(LU/LC) ☒ Pedology ☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9

Matrix

Name	Elevation	Slope	Aspect	Land Use/...	Pedology	Weights
Elevation	1.00	0.20	2.00	2.00	2.00	0.18
Slope	5.00	1.00	7.00	4.00	2.00	0.46
Aspect	0.50	0.14	1.00	0.33	0.33	0.06
Land Use/Land Cover(LU/LC)	0.50	0.25	3.00	1.00	0.33	0.11
Pedology	0.50	0.50	3.00	3.00	1.00	0.19

Consistency Ratio (CR): 0.08

Execute WLC Help

Agrifoodtech Widget

Configuration

AHP OLIVE Consistency calculation

Normalized Matrix

Name	Elevation	Slope	Aspect	Land Use/...	Pedology	Autovector
Elevation	0.133	0.096	0.125	0.194	0.353	0.180
Slope	0.667	0.478	0.438	0.387	0.353	0.464
Aspect	0.067	0.068	0.063	0.032	0.059	0.058
Land Use/Land Co...	0.067	0.119	0.188	0.097	0.059	0.106
Pedology	0.067	0.239	0.188	0.290	0.176	0.192
Sum	1.000	1.000	1.000	1.000	1.000	1.000

Lambda: 5.373

CI: 0.093

RI: 1.12

CR (< 0.1): 0.083

Close

Fig. 6. A screenshot of the WebGIS Suitability Olive / MC-SDSS platform displays the AHP Widget panel above the Weighted Linear Combination box. At the bottom, the matrix box presents the scores for each factor. The second screenshot illustrates a normalized matrix within the consistency calculation panel.

the classes being reclassified. Overall, a more significant consensus was noted in the reclassification of olive groves in regions already occupied by tree crops compared to those designated for other crops. Likewise, classes identifiable as populated by marginal crops, scattered vegetation, and grasslands with little or moderate human influence were deemed not entirely appropriate for olive cultivation by half of the experts.

As for the five pedology sub-factors (i.e., texture, salinity, depth, AWC, and carbonate content), experts consider texture to be significantly more important than other factors, such as soil depth, carbonate presence, and salinity. Texture refers to the composition of the soil, expressed as the ratio of particles of various sizes that compose it. The most suitable soils for olive growing maintain a balance between sand, silt, and clay. Predominantly sandy soils have a low capacity for retaining water and mineral elements but provide excellent soil aeration. Additionally, clay content should not exceed 40–45 % to prevent issues with air circulation, water stagnation, and soil management challenges. Soils with high clay content impede the movement of nutrients like phosphorus and potassium, making mechanical mixing of fertilizers essential. Consequently, losses are significantly reduced (Palese et al., 2012).

When considering soil depth, it is essential to note that the olive tree's root system primarily extends within the first 50–70 cm of soil, with some roots reaching deeper than 1 m for additional water supply. (International Olive Council, 2007). Therefore, the soil must be optimal in texture, structure, and composition to a depth of at least 1 m. Economically viable modifications to soil depth are possible only when the constraints imposed by compacted horizons can be addressed through excavation (Fiorino, 2018). Carbonates promote the formation of soil structure by providing calcium and magnesium, the content of which is expressed as the percentage of calcium carbonate (CaCO₃). While necessary for nutritional purposes, excess amounts (not exceeding 50–60 %) can lead to surface crusting, pH elevation, and the insolubilization of Fe and P (Perelli et al., 2009). Tolerant olive varieties should be selected in areas with high lime content and a pH level exceeding 8. In soils where the pH exceeds 8.3, the presence of sodium carbonate hinders clay flocculation and particle structuring, resulting in hard, asphyxiated, and impermeable soil. This condition typically occurs in arid climates with little or no runoff and where soluble salts rise from deep layers due to intense evaporation (Chartzoulakis, 2005). In soils where the concentration of dissolved salts in the circulating solution, such as sulfates and chlorides, is high, root uptake becomes challenging

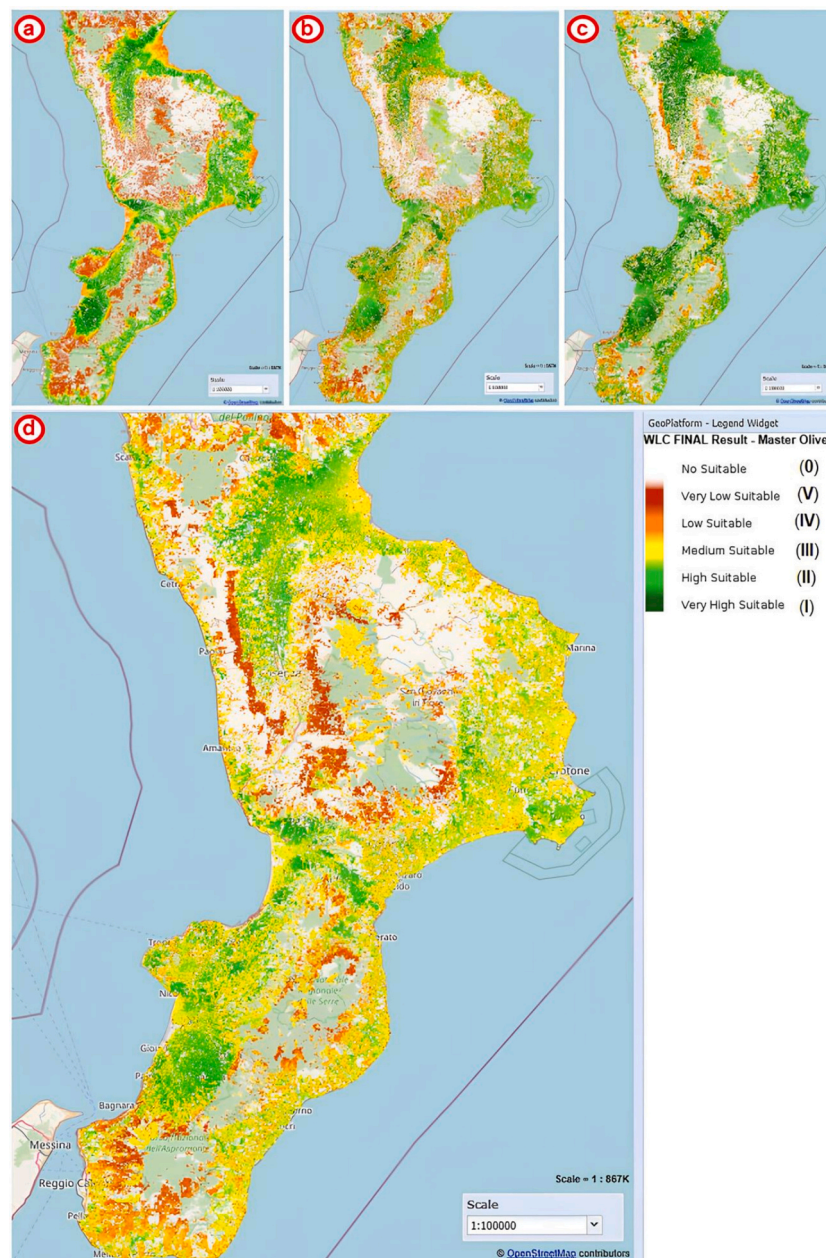


Fig. 7. The top screenshot shows the WebGIS Suitability-Olive / MC-SDSS platform, which includes three final maps from three experts (a-b-c). The screenshot at the bottom shows the final suitability map (d) produced based on the opinions of the 15 experts questioned.

(International Olive Council, 2007). The response to salinity is influenced by growing conditions, including climate and soil factors, agronomic and irrigation management, olive cultivar, and its sensitivity at various growth stages (Chartzoulakis, 2005). In this regard, the olive is a moderately salt-tolerant plant (Rugini and Fedeli, 1990). When the electrical conductivity of the soil, which measures the concentration of salts, exceeds 4 dS/m, negative effects start to emerge; at levels of 10–15 dS/m, they become significant, with production declines ranging from 25 to 50 % (International Olive Council, 2007). In addition, high salinity causes a decrease in fruit weight and an increase in the moisture content of fruits (Stefanoudaki, 2004).

Considering the importance of water and the increasingly frequent water crises during warmer seasons, experts have focused on AWC as a critical parameter. AWC, which represents the amount of water that can be stored in a soil profile and be available for plants, depends on soil texture and structure. In marginal soils, absorptive roots can reach the

first 50 cm, while in deep soils, they can extend to 2–3 m (Gucci, 2012; Therios, 2009). The limited availability of water in the Mediterranean basin, particularly in arid countries experiencing high rates of population growth, urbanization, and industrialization, can be a major factor restricting agricultural development (Chartzoulakis, 2005). Although the olive tree is considered one of the best-adapted species and can tolerate high levels of water stress, its shoot growth and fruiting may be impacted under extreme climate and water conditions. Olive cultivation heavily relies on the effective use of winter and spring rainfall for productivity (Fraga et al., 2020). Considering the already known problems that the Mediterranean area (historically characterized by an amount of rainfall ranging from 150 to 800 mm year⁻¹) is facing due to climate change affecting temperature and rainfall (Maesano et al., 2021; Norrant and Douguédroit, 2006; Orlandi et al., 2020), alternative strategies to irrigation are represented by a series of arrangements to reduce plant water stress such as careful weed control, fewer olive trees per hectare

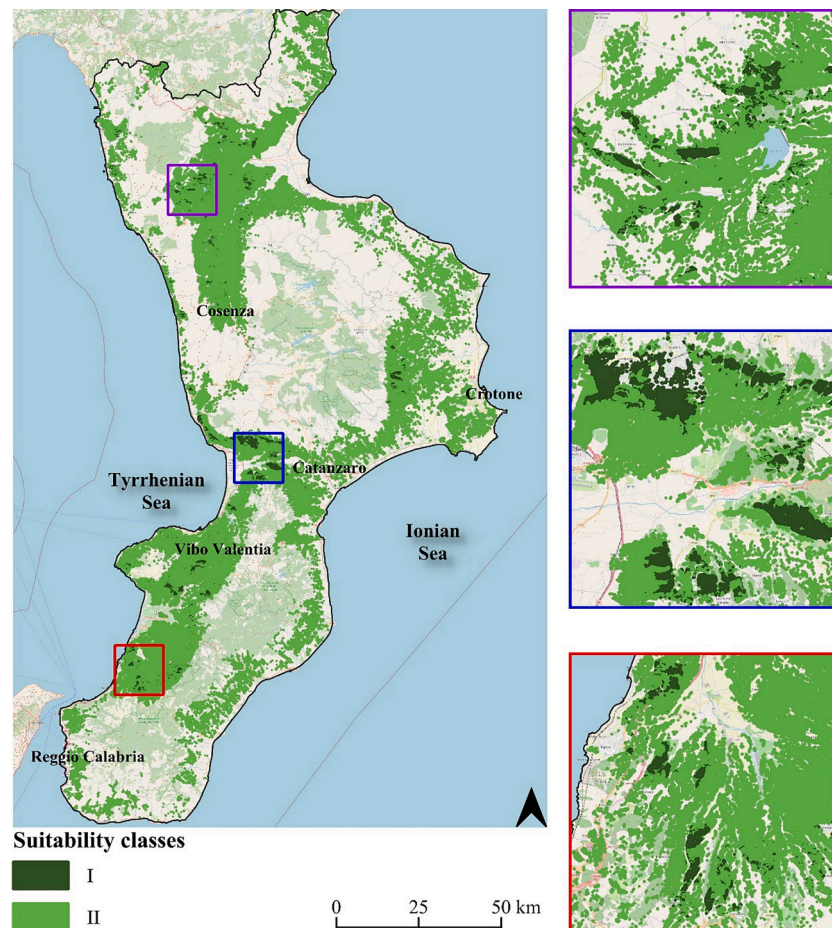


Fig. 8. Map showing the two highest suitability classes (I - very high suitable, in dark green, and II - high suitable, in light green), with ranges >85 % and 75–85 %, respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

and adequate pruning intensity (Fraga et al., 2020; Popolizio et al., 2023; Rallo et al., 2013).

In comparing the five factors- elevation, slope, aspect, LU/LC, and pedology- using the pairwise comparison technique, it should be noted that elevation and slope have been given increasing importance compared to the other parameters. The same applies to pedology and LU/LC when compared to aspect. The benefits of the proposed methodology relate to an objective analytical procedure aimed at highlighting the richness and relevance of the information provided by the indicators. It also offers an opportunity to exclude irrelevant indicators with low weights. Moreover, the evaluation process using spatially explicit data and mapping presents significant potential for communication and visualization of results during the decision-making process. This is achieved by generating a comprehensive picture of the spatial patterns of the landscape and its multifunctional features.

The final suitability map reveals that only 13.11 % of suitable areas fall within the top two suitability classes (i.e., high suitable and very high suitable). These classes represent the best areas for sustainable olive cultivation in the Calabria Region. Therefore, these areas should be prioritized for protection and investment to enhance regional olive productivity, safeguarding them from disruptive anthropogenic factors, such as soil sealing, as well as natural threats like wildfires. Less than 25 % (24.05 %) of Calabrian olive groves are located in the highest quality areas (classes I and II). To promote sustainable management, decision-makers need to focus on strategies to increase the percentage of olive groves in these quality areas. The implementation of the MC-SDSS approach, as outlined in this research, serves as an effective tool to improve the decision-making process in landscape planning and

management, specifically targeting the identification and enhancement of areas considered crucial for cultivating Calabrian olive groves.

Several authors combined MCDA, AHP, and GIS analysis to assess suitability for different agricultural contexts. D'Antonio et al. (2025) proposed an integrated use of MCDA techniques, AHP, and GIS analysis considering variables such as temperature, soil texture, slope, elevation, and contents of nutrients to assess suitability for grapevines. Mushtaq et al. (2023) combined MCDA and GIS to highlight the suitable areas for mulberry agroforestry considering factors such as LU/LC, slope and physical and chemical soil properties. Seyedmohammadi et al. (2018, 2019a) implemented MCDA and GIS to improve an LSE method for planning crop priorities for rape, maize, barley, and soybean. Seyedmohammadi et al. (2019b) and Seyedmohammadi and Navidi (2022) exploited fuzzy set theory, analytic network process combined with RS and GIS to evaluate the suitability of irrigated maize and wheat. Sabljic et al. (2024) presented an integrated approach of GIS and AHP considering pedology, elevation, LU/LC, distance from rivers and aridity indices to assess agricultural suitability in a river basin in Bosnia and Herzegovina. Similar approaches have also been used for maize, rice, wheat, and coffee (Liu et al., 2025; Wang et al. (2023)). However, these authors just presented the results of their analysis without implementing a web-based MC-SDSS. To our knowledge, there are few platforms similar to the present one, and most are not about the LSE for olive growing. Lombardi et al. (2017) developed an MC-SDSS tool for identifying and evaluating alternative energy urban scenarios. Cerreta and Poli (2017) tested a GIS-based evaluation methodology for identifying, quantifying, and assessing multi-functional landscape features. Agrawal et al. (2024) proposed measuring land suitability for crops by

integrating the AHP MCDA method, GIS, and ensemble-based machine learning techniques considering soil, topography, and environmental parameters. Hussain et al. (2024) proposed identifying a suitable area for the growth of agriculture using AHP and GIS technology and analyzing soil parameters and LU/LC changes. The approach of Romano et al. (2015) generated a suitable composite map using GIS–MCDA techniques, emphasizing the effects of environmental, socio-economic, and territorial management features with the aim to identify sites where structural measures could support socio-economic interventions based on rural tourism, which integrates the use of agricultural, natural, and architectural resources. The work of Bilgilioglu (2021) was similar in objectives to the present work as the aim was, with the help of AHP–GIS integration, to determine the agricultural lands suitable for olive cultivation in the Mediterranean city of Mersin, Turkey. However, despite having similar approaches and methodologies, it was not based on using a WebGIS platform as in the case of *Suitability-Olive*. In other scientific works, WebGIS platforms were developed for SDSS, not just for agriculture. Krügel et al. (2024) presented a web application for supporting and planning decisions in the framework of public service infrastructures. Coutinho-Rodrigues et al. (2011) implemented an SDSS prototype to plan and analyze a large-scale urban infrastructure investment decision. Zhang et al. (2019) showed a cyber GIS-enabled MCSDSS, which can be exploited in flood emergency management. Manna et al. (2020) developed the open-source Geospatial Cyberinfrastructure platform *GeOlive*, supporting the acquisition, management, and processing of both static and dynamic data such as pedologic and daily climate, data visualization to support olive grove planning and management, and providing operational assistance for farmers. To our knowledge, no other works combine using a WebGIS platform to process MCDA for LSE in olive growing, making data available and usable for the public for free through a simple and user-friendly graphical interface.

5. Conclusions

In this study, a Web-based MC-SDSS designed for performing LSE was exploited to conduct spatial and environmental analyses, support decision-making processes, and identify areas most suitable for sustainable olive cultivation growing.

In this research, a significant effort was made to select a robust and sufficiently large panel of experts to produce the final land suitability map for olive cultivation in the Calabria region. The platform can be easily duplicated and the same dataset can be used to implement an LSE for other crops grown in the region. This also enabled testing the robustness, flexibility, and ease of use of the proposed web-based MC-SDSS.

The final suitability map enabled us to identify the most suitable areas for sustainable olive cultivation. By following the outlined procedure, we simulated the entire decision-making process leading to the LSE, highlighting 109,595.10 ha as the most suitable areas, of which only 46,912.17 ha (less than 43 %) are currently occupied by olive groves. Finally, all the geospatial data and analyses produced are shared with stakeholders and decision-makers to support the planning process and ensure easy and free accessibility for all users (Guest level). FOSS4G can promote the concept of the information society and sustainable spatial development by providing data in a user-friendly format that will be user-friendly, interpreted, ready for digital processing, and easily upgradeable (Burdziej, 2012).

From the earliest stages of its development, the proposed platform was conceived and designed as an open and spatially explicit tool to assist decision-makers in implementing operational sustainable landscape planning. This tool aims to support more complex planning processes that involve multi-temporal and multi-actor approaches needed to evaluate various alternatives and propose different sustainable solutions from environmental and landscape perspectives.

A potential drawback of the proposed method is related to the involvement of experts in the production of suitability maps. The

improper choice of experts represents a limit of the described methodology, because experts with different scientific and/or technical backgrounds produce different suitability maps. Another aspect to be considered is that experts should be trained about AHP methodology and about the use of the platform (in our proposed experience we organized a two hours training seminar with the all involved experts).

As a future development, the platform will be updated and improved by migrating the application to a more flexible geospatial content management system such as GeoNode (<https://geonode.org>, last access 20 December 2024). This migration will allow for the implementation of additional features, such as – for example – suitable graphs and reports. Furthermore, this flexibility enables the addition of more geospatial layers, for example, those uploaded by an expert, and the management of more variables to allow for expert judgment and produce a more accurate suitability map. It is worth noting that GeoNode has also been utilized by various researchers across different domains, such as precision agriculture (Jeppesen et al., 2016), long-term ecological research (Lanucara et al., 2017), and geology (Buonanno et al., 2019). This enables various degrees of customization in its functionalities while preserving geospatial management content capabilities and OGC standard interoperability.

CRedit authorship contribution statement

Giuseppe Modica: Writing – review & editing, Writing – original draft, Visualization, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Maurizio Pollino:** Writing – review & editing, Writing – original draft, Validation, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Gaetano Messina:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Simone Lanucara:** Writing – review & editing. **Salvatore Praticò:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation.

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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.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.agry.2025.104375>.

Data availability

User “Guest level” demo is accessible by inserting the following credentials, User “evaluator50” and Password “evaluator50” in the following link: <https://apic.casaccia.enea.it/DemoSuitability/BaseApp.html>.

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