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LAND SUITABILITY ASSESSMENT FOR SUNFLOWER USING GIS IN SIC (CLUJ COUNTY)

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Abstract. *This study presents an integrated geospatial analysis of land suitability for sunflower cultivation in Sic locality (Cluj County, Romania), using GIS techniques and data derived from satellite imagery and digital elevation models. The main objective is to identify and map optimal agricultural areas by considering a set of key environmental and pedological factors, including soil type and texture, terrain slope, groundwater depth, erosion risk, and relief characteristics. The methodology involves the integration of thematic spatial datasets within a GIS environment, followed by the extraction of morphometric parameters such as slope and terrain configuration from a digital elevation model. Soil texture and type are analyzed using available pedological maps, while erosion susceptibility is assessed through terrain analysis and spatial modeling. Groundwater depth is incorporated as a limiting factor, given the sensitivity of sunflower crops to excessive soil moisture conditions. A multi-criteria evaluation approach based on the Weighted Overlay method is applied to combine all influencing factors and to classify the study area into different suitability classes. The resulting maps highlight spatial patterns of highly suitable, moderately suitable, and unsuitable areas for sunflower cultivation. The results demonstrate the effectiveness of GIS-based approaches in agricultural land assessment and provide valuable decision-support tools for sustainable land management, crop planning, and erosion risk mitigation in rural environments.*

Keywords: *GIS, sunflower, groundwater*

INTRODUCTION

Land suitability assessment for sunflower cultivation represents an important step in agricultural planning and in the efficient use of soil and land resources. Sunflower development is influenced by several natural factors, including soil units, soil texture, relief, erosion, groundwater depth, and the general suitability of arable land. This study was carried out for the Sic area, Cluj County, using **Python scripts integrated with ArcGIS Pro geoprocessing tools**. The analysis was based on several thematic polygon layers, which were processed, reclassified, and combined in order to determine the most suitable areas for sunflower cultivation.

Each thematic layer was assigned a suitability score according to its influence on sunflower crop development. The scoring and spatial processing steps were automated in Python using the ArcPy library from ArcGIS Pro. A weighted multicriteria analysis was then applied, with weights defined according to the pedological and agronomic importance of each factor. [1] The resulting map was classified into five suitability classes, ranging from **not suitable** to **very high suitability**. In addition, the final suitability map generated through the Python–ArcGIS Pro workflow was compared with the existing land evaluation map in order to identify areas of agreement and areas with classification differences. This approach highlights the usefulness of combining GIS tools and Python automation for spatial agricultural suitability assessment.

MATERIAL AND METHOD

The study was conducted in the Sic area, Cluj County, Romania, with the aim of identifying the most suitable areas for sunflower cultivation using GIS analysis and Python automation in ArcGIS Pro. The spatial data used in this study were provided by OSPA Cluj and consisted of several thematic polygon layers representing the main pedological and environmental factors that influence sunflower development. These layers included soil units, soil texture, relief, erosion, groundwater depth, and arable land suitability. All spatial datasets were processed in ArcGIS Pro and projected to a common coordinate reference system in order to ensure spatial consistency during the analysis. [2]

The methodological workflow was implemented using Python scripts and the ArcPy library. First, each thematic layer was checked, cleaned, and prepared for spatial analysis. The relevant attribute fields were used to assign suitability scores to each factor. [3] The scores ranged from low to high suitability, according to the influence of each factor on sunflower cultivation. [4] After the reclassification stage, a weighted multicriteria analysis was applied. Each factor received a specific weight based on its pedological and agronomic importance. Soil units and soil texture were assigned the highest weights, as they have a major influence on crop development. Relief, erosion, groundwater depth, and arable land suitability were included as additional conditional or restrictive factors. [5]

The final suitability score was calculated using the following weighted formula:

Final score =Soil units × 0.35 +Soil texture × 0.25 +Relief × 0.10 +Erosion × 0.10 +Groundwater depth × 0.10 +Arable land suitability × 0.10. The resulting values were classified into five suitability classes: not suitable, low suitability, moderate suitability, high suitability, and very high suitability.

Finally, the suitability map generated through the Python–ArcGIS Pro workflow was compared with the existing land evaluation map. This comparison was carried out by intersecting the two polygon layers and calculating the difference between the calculated class and the reference class. The differences were grouped into three categories: exact agreement, one-class difference, and difference of two or more classes. This workflow allowed both the automated generation of the final sunflower suitability map and the evaluation of its agreement with the reference land evaluation data.

RESULTS AND DISCUSSION

The GIS-based workflow developed in this study enabled the integration of several pedological and environmental factors relevant for assessing land suitability for sunflower cultivation in the Sic area, Cluj County. The spatial database included thematic layers related to soil units, soil texture, relief, erosion, groundwater depth, arable land suitability, and existing sunflower suitability classes. These datasets, provided by OSPA Cluj, were processed in ArcGIS Pro using Python scripts, which allowed the automation of the main geoprocessing operations, including data preparation, score assignment, weighted overlay analysis, final classification, and spatial comparison. A key stage of the analysis consisted of assigning suitability scores to each input factor. This step allowed the transformation of qualitative or categorical pedological information into comparable numerical values. The scoring system reflected the relative influence of each factor on sunflower crop development. Soil units and soil texture were considered the most important criteria, as they directly affect root development, water retention, nutrient availability, and overall crop productivity. Relief, erosion, groundwater depth, and arable land suitability were included as additional factors that may either support or restrict agricultural use depending on local conditions.

The weighted overlay model combined all reclassified layers into a single suitability score. The applied weights were established according to the pedological and agronomic relevance of each factor, with soil units and soil texture receiving the highest importance. This approach made it possible to generate a spatially explicit suitability model, in which each polygon received a final score based on the combined influence of all selected criteria. The resulting map was classified into five suitability classes: **not suitable**, **low suitability**, **moderate suitability**, **high suitability**, and **very high suitability**. The final classification shows the spatial variability of the agricultural potential for sunflower cultivation within the study area. Areas classified as highly or very highly suitable correspond to locations where the combination of soil characteristics, texture, relief conditions, erosion intensity, and groundwater depth is favorable. In contrast, areas with lower suitability are generally associated with limiting factors such as less favorable soil units, restrictive relief conditions, higher erosion risk, or unsuitable groundwater depth.

The comparison between the calculated suitability map and the existing sunflower suitability classes highlighted both areas of agreement and areas with classification differences. Areas of agreement indicate that the GIS-based weighted model produced results consistent with the reference land evaluation data. Differences between the two maps may be explained by the different methodological approaches. The reference suitability map represents an integrated pedological assessment, while the map generated in this study is based on a multicriteria GIS model with explicitly defined scores and weights. Therefore, these differences should not be interpreted only as errors, but also as an indication of the sensitivity of the results to the selected criteria, scoring system, weighting scheme, and classification thresholds. Overall, the results demonstrate that the integration of Python scripting with ArcGIS Pro provides a reproducible and efficient approach for agricultural land suitability assessment. The proposed workflow allows rapid processing of multiple spatial layers, transparent application of scoring and weighting rules, and objective comparison with existing evaluation maps. This methodology can be adapted for other crops or study areas by modifying the input factors, suitability scores, weights, and classification thresholds according to specific agronomic requirements.

Figure 1 presents two stages of the soil unit analysis used in the land suitability assessment for sunflower cultivation. The map on the left shows the initial spatial distribution of soil units within the study area. Each soil unit is represented by a distinct colour and corresponds to a specific pedological category, such as Calcaric Regosol, Fluvisol, Phaeozem, Preluvosol, Gleysol/Solonetz, Erodic Anthrosol, or degraded and eroded soils. This map provides the primary pedological information and highlights the spatial heterogeneity of soil conditions in the Sic area.

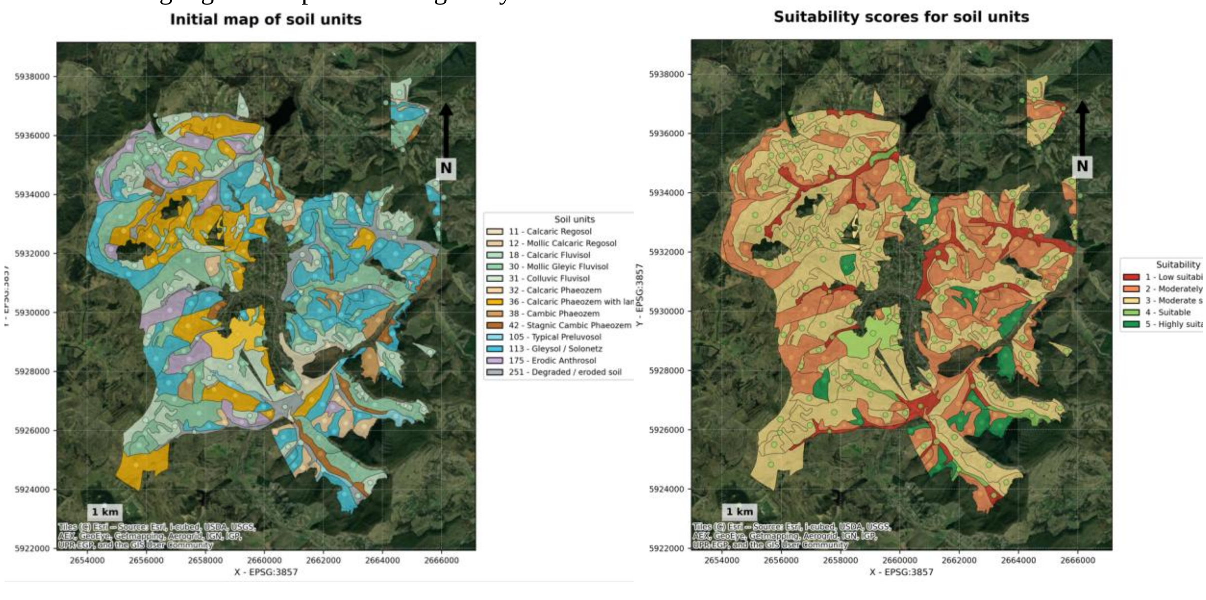

Figure 1. Initial soil unit map (left) and reclassified suitability score map for sunflower cultivation (right)

The map on the right illustrates the reclassification of the initial soil units into suitability scores for sunflower cultivation. In this stage, each soil unit was assigned a numerical score according to its agronomic suitability, ranging from low suitability to highly suitable conditions. This transformation converts the categorical soil information into comparable quantitative values that can be integrated into the weighted multicriteria GIS model. The comparison between

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the two maps shows the transition from the original pedological dataset to a suitability-based representation. While the initial soil unit map describes the spatial distribution and diversity of soil types, the suitability score map expresses the relative potential of these soils for sunflower cultivation. Areas classified with higher scores indicate soil units with more favourable properties for crop development, whereas lower scores correspond to soil units affected by limiting conditions such as erosion, poor drainage, or reduced agricultural potential. Therefore, the reclassification of soil units represents an essential step in the modelling process, as it allows the integration of pedological information into the final land suitability assessment. This procedure supports a more objective evaluation of the role of soil characteristics in determining the spatial variability of sunflower suitability.

Figure 2 presents the initial erosion map and its reclassification into suitability scores for sunflower cultivation. The map on the left shows the spatial distribution of erosion types within the study area. The dominant category is **slightly eroded soil**, which occupies most of the analysed territory, while areas affected by **excessive erosion**, **strongly eroded soil**, and **deep erosion** occur more locally.

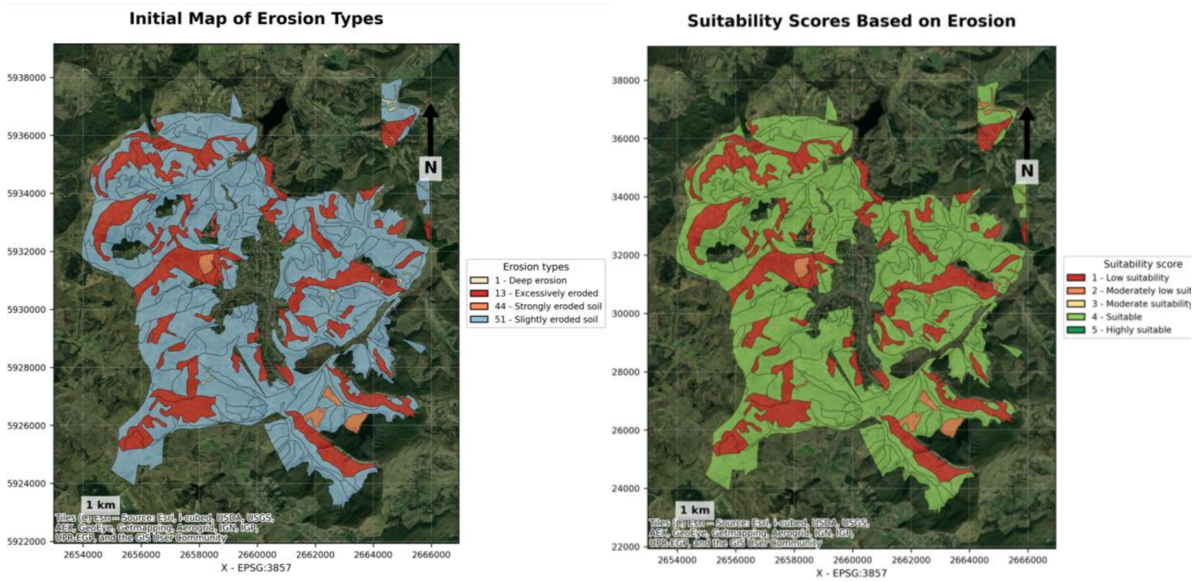

Figure 2. Initial map of erosion types (left) and suitability scores based on erosion intensity (right)

The map on the right illustrates the transformation of erosion classes into suitability scores. Areas with slight erosion were assigned higher suitability values, as they present fewer limitations for agricultural use. In contrast, zones affected by excessive or strong erosion received lower suitability scores, reflecting their restrictive influence on sunflower cultivation. These areas are mainly associated with reduced soil stability, potential loss of fertile topsoil, and lower agricultural productivity. The comparison between the two maps highlights the role of erosion as a limiting factor in the suitability model. While the initial map describes the erosion types, the reclassified map expresses their relative impact on sunflower cultivation. This transformation allowed the erosion layer to be integrated into the weighted multicriteria GIS model together with the other environmental and pedological factors.

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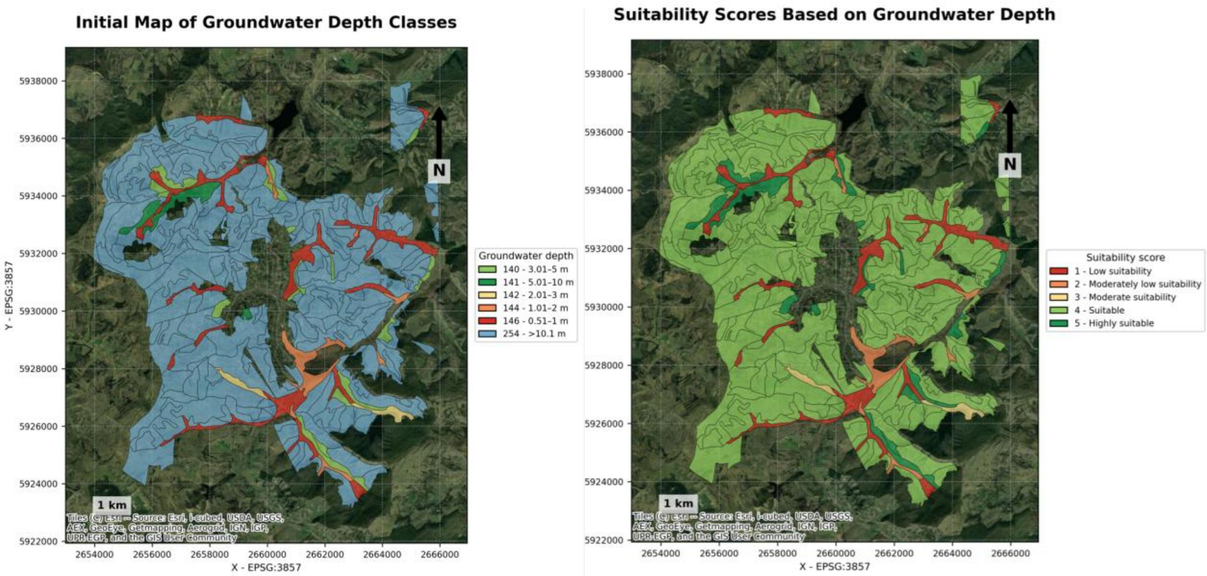

Figure 3. Initial map of groundwater depth classes (left) and suitability scores based on groundwater depth (right)

Figure 3 presents the initial groundwater depth classes and their reclassification into suitability scores for sunflower cultivation. The map on the left shows the spatial distribution of groundwater depth within the study area. Most of the territory is characterized by groundwater depths greater than **10.1 m**, while shallower groundwater classes occur locally, especially along narrow elongated areas and valley zones.

The map on the right illustrates the transformation of groundwater depth classes into suitability scores. Areas with groundwater depths between **3.01–5 m** and **5.01–10 m** were assigned higher suitability scores, as these conditions are considered more favourable for sunflower cultivation. In contrast, areas with very shallow groundwater, especially **0.51–1 m** and **1.01–2 m**, received lower suitability scores because excess moisture can negatively affect root development, soil aeration, and crop productivity.The comparison between the two maps highlights the importance of groundwater depth as a conditional factor in the suitability model. While the initial map describes the spatial distribution of groundwater classes, the reclassified map expresses their influence on sunflower cultivation. The areas with lower suitability are generally concentrated in narrow zones, whereas most of the study area presents moderate to high suitability according to groundwater depth This reclassification allowed the groundwater depth layer to be integrated into the weighted multicriteria GIS model together with the other pedological and environmental factors.

Figure 4 presents the initial relief type map and its reclassification into suitability scores for sunflower cultivation. The map on the left shows the spatial distribution of the main relief categories in the study area, including long uneven slopes, short uniform slopes, short uneven slopes, long uniform slopes, and low alluvial plains. These relief units are unevenly distributed across the analysed territory and reflect the local geomorphological variability. The map on the right illustrates the transformation of relief types into suitability scores. Relief categories considered more favourable for agricultural use, such as low alluvial plains and more uniform slope areas, were assigned higher suitability values. In contrast, uneven or more restrictive slope conditions received lower scores, as they may influence soil stability, water runoff, erosion susceptibility, mechanization, and crop development.

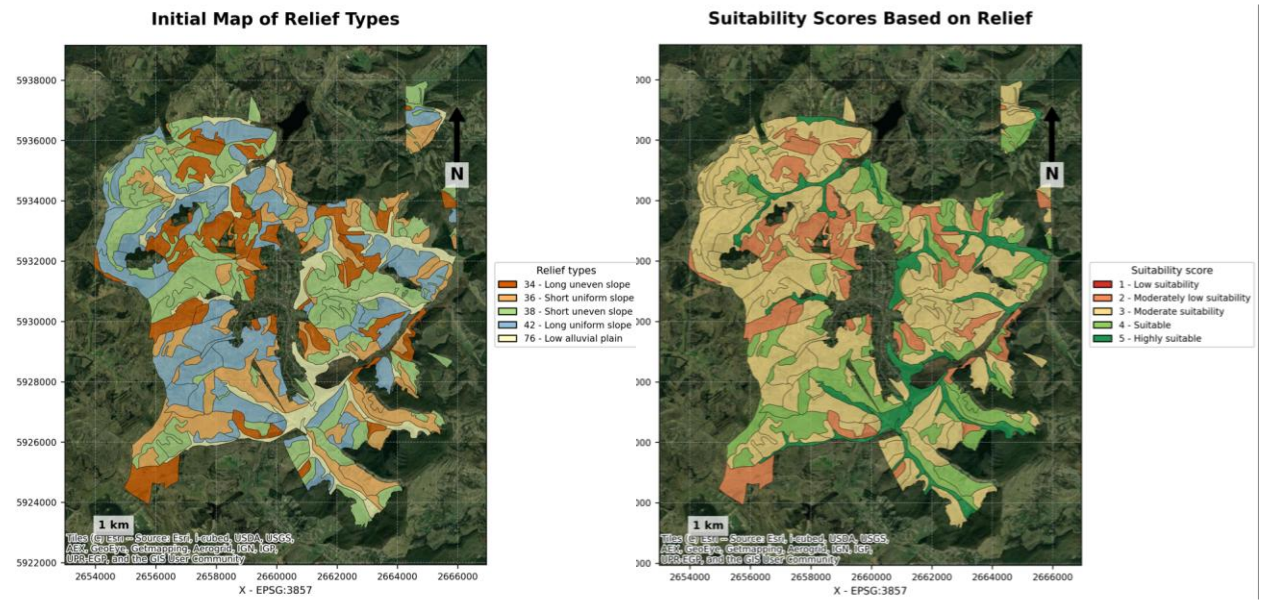

Figure 4. Initial map of relief types (left) and suitability scores based on relief conditions (right)

The comparison between the two maps highlights the role of relief as a conditional factor in the land suitability model. While the initial map provides geomorphological information, the reclassified map expresses the relative influence of relief conditions on sunflower cultivation. Areas with high suitability are mainly associated with more stable and accessible terrain, whereas lower suitability classes occur in zones where slope configuration may limit agricultural use. This reclassification was necessary in order to convert the qualitative relief information into numerical suitability scores, allowing its integration into the weighted multicriteria GIS model together with soil units, soil texture, erosion, groundwater depth, and arable land suitability.

Figure 5 presents the initial soil texture map and its reclassification into suitability scores for sunflower cultivation. The map on the left shows the spatial distribution of the main soil texture classes within the study area. Three texture categories are represented: loamy-sandy texture, clay-loamy texture, and loamy-clayey texture. These classes are unevenly distributed across the territory, reflecting the spatial variability of soil physical properties. The map on the right illustrates the transformation of soil texture classes into suitability scores. Soil textures considered more favourable for sunflower cultivation were assigned higher suitability values, while less favourable textures received lower scores. In this case, loamy-sandy and loamy-clayey textures generally show higher suitability, whereas clay-loamy texture appears more restrictive in some areas.

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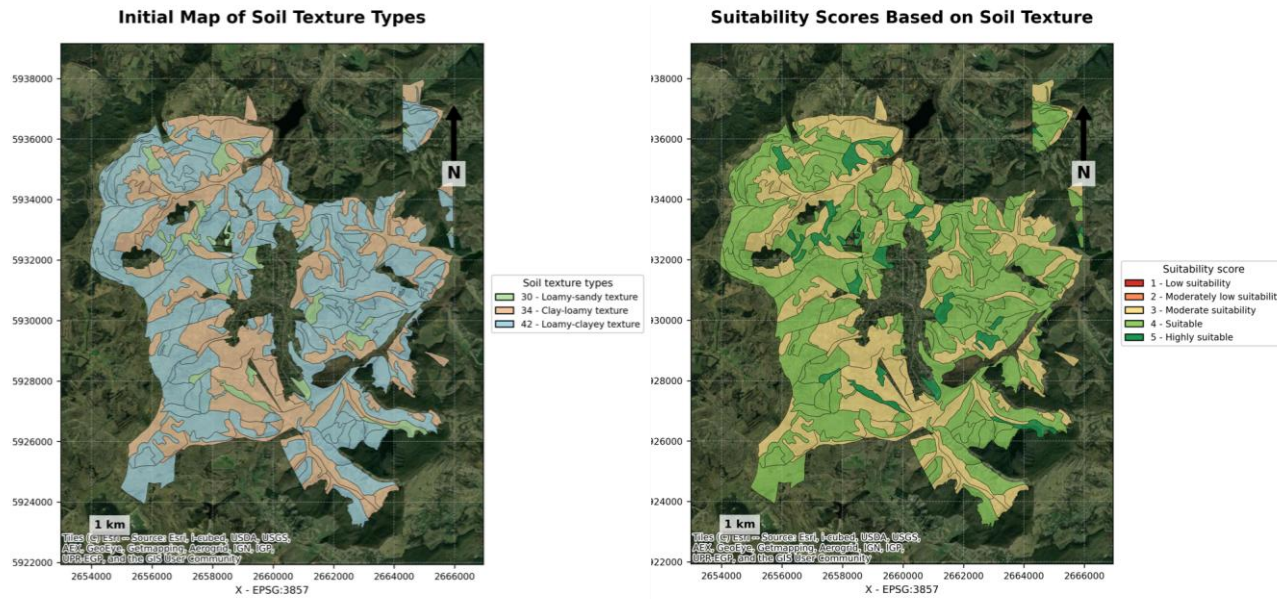

Figure 5. Initial map of soil texture types (left) and suitability scores based on soil texture (right)

The comparison between the two maps highlights the importance of soil texture in the suitability assessment. While the initial map describes the spatial distribution of texture types, the reclassified map expresses their relative influence on sunflower crop development. Soil texture affects water retention, soil aeration, root penetration, nutrient availability, and the overall physical conditions required for plant growth. This reclassification step was necessary to convert the qualitative texture information into numerical suitability scores. The resulting score layer was then integrated into the weighted multicriteria GIS model together with soil units, relief, erosion, groundwater depth, and arable land suitability.

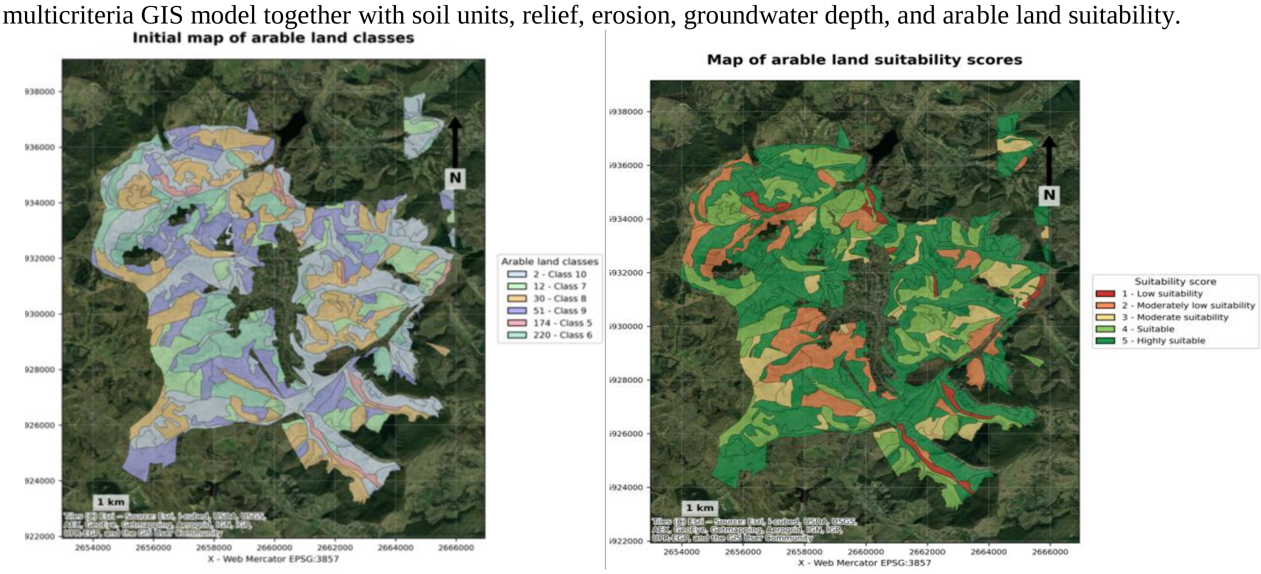

Figure 6. Initial map of arable land classes (left) and arable land suitability scores for sunflower cultivation (right)

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Figure 6 presents the initial arable land class map and its reclassification into suitability scores for sunflower cultivation. The map on the left shows the spatial distribution of arable land classes within the study area. These classes represent different levels of agricultural favourability and are spatially distributed across the territory in a heterogeneous pattern. The map on the right illustrates the transformation of the initial arable land classes into suitability scores. Through this reclassification, each arable land class was converted into a numerical value expressing its relative suitability for sunflower cultivation. Higher scores indicate areas with more favourable agricultural conditions, while lower scores correspond to areas where arable land characteristics may impose limitations on crop development. The comparison between the two maps highlights the role of arable land suitability as an additional factor in the multicriteria model. While the initial map describes the original classification of arable land, the reclassified map expresses its contribution to the final sunflower suitability assessment. Areas classified with high and very high suitability are more favourable for sunflower cultivation, whereas low and moderately low suitability areas indicate zones with more restrictive agricultural conditions. This reclassification step allowed the arable land layer to be integrated into the weighted GIS model together with soil units, soil texture, relief, erosion, and groundwater depth. Although arable land suitability was assigned a lower weight than soil units and soil texture, it contributed to refining the final spatial distribution of suitability classes.

Figure 7 presents the initial sunflower suitability classes and the resulting sunflower suitability score map obtained after GIS-based reclassification. The map on the left shows the initial suitability classes for sunflower cultivation in the study area. These classes represent the reference pedological evaluation and include several initial categories, such as Class 7, Class 8, Class 9, and Class 10.

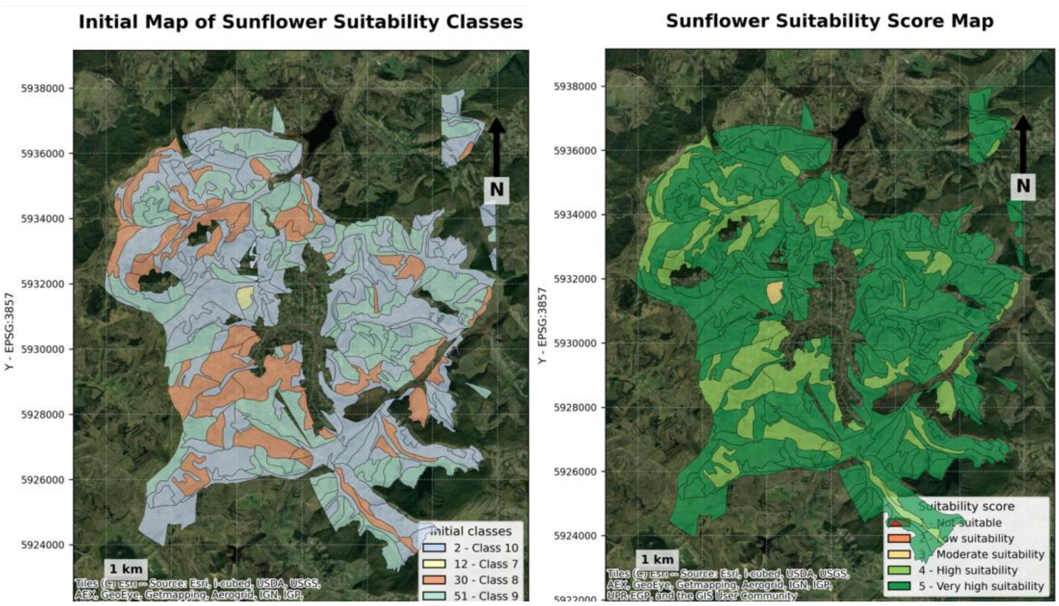

Figure 7. Initial map of sunflower suitability classes (left) and sunflower suitability score map (right)

The map on the right illustrates the reclassified suitability score map. In this stage, the initial sunflower suitability classes were transformed into numerical suitability scores ranging from low suitability to very high suitability. This conversion allowed the reference sunflower suitability information to be expressed in a standardized form and compared with the results obtained through the weighted multicriteria GIS model. The comparison between the two maps highlights the transition from the initial categorical suitability classification to a score-based representation. The initial map shows the spatial distribution of the original sunflower suitability classes, while the score map expresses their relative agricultural

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potential. Areas with higher suitability scores indicate more favourable conditions for sunflower cultivation, whereas areas with lower scores correspond to more restrictive conditions. The reclassified sunflower suitability score layer was used as a reference dataset for comparison with the final suitability map generated through the Python–ArcGIS Pro workflow. This step made it possible to identify areas of agreement and areas where classification differences occurred between the existing pedological evaluation and the GIS-based weighted model.

Figure 8 presents the final outputs of the GIS-based land suitability assessment for sunflower cultivation. The figure includes the calculated suitability map, the sunflower suitability score map, and the comparison map between the calculated model and the reference sunflower suitability layer.

The calculated sunflower suitability map shows the final classification obtained through the weighted multicriteria model. The model integrated six spatial factors: soil units, soil texture, relief, erosion, groundwater depth, and arable land suitability. The applied weights indicate that soil units and soil texture had the highest influence on the final result, while relief, erosion, groundwater depth, and arable land suitability acted as additional conditional or restrictive factors.

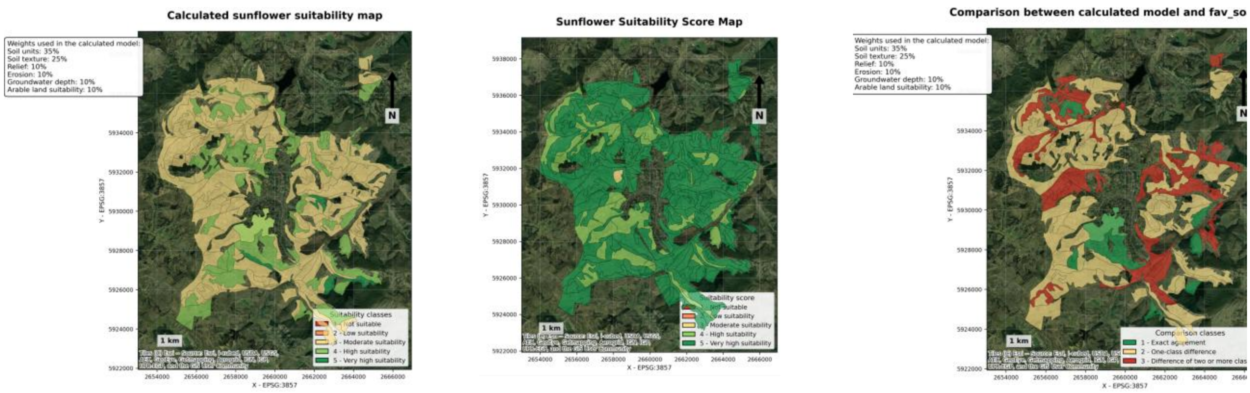

Figure 8. Final suitability assessment for sunflower cultivation and comparison between the weighted GIS model and reference suitability classes

The resulting suitability classes show that moderate suitability occupies a large part of the study area, while high and very high suitability areas are more spatially limited. These favourable areas are mainly located where the combined pedological and environmental conditions are suitable for sunflower cultivation. The low suitability classes occur locally and indicate areas affected by one or more limiting factors. The sunflower suitability score map represents the score-based distribution of suitability values. Compared with the final classified map, this map shows a more favourable distribution, with larger areas classified as high and very high suitability. This difference is related to the scoring and classification procedure: the score map reflects the direct result of the weighted calculation, while the final map applies classification thresholds that provide a more generalized and conservative interpretation. The comparison map highlights the spatial agreement and differences between the calculated model and the reference fav_soare layer. Green areas indicate exact agreement between the two maps, yellow areas show a one-class difference, and red areas indicate a difference of two or more classes. The presence of both agreement and disagreement zones suggests that the GIS-based model generally captures the spatial pattern of sunflower suitability, but the results are sensitive to the selected factors, assigned scores, weights, and classification thresholds.

Overall, the comparison confirms the usefulness of the Python–ArcGIS Pro workflow for generating and validating sunflower suitability maps. The method provides a reproducible approach for agricultural land suitability assessment and can be further adjusted by modifying the weights or classification thresholds according to local agronomic conditions.

CONCLUSIONS

This study demonstrated the applicability of a GIS-based multicriteria approach for assessing land suitability for sunflower cultivation in the Sic area, Cluj County. The integration of thematic spatial layers provided by OSPA Cluj allowed the evaluation of the main pedological and environmental factors influencing sunflower development, including soil units, soil texture, relief, erosion, groundwater depth, and arable land suitability. The use of Python scripts within ArcGIS Pro enabled the automation of the main geoprocessing steps, including data preparation, score assignment, spatial overlay, weighted calculation, final classification, and comparison with the reference sunflower suitability layer. This workflow improved the reproducibility and transparency of the analysis, making it possible to clearly define the contribution of each factor to the final suitability result. The results indicated that soil units and soil texture had the greatest influence on the final suitability score, due to their direct impact on soil fertility, water retention, root development, and crop productivity. Relief, erosion, groundwater depth, and arable land suitability acted as additional conditional or restrictive factors, contributing to the spatial differentiation of suitability classes.

The final suitability map showed that a large part of the study area falls within the moderate suitability class, while high and very high suitability areas are more spatially limited. These favourable areas correspond to zones where the combined soil and environmental conditions are more appropriate for sunflower cultivation. Low suitability areas occur locally and are generally associated with limiting factors such as erosion, restrictive relief conditions, unsuitable groundwater depth, or less favourable soil units.

The comparison between the calculated model and the reference sunflower suitability map highlighted both areas of agreement and areas with classification differences. These differences are mainly related to the methodological distinction between the reference pedological evaluation and the GIS-based weighted multicriteria model. Therefore, they should not be interpreted only as errors, but also as evidence of the sensitivity of the results to the selected criteria, assigned scores, weighting scheme, and classification thresholds.

Overall, the proposed Python–ArcGIS Pro workflow provides a useful and reproducible method for agricultural land suitability assessment. The approach can support decision-making in land-use planning, sustainable agricultural management, and the identification of areas with higher potential for sunflower cultivation. The methodology can also be adapted for other crops or study areas by modifying the input factors, scores, weights, and classification thresholds according to specific agronomic requirements.

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