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A MULTIDISCIPLINARY APPROACH TO THE SUSTAINABLE MANAGEMENT OF AGRICULTURAL LAND AND RURAL RESILIENCE DEVELOPMENT

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Abstract

This research intricately explores the interconnections among biodiversity conservation, climate change, territorial fragmentation, and socio-economic challenges, with a specific focus on the Northwest side of Romania villages. Emphasizing the national importance of discerning land utilization practices, this paper draws on land distribution impact and consolidation. Adopting a multidisciplinary approach, the study integrates specialized studies to unravel the nuanced evolution of land management and rural resilience development. The research, traversing subsequent chapters, elucidates methodological intricacies, conducts a comparative analysis, and globally contextualizes discussed issues, additionally implementing a suitable analysis to develop viable solutions in the global context of land conservation. With a focus on identifying land parcels, ascertaining ownership, and updating land use dynamics the meticulous analysis contributes nuanced insights into sustainable land management. The rural resilience concept is valued by suitable analysis performed using Geographical Information System, which will serve as decision-making factor.

Key words: *biodiversity conservation; land consolidation; rural resilience; suitability analysis; sustainable land management.*

INTRODUCTION

Land is the most precious production factor which assure food for the globe population, life and perenity [12].

The sustainable management of agricultural land is one of the most important aspects of agricultural production and land use planning. Proper land management helps ensure a stable source of income for residents in rural areas, contributes to food security, preserves soil healt, and mitigates environmental degradation in the face of global challenges such as climate change.

Additionaly, land use suitability assessment plays a key role in planning for both agricultural and urban development, helping to optimize land use while balacing economic, environmental and social needs [2, 13].

During the World War II, the concept of development has been increasingly utilized across various domains related to modernization and economic progress.

Numerous theories examine the most effective methods for achieving development; however, a fundamental aspect of sustainable development lies in addressing citizens' perceived needs and resolving issues that directly or indirectly impact their quality of life, resulting high impacts in the demografic results such as history, tradition or economic approach. (Williamson *et al.,* 2010; UNECE, 1996) [16, 14].

Land fund needs to be preserved and that is why important strategies are set up to protect land from degradation and preserve its qualities and fertility [1].

However, land property is the limiting factor in strengthening the agricultural farms [3].

In Romania, moving to the Northwest region, one of the main challenges is the excessive fragmentation of land, a consequence of post-communist restitution policies and successive inheritances [5].

This fragmentation negatively impacts agricultural productivity by hindering mechanization, irrigation, and the establishment of efficient farming operations [9].

Additionally, the absence of coherent policies for land consolidation and sustainable management exacerbates economic and social issues in rural areas, limiting investmentopportunitiesand infrastructure development [15, 4].

Land administration establish ownership, assess land value, and regulate land use, functioning as a driver of economic development supporting agricultural productivity and contributing to sustainable territorial planning [11].

Land used for agriculture looks to be diminished by receiving other destinations in the peri-urban areas [6].

Recent research highlights the interconnections between biodiversity conservation, climate change, territorial fragmentation, and socio-economic challenges, emphasizing the national importance of effective land-use practices.

This paper aimes to develope a strategy of rural resiliencedevelopment, including the importance of accurancy of land parcels, in according with clarification of ownership rights, and continuous assessment of land-use dynamics.

The analysis will integrate two sectors from the studied area situated in Maramureș county using a multidisciplinary approach, integrating advanced methods such as geospatialanalysis and suitability analysis using Geographic Information Systems (GIS) to provide viable solutions within theglobal context of land conservation and sustainable development.

The research aims to answer to questions such as: *Is land consolidation a solution for agricultural facilities?*

The use of such technologies supports informed decision-making regarding land consolidation strategies and the implementationof policies aimed at addressing territorial fragmentation.

As highlighted above, land fragmentation in the hilly regions of North – West Romania presents a barrier to the sustainable development of rural area. This research aims to propose a practical solution that integrates local customs and lifestyle with scientific finding, ultimately contributing to the well-being of local communities.

MATERIALS AND METHODS

Study Area

The territorial organization of Maramureș County into four distinct "lands," resulting from the consolidation of regionalsocio-economic development micro-associations, positions the commune of Botiza in the southern part of *"Țara Maramureșului,"*at the border with *"Țara Lăpușului."*

This region is characterized by diverse landforms, a temperate continental climate, an extensive hydrographic network, and a mineral rich subsoil containing gold-silver ores and complex deposits.

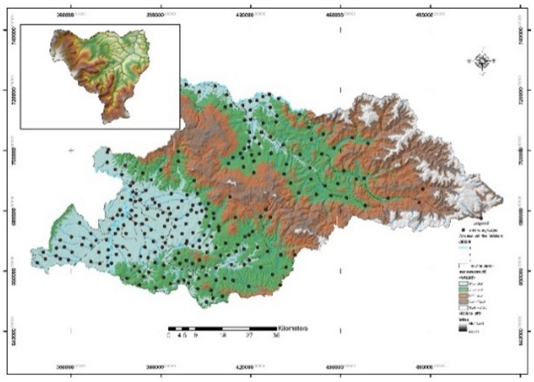

Fig. 1. Localization Map
Source: Original Neag et al, 2024 [10].

There are two main paradigms of research: to create a suitability analysis for providing solutions to the land fragmentation issue and to unravel the nuanced evolution of land management.

Determination of aggregation weight

Based on land use suitability principles, the availability of local experimental data relating factors to land use suitability, and well-defined workflow for data collection, this study aims to develop a suitability analysis framework.

By systematically organizing inputs and outputs within the analysis, the proposed methodology seeks to provide insights into mitigating the effects on land fragmentation and promoting sustainable agricultural practices. As presented in the Figure 2, the workflow outlines the key steps involved, ensuring a structured and reproducible approach.

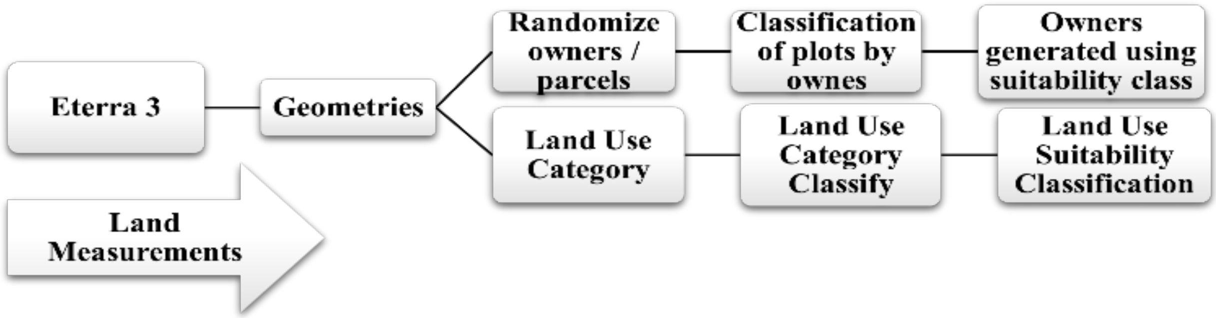

Fig. 2. Workflow for data collection
Source: Figure created by the authors.

Determination of data collected for analysis

To enhance understanding, it is important to introduce a schematic representation of data acquisition and the sequential processing steps involved in the analysis, highlighting the approach used for assessing land fragmentation and evaluating the evolution of land management.

The paper divides into three important sections of data collection, combined to data analysis:

-*Topographical measurements* – consisting in the use of GNSS technology for data collection within the framework of the systematic cadastral survey.

-*Information about land management and land category*, using an authorized platform of ANCPI.

-*Data provided from ANCPI* (National Agency For Cadastre and Land Registration) [17].

Each of the previously mentioned steps corresponds to a distinct component of the analysed sectors, individually characterized and allocated exclusively to the studied area. This process was made possible using ArcGIS Pro software, employing various methods to conduct the suitability analysis effectively.

The challenges of agriculture

A major challenge in rural areas, including the commune of Botiza, is the predominance of subsistence farming, which remains largely unproductive due to inadequate land consolidation, minimal mechanization, and excessive parcel fragmentation. These structural deficiencies hinder agricultural efficiency and limit economic growth in the region.

In the recent studies is proved that Botiza officially encompasses approximately 7,500 hectares of which 1,527 hectares are registered with the Agency of Payments and Intervention in Agriculture (APIA) for subsidy eligibility, comparing to the total surface to analyse of 199.34 ha. As will be presented in the analysis, the remaining land consists primarily of forested areas, while approximately 500 hectares area classified as non – agricultural land.

Analysing the current statistics from APIA [18] regarding land distribution and usage, alongside the data collected in this study, reveals significant insights into land ownership and utilization. The most prevalent land use consists of individually owned meadows, followed by communal permanent grasslands designated for individual use, and individually owned permanent grasslands.

A comparison between statistics and the findings of this research shows that from a total area of 458 parcels owned by 289 individuals, 78 hectares are distributed among 198 owners, each holding a single parcel. It is important to note that for the 289 property-owners, randomized names were employed to ensure compliance with GDPR regulations, such as: *Owner_1* or *Owner 1*.

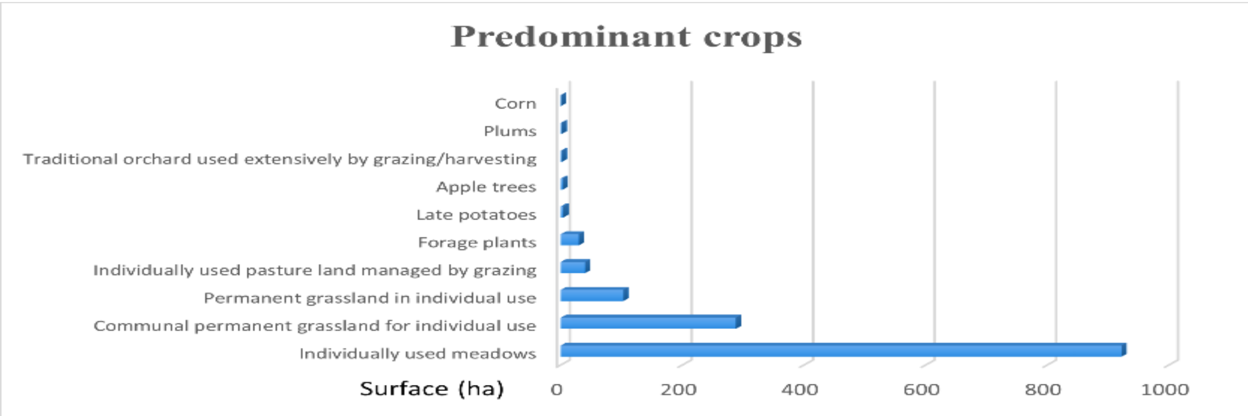

Fig. 3. Predominant crops
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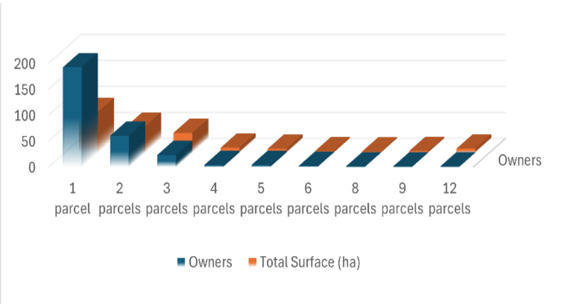


Fig. 4. Landowners' statistics and total surface of parcels
Source: Figure created by the authors.

Data acquisition and standardization

For conducting a suitability analysis, it is necessary to collect and process a variety of relevant geospatial data that reflect the land`s condition and characteristics. These data include information on landowners, land use categories, and land type – important factors in assessing land suitability for various use. It is important to note that land suitability analysis programs are often conducted at various scales, and harmonizing the data inputs and results in a way that is effective for decision-making presents a significant challenge [8].

In the present paper, data was sourced from two specific sectors: Sector 7, respectively Sector 22. In Sector 7, the integrated data for suitability analysis were obtained from topographic measurements conducted in 2021 as part of the systematic cadastral re-establishment process, while for Sector 22, geometries were retrieved from the Eterra platform.

All these data were processed and standardized in attribute tables associated with the respective geospatial layers, providing a solid foundation for the suitability analysis. For the current analysis the impact factors selected include landowners, land use categories and land type which represent important factors in assessing the potential land use in the context of agricultural land fragmentation.

It is important to highlight that, in the suitability analysis, parcels that were unclaimed at the time of the systematic cadastral survey were excluded. The issue of unclaimed land is one that cannot be overlooked, as it has become increasingly prevalent due to the high number of property owners who have emigrated. The absence of local landowners further complicates effective land management and poses challenges in consolidating land for agricultural use or other development purposes.

As the unclaimed parcels, roads were excluded from the suitability analysis to prevent the inclusion of unproductive areas and to ensure an accurate assessment of the land`s potential for consolidation and sustainable use. Another key factor in the suitability analysis was the Digital Elevation Model, created for the area studied using the boundaries of the sectors of interest. This model allowed for the determination of the land`s slope, essentially in assessing its agricultural potential. Lands with steep slopes is more difficult to work with mechanically and has lower agricultural productivity. Additionally, such lands are more prone to erosion, making them less suitable for intensive agricultural use.

The preparation of inputs for suitability modeling begins with defining the goals that characterize the studied phenomenon and the purpose of the analysis. There are three possible approaches to suitability modeling: a) simple suitability model, b) fuzzy suitability model and c) weighted suitability model. Given the complexity of land use patterns in the study area, the third approach was selected as it enables a more detailed and context – sensitive evaluation.

During the derivation stage, the data that characterize the model variables are defined based on the imposed criteria. For instance, the slope was classified into four categories based on the steepness of the terrain, which determines the type of machinery that can be used: slopes of less than 12 degrees are suitable for all agricultural machinery, between 12 and 20 degrees can accommodate most agricultural machinery, up to 35 degrees can be worked by tracked vehicles, and greater than 35 degrees are only suitable for work by animals or humans. These derived inputs were incorporated into the Suitability Modeler after the data transformation process.

The layers representing Owners and Land Use Category were classified using single-value classification according to the respective owners and land use types, then transformed into raster format.

In the Suitability Modeler [7], the derived rasters serve as the inputs for the model. These layers were transformed in accordance with the defined suitability criteria, using a suitability scale ranging from 1 to 3. The transformation process is depicted with corresponding images that demonstrate the changes applied.

The final step of the process is defined by the *locate and analysis,* represented in Fig. 5.

Furthermore, a suitability weight model was introduced, assigning weights of 15% for land use category, 60% for owners, and 25% for slope Subsequently, a suitability map was generated, followed by a Suitability Location map. Finally, a sensitivity analysis was conducted by varying the weights to assess the impact of these changes on the suitability results.

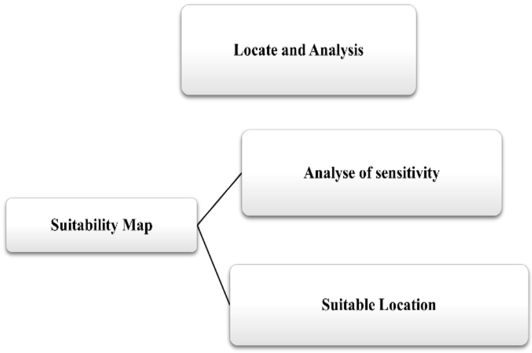
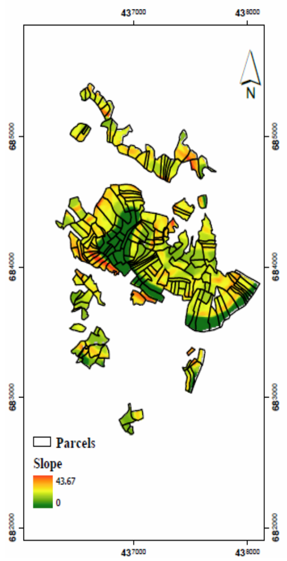


Fig. 5. Locate and Analysis results
Source: Figure created by the authors.



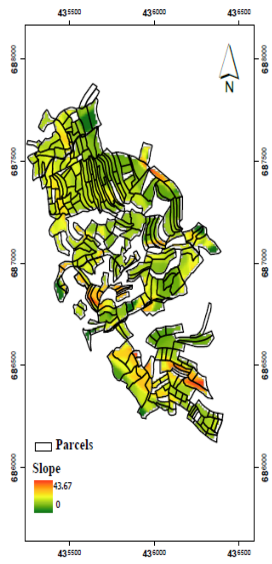


Fig. 6. Slope for Sector 7 Fig. 7. Slope for Sector 22
Source: Figure created by the authors.

In this study, the analyzed land parcels are classified as either outside the built-up areas or within the built-up areas in both sector 7 and 22. Given the objectives of the suitability analysis and land consolidation assessment, the focus is primarily on the within the built-up areas parcels, as they constitute the majority and serve as the pilot units for the final evaluation. The data processing and analysis were conducted using ArcGIS Pro for spatial analysis and SPSS 26 software for statistical evaluation, ensuring methodological rigor and accuracy in the results (Suitability Modeler) [7].

RESULTS AND DISCUSSIONS

The studied area encompasses a total of 199.34 hectares, subdivided into 458 parcels, owned by 289 individuals as mentioned above. Of these, extravilan parcels cover a total of 196.78 hectares, while the remaining 9, located within the built-up area, accounts for 2.56 hectares. Given the constraints of land consolidation, which requires uniform land use types, these 9 parcels were excluded from further analysis. The distribution of parcel size indicates a considerable degree of variability, which is further influenced by the presence of outliers. The smallest parcel measures 198.86 m^2 , while the largest covers 6.94 hectares.
For this analysis, the parcels were ranked according to their size, and the median was determined as the central value of this ordered dataset, resulting in the median parcel value of 3,245.35m^2 , with an interquartile range (IQR) of 3,482.28 m^2 . These findings highlight the significant challenges posed by land fragmentation, emphasizing the need for targeted strategies to address these issues.
Furthermore, these results underscore the importance of accounting for parcels size variability when developing land consolidation strategies. The differences in parcel sizes can greatly influence the feasibility of consolidation efforts and the potential for agricultural optimization. A detailed statistical overview of the parcels, along with additional attributes relevant to suitability analysis, is presented in Table 1. These outcomes emphasize the complexity of land distribution and reinforce the need for customized strategies to ensure effective land management and optimization of land use in the studied area.

Table 1. Parcels characterization

	Number of parcels	Numbers of owners	Surface area [m^2]			
			Median	IQR	Minimum	Maximum
Sector 7	262	162	2,215.25	2,090.43	198.86	15,079.15
Sector 22	196	138	5,002.86	4,506.73	221.26	69,448.18

Source: Table created by the authors.

Some landowners possess parcels in both sectors; however, this factor is not relevant for the suitability analysis, as parcels located in different sectors cannot be consolidated due to the considerable distance between them. This spatial separation restricts the feasibility of land consolidation and affects the potential for agricultural optimization within the study area.
During the documentation process, it was found that due to the lack of land claims at the time of the cadastral update, the land was transferred into the possession of the Botiza Municipality. This is reflected above in Figure 8 (b), where it is shown that the municipality owns a total of 11 parcels. Additionally, the municipality holds another parcel located in Sector 7, which is categorized separately by owners with a single parcel.

Preparing raster`s for suitability analysis

Suitability modeling for land parcel consolidation represents an analytical approach used to identify areas that are suitable for consolidation, based on criteria tailored to the specific characteristics of the studied region.
As presented in the previous section, in the first stage of the suitability analysis, the criteria were defined, relevant variables were selected and the methods for representing these variables were determined.
The main objective of this article is to find feasible solutions for consolidating land parcels.
Analysing the results from the previous subsection, it was observed that the most important factor is land ownership. To identify a suitable consolidation solution, the new plots must be suitable for mechanized work. Therefore, the second criterion is based on the study of the land slope, in conjunction with the potential for mechanized work on the meadows.
The study of the land parcels identified that the parcels belong to three different land use categories: *hayfields, pasture* and *forest.*

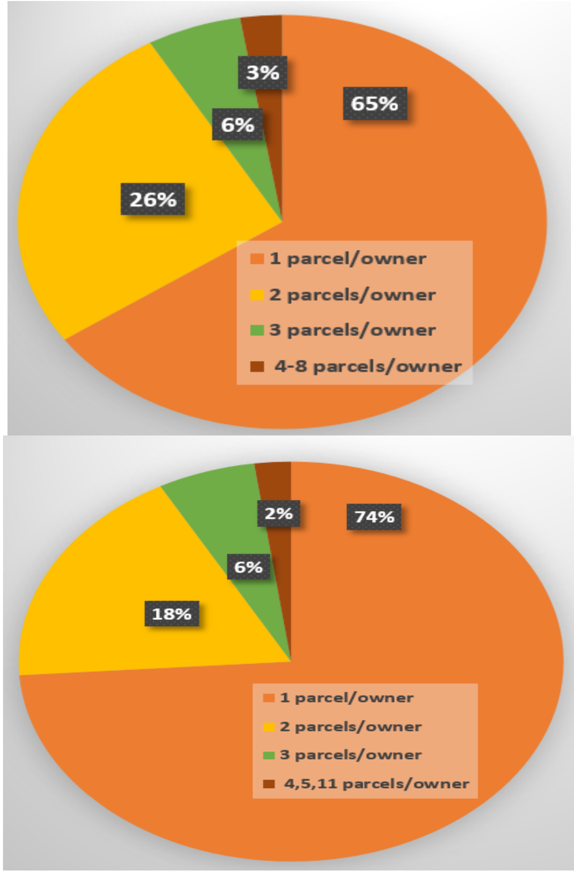


Fig. 8. Number of parcel(s)/owner
Source: Figure created by the authors.

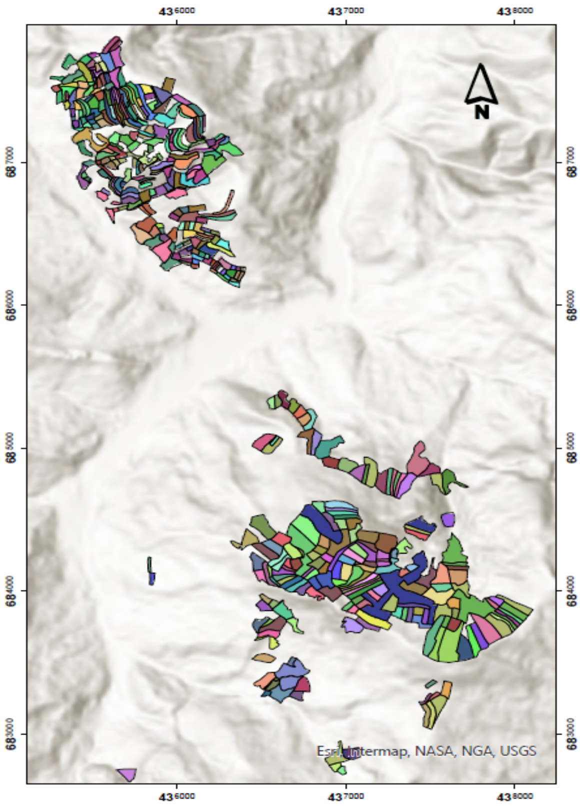


Fig. 9. Parcel(s)/owners
Source: Figure created by the authors.

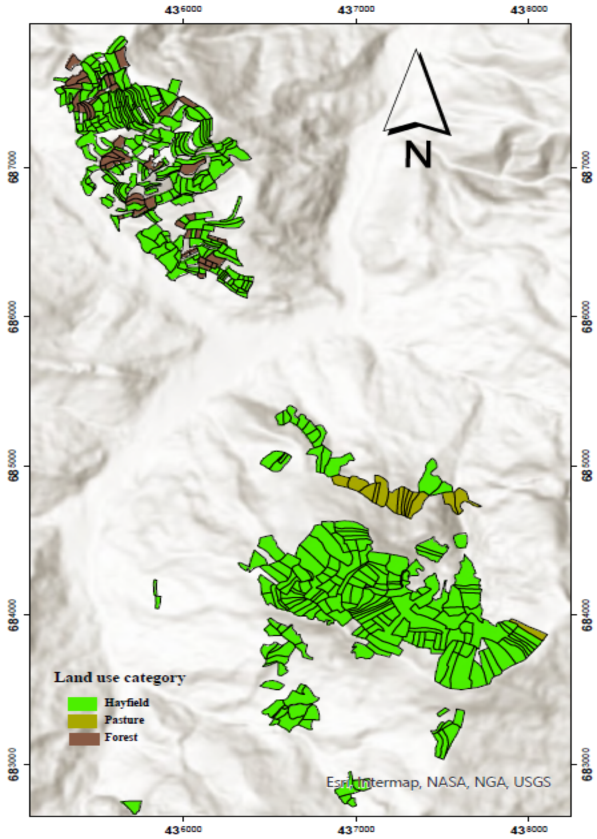


Fig. 10. Land use category
Source: Figure created by the authors.

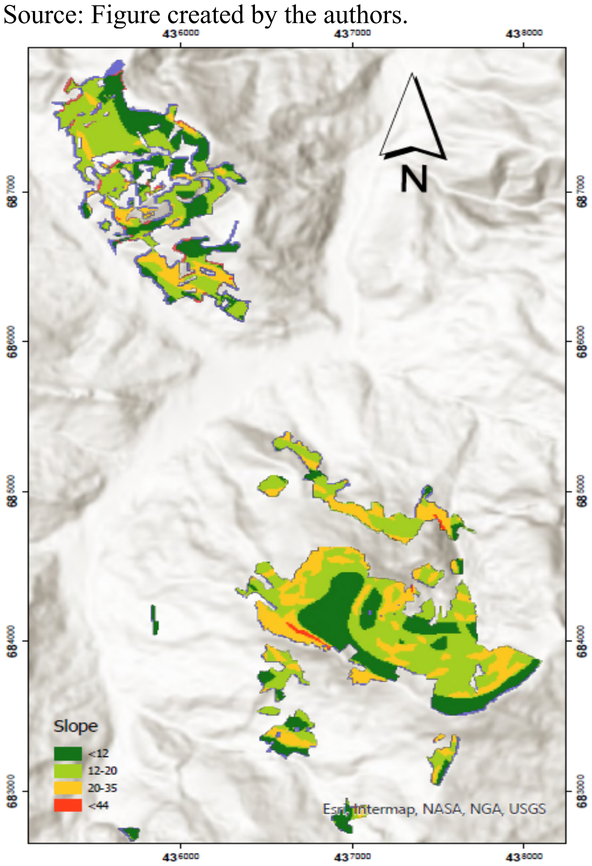


Fig. 11. Slope
Source: Figure created by the authors.

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The derive stage of suitability model preparation consists in generating derived layers for data normalization and reclassification.

The collected data were analysed using geoprocessing tools in ArcGIS Pro and the results were consist in classified parcel layer by owners and by land use category followed by their transformation in raster files with 10 m resolution.

The slope raster was reclassified by four classes as presented in Figure 11, with the same resolution as the previous raster files from Figure 9 and Figure 10.

Transformation of derived data and imposing weight to the model

In each derived dataset the values are transformed by assigning to each cell from the studied surface a suitability score.

In this research the suitability scores range from 1 and 3 to each cell, where 3 indicates the most suitable areas.

The transformation process for raster data assigns scores between 1 and 3 to each cell, ensuring that the consolidated parcels are suitable for mechanized work. Areas with a slope of less than 12^0 are considered the most suitable and are assigned a score of 3. Areas with slope between 12^0 and 35^0 receive a score of 2, while areas with steeper slopes are assigned the lowest suitability score. The distribution of suitability based on slope is illustrated in Figure 12.

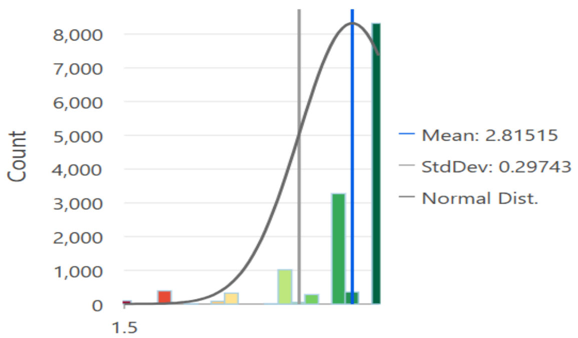

Fig. 12. Distribution of the suitability after slope transformation
Source: Figure created by the authors.

Figure 13 displays the transformed slope on the left side and the derived raster on the right, along with a detailed view of the transformation process. No significant differences are observed, as the regions with slopes greater than 35 are relatively small. However, these areas still contribute to land fragmentation, as illustrated in Figure 4.

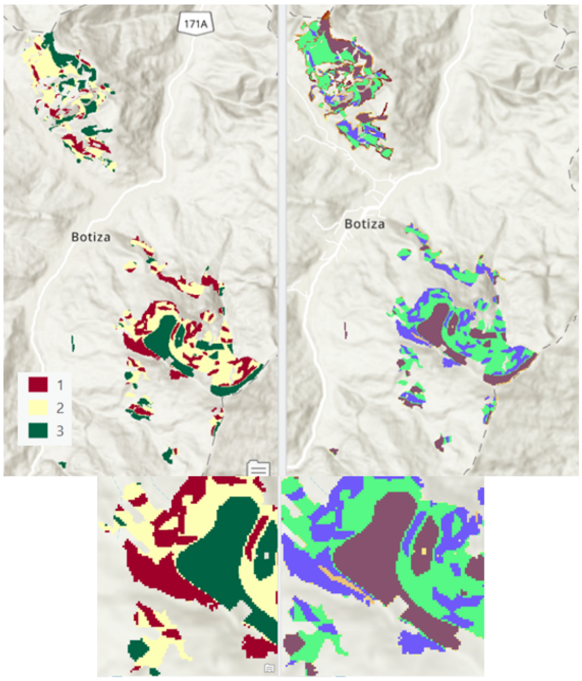

Fig. 13. Slope transformation
Source: Figure created by the authors.

The transformation of land use categories involved categorizing each land type based on its suitability. Hayfields, considered the most suitable for consolidation, were given the highest score of 3, while pasture received a score of 2. Forested areas were deemed the least suitable due to the significant effort needed for conversion and environmental regulations that limit such changes. The distribution of suitability after this transformation is illustrated in Figure 14.

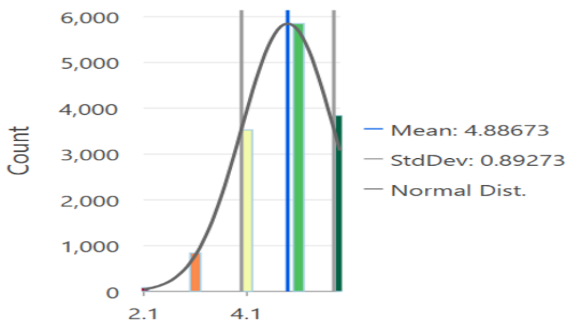

Fig. 14. Suitability distribution for land use category
Source: Figure created by the authors.

The most notable transformation occurs with the ownership data. The derived raster file includes 286 owners, with only a few owning more than two parcels. The consolidation solution lies in fostering cooperation among owners to create larger land parcels, which can contribute to higher income and sustainable development in the area. Owners with one, two, or three parcels, as well as parcels assigned to the Botiza Municipality, were given a suitability score of 3. Owners holding four, five, or six parcels received a suitability score of 2, while others received a score of 1. The transformation of the ownership data is presented in Figure 15.

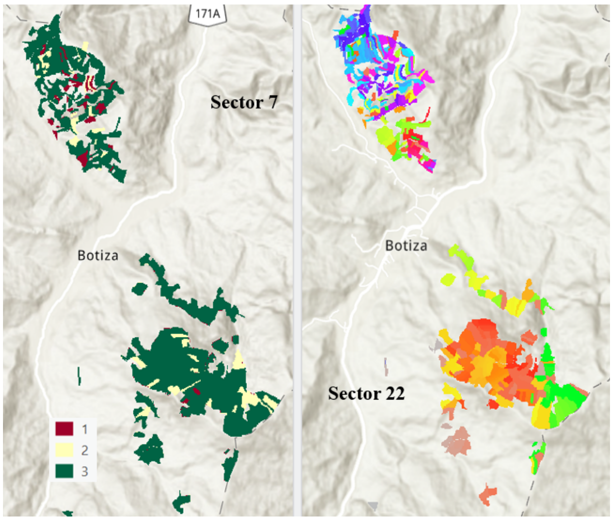

Fig. 15. Transformation of owner`s raster
Source: Figure created by the authors.

This transformation emphasized that many of the parcels from Sector 7 have a low suitability score due to the fact that there are owners that have more than 3 parcels of small areas.

Suitability map

Figure 16 highlights the suitability map, revealing that the majority of the land suitable for consolidation is concentrated in Sector 22. In contrast, Sector 7 has numerous areas deemed unsuitable due to the scattered presence of forests as a land use category and the fragmentation of property rights, which creates isolated „islands" within the sector.

The contribution of the transformed raster to the suitability map were 60% owners, 25% slope and 15% land use category. Over the 84% of the area is appropriate for consolidation with a score over 2.6 from a maximum of 3 points.

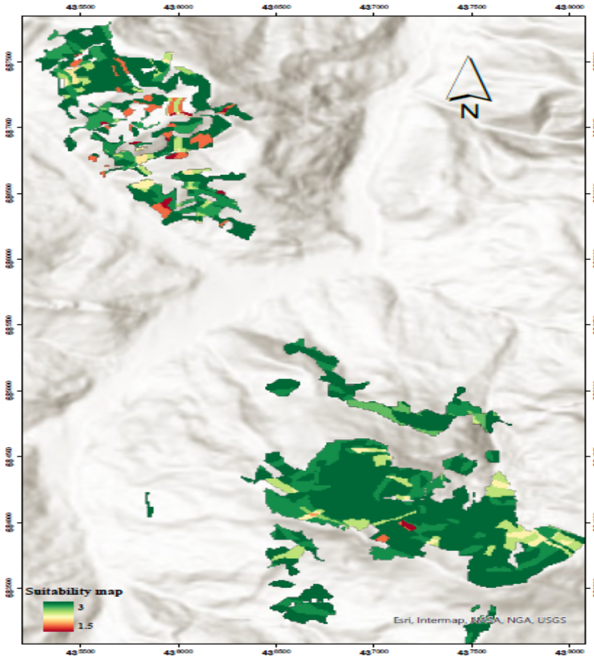

Fig. 16. Suitability map for Sector 7 and Sector 22
Source: Figure created by the authors.

Suitable regions

Suitable Regions are distinct, well-defined areas that meet specific suitability criteria.

To achieve parcel consolidation, the criteria were designed to ensure economic efficiency while remaining practical for implementation.

A balance was established between parcel geometry and suitability score, with a Shape/Utility trade-off set at 20%. Additionally, a minimum area requirement of 3,000 m² was imposed, aligning with the threshold set by the Paying and Intervention Agency for Agriculture for agricultural subsidies.

Figure 17 presents the suitability map, highlighting the parcels eligible for the consolidation process.

The findings about sustainable regions shows that 214 parcels are appropriate as suitable region for consolidation, covering 54.80% from entire era.

In the following Table 2, the suitable regions for both sectors is emphasized.

Table 2. Suitable regions

	Number of parcels	Sector's contribution to the suitable regions area (%)
Sector 7	96	25.06
Sector 22	118	74.94

Source: Table created by the authors.

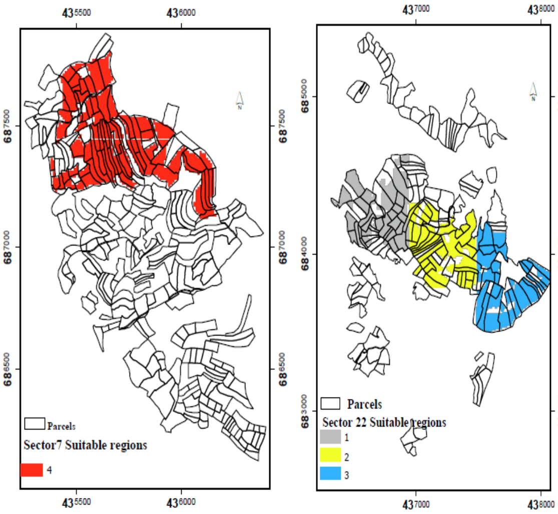

Fig. 17. Suitable region for Sector 7 and Sector 22
Source: Figure created by the authors.

Sensitivity analysis
To validate the proposed model, a sensitivity analysis was conducted by examining how variations in weight allocations impact the suitability map. Two additional models were generated using the same parameters as the initial model, differing only in weight distribution.
-*In the first scenario* (Sensitivity 1), weights were assigned as follows: 35% for land use category, 40% for owners, and 25% for slope.
-*In the second scenario* (Sensitivity 2), the weights were adjusted to 35% for land use category, 30% for owners, and 35% for slope.
The raster files generated by computing the differences between the new suitability maps and the original suitability map showed values ranging from -1.5 to 1.45.
These differences were then reclassified into three categories, with values between -0.1 and 0.1 considered as indicating no significant change. The results of this analysis are presented in Table 3.

Table 3. Sensitivity analysis results express in percent of values in raster files

	Small changes Between -0.1 and 0.1 (%)	Other changes (%)
Suitability(35*LU*,40*O*,25 *S*)-Suitability (15 LU,60 O,25 S)*	96.23	3.77
Suitability(35 LU,30 O,35 S)-Suitability (15 LU,60 O,25 S)*	75.01	24.99

*LU-Land use category raster, O – Owners, S- Slope
Source: Table created by the authors.

CONCLUSIONS

In the context of sustainable land management, our research on land consolidation in the hilly region of North-West Romania highlights that landowners play a central role in the process. This conclusion is strongly supported by the results of the suitability and sensitivity analyses.To identify suitable regions for consolidation, we applied specific conditions regarding minimum and maximum area constraints while ensuring the absence of isolated "islands" within the consolidated zones.
However, computational processing to determine these areas proved to be highly time-consuming. In Sector 7, it was not possible to identify viable solutions due to the presence of steep slopes, contiguous parcels with differing land use categories, and the existence of plots with incomplete ownership information.
It is important to note that the workflow presented in Figure 2 and Figure 5, can be applied to other hilly regions in North-West Romania.
To enhance the effectiveness of land consolidation efforts, we propose the following recommendations:
-Exclude forested areas subject to other administrative regulations and ensure continuity of land use categories between neighboring parcels.
-Resolve any outstanding issues related to land ownership status.
-Establish access routes to facilitate mechanized agricultural operations in the consolidated areas.

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