13. JEEP MEĐUNARODNA NAUČNA AGROBIZNIS KONFERENCIJA-MAK 2026
13th JEEP INTERNATIONAL SCIENTIFIC AGRIBUSINESS CONFERENCE-MAK 2026
"GREEN TRANSFORMATION OF AGRIBUSINESS: INNOVATION AS THE KEY TO SUSTAINABLE AGRICULTURE"
January 29th to February 1st, 2026., KOPAONIK, GRAND HOTEL

Doi: 10.46793/MAK2026.249S

APPLICATION OF GIS AND REMOTE SENSING FOR AGRICULTURAL LAND SUITABILITY ASSESSMENT: A CASE STUDY IN SERBIA

Demir Saćirović[1]*, Elvir Muslić[2], Fadil Novalić[3]

[1]Faculty of Teacher Education, University of Belgrade, Belgrade, Serbia,
[2]Faculty of Sciences and Mathematics, University of Niš, Niš, Serbia,
[3]Department of Computer Science, International University of Novi Pazar, N. Pazar, Serbia,
***Corresponding author: demirsacirovic@hotmail.com**

Abstract: This study presents a GIS-based multi-criteria analysis for agricultural land suitability assessment in the Mačva District, Serbia. Satellite imagery from Sentinel-2 and spatial datasets including soil type, slope, precipitation, and land use were integrated using the Analytical Hierarchy Process method. Results indicate that 42.3% of the study area is highly suitable for crop production, while 28.7% require improvement measures. The developed methodology provides a framework for sustainable agricultural land use planning.

Keywords: GIS, Remote sensing, Land suitability, Sustainable agriculture, Multi-criteria analysis

INTRODUCTION

Sustainable agricultural development requires optimal utilization of land resources based on their inherent capabilities and limitations. Geographic Information Systems (GIS) and remote sensing technologies have become essential tools for agricultural land evaluation, enabling the integration of multiple spatial datasets and supporting evidence-based decision-making processes (FAO, 2007; Akinci et al., 2013). The growing pressure on agricultural land from urbanization, climate change, and population growth necessitates comprehensive land evaluation approaches that can guide sustainable land use planning.

Serbia, as a country with significant agricultural potential, faces challenges related to land degradation, climate change impacts, and suboptimal land use practices. Agriculture contributes approximately 7% to the national GDP and employs about 15% of the workforce, making it a crucial sector for economic development (Statistical Office of the Republic of Serbia, 2023). The Mačva District, located in western Serbia, represents one of the most productive agricultural regions, yet comprehensive spatial assessments of land suitability remain limited. Traditional land evaluation methods often fail to account for the complex interactions between environmental factors that determine agricultural productivity (Feizizadeh and Blaschke, 2013).

Multi-criteria decision analysis (MCDA) combined with GIS provides a robust framework for integrating diverse spatial datasets and expert knowledge into land suitability models. The Analytical Hierarchy Process (AHP), developed by Saaty (1980), has been widely applied in agricultural land evaluation due to its ability to handle both quantitative and qualitative criteria while maintaining methodological transparency (Kazemi and Akinci, 2018). The AHP method allows decision-makers to decompose complex problems into hierarchical structures and derive priority weights through pairwise comparisons.

Remote sensing data, particularly from the Sentinel-2 satellite constellation operated by the European Space Agency, offers high spatial and temporal resolution imagery suitable for monitoring vegetation health and land cover dynamics. The Normalized Difference Vegetation Index (NDVI) derived from satellite imagery serves as a reliable indicator of crop vigor and agricultural land productivity (Rouse et al., 1974). The free availability of Sentinel-2 data since 2015 has significantly enhanced the accessibility of remote sensing applications for agricultural monitoring.

The objective of this study is to develop and apply a GIS-based multi-criteria methodology for agricultural land suitability assessment in the Mačva District, integrating remote sensing data with environmental variables to support sustainable land use planning and agricultural policy development. The specific aims include: (1) identifying and weighing relevant criteria for agricultural land evaluation, (2) mapping land suitability classes across the study area, and (3) comparing the results with current land use patterns to identify optimization opportunities.

MATERIAL AND METHODS

Study Area

The Mačva District is located in western Serbia, between 44°30' and 45°00' N latitude and 19°00' and 19°45' E longitude (Figure 1).

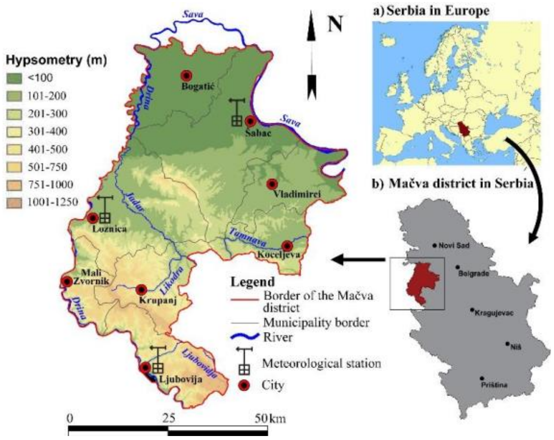

Figure 1. Location of the Mačva District study area in western Serbia, with hypsometry and administrative boundaries. Source: Adapted from Milentijević et al. (2020)

The district covers approximately 3.270 km² and includes eight municipalities: Šabac, Bogatić, Vladimirci, Koceljeva, Krupanj, Ljubovija, Loznica, and Mali Zvornik. The terrain is predominantly flat to gently undulating, with elevations ranging from 80 m in the alluvial plains to 600 m in the hilly southern portions. The climate is temperate continental, with mean annual temperature of 11.2°C and precipitation of 700-850 mm (Republic

Hydrometeorological Service of Serbia, 2023). The region is characterized by fertile alluvial soils along the Sava River and its tributaries, supporting intensive crop production including maize, wheat, sugar beet, and various vegetables.

Data Sources

The following spatial datasets were utilized in this study:

Sentinel-2 imagery: Multispectral imagery (10 m resolution) acquired during the growing season (May-August 2022) was obtained from the Copernicus Open Access Hub (https://scihub.copernicus.eu/). A total of 12 cloud-free images were selected for NDVI calculation and land cover classification. The Sentinel-2 Level-2A products with atmospheric correction were used to ensure radiometric consistency (ESA, 2022).

Digital Elevation Model (DEM): A DEM with 25 m spatial resolution was obtained from the Copernicus Land Monitoring Service EU-DEM v1.1 (https://land.copernicus.eu/imagery-in-situ/eu-dem). Slope and aspect layers were derived from the DEM using standard GIS algorithms implemented in QGIS (EEA, 2016).

Soil data: Soil type, texture, and depth data were digitized from the Basic Pedological Map of Yugoslavia (1:50.000 scale) produced by the Institute of Soil Science, Belgrade (Tanasijević et al., 1964). The original soil classification follows the Classification of Yugoslav Soils (Škorić et al., 1985), which remains the official system in Serbia (Pavlović et al., 2017). For international comparability, soil classes were correlated to the World Reference Base for Soil Resources (IUSS Working Group WRB, 2015) following established correlation approaches for Serbian soils (Radmanović et al., 2020).

Climate data: Mean annual precipitation and temperature data were interpolated from 15 meteorological station records obtained from the Republic Hydrometeorological Service of Serbia (RHMSS) for the period 2014-2022. Data was accessed through the RHMSS official database (www.hidmet.gov.rs/). Spatial interpolation was performed using the Inverse Distance Weighting (IDW) method following the approach described by Gocić and Trajković (2013).

Land cover classification: The Random Forest algorithm was applied for supervised classification with an overall accuracy of 87.3%, which is consistent with reported accuracies for Random Forest classification of Sentinel-2 imagery in Central-Eastern European landscapes, typically ranging from 82 to 89% (Pflugmacher et al., 2019; Immitzer et al., 2016).

Hydrological data: River networks and water bodies were obtained from the OpenStreetMap database (www.openstreetmap.org/) and verified using Sentinel-2 imagery. Distance to water sources was calculated using Euclidean distance analysis.

Methodology

The land suitability assessment followed the FAO Framework for Land Evaluation (FAO, 1976) adapted for local conditions, as recommended by Rossiter (1996). Five criteria were selected based on literature review and expert consultation: soil quality, slope gradient, precipitation, NDVI values, and distance to water sources. The selection of criteria was guided by their relevance to agricultural productivity and data availability, consistent with similar studies in the region (Akinci et al., 2013; Bandyopadhyay et al., 2009).

Each criterion was standardized to a common scale (1-5) where 5 represents the highest suitability and 1 represents the lowest suitability. The standardization thresholds were defined based on literature recommendations (Akinci et al., 2013; Bandyopadhyay et al., 2009) and expert knowledge as shown in Table 1.

Table 1. Standardization thresholds for land suitability criteria

Criterion	Score 5	Score 4	Score 3	Score 2	Score 1
Soil quality	Chernozem, Alluvial	Cambisol	Fluvisol	Vertisol	Skeletal, Hydromorphic
Slope (%)	0-2	2-5	5-8	8-15	>15
Precipitation (mm)	>800	750-800	700-750	650-700	<650
NDVI	>0.7	0.5-0.7	0.3-0.5	0.1-0.3	<0.1
Distance to water (m)	<500	500-1.000	1.000-2.000	2.000-3.000	>3.000

The Analytical Hierarchy Process (AHP) was employed to determine criterion weights through pairwise comparisons, following the methodology established by Saaty (1980) and applied in agricultural land suitability studies by Akinci et al. (2013) and Feizizadeh and Blaschke (2013). A questionnaire based on Saaty's 9-point scale was distributed to 12 agricultural and soil science experts from Serbian universities and research institutes, including the Faculty of Agriculture in Belgrade, Faculty of Agriculture in Novi Sad, and the Institute for Soil Science. The geometric mean of individual responses was used to construct the final comparison matrix, and weights were derived using the eigenvector method.

The consistency ratio (CR) was calculated to verify the reliability of judgments using the formula:

$$\mathbf{CR = CI / RI}$$

where CI is the consistency index and RI is the random index. A CR value below 0.10 was considered acceptable (Saaty, 1980).

The final land suitability index (LSI) was calculated using the weighted linear combination:

$$\mathbf{LSI = \Sigma (W_i \times S_i)}$$

where W_i represents the weight of criterion *i* and S_i represents the standardized score of criterion *i*. The LSI values were reclassified into five suitability classes according to FAO (1976): highly suitable (S1: LSI > 4.0), moderately suitable (S2: LSI 3.0-4.0), marginally suitable (S3: LSI 2.0-3.0), currently not suitable (N1: LSI 1.0-2.0), and permanently not suitable (N2: LSI < 1.0).

All spatial analyses were performed using QGIS 3.34 LTR software (QGIS Development Team, 2023) with Python scripting (GeoPandas, Rasterio libraries) for batch processing and automation. The final maps were produced at 25 m spatial resolution to match the coarsest input dataset.

RESULTS AND DISCUSSION

Criterion Weights

The AHP analysis yielded the criterion weights presented in Table 2. The consistency ratio of 0.047 confirmed the reliability of expert judgments, as it falls well below the acceptable threshold of 0.10.

Table 2. Criterion weights derived from AHP analysis

Criterion	Weight	Rank
Soil quality	0.35	1
Slope	0.25	2
Precipitation	0.18	3
NDVI	0.12	4
Distance to water	0.10	5

Soil quality received the highest weight (0.35), reflecting its fundamental importance for agricultural productivity. This finding is consistent with similar AHP-based land suitability studies where soil-related factors typically receive weights ranging from 0.23 to 0.41 (Akbari et al., 2019; Bandyopadhyay et al., 2009; Akinci et al., 2013).

Spatial Distribution of Criteria

The soil quality map revealed that high-quality agricultural soils (chernozem and alluvial) dominate the central and northern portions of the study area, covering approximately 58% of the total area. These soils are characterized by high organic matter content (2.5-4.0%), good water retention capacity, and favorable pH levels (6.5-7.5), consistent with documented properties of chernozem and alluvial soils in the Pannonian Basin (Pavlović et al., 2017; Hadžić et al., 2002). Lower quality soils are concentrated in the southern hilly terrain and along poorly drained lowlands.

Slope analysis based on EU-DEM data indicated that 72% of the study area has slopes below 5%, favorable for mechanized agriculture. Steeper slopes exceeding 15% are limited to the southern portions (Cer and Iverak mountains), representing approximately 8% of the total area. The predominantly flat terrain in the Mačva plain, characteristic of the Pannonian Basin margin, provides excellent conditions for large-scale crop production (Pavlović et al., 2017).

Precipitation patterns show a gradient from northwest (750 mm) to southeast (850 mm), with the entire study area receiving adequate rainfall for rainfed agriculture. However, seasonal distribution analysis revealed that summer precipitation deficits (June-August average: 180 mm) may limit crop yields in certain years without supplementary irrigation (Gocić and Trajković, 2013).

NDVI analysis from Sentinel-2 imagery demonstrated strong vegetation vigor (NDVI > 0.5) across 65% of agricultural lands during the peak growing season (July 2022). Lower NDVI values were observed in areas with sandy soils along the Drina River and in fields with inadequate irrigation infrastructure. The temporal NDVI analysis revealed significant interannual variability, with 2022 showing above-average vegetation conditions compared to the 2018-2021 baseline.

Land Suitability Assessment

The integration of weighted criteria produced a land suitability assessment with the distribution of suitability classes presented in Table 3.

Table 3. Distribution of land suitability classes in the Mačva District

Suitability Class	LSI Range	Area (km²)	Percentage (%)
Highly suitable (S1)	>4.0	1.383	42.3
Moderately suitable (S2)	3.0-4.0	938	28.7
Marginally suitable (S3)	2.0-3.0	621	19.0
Currently not suitable (N1)	1.0-2.0	262	8.0
Permanently not suitable (N2)	<1.0	66	2.0

Highly suitable lands (S1) cover 1.383 km² (42.3% of the study area), concentrated in the Mačva plain where optimal soil, slope, and water availability conditions converge. These areas are currently utilized primarily for intensive crop production including maize, wheat, and sugar beet. The spatial clustering of S1 lands along the Sava River floodplain reflects the high agricultural potential of alluvial soils.

Moderately suitable lands (S2) encompass 938 km² (28.7%), located in transitional zones between the alluvial plains and hilly terrain. These areas are suitable for a range of crops with appropriate management practices, including fruit orchards and vegetable production. With targeted investments in soil improvement and irrigation, portions of S2 land could potentially be upgraded to S1 status.

Marginally suitable lands (S3) cover 621 km² (19.0%), primarily in areas with soil limitations or steeper slopes. These lands require improvement measures such as drainage, irrigation, or erosion control for sustainable agricultural use. Alternative land uses such as pasture, agroforestry, or organic farming may be more appropriate for these areas.

Currently not suitable lands (N1) represent 262 km² (8.0%), mainly in areas with severe slope or soil limitations. With significant investment in land improvement, some portions may be converted to agricultural use. However, the cost-benefit analysis should be carefully considered before undertaking such investments.

Permanently not suitable lands (N2) cover only 66 km² (2.0%), consisting of built-up areas, water bodies, protected areas, and extremely steep terrain where agricultural use is not feasible or permitted.

Comparison with Current Land Use

Overlay analysis between the suitability map and current land use revealed that approximately 89% of highly suitable lands (S1) are currently under agricultural use, indicating generally appropriate land allocation. However, 11% of S1 lands are underutilized or converted to non-agricultural uses (settlements, infrastructure), representing potential for agricultural expansion or protection through zoning policies.

Conversely, approximately 15% of marginally suitable lands (S3) are under intensive cultivation, suggesting potential sustainability concerns. These areas may benefit from conversion to less intensive uses such as pasture or agroforestry systems. The mismatch between suitability and current use highlights opportunities for land use optimization to enhance both productivity and environmental sustainability.

Implications for Sustainable Agriculture

The results support evidence-based agricultural zoning and land use planning at the district level, aligning with recommendations by Rossiter (1996) and FAO (2007) for integrating land evaluation into spatial planning frameworks. The methodology can be readily adapted for other regions in Serbia by adjusting criteria weights based on local conditions and expert knowledge. The integration of freely available satellite data (Sentinel-2) and open-source GIS software (QGIS) makes the methodology accessible to local planning authorities with limited resources.

Climate change projections suggest increasing frequency of drought events in the region, which may alter suitability patterns in the coming decades (Ruml et al., 2012). According to the World Bank Serbia Country Climate and Development Report, temperatures in Serbia are expected to rise by 3-5°C by the end of the century, with increasing precipitation variability potentially reducing agricultural productivity if irrigation infrastructure is not expanded (World Bank, 2023). Integration of climate scenario analysis into the suitability model represents an important direction for future research.

The study provides valuable inputs for the Strategy of Agriculture and Rural Development of the Republic of Serbia, which emphasizes sustainable management of resources and environmental protection (Government of the Republic of Serbia, 2014). The suitability maps can guide decisions regarding agricultural subsidies, irrigation investments, and land consolidation programs. Furthermore, the methodology supports Serbia's alignment with EU agricultural policies and the Common Agricultural Policy (CAP) requirements for evidence-based land management.

CONCLUSION

This study successfully developed and applied a GIS-based multi-criteria methodology for agricultural land suitability assessment in the Mačva District, Serbia. The integration of Sentinel-2 satellite imagery with environmental datasets through the AHP method provided a comprehensive evaluation of land resources for sustainable agricultural planning.

Key findings indicate that 42.3% of the study area is highly suitable for intensive crop production, while 28.7% is moderately suitable. The methodology identified areas where current land use does not align with inherent suitability, providing guidance for land use optimization. Soil quality and slope emerged as the most influential factors determining agricultural suitability.

The developed framework can be applied to other regions in Serbia and the Western Balkans to support agricultural policy development and sustainable land management. Future research should incorporate climate change scenarios, socioeconomic factors, and crop-specific suitability assessments to enhance the practical applicability of land suitability models.

The study demonstrates the potential of geospatial technologies for supporting the green transformation of agribusiness in Serbia, contributing to the sustainable development goals and climate adaptation strategies in the agricultural sector.

ACKNOWLEDGMENT

The authors thank the Republic Hydrometeorological Service of Serbia and the Copernicus Programme for providing data used in this study. We also acknowledge the agricultural and soil science experts from Serbian universities and research institutes who participated in the AHP survey. Special thanks to the Institute for Soil Science, Belgrade for providing access to soil mapping data.

REFERENCES

Akbari, M., Neamatollahi, E., Neamatollahi, P. (2019). Evaluating land suitability for spatial planning in arid regions of eastern Iran using fuzzy logic and multi-criteria analysis. Ecological Indicators, 98, 587-598. doi: 10.1016/j.ecolind.2018.11.035

Akinci, H., Ozalp, A.Y., Turgut, B. (2013). Agricultural land use suitability analysis using GIS and AHP technique. Computers and Electronics in Agriculture, 97, 71-82. doi: 10.1016/j.compag.2013.07.006

Bandyopadhyay, S., Jaiswal, R.K., Hegde, V.S., Jayaraman, V. (2009). Assessment of land suitability potentials for agriculture using a remote sensing and GIS based approach. International Journal of Remote Sensing, 30(4), 879-895. doi: 10.1080/01431160802395235

EEA (European Environment Agency) (2016). EU-DEM v1.1: Copernicus Land Monitoring Service. https://land.copernicus.eu/imagery-in-situ/eu-dem

ESA (European Space Agency) (2022). Sentinel-2 User Handbook. ESA Standard Document. https://sentinel.esa.int/

FAO (1976). A Framework for Land Evaluation. FAO Soils Bulletin No. 32. Food and Agriculture Organization of the United Nations, Rome.

FAO (2007). Land Evaluation: Towards a Revised Framework. Land and Water Discussion Paper No. 6. Food and Agriculture Organization of the United Nations, Rome.

Feizizadeh, B., Blaschke, T. (2013). Land suitability analysis for Tabriz County, Iran: A multi-criteria evaluation approach using GIS. Journal of Environmental Planning and Management, 56(1), 1-23. doi: 10.1080/09640568.2011.649716

Gocić, M., Trajković, S. (2013). Analysis of precipitation and drought data in Serbia over the period 1980-2010. Journal of Hydrology, 494, 32-42. doi: 10.1016/j.jhydrol.2013.04.044

Government of the Republic of Serbia (2014). Strategy of Agriculture and Rural Development of the Republic of Serbia for the period 2014-2024. Official Gazette of the Republic of Serbia, No. 85/2014.

Hadžić, V., Nešić, L., Belić, M., Furman, T., Savin, L. (2002). Organic matter content in Vojvodina soils and the need for increasing it. Tractors and Power Machines, 7(4), 13-19. (in Serbian)

Immitzer, M., Vuolo, F., Atzberger, C. (2016). First experience with Sentinel-2 data for crop and tree species classifications in Central Europe. Remote Sensing, 8(3), 166. doi: 10.3390/rs8030166

IUSS Working Group WRB (2015). World Reference Base for Soil Resources 2014, Update 2015. International Soil Classification System for Naming Soils and Creating Legends for Soil Maps. World Soil Resources Reports No. 106. FAO, Rome.

Kazemi, H., Akinci, H. (2018). A land use suitability model for rainfed farming by multi-criteria decision-making analysis and geographic information system. Ecological Engineering, 116, 1-6. doi: 10.1016/j.ecoleng.2018.02.021

Milentijević, N., Bačević, N., Ristić, D., Valjarević, A., Pantelić, M., Kićović, D. (2020). Application of Mann-Kendal (MK) test in trend analysis of air temperature and precipitation: Case of Mačva district (Serbia). University Thought - Publication in Natural Sciences, 10(1), 37-43. doi: 10.5937/univtho10-24774

Pavlović, P., Kostić, N., Karadžić, B., Mitrović, M. (2017). The Soils of Serbia. World Soils Book Series. Springer, Dordrecht. doi: 10.1007/978-94-017-8660-7

Pflugmacher, D., Rabe, A., Peters, M., Hostert, P. (2019). Mapping pan-European land cover using Landsat spectral-temporal metrics and the European LUCAS survey. Remote Sensing of Environment, 221, 583-595. doi: 10.1016/j.rse.2018.12.001

QGIS Development Team (2023). QGIS Geographic Information System. Open-Source Geospatial Foundation Project. www.qgis.org/

Radmanović, S.B., Gajić-Kvaščev, M.D., Mrvić, V.V., Đorđević, A.R. (2020). Characteristics of Rendzina soils in Serbia and their WRB classification. Journal of Agricultural Sciences, Belgrade, 65(3), 251-261. doi: 10.2298/JAS2003251R

Republic Hydrometeorological Service of Serbia (2023). Meteorological Yearbook 2023. RHMSS, Belgrade. www.hidmet.gov.rs/

Rossiter, D.G. (1996). A theoretical framework for land evaluation. Geoderma, 72(3-4), 165-190. doi: 10.1016/0016-7061(96)00031-6

Rouse, J.W., Haas, R.H., Schell, J.A., Deering, D.W. (1974). Monitoring vegetation systems in the Great Plains with ERTS. In Proceedings of the Third Earth Resources Technology Satellite-1 Symposium, 309-317. NASA SP-351, Washington D.C.

Ruml, M., Vuković, A., Vujadinović, M., Djurdjević, V., Ranković-Vasić, Z., Gavrilović, Z., Matović, G., Petrović, N., Lalić, B. (2012). On the use of regional climate models: Implications of climate change for viticulture in Serbia. Agricultural and Forest Meteorology, 158-159. doi: 10.1016/j.agrformet.2012.02.004

Saaty, T.L. (1980). The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation. McGraw-Hill, New York.

Statistical Office of the Republic of Serbia. (2023). Statistical Yearbook of the Republic of Serbia 2023. SORS, Belgrade.

Škorić, A., Filipovski, G., Ćirić, M. (1985). Klasifikacija zemljišta Jugoslavije. Posebna izdanja, knjiga LXXVIII. Akademija nauka i umjetnosti Bosne i Hercegovine, Sarajevo. (in Serbian)

Tanasijević, Đ., Pavićević, N., Antonović, G., Filipović, Đ., Spasojevic, M., Aleksić, Ž. (1964). Pedološka karta SAP Vojvodine i uže Srbije 1:50.000 [Pedological Map of SAP Vojvodina and Narrower Serbia 1:50,000]. Institut za proučavanje zemljišta, Beograd. (in Serbian)

World Bank (2023). Serbia Country Climate and Development Report. World Bank Group, Washington D.C. www.worldbank.org/en/country/serbia/publication/serbia-country-climate-and-development-report