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An Integrated Geospatial Framework for Assessing Agricultural Suitability Using Multi-Source Environmental Criteria

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INTRODUCTION & AIM

Groundwater is a critical resource for agriculture in arid regions like Iran's Anjir Plain, supporting food security and sustainable development. However, climate change, population growth, prolonged droughts, and excessive groundwater extraction have led to a severe decline in aquifer levels, threatening agricultural productivity and causing issues like land subsidence, increased groundwater salinity, and ecosystem degradation. The Anjir Plain, a key agricultural hub in Yazd Province covering 618,927.7 hectares, has been designated a "prohibited zone" by Iran's Ministry of Energy, imposing strict restrictions on groundwater use to prevent further depletion. To address this crisis, this study integrates hydrogeological and climatic parameters to assess land potential, proposing artificial groundwater recharge, improved water use efficiency, and alternative water sources like treated wastewater. By combining object-based image analysis (OBIA) with Geographic Information System (GIS) and multi-criteria decision-making (MCDM) methods, including Analytic Hierarchy Process (AHP) and Weighted Linear Combination (WLC), the research identifies suitable agricultural lands under water-stressed conditions. This innovative approach enhances spatial analysis precision, offering a scientific basis for sustainable agricultural planning and water resource management in arid regions.

METHOD

The study focuses on the Anjir Plain watershed in Yazd Province, Iran, a critical agricultural zone spanning 618,927.7 hectares, facing severe groundwater depletion due to population growth, intensified agricultural demands, prolonged droughts, and unregulated withdrawals, with an annual aquifer decline of approximately 0.6 meters (Figure 1).

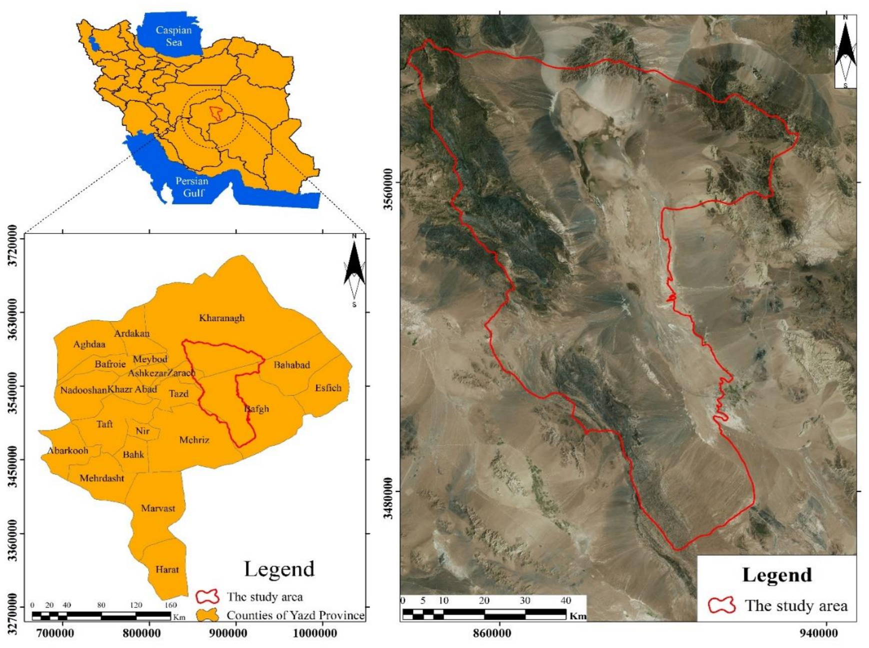

Figure 1. Map of the study area

This research evaluates agricultural land potential using a hybrid object-based and hydro-climatic-topographic approach to support sustainable land management. Utilizing ArcGIS 10.5, hydro-climatic and topographic criteria were selected, and spatial data layers were standardized. The Ordered Weighted Averaging (OWA) method integrated weighted criteria, allowing flexibility in modeling risk preferences, while the Best-Worst Method (BWM) determined criterion weights through pairwise comparisons, ensuring high consistency (ratio near 0). Landsat-9 satellite imagery (November 2024) was segmented using the Multi Resolution Segmentation (MRS) method, with 30-meter resolution bands (blue, green, red, NIR, SWIR) and adjusted scale parameters (1857–10,522 hectares) for optimal spectral and geometric coherence. Each segmented object was assessed for agricultural suitability using OWA, assigning scores (0–1); objects scoring above 0.9 were deemed suitable for agricultural development under water-stressed conditions. This hybrid approach, combining pixel-based and object-based analyses, enhances spatial precision, offering a robust decision-support tool for sustainable agricultural planning and water resource management in arid regions.

RESULTS & DISCUSSION

This study evaluates agricultural land potential in the Anjir Plain, Iran, using a hybrid object-based and pixel-based approach integrating hydro-climatic and topographic criteria. The Best-Worst Method (BWM) assigned weights to criteria, with slope (0.203) as the most influential and microclimate (0.008) the least, achieving a consistency ratio below 0.05, indicating high reliability (Table 1).

Table 1. Weights of research sub-criteria

No	subcriterion	OWA weight	BWM weight
1	Elevation	0.122	0.123
2	Slope	0.188	0.248
3	Pedology	0.091	0.085
4	Geology	0.06	0.049
5	Distance from the aquifer	0.105	0.113
6	Microclimate	0.01	0.01
7	Distance from temperature	0.022	0.018
8	Distance from precipitation	0.032	0.027
9	Distance from evaporation	0.067	0.061
10	Distance from the protected area	0.14	0.126
11	Land use	0.163	0.14

Compared to the Analytic Hierarchy Process (AHP), BWM requires fewer pairwise comparisons, enhancing efficiency and precision. Key sub-criteria were selected based on prior studies emphasizing climatic, topographic, and hydrological integration. Elevation: Measured in meters, ranging from 0.5 to 1587.186, with sublimits of 0.5=1786-1996, 0.6=1496-2225, 0.3=2225, and 0.8=2494, Slope: Measured in degrees, ranging from 0 to 2, with sublimits of 0.3=4-8 and 0.8=8, Pedology: Classified into clay levels—low to medium (clay=0.7), medium to high (clay=0.5), very high (clay=0.3), and pure (clay=0). Geology: Classified into fine to coarse-grained sandstone (grain=0.7), polymictic conglomerate and sandstone (grain=0.7), polygenic conglomerate, gypsum, acidic lavas (grain=0.5), dolomite, tuffaceous shale, calcareous shale, and tuff (grain=0.3), Distance from the aquifer: Measured in meters, ranging from 0.5 to 1 (0.5=1, 1.5=0 × x, x=1=0), Microclimate: Classified as hyper-arid (0.8), arid (0.9), semi-arid (1), Distance from temperature: Measured in meters, ≤0.5. Distance from precipitation: Measured in meters, ≤0.50, Distance from evaporation: Measured in meters, ≤0.5, Distance from the protected area: Measured in meters, ranging from 0.5 to 1.5 (0.5=0 × 1, x=1.5=1), Landuse: Classified as aquifer and wetland (1), barren land (0.8), rangeland (0.6), woodland (0.4), rock outcrop, salt flat, and land exemptions (0). The Ordered Weighted Averaging (OWA) method modeled spatial suitability for groundwater recharge, supporting risk-averse and risk-seeking scenarios (Figure 2). Correlation analysis of 11 sub-criteria revealed elevation (r = 0.75), geology, and soil type (r = 0.67) as top predictors, while microclimate (r = -0.62) and isotherm distance (r = -0.65) negatively impacted suitability . Slope (r = 0.57) and proximity to aquifers (r = 0.65) supported agriculture, while precipitation and evapotranspiration had minimal influence. Landsat-9 imagery (November 2024) was segmented into 525 objects using Multi Resolution Segmentation, aligning with natural boundaries (Figure 3).

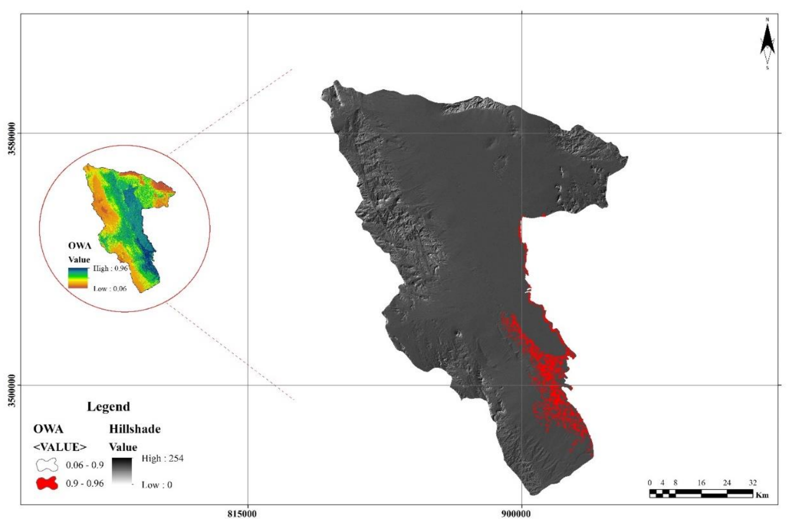

Figure 2. Agricultural sustainability map in the study area

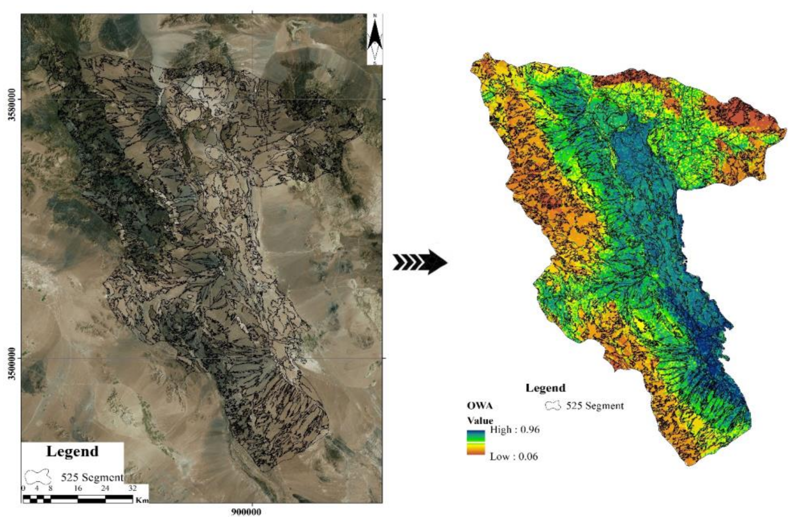

Figure 3. Segmentation with Landsat 9

Only 7 objects (8,670 hectares) scored above 0.9 via OWA, marking them as highly suitable for agriculture (Figure 4). Validation using 40 ground-truth points yielded 92.5% overall accuracy and an 85% Kappa coefficient, confirming the model's robustness (Figure 5). This hybrid approach enhances spatial precision, providing a reliable tool for sustainable agricultural planning in water-scarce regions.

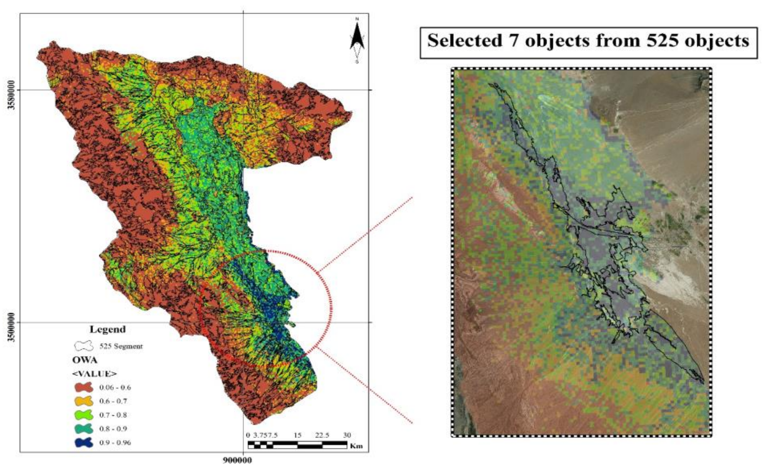

Figure 4. Agricultural Suitability (Hybrid Method)

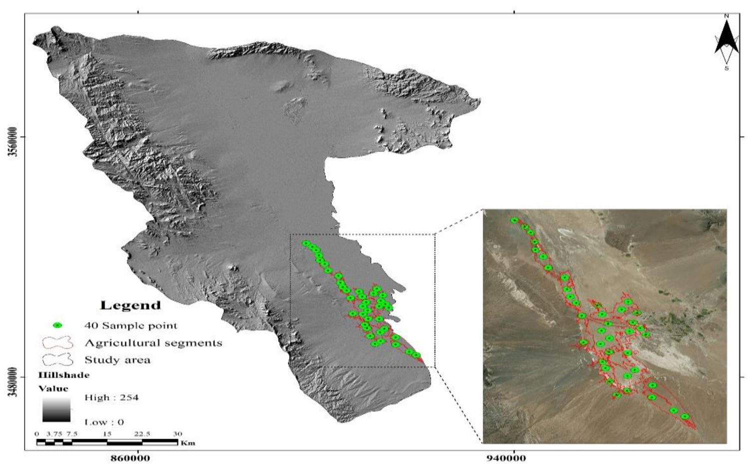

Figure 5. Sampling points in the study area

CONCLUSION

This study showcased the effectiveness of a hybrid object-based and pixel-based approach in assessing agricultural land suitability in arid and semi-arid regions, using the Anjir Plain as a case study. The method improved spatial coherence and ecological accuracy by combining object-based segmentation with pixel-level analysis, aligning suitability zones with natural landforms. The Ordered Weighted Averaging (OWA) technique enabled flexible aggregation of eleven hydro-climatic and topographic criteria, with key factors like elevation, geology, and groundwater proximity enhancing suitability, while microclimate and isothermal distance posed limitations. Of 525 segmented objects, only seven (covering 8670 hectares) scored above 0.9, marking them as prime areas for sustainable agriculture. Field validation with 40 GPS points confirmed 92.5% accuracy and an 85% Kappa coefficient, validating the model's reliability for land-use planning and water management in water-scarce regions, with potential for broader application.

FUTURE WORK / REFERENCES

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