



Military Site Selection Based on Passive Defense Approach (Integrating RS, GIS, and the Analytic Network Process [ANP] Model) at Ardabil Township¹

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Received Date: 03 February 2025 Accepted Date: 10 May 2025

Abstract

Background and Objective: In this study, the Analytic Network Process (ANP) model was employed within a Geographic Information System (GIS) framework to zone Ardabil County for the purpose of optimal military site selection. The primary objective was to identify and prioritize the most suitable areas for the establishment of military bases, taking into account environmental, climatic, and human-related criteria.

Methodology: This research is of an applied type and has been conducted using a descriptive-analytical method. For this purpose, fourteen important indicators including altitude, slope, slope direction, geology, vegetation, temperature, humidity, soil, distance from road, village, fault, land use, distance from waterway were classified into three main groups (minor, human and environmental). First, using the ANP model and Super Decisions software, the weight of each of them (using a questionnaire and 30 experts and news) was calculated based on pairwise comparisons and internal and external relationships among them. Then, using the GIS environment, spatial information layers related to each indicator were prepared and processed, and the final weight of each layer was integrated using the Raster Calculator tool. In the next step, the final zoning map of the garrison location was divided into five classes from completely suitable to completely unsuitable.

Results and Findings: Results indicated that approximately 30% of the study area falls within the "highly suitable" and "suitable" classes, mainly located in the central and western parts of the county. In contrast, about 30% of the area was found to be "moderately suitable," predominantly covering the northern and central regions. Additionally, 40% of the area was classified as "unsuitable" or "highly unsuitable," with most of these areas situated in the northern and southern parts of the county. The findings of this research can serve as an effective decision-making tool for defense institutions and urban management authorities in the optimal placement of military facilities.

Keywords: Analytic Network Process (ANP), Geographic Information System (GIS), Remote Sensing (RS), Site Selection, Ardabil Site Selection, Ardabil.

¹ This article is extracted from the elite research project titled "Survey and optimal location of military barracks using remote sensing data in a GIS environment (Case study: Ardabil Province)" conducted at the University of Mohagheh Ardabili, Ardabil, Iran. Employer: University of Mohagheh Ardabili Project, Supervisor: Mousa Abedini, Elite Soldier: AmirHesam Pasban.

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Cite this article: Pasban, A. and Abedini, M. (2025). Military Site Selection Based on Passive Defense Approach (Integrating RS, GIS, and the Analytic Network Process [ANP] Model) at Ardabil Township. *Journal of Sustainable Urban & Regional Development Studies (JSURDS)*, 6(2), 381-396.

Extended Abstract

Introduction:

Optimal site selection is a critical aspect of spatial planning, particularly when it comes to sensitive and strategic infrastructures such as military bases. In the context of national and regional security, military site planning must balance environmental resilience, operational functionality, and safety against natural and anthropogenic threats. Incorrect siting of military facilities can exacerbate risks such as increased vulnerability to attacks, environmental degradation, land use conflict, and logistical inefficiencies. Passive defense principles aimed at minimizing vulnerability without engaging in active combat emphasize the importance of location in ensuring strategic concealment, access control, and resilience to natural disasters. These considerations necessitate a data-driven, multi-criteria decision-making approach. Ardabil County, located in the northwestern region of Iran and bordering the Republic of Azerbaijan, holds strategic geopolitical importance. Its varied topography, moderate vegetation, and position along key transportation corridors further highlight the necessity of a systematic and defensible method for selecting suitable sites for military infrastructure. This study utilizes the Analytic Network Process (ANP) in combination with Geographic Information Systems (GIS) and Remote Sensing (RS) to zone Ardabil County according to the suitability of land for military facility development, incorporating environmental, climatic, and human criteria. The outcome supports sustainable spatial development and strategic defense planning.

Methodology:

This applied research adopts a descriptive-analytical methodology, integrating expert judgment with geospatial data analysis. Fourteen relevant indicators were identified and categorized into three principal groups: environmental (e.g., elevation, slope, aspect, geology, proximity to faults and waterways, vegetation), climatic (e.g., rainfall, temperature, soil moisture), and human factors (e.g., land use, distance from roads and settlements). Spatial data sources included ASTER-derived DEMs, Landsat 9 imagery (2024), geological maps, meteorological data, and infrastructural layers. Each criterion was standardized in the GIS environment. To determine the relative importance of each criterion, ANP was used via Super Decisions software, incorporating expert input from 30 professionals through pairwise comparisons. The ANP approach allows for internal and external dependencies among factors, which makes it more robust than simpler methods like AHP. The resulting weights were used to perform a weighted overlay in ArcGIS using the Raster Calculator tool. The final output classified the county into five suitability zones for military site establishment: completely suitable, suitable, moderately suitable, unsuitable, and completely unsuitable. This classification supports strategic decision-making by highlighting optimal zones that balance accessibility, security, environmental stability, and defense requirements.

Results and Discussion:

The final zoning map reveals that approximately 30% of Ardabil County is categorized as either "completely suitable" or "suitable" for military base development. These zones are mainly located in the central and western parts of the county, which benefit from moderate slopes, distance from active faults, balanced climatic conditions, and suitable geological formations. The analysis shows that these areas offer the best compromise between operational needs and passive defense principles. An additional 30% of the land is classified as "moderately suitable," covering northern and mid-regions. These areas have certain advantages but also present challenges such as proximity to sensitive ecological zones or moderate geological risk. Finally, 40% of the county — predominantly in the northern and southern margins — falls into the "unsuitable" or "completely unsuitable" categories. These regions face constraints including steep slopes, seismic risks, insufficient accessibility, or proximity to populated areas and vulnerable infrastructure. Environmental and climatic analyses showed that areas with moderate elevation (2000–3000 m), gentle slopes (<math><10^\circ</math>), and balanced soil

moisture levels (28–34%) provided optimal conditions. High elevations and steep terrain, while offering defense visibility, posed logistical and climatic challenges. Climatic data indicated that zones with annual rainfall between 500–700 mm and average temperatures around 18–24°C were best suited for sustainable infrastructure, avoiding extremes of heat, cold, and erosion. Vegetation cover analysis revealed that moderately vegetated areas provided natural camouflage without the risks associated with dense forest (e.g., limited access, fire hazards). Proximity analyses showed that safe distances from roads (for logistical access yet low visibility), villages (to avoid civilian endangerment), and watercourses (to minimize flood risks) were essential for site suitability. Additionally, geological assessments prioritized stable lithological units like Mur and Mlav formations over loose quaternary sediments (e.g., Qft, Qal), which are prone to erosion and liquefaction. In terms of importance weighting derived from ANP, geological stability and slope were among the highest weighted criteria, reflecting their foundational impact on the physical feasibility and safety of military site development. Climatic parameters like rainfall and soil moisture also received significant weight due to their influence on long-term structural integrity and environmental sustainability.

Conclusion:

This study successfully demonstrates a robust, integrative methodology for military site selection in Ardabil County, combining ANP with GIS and RS technologies. The approach ensures the consideration of multiple, interrelated spatial factors—both quantitative and qualitative—to support passive defense objectives. The findings identify the central and western areas of the county as the most appropriate zones for military development, offering a blend of operational accessibility, environmental resilience, and security advantages. The zoning map, which classifies the county into five categories based on suitability, can guide defense authorities, urban planners, and policy makers in making informed decisions that align with both strategic and sustainable development goals. The results not only improve spatial efficiency in military planning but also minimize environmental degradation, social conflict, and logistical inefficiencies. Future studies should consider dynamic factors such as climate change scenarios, urban sprawl, and emerging military threats to improve resilience and adaptability of site selection frameworks. Additionally, the integration of real-time monitoring, community feedback, and economic analysis could enhance the practical application of such spatial decision support systems.

Declarations

- Funding:** There is no funding support for this study.
- Authors' Contributions:** All authors contributed equally to the conceptualization and writing of the article. The authors approved the manuscript's content and agreed on all aspects of the work.
- Conflict of Interest:** The authors declare no conflict of interest.
- Acknowledgments:** The authors extend their gratitude to all scientific consultants who provided invaluable insights during this research.

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