

DEMOCRATIA

DEMOCRATIA - AQUA - TECHNICA

AN INTEGRATED GIS-MCDA AND MACHINE LEARNING FRAMEWORK FOR GEOTHERMAL

SHORT INTRODUCTION

NORTHERN PORTUGAL HAS A TEMPERATE MEDITERRANEAN CLIMATE WITH ATLANTIC INFLUENCE, RESULTING IN VARIABLE PRECIPITATION AND GROUNDWATER RECHARGE. ITS GEOLOGY IS DOMINATED BY FRACTURED GRANITES, SCHISTS, AND GREYWACKES, WHERE FAULTS AND FRACTURES CONTROL GROUNDWATER CIRCULATION AND STORAGE.

STUDY AREA

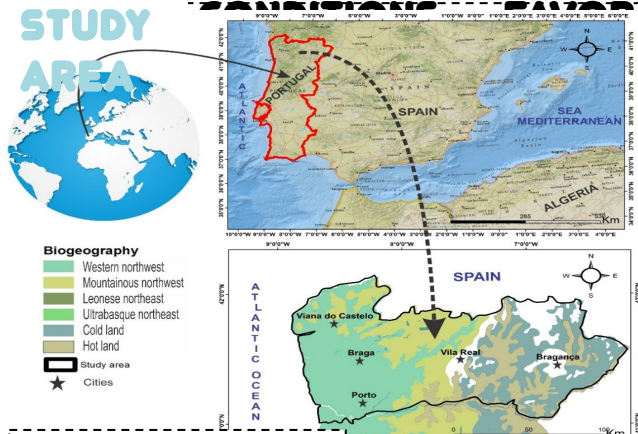


FIG 1. LOCATION OF THE STUDY REGION

OBJECTIVES

- IDENTIFY KEY GEOTHERMAL CONTROLS.
- INTEGRATE MULTI-SOURCE DATA IN GIS.
- WEIGHT FACTORS USING AHP AND ANP.
- MODEL POTENTIAL USING SVM AND RF.
- GEOTHERMAL POTENTIAL MAPING.
- COMPARE MODEL PERFORMANCE.
- SUPPORT SUSTAINABLE RESOURCE MANAGEMENT.

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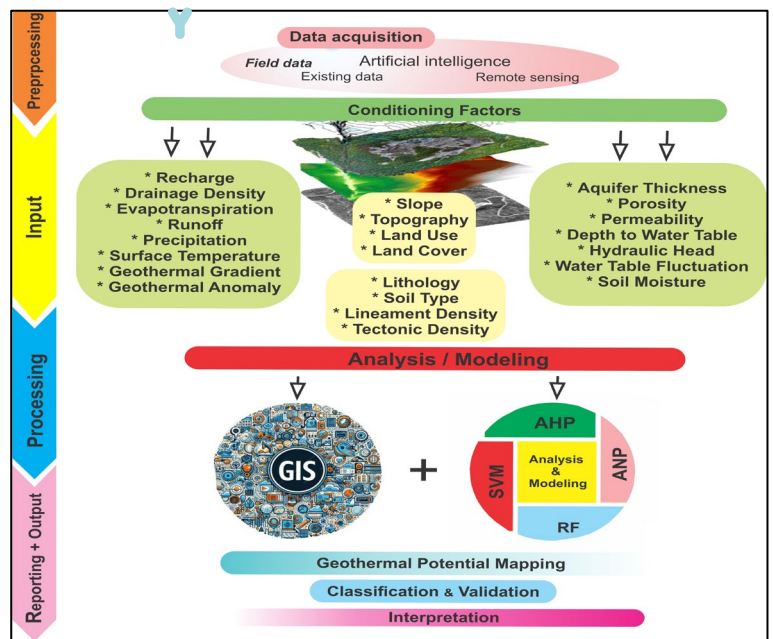


FIG 2. FLOWCHART OF APPLIED METHODOLOGY

GIS DATABASE INTEGRATING 22 GEOTHERMAL FACTORS WAS DEVELOPED FOR NORTHERN PORTUGAL. FACTORS WERE WEIGHTED USING AHP AND ANP, WHILE SVM AND RANDOM FOREST MODELS MAPPED GEOTHERMAL POTENTIAL. MODEL PERFORMANCE WAS VALIDATED USING ROC-AUC, AND RESULTS WERE CLASSIFIED INTO FIVE POTENTIAL ZONES.

RESULTS

THE AHP, ANP, RF, AND SVM MODELS PRODUCED CONSISTENT GEOTHERMAL POTENTIAL MAPS, IDENTIFYING A MAJOR HIGH-POTENTIAL CORRIDOR FROM BRAGANÇA THROUGH VILA REAL TO NORTHERN BRAGA. IN CONTRAST, COASTAL LOWLANDS AND THE PORTO

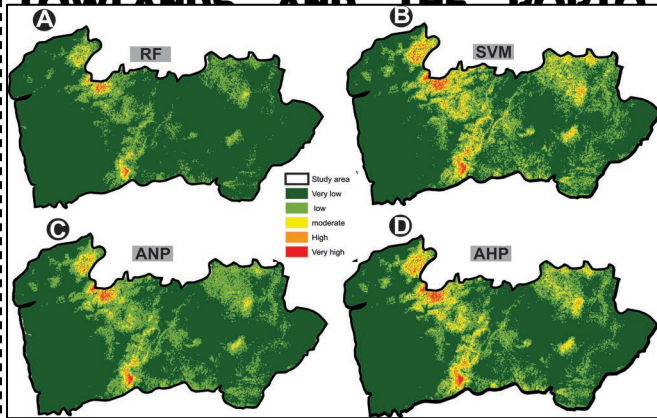


FIG 3. COMPARATIVE GEOTHERMAL POTENTIAL ZONATION MAPS OF NORTHERN PORTUGAL DERIVED FROM RF, SVM, ANP, AND AHP MODELS.

CONCLUSION

THE INTEGRATION OF GIS, AHP-ANP, AND MACHINE LEARNING TECHNIQUES [SVM AND RF] PROVED EFFECTIVE FOR GEOTHERMAL POTENTIAL ASSESSMENT IN NORTHERN PORTUGAL. THE RESULTS CONSISTENTLY IDENTIFY THE BRAGANÇA-VILA REAL CORRIDOR AS THE MOST FAVORABLE GEOTHERMAL ZONE, DRIVEN BY THE INTERACTION OF GEOLOGICAL STRUCTURES, THERMAL GRADIENTS, AND GROUNDWATER CIRCULATION. THE STRONG AGREEMENT AMONG ALL MODELS VALIDATES THE RELIABILITY OF THE METHODOLOGY AND HIGHLIGHTS ITS POTENTIAL AS A DECISION-SUPPORT TOOL FOR SUSTAINABLE GEOTHERMAL RESOURCE DEVELOPMENT..

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TABLE 1. SPATIAL CORRESPONDENCE BETWEEN GEOTHERMAL MODELS.

Model Comparison	Spatial Correspondence (%)	Estimated Disagreement (%)	Scientific Interpretation
AHP vs ANP	91	9	Very strong agreement due to similarity in expert-based weighting frameworks
AHP vs RF	86	14	High consistency; RF detects more localized statistical anomalies
AHP vs SVM	84	16	Strong agreement with minor differences in hotspot boundaries
ANP vs RF	88	12	High agreement reflecting effective factor interdependency modeling
ANP vs SVM	90	10	Very strong consistency in structural anomaly delineation
RF vs SVM	87	13	Strong machine-learning convergence with localized variability

