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SMART LAND ANALYSIS PLATFORM: A GIS-BASED DECISION SUPPORT SYSTEM FOR BUILDING SUITABILITY AND ENVIRONMENTAL RISK ASSESSMENT

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2. ABSTRACT

Assessment of land suitability and pre-construction risks has been done through laborious, manual site surveys that cannot easily incorporate real-time geospatial and environmental information. In order to address these drawbacks, this paper proposes a Smart Land Analysis Platform, an automated, web-based decision support tool designed for engineers, urban planners and real estate developers. The system architecture consists of a responsive frontend developed using the React/Vite framework together with a fast backend based on FastAPI that runs asynchronously on top of five external spatial APIs: Nominatim for geocoding, ISRIC SoilGrids for soil structure analysis, ESA WorldCover 10 m for satellite land cover classification, OpenStreetMap (Overpass) for mapping of infrastructure and road accessibility, and Open-Meteo Flood for flood risk analysis. The core of this platform is the Multi-Factor Weighted Scoring Algorithm, which aggregates different types of parameters (flood risk, soil load-bearing capacity, environmental constraints and road accessibility) and produces a land suitability percentage and an associated risk category. The platform is intended as a preliminary screening aid and does not replace site surveys, laboratory soil testing or statutory approval.

3. KEYWORDS: Smart Land Analysis Platform; Multi-Factor Weighted Scoring Algorithm; Spatial APIs; GIS Integration; Construction Suitability.

4. INTRODUCTION

With the pace of urbanization increasing and real estate development expanding, there is a need to employ intelligent land evaluation techniques. Traditionally, land evaluations are based on manual surveys, which can be very lengthy, carry an elevated margin of error and are not integrated with environmental and geographical information systems [1]. For these reasons, modern land development and construction require automated solutions that can gather multi-source geographical, geological and infrastructural information.

In this paper, we describe the Smart Land Analysis Platform, a solution aimed at automating the process of land suitability scoring and risk assessment for construction projects. The architecture of the system combines a responsive React/Vite frontend with a stable FastAPI backend that communicates asynchronously with multiple spatial and environmental APIs. In particular, the platform uses Nominatim for geocoding, ISRIC SoilGrids for soil composition and structure assessment, ESA WorldCover 10 m for land cover classification from satellite imagery, OpenStreetMap (Overpass) for infrastructure and road accessibility mapping, and Open-Meteo Flood to estimate risks based on hydrology and elevation.

The main contribution of this work is the Multi-Factor Weighted Scoring Algorithm, which standardizes and processes heterogeneous data received from multiple web services. By assigning specific weights to critical factors (flood susceptibility, soil bearing capacity, environmental limitations and road accessibility), the platform calculates an overall suitability percentage as well as a risk level. As a result, the Smart Land Analysis Platform gives engineers, urban planners and developers a transparent tool for efficient land selection and early identification of pre-construction risks.

4.1 Traditional Land Suitability Assessment Methods and Limitations

Traditional land suitability assessment relies on site surveys, exploratory boring, and visual inspections. Though these methods offer a wide range of primary observations and data, they are costly, time-consuming, and prone to human errors. Moreover, traditional methods do not provide an opportunity for real-time integration of environmental and spatial data into the pre-construction planning phase.

4.2 Evolution of Geographic Information Systems (GIS) and Spatial APIs

As the result of the evolution of web technologies and spatial databases, automated geographic information systems (GIS) became prevalent in urban planning practices.

Research has shown that utilization of open-source databases and web-based services (OpenStreetMap [6], [7] and various infrastructure maps, open-source frameworks for digital soil mapping – ISRIC SoilGrids [3], [4], etc.) improves accuracy of pre-feasibility analysis significantly. At the same time, current solutions lack automation of separate database queries and their integration into one decision-making system.

4.3 Integration of Environmental and Hydrological Risk

The advancement of remote sensing and satellite earth observation technologies through advanced land cover databases such as ESA WorldCover [5] has made automatic land use classification possible. Furthermore, hydrological models through open meteorological and flood APIs enable the accurate assessment of flood vulnerability and elevation. The integration of these disparate environmental parameters within one automated decision-making system is an important need in reducing risks prior to construction.

4.4 Multi-Factor Weighted Decision Models

In order to integrate multiple parameters into practical solutions, multi-factor scoring and weighting models and analytical hierarchy process are commonly employed in spatial decision making [1], [2]. Through the application of specific weights to significant parameters such as soil load carrying capacity, access via roads, and flood vulnerability, planners are able to create objective criteria of land suitability, which serves as the basis of the automated approach in this research project.

4.5 Research Gap

Traditional techniques for land assessment employ geographic information systems, remote sensing data and environmental data to analyse land features and to plan development. However, in order to assess a land parcel for its suitability for a certain purpose, it may be necessary to consider information from different areas such as land cover, soil characteristics, topography, weather, flood-related and infrastructure information.

When this information is analysed separately, users may find it difficult to obtain an integrated view of the land parcel in terms of its appropriateness and the risks related to development. Also, access to nearby infrastructure data alone may not be enough to understand environmental restrictions and the suitability of the land parcel for certain building types.

The Smart Land Analysis Platform provides a way of integrating geospatial information, environmental indicators, information about nearby infrastructure and a weighted scoring algorithm. In particular, the platform seeks to assist in assessing and comparing land parcels for different development purposes, which include residential, apartment, hospital, school and commercial buildings. The platform also presents the results of the assessment in the form of an interactive map, categorized indicators and reports.

4.6 Problem Statement

Choosing proper land for development involves a number of geographical, environmental and infrastructural criteria. Analysing these criteria separately can make it difficult to understand the overall suitability of the selected land and its potential constraints before the construction is designed.

The primary issue addressed in this research is the absence of a single assessment flow that unites all the relevant land criteria needed for development decisions. The Smart Land Analysis Platform analyses the selected land using the available geospatial and environmental data. It evaluates the relevant criteria, applies the Multi-Factor Weighted Scoring Algorithm and delivers the results of the analysis through an interactive interface.

The platform is meant to be a decision-support tool and not an alternative to the site survey or to the engineering and legal assessment of the land.

5. MATERIALS AND METHODS

5.1 Proposed Methodology

The Smart Land Analysis Platform is an integrated geospatial decision support system that offers a preliminary suitability analysis of a given land parcel. Various environmental, geographical and infrastructure considerations are incorporated to assess a particular parcel and to determine possible limitations of developing it. The system uses the Multi-Factor Weighted Scoring Algorithm to combine the assessment factors.

5.1.1 Land Parcel Identification

The user chooses a land parcel through the interactive map, either by identifying the geographical location of the parcel or by defining its boundaries. The chosen location and the corresponding spatial information form the base for the further analysis. The land area can be calculated from the defined boundaries in order to assess the land.

5.1.2 Geospatial and Environmental Data Integration

The platform integrates the geospatial, environmental and infrastructure data related to the selected land parcel. The assessment takes into account land cover properties, soil information, weather conditions and nearby infrastructure. These inputs provide extended information about the chosen parcel and its surroundings.

5.1.3 Multi-Factor Assessment

The selected land parcel is assessed according to several factors, including flood risk, infrastructure accessibility, nearby facilities and environmental factors. Each factor contributes its specific information regarding the suitability of the land for development. The individual assessment results are translated into suitable scores according to the defined assessment rules. This allows several factors to be considered simultaneously instead of assessing the land according to only one aspect.

5.1.4 Weighted Scoring Algorithm for Multiple Factors

The proposed solution incorporates a weighted scoring method for merging the chosen assessment factors into an overall land suitability score. The weight of each factor depends on its importance in the assessment process, and the weights of all factors are taken into account when the overall result is calculated. The general formula for the weighted score is

$$S = \Sigma\, w_i\, s_i, \quad i = 1, 2, \ldots, n \tag{1}$$

where S is the overall score, w_i is the weight of the i-th factor and s_i is the normalized score of that factor. The weights of all factors sum to one:

$$\Sigma\, w_i = 1, \quad 0 \le w_i \le 1, \quad 0 \le s_i \le 1 \tag{2}$$

For risk factors, the score calculation direction is reversed so that a higher suitability score always means better suitability.

5.1.5 Interpretation of the Suitability Assessment Score

The assessment score calculated for the chosen land parcel is interpreted according to the scoring rules implemented in the system. The score is accompanied by relevant environmental and infrastructure indicators that help explain the reasons for the final suitability score.

The platform can also be used to compare different development categories, such as residential, apartment, hospital, school and commercial buildings. Such comparisons have to be based on the corresponding criteria and should not assume that one single assessment score defines suitability for all building types.

5.1.6 Visualization and Reporting

The assessment results are shown to the user on an interactive map and dashboard, which allows the user to analyse land characteristics, neighbouring facilities, assessment indicators and suitability data. The system can also create a report that can be downloaded for later use. This functionality improves access to land-related information and supports preliminary development planning.

5.1.7 Expected Contribution

The proposed solution brings geospatial information, environmental assessment, infrastructure analysis and land suitability scoring into one platform. Instead of looking at different sources of information separately, the system gives an overview of the relevant land characteristics and possible limitations. It is a tool for preliminary decision making and cannot substitute for field survey, engineering analysis or legal land-use approval processes.

5.2 System Architecture

The architecture of the Smart Land Analysis Platform follows a decoupled, modern client-server approach intended to provide concurrency, fast responses and asynchronous communication (Fig. 1).

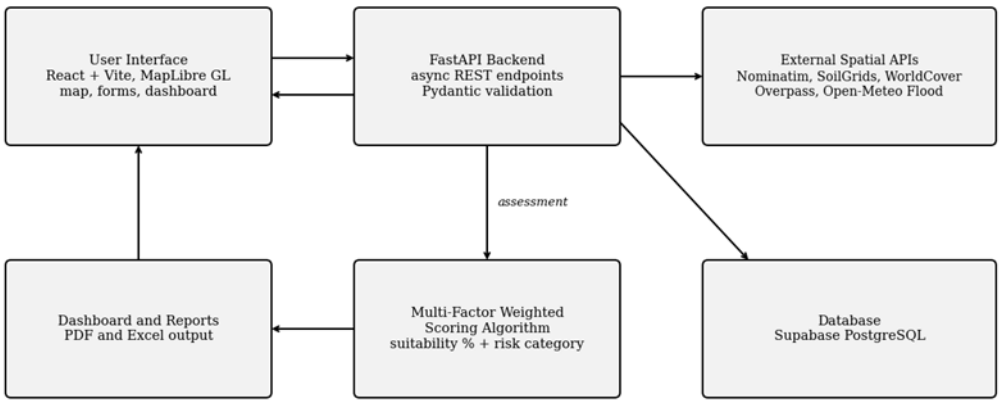


Fig. 1. Architecture diagram of the proposed system.

5.2.1 Frontend and Backend Integration

The presentation layer utilizes React [8] and Vite to provide a responsive interface enabling users to select land parcels, draw spatial boundaries, and review assessment reports. The backend is powered by FastAPI [9] (Python), chosen for high concurrency, asynchronous support, and Pydantic-based data validation. Asynchronous RESTful communication between the frontend and backend ensures the main application thread remains unblocked during intensive geospatial processing.

5.2.2 Integration with External Spatial APIs

To ensure a comprehensive evaluation, the backend interfaces asynchronously with specialized geospatial web services, including Nominatim [10] and Open-Meteo [11], as summarized in Table 1.

Table 1: External spatial services integrated in the platform.

Service	Provider	Role in the platform
Nominatim API	OpenStreetMap	Reverse geocoding: readable location addresses from geographical coordinates
ISRIC SoilGrids API	ISRIC - World Soil Information	Soil composition and structural properties used to evaluate load-bearing capacity
ESA WorldCover 10 m	European Space Agency	Satellite-based land cover classification
Overpass API (OpenStreetMap)	OpenStreetMap contributors	Local road network, accessibility criteria and nearby infrastructure
Open-Meteo Flood API	Open-Meteo	Hydrological conditions, elevation and river discharge data

5.3 Experimental Setup and Implementation

5.3.1 Experimental Setup

The proposed Smart Land Analysis Platform was implemented as a web-based application for preliminary land suitability assessment. The system integrates a frontend interface, backend processing services, geospatial data sources, database storage and report generation facilities.

The frontend was developed using React.js, with MapLibre GL providing interactive map visualization. The backend was developed using FastAPI to manage application requests and coordinate land analysis operations. Supabase PostgreSQL was used for database management.

External geospatial and environmental information was obtained from available services, including OpenStreetMap, SoilGrids, Open-Meteo and ESA WorldCover. These data sources support the identification of nearby infrastructure and the assessment of available environmental and land cover characteristics. The application was deployed as a web-based system, allowing users to select a land parcel and access the generated assessment through the interface.

5.3.2 Implementation

The implementation consists of the following functional modules.

Land Parcel Selection: Users can select a geographical location using the interactive map and define a land boundary for analysis. The selected coordinates and boundary information serve as inputs to the assessment process.

Geospatial Processing: The system processes the selected location and boundary to calculate land area and identify nearby facilities. Distance calculations are used to represent the proximity of infrastructure such as roads, hospitals, schools, transport facilities and commercial locations.

Environmental and Infrastructure Assessment: Available geographical and environmental information is organized into relevant assessment categories. The resulting indicators provide information about the selected parcel and its surroundings.

Land Suitability Scoring: The Multi-Factor Weighted Scoring Algorithm combines the applicable assessment factors using assigned weights. The overall score is calculated from the factor scores according to the implemented scoring rules.

Visualization and Reporting: Assessment results are displayed through the interactive interface and dashboard. The platform also supports generating downloadable PDF and Excel reports containing the available assessment information.

5.3.3 Experimental Procedure

The evaluation procedure involves selecting representative land locations, obtaining the available geographical and environmental information, processing the selected parcel and examining the generated assessment outputs. The system is evaluated on the correctness of land area calculation for user-defined boundaries, the availability and relevance of nearby infrastructure results, the successful retrieval and processing of available environmental

information, the consistency of weighted scoring calculations, the correct display of assessment results in the user interface, and the successful generation and readability of PDF and Excel reports.

The evaluation records the selected locations, test conditions, expected outcomes, actual outputs and any errors observed during execution.

5.3.4 Implementation Considerations

The availability and quality of external data may vary with geographical coverage and service availability. Consequently, assessment results depend on the information retrieved for each selected location. The platform is intended to support preliminary land assessment, and its outputs should be interpreted alongside appropriate professional site investigations and regulatory requirements.

6. RESULTS AND DISCUSSION

6.1 Results

The proposed Smart Land Analysis Platform integrates geospatial information, environmental indicators, and nearby infrastructure data to support preliminary land suitability assessment. The implemented system provides an interactive interface through which users can select a land parcel, examine its surrounding environment, and access the available assessment results.

The platform supports land area calculation based on the defined parcel boundary and provides information about nearby facilities, including roads, hospitals, schools, public transportation facilities, and commercial locations. The availability of these facilities depends on the geographical coverage and completeness of the retrieved data.

The land assessment module combines applicable assessment factors using the Multi-Factor Weighted Scoring Algorithm. The resulting score provides a consolidated representation of the evaluated factors according to the scoring criteria defined by the system.

The platform also presents the assessment information through a dashboard and supports the generation of downloadable PDF and Excel reports. These features allow users to review and document the available results in a structured format.

6.2 Discussion

The integration of geospatial and environmental information provides a broader view of the selected land parcel than examining individual geographical characteristics separately. The identification of nearby infrastructure helps users understand accessibility and the availability of relevant facilities around the selected location.

The weighted scoring approach provides a systematic method for combining multiple assessment factors into an overall score. However, the usefulness of the resulting score depends on the selection of appropriate factors, the justification of their weights, the consistency of the scoring scales, and the quality of the underlying data.

The interactive map and reporting facilities improve the accessibility of the assessment information by presenting spatial details and analytical outputs through a unified interface. This can assist users during preliminary land evaluation and development planning.

Nevertheless, the assessment has certain limitations. External data services may contain incomplete or outdated information, and environmental datasets may differ in spatial resolution and geographical coverage. A weighted suitability score should therefore be interpreted as a decision-support indicator rather than a guarantee that a parcel is safe or legally suitable for a particular construction project.

Further evaluation using representative land parcels, verified reference data, and documented test cases is necessary to establish the reliability and practical effectiveness of the platform.

6.3 Summary of Findings

This approach presents an integration of the workflow for choosing land parcels, acquiring geographical data, assessing the distance to infrastructure, computing scores based on several factors, visualizing the data and generating reports. The system forms the basis for a preliminary evaluation of land parcels by combining information in one software product.

Quantitative claims regarding the performance of the platform will be made only after testing and measuring its performance.

7. CONCLUSION

The Smart Land Analysis Platform allows for the integration of geospatial information, environmental assessment, and infrastructure proximity analysis into a comprehensive web-

based tool that is used for preliminary land assessment. Users can choose a certain land parcel and explore the nearby facilities, assess land characteristics, and look through the obtained results using the interactive interface.

The Multi-Factor Weighted Scoring Algorithm is a good tool to combine several factors into the final assessment score. Using the integration of geographical information, environmental assessment, and infrastructure analysis, users may explore possible advantages and restrictions associated with a certain land parcel. Moreover, the use of the dashboard and downloadable reports improves the presentation of assessment information.

The described platform aims to make the preliminary land development decisions well-informed by integrating all relevant information into one system. Nevertheless, the reliability of assessment results is highly dependent on the quality of datasets, selection of assessment factors, and validation of the scoring methodology. Thus, the platform should be viewed as a decision-support tool and not as an alternative to professional site surveying, engineering assessment, and official approval.

7.1 Future Work

Future work will be directed at enhancing the accuracy, reliability, and analytics of the platform. The following improvements are proposed:

1. Advanced Flood Risk Assessment: Integrate more accurate hydrological data, flood history, and detailed elevation data to enhance assessment of flood risk.

2. Improved Assessment of Suitability for Development: Improve scoring criteria and factor weightings based on expert opinion, validated reference data, and validation of the model.

3. Comprehensive System Validation: Validate the system using representative land parcels and reference data in order to estimate consistency and reliability of assessments produced by the system.

These improvements may help to increase the scope of applicability of the developed platform.

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