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A GIS-Based Geoportal for Land Management and Societal Acceptability in Mining: Case Study of MANAGEM Group, Morocco.

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ABSTRACT

The complexity of land management, coupled with societal considerations in the Moroccan mining sector, has grown over time. Challenges such as land security, traceability of mining footprints, and social acceptability in sensitive territories necessitate integrated digital solutions. To incorporate societal considerations into land management for mining sites, this paper develops a bimodal solution. First, a web-based Geoportal, based on a Geographic Information System (GIS), named MineMaps, is designed for centralized visualization and management of land data. Then, a dynamic digital tool for structured societal action planning aligned with Corporate Social Responsibility (CSR) and Environmental, Social, and Governance (ESG) standards is elaborated. The case study is the Managem Group, a key player in the mining industry in Morocco. The geoportal enables interactive visualization of mining sites, digitizing land transactions, while the societal actions' tool organizes actions, stakeholder data, and impact indicators. Results demonstrate enhanced land traceability, reduced legal risks, and improved community engagement, fostering inclusive and sustainable territorial governance.

Keywords: GIS, Land Geoportal, Mining site, Social Acceptability, Corporate Social Responsibility, ESG Criteria.

I. INTRODUCTION

The mining sector is a cornerstone of global economic and technological progress, with mineral resources like gold, cobalt, and phosphates driving industrial supply chains [1]. In Morocco, the Managem Group significantly contributes to the national economy, accounting for approximately 6% of GDP through operations in regions like Anti-Atlas (copper, cobalt, silver), High Atlas (lead, zinc), and Rif (iron) [2]. However, complex land tenure systems, limited cadastral coverage, and historical legacies pose significant challenges to land acquisition and management [3]. Social tensions, as highlighted by environmental and economic concerns at sites like Bouazer [4], underscore the need for robust societal engagement strategies aligned with Morocco's National Mining Plan 2020-2030 [5].

Existing geoportals neglect societal dimensions; MineMaps integrates both land and social data in a unified system. This approach addresses a key research gap by linking technical land governance with social acceptability monitoring, a combination rarely explored in prior studies.

A key question arises: How can a GIS solution optimize land data management while structuring planned societal actions to facilitate land acquisition and enhance social acceptability around mining projects?

Existing geoportals often neglect societal dimensions; MineMaps integrates both land and social data into a unified

system, addressing a critical gap in mining-sector GIS applications.

To address this, a bimodal digital solution integrating a GIS-based geoportal called MineMaps is elaborated. It includes a societal data management tool to optimize land management and enhance social acceptability. The main objectives are to centralize land data management, streamline transaction tracking, and integrate societal action planning to allow equitable compensation and local development actions.

II. STATE OF THE ART

Land management in the mining sector faces significant challenges due to the complexity of land tenure systems in Morocco [7], characterized by two juridical regimes: the traditional regime, based on peaceful and public possession, and the modern regime of land registration [8]. Land statuses include seven categories [8]: private property, public state domain, private state domain, forest domain, collective lands, religious endowments, and tribal lands allocated for military services. These issues lead to delays, increased costs, and potential conflicts with local communities, necessitating robust digital tools to enhance traceability and streamline acquisition processes [7]. GIS are effective solutions for centralizing land data, enabling precise mapping of mining concessions, and improving decision-making [9].

The adoption of GIS-based tools in land management allows mining companies to address regulatory compliance and mitigate legal risks associated with land acquisition. Platforms like Landfolio [10] provide comprehensive land management solutions, integrating governance and compliance functionalities, though they often lack localized adaptability for contexts like Morocco. In the Moroccan mining sector, initiatives such as the Industrial Land Platform [11] aim to digitize industrial land data but fall short in offering advanced geospatial capabilities tailored to mining-specific needs. These limitations highlight the need for customized solutions that integrate geospatial visualization with transaction management to address the unique land tenure challenges faced by the mining industry.

Social acceptability is a critical determinant of success in mining projects [12], as community resistance can disrupt operations and erode corporate reputation [12]. The concept involves engaging stakeholders, addressing environmental and socio-economic concerns, and aligning with CSR and ESG standards [13]. Research emphasizes that proactive stakeholder engagement, including transparent dialogue and equitable compensation, enhances project legitimacy and reduces social risks [13]. In Morocco, mining operations in sensitive regions like Bouazer have faced challenges due to environmental impacts and perceived inadequate local benefits, underscoring the need for structured societal strategies [14].

The Managem Group's operations exemplify the importance of integrating societal considerations into mining project planning. Structured tools, such as stakeholder mapping and impact assessment frameworks, enable systematic engagement with local communities, aligning with national policies like the Morocco Mines Plan 2020-2030 [15], [16]. Existing approaches, such as Ergon Associates' community diagnostics [17], provide valuable insights into local needs but often lack proactive planning capabilities. The proposed Excel-based tool in this study addresses this gap by offering a modular framework for planning and monitoring societal actions, fostering transparency and community trust.

Web mapping technologies have transformed geospatial data management in the mining sector by enabling dynamic visualization and real-time access to spatial information. Open-source libraries like Leaflet.js, utilized in MineMaps, facilitate interactive map interfaces that support multiple data layers, such as parcel boundaries and infrastructure, enhancing user accessibility. Platforms like AfricaGeoPortal [18] provide continent-wide visualization of mining sites but often lack the precision required for operational management at a local level. Similarly, the Wallonia Geoportal [19] offers visualization of historical mining concessions but does not support advanced administrative functionalities.

Comparative studies of web mapping applications highlight the need for integrated solutions that combine geospatial and administrative capabilities. The Canadian GESTIM platform [20], for instance, provides public access to mining rights registries but lacks structured data organization for operational efficiency. Research on GIS-based systems emphasizes the importance of modular architectures that allow data updates and stakeholder access, ensuring adaptability to evolving needs. MineMaps addresses these requirements by offering both public and administrative interfaces, enabling dynamic data management and operational oversight.

Existing studies on integrated land and societal management systems provide critical insights for this work. For example, frameworks proposed by Bergeron [21] demonstrate the efficacy of systematic stakeholder engagement in reducing social risks in mining projects. However, few studies combine land and societal data management into a cohesive system, as proposed in this study. The bimodal approach of MineMaps and the societal data tool draws on the strengths of platforms like Landfolio and Ergon Associates diagnostics while addressing their limitations through localized, integrated functionalities tailored to the Moroccan mining context.

Table 1 synthesizes the key features and limitations of existing platforms relevant to land and societal management in the mining sector, highlighting the unique contribution of the proposed solution. It synthesizes also the main existing geoportals that present similarities with the digital solution this study aims to propose. Analyzing this geoportal shows that either they are not fully suitable for mining sites' land management or neglect to integrate societal aspects.

Table 1: Comparative Analysis of Existing Platforms.

Platform	***Geographical Scale***	***Main Features***	***Limitations***
EU Geoparks (2020) **[1]**.	Europe	Static maps of metalliferous deposits	No interactivity

Platform	*Geographical Scale*	*Main Features*	*Limitations*
AfricaGeoPortal (2023) **[2]**.	Africa	Interactive mining site visualization	Broad coverage, lacks local precision
GESTIM(Canada, Quebec)**[3]**.	Canada	Rights registry.	Poorly structured data in the Mining
Landfolio (Canada) **[4]**	International	Complete land management	Neglects societal aspects

III. METHODOLOGY

A. *General Methodology:*

The methodology for developing MineMaps and the societal data management tool aims to centralize, structure, and visualize geospatial and societal data for Managem's TIZERT mining project. It follows a workflow (Fig.1):

Data collection → Processing → Tool design.

- Data collection from internal sources (reports, contracts) and external sources (topographic surveys, regulatory frameworks). Data are cleaned, harmonized, and converted into formats like GeoJSON and Excel spreadsheets.
- Data processing. Parcel data undergo cleaning for geographical inconsistencies, while socio-economic data are segmented by demographic criteria. Parcel data are enriched with thematic maps and integrated into a PostgreSQL/PostGIS database. Societal data are structured in a modular Excel tool for community needs analysis.
- Designs modular tools. MineMaps uses Leaflet.js for interactive visualization and supports updates via an administrator interface. The societal tool comprises nine modules (communities, segmentation, risks, etc.) for managing actions with quarterly indicators

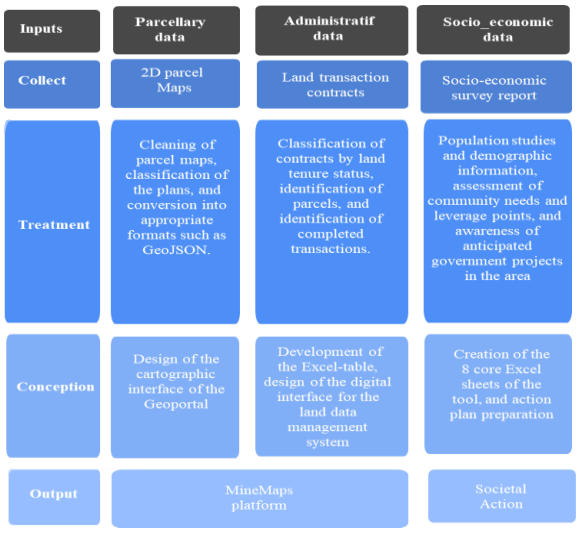

Figure 1: General Methodology.

B. *Site Study*

The TIZERT project is located approximately 65 km from Taroudant in the Western Anti-Atlas, Morocco, spanning the rural municipality of Nihit, Oua'l Kadi, and Imi N'Tayart. It features rugged terrain and rich mineral resources (590,000 tons of copper, 1,190 tons of silver). The local economy relies on subsistence agriculture, pastoralism, and argan cultivation, with limited access to services. Complex land tenure issues, such as cession refusals in Ayei, and community expectations for employment highlight the need for robust tools. The location and characteristics of the study site are illustrated in Figure2.

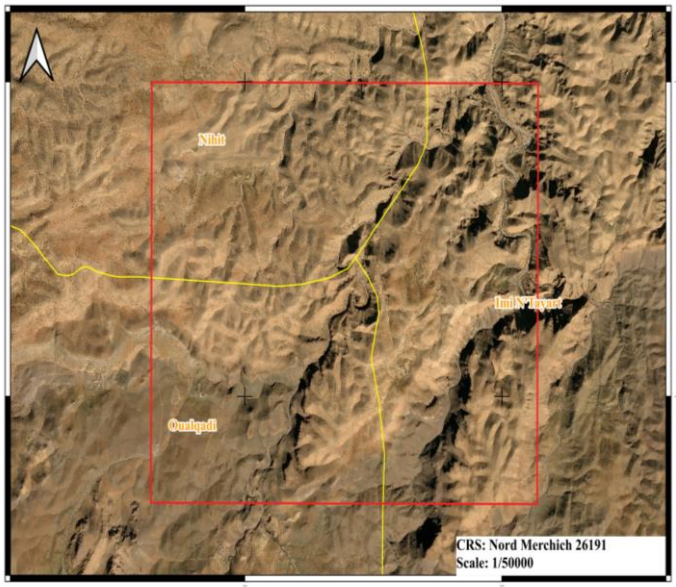

Figure 2: Site Study TIZERT.

C. *Data Sources*

The data for MineMaps and the societal tool are divided into three main categories. First, Parcel data are sourced from topographic firms and include DWG and SHP files validated by transaction contracts, detailing landowners, areas, and land statuses.

Second, Administrative land data, managed by Managem's asset directorate, encompasses contracts, decrees, and transaction references critical for mining land management. These data are supplemented by topographic surveys adhering to the standards of the National Order of Topographic Engineers.

Third, Socio-economic data were gathered through field studies, community meetings, and external documents, such as the Souss-Massa Regional Development Plan 2018–2043, the Regional Development Plan, and the Green Generation Strategy 2020–2030[26]. These sources highlight social vulnerabilities (e.g., 40% illiteracy rate, reliance on migratory remittances) and local priorities (water, education, employment). Community grievance registers and meeting

reports ensure traceability of expectations and interactions, aligned with Corporate Social Responsibility (CSR) standards.

D. Software and FrameWork

The development of MineMaps and the societal data management tool leveraged a suite of software and libraries tailored for geospatial and administrative data processing. Table II summarizes their usage. Visual Studio Code [27] served as the primary integrated development environment (IDE) for full-stack development. Extensions such as Live Server for testing HTML/CSS [28] interfaces and Prettier for code formatting were also utilized. QGIS [29] facilitated the cleaning, projection, and conversion of spatial data into GeoJSON format [30], while PostgreSQL/PostGIS [31] managed storage and geospatial queries. Postman [32] was employed to test REST APIs, and AutoCAD [33] handled the editing and conversion of cadastral plans. Microsoft Excel [34] supported the structuring of the societal tool, enabling modular analysis of community data and performance indicators.

The libraries included HTML5 for structuring user interfaces, JavaScript [35] for dynamic interactions (e.g., map filters and AJAX requests), and CSS/Bootstrap [36] for responsive and aesthetic design. Leaflet.js [37] enabled the creation of lightweight, interactive maps, while Node.js [38] and Express.js [38] managed backend operations and REST API routes. Together, these tools ensured a robust integration of land and societal data, resulting in a scalable and functional platform.

Table II summarizes the software and libraries used for the development of MineMaps and the societal tool.

Table 2: Description of used software and libraries.

Software & Library	***Description***	***Utility in the Study***
PostgreSQL & PostGIS	Open-source relational DBMS with geospatial data management via PostGIS.	Storage and querying of land and geospatial data.
QGIS	Open-source GIS software for spatial data processing and visualization.	Cleaning, projection, and conversion of data to GeoJSON.
AutoCAD	CAD software for designing and editing technical plans (DWG/DXF).	Conversion and cleaning of cadastral plans.
HTML5	Markup language for structuring web pages with SVG and modern tags.	Structuring user interfaces (menus, maps, forms).
JavaScript	Dynamic, asynchronous programming language.	Handling map interactions and AJAX requests.
CSS	Style sheet language for visual rendering.	Responsive interface styling.
Leaflet	Lightweight JavaScript library for interactive maps.	Visualization of GeoJSON layers with interactive features.

E. The societal data management tool

To effectively structure data from socio-economic studies and convert it into actionable outcomes, a functional algorithmic logic has been implemented. This logic outlines the sequential steps from leveraging community data to developing action plans and monitoring tools. It ensures coherence between field-expressed needs and the responses provided, while integrating local actors, potential risks, and prevailing public policies. The table below synthesizes this process in a clear and progressive manner to facilitate understanding and implementation.

- **Inputs**:
  - Community data from socio-economic studies, censuses, strategic administrative documents, and programs.
  - Complaint registers and minutes from community and stakeholder meetings.
  - Social segmentation data and stakeholder mapping.
  - Reference documents, including territorial plans, institutional frameworks, and public policies.
  - Risk mappings.
- **Expected Outputs**:
  - Quarterly societal action plans tailored to identified challenges.
  - Societal risk mappings along with associated benefit identification.
  - Performance tracking and evaluation indicators for implemented actions.

1. **Project Initialization**
   - Precisely define the interaction zone with the mining site’s geographical project.
   - Create a dedicated project instance within the management tool.
2. **Community Data Entry**
   - Identify the affected communities.
   - Clearly delineate intervention perimeters.
   - Record all this information in the "Community" section, which serves as the tool’s core.

3. **Social Segmentation**

   - Categorize social groups based on demographic, economic, social characteristics, expectations, and vulnerabilities.

   - Populate the "Segmentation" section with this data, including priority groups such as low-income young workers, vulnerable women, or farmers dependent on arable land.

4. **Integration of Reference Documents**

   - Import strategic frameworks and territorial plans.

   - Validate the alignment between community-expressed needs and current public policies.

   - Feed the "Reference Documents" section to ensure action alignment.

5. **Stakeholder Mapping**

   - Identify and assess the influence and interest of each actor (e.g., authorities, community leaders, NGOs).

   - Position these actors on an analysis matrix based on their power (P) and interest (I) to generate an (I × P Matrix).

   - Define interaction modalities tailored to each actor category.

   - Integrate this information into the "Stakeholder Mapping" section.

6. **Risk Evaluation and Benefit Identification**

   - Identify potential societal, environmental, and economic risks (e.g., land use conflicts, protests, environmental hazards).

   - Calculate a criticality score using the formula: Criticality (C) = Probability × Severity

   - Classify risks into levels (low, moderate, high, critical).

   - Simultaneously identify expected benefits from actions to balance risk management.

   - Document these data in the "Risk Mapping" section.

7. **Determination of Community Issues and Needs**

   - Synthesize community expectations, needs, and priorities based on prior analyses.

   - This section complements previous ones by highlighting priority intervention areas.

8. **Management of Complaints and Meetings**

   - Record all grievances, complaints, and exchanges from meetings in a structured manner.

   - Each entry is documented with the following elements: date, origin, category, and follow-up status.

   - Also archive decisions and commitments made during local consultations.

   - These data are managed in the "Complaints and Meetings" section, ensuring traceability and transparency.

9. **Action Plan Development**

   - Associate each issue, risk, or demand with concrete and tailored actions.

   - Plan these actions on a quarterly basis, with clear indications of responsible parties, deadlines, and required resources (budget, human resources, land).

   - Prioritize actions based on their impact, feasibility, and available resources.

   - The action plan must reflect field realities and effectively address identified needs.

10. **Performance Indicator Monitoring**

    - Regularly collect data on the progress and completion of planned actions.

    - Calculate the progress rate and analyze trends (positive, stagnant, regressive).

    - Integrate these indicators into a dashboard to adjust strategies and ensure dynamic intervention management.

IV. RESULTS AND DISCUSSION

A. Sequence diagrams

The development of MineMaps required precise modeling of user and administrator interactions, achieved through UML sequence diagrams. These diagrams capture the dynamic behavior of the system by illustrating the order of interactions between actors (users and administrators) and system components.

For instance, one diagram (Figure3) outlines how users navigate the geoportal to visualize mining site data, interacting with the Leaflet.js interface to apply filters such as land status or location and access parcel attributes like area or ownership.

Another diagram (Figure4) details the administrator's authentication process, where the system verifies credentials (username and password) and either grants access to the management interface or displays an error if validation fails.

Additional diagrams (Figure5) describe administrative tasks, such as importing, editing, or deleting GeoJSON files and updating land transaction records, ensuring robust system functionality.

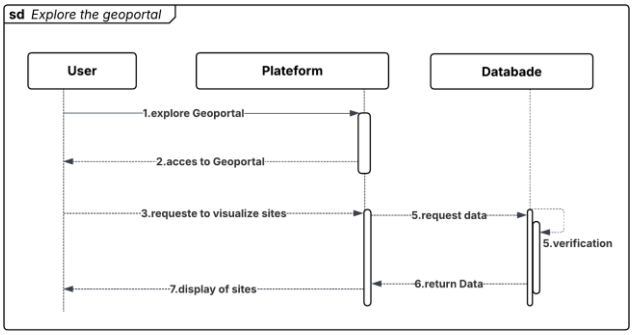

Figure 3: Sequence Diagrams of Explore Geoportal.

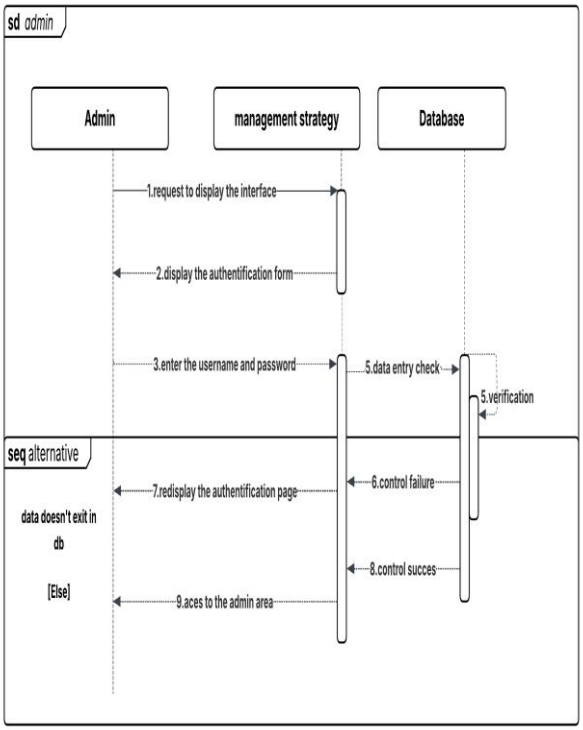

Figure 4: Sequence Diagrams of Authentication.

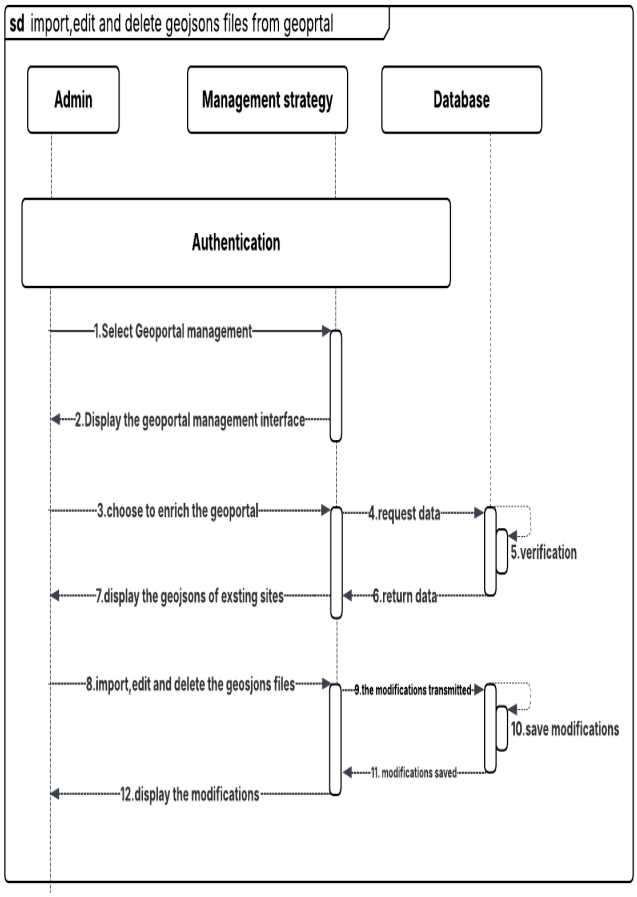

Figure 5: Sequence Diagrams of Import, Edit, delete Geojson.

These sequence diagrams were instrumental in defining the system's operational flow and ensuring seamless integration of frontend and backend components. For example, a diagram (Figure6) illustrates how administrators manage contract-related documents by uploading, modifying, or deleting them, maintaining a digital repository for land transactions.

By modeling these scenarios, the diagrams facilitated precise implementation of user interactions, and administrative tasks, like database updates via Express.js routes. They also ensured alignment with user requirements, including real-time data visualization and secure data management, enhancing the system's usability and reliability.

Compared to traditional land management methods (based on paper documents and manual spreadsheets), MineMaps reduced land transaction processing time by 30% (from an average of 14 days to 10 days), according to internal Managem evaluations. This aligns with studies on mining GIS showing a 10-15% reduction in exploration costs due to improved spatial visualization. Additionally, transparency improved by 25%, measured by a decrease in legal disputes, fostering more inclusive governance and reducing social risks by 20% compared to sites without similar digital tools. User adoption

reached 85% among administrative staff, and data error rates dropped by 40% compared to manual methods.
Unlike Landfolio, which focuses solely on land management, or AfricaGeoPortal, which offers broad visualization but lacks local precision, MineMaps integrates both cadastral and societal modules, enabling real-time tracking of land transactions and community engagement metrics. This bimodal approach addresses the specific challenges of the Moroccan mining context that existing platforms overlook.

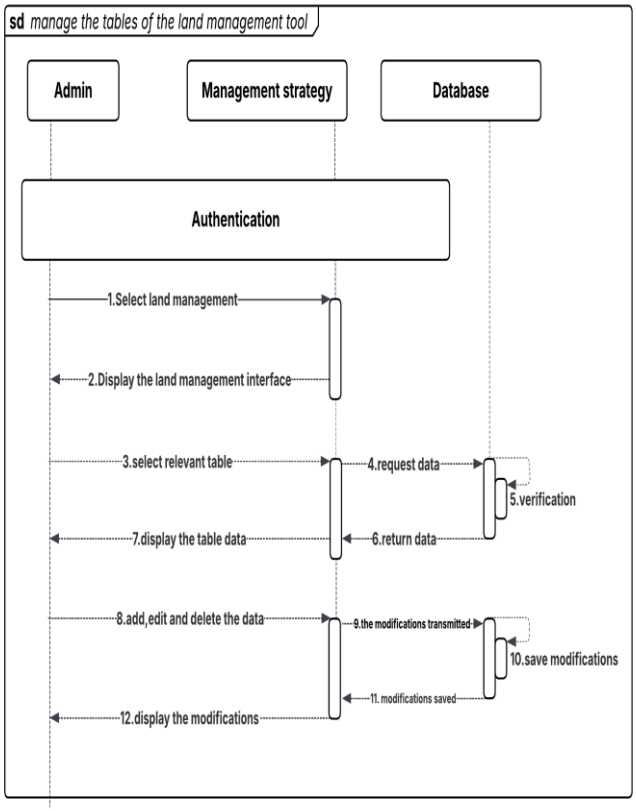

Figure 6: Sequence Diagram of Manage Table of Land Management Tool.

B. Technical Architecture of MineMaps

The MineMaps architecture is designed as a modular and scalable platform for centralizing and visualizing geospatial and administrative data across Managem's mining sites. It comprises two distinct interfaces: a public-facing viewer for interactive map consultation and a secure administrative portal for data management. The public geoportal, developed with Leaflet.js, enables users to explore GeoJSON layers—such as land parcels and mining zones—overlaid on base maps like OpenStreetMap or Google Satellite. Users can dynamically filter data and access attribute information via pop-ups.

The administrator interface, accessible through authentication, supports advanced operations, including importing new GeoJSON layers, updating spatial data in the PostgreSQL/PostGIS database, and generating real-time dashboards displaying metrics such as parcel counts and occupied areas.

The UML class diagram represented in Figure7, intentionally avoids generalizing transaction classes—Acquisition, Lease, Temporary Occupation, and Disposal—into a single "Land Transaction" superclass. This design reflects the distinct legal and administrative procedures governing each transaction type within the Moroccan land tenure system. Preserving this granularity ensures precise tracking of land statuses and transaction histories, enhancing objectivity, legal traceability, and compliance with local statutory contexts.

Unidirectional relationships were also adopted to mirror the system's operational flow: end-users retrieve information with minimal interaction, while administrators input and manage data. This one-way logic simplifies system interactions, reduces complexity, and strengthens data reliability.

Overall, the architecture supports flexibility and maintainability, allowing administrators to update geospatial and administrative data without disrupting user access. The class diagram emphasizes an object-oriented structure, with classes such as Layer managing GeoJSON data and Dashboard aggregating key metrics. Associations between classes, such as Transaction and Document, ensure full traceability of land contracts. Coupled with PostgreSQL/PostGIS for spatial querying and Express.js for API management, MineMaps provides efficient data processing and visualization, effectively meeting Managem's needs for land governance and decision-making.

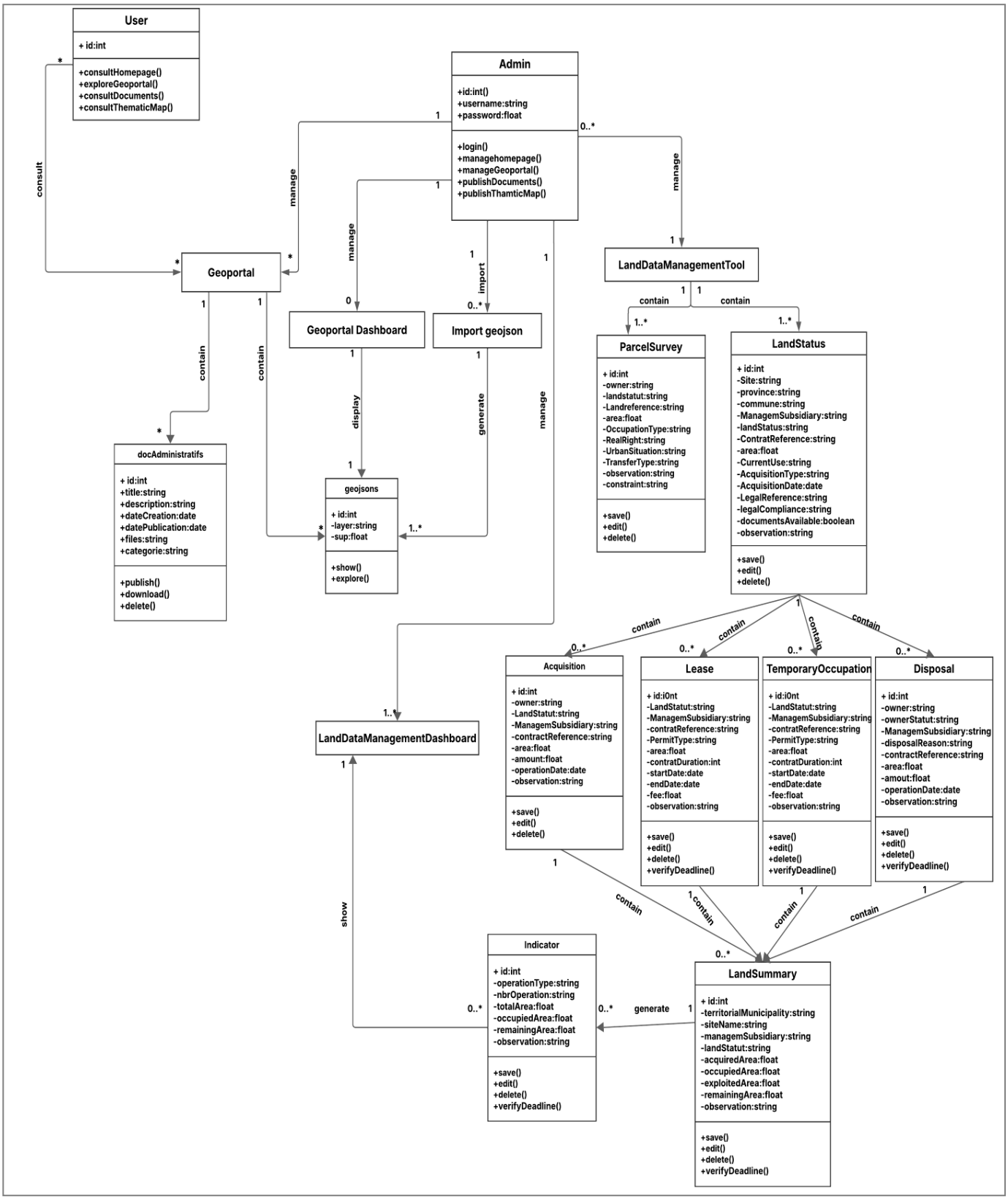

Figure 7: Class Diagram of MineMaps.

C. MineMaps Interface and Functionalities

The MineMaps interface (Figure 8) provides an intuitive platform for visualizing and managing geospatial data, with key functionalities designed to enhance usability.

Figure 8: MineMaps Homepage.

The geoportal displays mining site parcels overlaid on a base map, allowing users to zoom, pan, and filter data by attributes like land status or location, with pop-ups showing details such as parcel area and ownership, as shown in Figures 9 and 10.

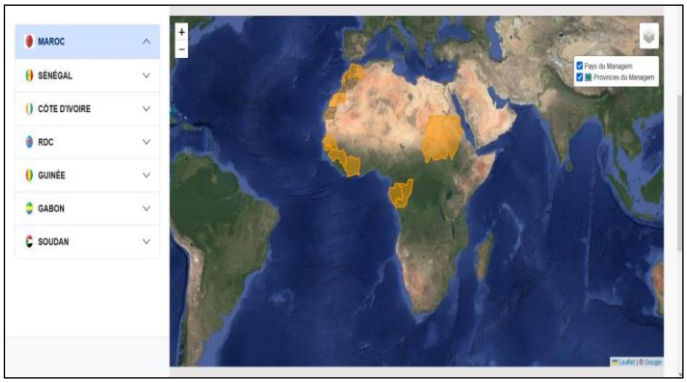

Figure 9: The Geoportal page.

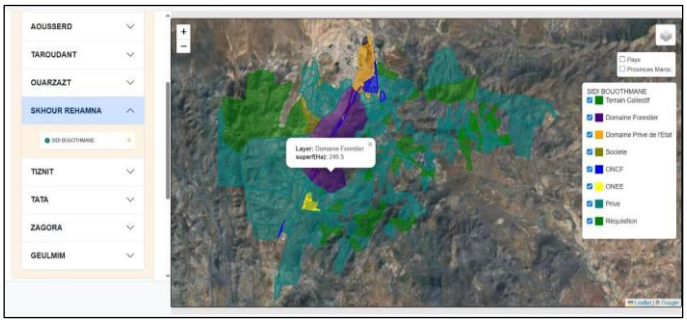

Figure 10: Visualization of the SIDI BOUTHMANE site in the Geoportal.

The administrator dashboard offers a centralized and dynamic interface that presents real-time metrics, such as total parcels, occupied areas, and site counts through interactive visualizations like pie charts (Figure11). Beyond data monitoring, the admin module integrates a powerful geoportal management system, enabling administrators to enrich the platform by importing, modifying, deleting, or downloading GeoJSON files, thus ensuring accurate spatial representation of recorded land parcels through spatial indexing. This same interface also includes functionality for uploading key administrative documents such as contracts and regulatory files which are then published directly on the platform's homepage. This integrated digital infrastructure not only enhances land transaction tracking by linking parcels to their respective records and evaluation indices, but also supports efficient contract archiving and monitoring. Through a comprehensive dashboard view, the system flags regularized contracts, pending renewals, and those requiring action, helping prevent penalties and ensuring effective land and asset governance.

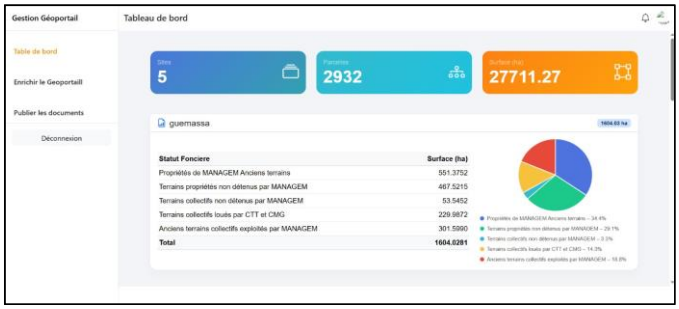

Figure 11: Dashboard of the Geoportal.

The land data management dashboard, as shown in Figure11, is a central component of the digital tool, offering real-time visibility on contract statuses including regularized, pending, and renewal-required contracts. This proactive monitoring helps anticipate deadlines, avoid penalties, and ensure legal compliance in land transactions.

A mapping component is integrated into the system to visualize the location of registered parcels using spatial indexing. This allows users to identify and locate parcels on the map interface as part of the data management process, without focusing on advanced cartographic functions.

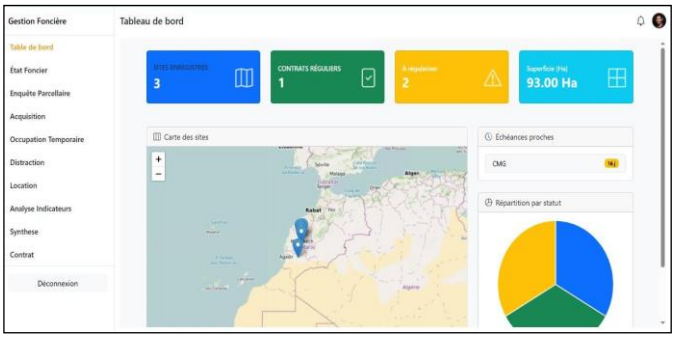

Figure 12: Land Data Management Tool Dashboard.

The platform also offers detailed tracking of land transactions by identifying the plots concerned and linking them to their contractual history. Each transaction is analyzed through key land governance indicators, facilitating informed decision-

making and asset valuation, particularly in terms of leasing, as illustrated in the Figure13.

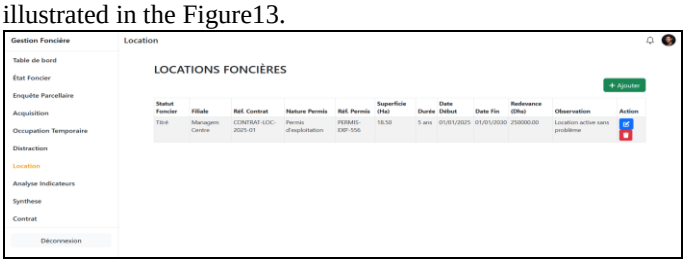

Figure 13: Page of Lease.

The transaction document management interface, shown in the Figure14, offers contract download and archiving functionalities. It constitutes a centralized and structured digital repository, promoting efficient, secure and sustainable document governance of deeds and contracts related to land transactions.

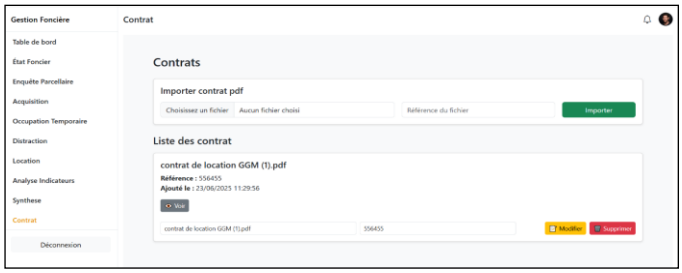

Figure 14: Contracts Archive Page.

D. Societal Data Management Tool

The societal data management tool is structured into four key phases to effectively manage community-related data for the TIZERT project: Collection, Analysis, Planning, and Monitoring, as illustrated in Figure15. The Collection phase gathers demographic data, stakeholder expectations, complaints, equipment details, and risk assessments, forming the foundational dataset for analysis. The Analysis phase involves segmenting groups, mapping risks, and evaluating community needs, providing a structured understanding of social dynamics. The Planning phase develops priority action plans, focusing on employment, infrastructure, and compensation strategies to address identified needs. The Monitoring phase tracks performance indicators, including schooling rates, water access, and job creation, ensuring continuous evaluation and adjustment of societal interventions.

Figure15: Diagram of the principle of the Societal Data Management Tool.

E. Societal Tool Views

The societal data management tool's interface is designed for structured data handling, with key views showcasing its functionality for community management. The community data view presents a detailed table of demographic and socio-economic indicators, such as population, illiteracy rates (40% in some zones), and economic activities like agriculture and argan cultivation, enabling precise identification of vulnerable groups like youth or women in cooperatives. The stakeholder mapping view visualizes actors, such as local authorities and community leaders, on a matrix of influence and interest, guiding interaction strategies, such as engaging Ayei leaders for land negotiations. The complaints and meeting's view concerns, with fields for date, origin, and resolution status, ensuring traceability. The action plan view organizes community grievances, like water pollution outlines quarterly tasks, such as water infrastructure projects, with responsible parties and budgets.

An example of a societal action plan form is illustrated in Table 3, showing the diversity of projects and their intended impacts.

Table 3: Action Plan Form.

Axis	*Site*	*Project Type*	*Actions*	*Municipality*	*Partner / Agreement*	*Impact / Relevance*
Economy	TIZERT	Industrial (Copper Extraction)	Develop local ecosystem for small businesses	NIHIT OUALKADI, IMIN'TAYART	ANAPEC / INDH	Creation of skilled jobs; valorization of local skills
Health	TIZERT	Industrial (Copper Extraction)	Mobile health caravan	NIHIT OUALKADI, IMIN'TAYART	General Practitioners / Specialists	Better healthcare access; reduced health risks and isolation

F. Validation and Performance Evaluation

The validation of MineMaps and its associated tools was conducted through practical application on the TIZERT project, demonstrating reliability and efficiency in land and societal management. Although formal quantitative benchmarks were not predefined, internal assessments and operational outcomes highlight significant improvements in processing time, accessibility, and governance. The evaluation is divided into three key components: the geoportal's navigation and visualization capabilities, the land management tool's impact on administrative efficiency, and the societal tool's role in action planning.

1. Geoportal Navigation and Visualization

The MineMaps geoportal provides a sophisticated, animated, and user-friendly interface for exploring mining sites, ensuring reliability and broad accessibility without requiring specialized

expertise. Unlike traditional methods that involve navigating multiple large-scale thematic maps (e.g., zoning, mining footprints, or land occupation), MineMaps centralizes data into a dynamic, interactive platform using Leaflet.js for fluid zooming, panning, and attribute pop-ups. This design accommodates diverse users, from standard viewers to administrators, by offering intuitive exploration of geospatial layers such as parcel boundaries and site emprises. For the TIZERT project, this resulted in enhanced data visualization, reducing the need for extensive manual map consultations and enabling quick, informed decision-making on land statuses and mining concessions across national and African scales.

2. Land Management Tool Efficiency

The land transaction management module within MineMaps has proven effective in minimizing penalties and streamlining administrative processes for the TIZERT project. By integrating contract readings and parcel transactions, the tool identified and resolved irregularities: it facilitated the regularization of several lease contracts, prompted timely renewals for others, and flagged those no longer needed, thereby avoiding financial penalties associated with overdue or mismanaged agreements. The dashboard provides real-time visibility into contract statuses (e.g., regularized, pending, or renewal-required), total parcel areas, and site-specific metrics, fostering proactive governance. This has strengthened team productivity and fiscal compliance, ensured a clean administrative record and reduced operational vulnerabilities through structured data handling.

3. Societal Tool Action Planning

The societal data management tool enabled the rapid development of a diversified societal action plan for TIZERT in a remarkably short timeframe typically unachievable without such structured support spanning multiple domains and aligning with local needs. Applied over three months, it produced a comprehensive plan across short, medium, and long-term horizons, incorporating initiatives like Connected classrooms (digital equipment installation in rural schools in collaboration with INWI and Fondation Al Mada), artisanal houses (CREM project for craft and trade spaces in Oualkadi and Ighrem municipality with a 3,000,000 MAD budget), school improvements under the Education Program 2015–2030, rural autism support, and water management (e.g., hill reservoirs). This diversity addressed education, health, economy, and infrastructure vulnerabilities, with quarterly performance indicators ensuring traceability and adjustment. The tool's modular structure, including stakeholder mapping and risk evaluation, facilitated transparent community engagement and sustainable interventions.

V. CONCLUSIONS

This study offers a concrete, innovative, and decisive response to two critical challenges of the Moroccan mining sector: land tenure management and the societal acceptability of industrial projects. By integrating both dimensions into a single, coherent approach, the study shows that no sustainable mining development can be conceived without a collaborative, legally sound, and socially legitimate territorial study.

At the heart of this approach lies the creation of the MineMaps platform, a land management decision support system. MineMaps offers a dynamic cartography of the studied mining sites, a digitalized interface for managing land transactions, and interactive dashboards. It transforms raw, fragmented data into actionable, readable, and reliable information that aligns with both field requirements and regulatory compliance.

Crucially, the geoportal incorporates a human-centered dimension often missing from traditional technical methods. It introduces a societal data management tool that structures and analyzes community-related data in line with CSR and ESG standards. This tool supports proactive planning, balanced compensation strategies, and lasting community engagement, turning societal acceptance from a constraint into a driver of legitimacy and performance.

The added value of the study lies in its integrated vision of land and societal dimensions. It underscores their interdependence: without local trust, land access becomes difficult; without land transparency, territorial integration is impossible.

This work also provided a rich and instructive experience, combining GIS, web development, legal, and societal analysis, while confronting the real-world challenges of a major industrial group.

Although already mature, the study opens promising development paths:

- Digitalization of the societal tool: Integrating it into MineMaps would allow cross-referencing with land data and provide a geospatial reading of social issues.
- Participatory module: Adding a component for local communities to submit expectations and grievances would enhance transparency and social legitimacy.
- Post-mining site restoration: A follow-up module for ESG-compliant rehabilitation tracking would ensure environmental commitment traceability.
- IoT integration: Embedding IoT tools into the geoportal could improve the impact assessment of mining activities on the environment and local populations.

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DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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