Ai-Powered Fra Atlas & Webgis Decision Support System

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***Abstract*—The Forest Rights Act (FRA), 2006 aims to recognize and secure the rights of forest-dwelling communities; however, its implementation is hindered by fragmented and non-digitized records, lack of spatial data integration, and absence of a centralized monitoring mechanism. This project proposes an AI-powered FRA Atlas integrated with a WebGIS-based Decision Support System (DSS) to address these challenges. The system digitizes and standardizes FRA records such as Individual Forest Rights (IFR), Community Rights (CR), and Community Forest Resource (CFR) using text extraction and Named Entity Recognition (NER). It further employs remote sensing and machine learning techniques to map key assets like agricultural land, forest cover, water bodies, and settlements. The WebGIS platform enables multi-layered visualization and tracking of FRA implementation across different administrative levels, while the DSS recommends suitable government schemes by linking beneficiaries with Central Sector Schemes. Overall, the system enhances transparency, improves accessibility to data, and supports informed, data-driven decision-making for effective FRA implementation and sustainable development.**

***Index Terms*—Forest Rights Act (FRA), WebGIS, Decision Support System (DSS), Artificial Intelligence (AI), Remote Sensing, Machine Learning, NER, Spatial Data Integration, Asset Mapping.**

I. INTRODUCTION

The Forest Rights Act (FRA), 2006 was enacted to recognize and grant land and resource rights to forest-dwelling communities, addressing historical injustices and improving their socio-economic conditions. However, its implementation faces significant challenges, including scattered and non-digitized records, lack of spatial data integration, and the absence of a centralized monitoring system, which hinder efficient data management and delay the delivery of benefits. With advancements in technologies such as Artificial Intelligence (AI), Machine Learning (ML), Remote Sensing, and Geographic Information Systems (GIS), there is strong potential to overcome these issues through improved data digitization, mapping, and analysis. In this context, the proposed project develops an AI-powered FRA Atlas integrated with a WebGIS-based Decision Support System (DSS) to digitize and standardize FRA records, provide interactive spatial visualization, and enable effective monitoring of implementation. The system also supports data-driven decision-making by linking beneficiaries with appropriate government schemes, thereby enhancing transparency, improving data accessibility, and contributing to efficient governance and sustainable development in forest regions.

II. LITERATURE REVIEW

Katiyar, S. S. "Study on the Implementation of Forest Rights Act-2006 in District Pratapgarh, Rajasthan, India", INDIAN FORESTER, 2024.
This research conducts a deep dive into the practical rejection rates and administrative hurdles of FRA claims between 2020 and 2021. The author highlights that nearly 57% of claims were rejected, often due to a lack of legal sanctity or evidentiary gaps. The study emphasizes the Supreme Court's direction for the Forest Survey of India to conduct satellite-based monitoring to verify encroachments. The relevance to your project lies in the urgent need for a spatial verification system (like your WebGIS) to provide

evidence-based claim processing and reduce the high rate of "unjust" rejections identified in the paper.

Sahoo, P. S., Bang, S. "Forest Conservation and Development in India: An Analysis of the FRA, 2006 and Its Impact on the Forest System", JURNAL CITA HUKUM, 2024.

This paper analyzes the shift toward decentralized forest governance and identifies a critical "lack of will" and administrative delays in developmental projects for tribal communities. The authors argue for a post-claim management framework to ensure that once rights are recognized, the land remains productive and sustainable. This research justifies your project's Decision Support System (DSS), which specifically aims to link recognized beneficiaries with government schemes to improve their socio-economic status after the "patta" is granted.

Ministry of Tribal Affairs (MoTA). "The Call for Justice Report: Barriers in Community Forest Rights", MOTA TECHNICAL PAPERS, 2024.

This high-level report identifies that FRA implementation has disproportionately focused on individual rights (IFR) while neglecting Community Forest Resource (CFR) rights. It calls for "Institutional Convergence" to fix fragmented data management. Your proposed system addresses this specific gap by providing a standardized Atlas that maps both IFR and CFR, ensuring that community-level conservation rights often ignored in manual records are digitized and protected.

Ford, L. "Geospatial Validations Using FastAPI and PostGIS", PYCON US RESEARCH, 2024.

This technical study demonstrates how to leverage FastAPI with PostGIS to implement custom geospatial validations for inbound data requests. The author focuses on maintaining data correctness through Spatial Reference Identifiers (SRID) and Geochem 2. This is highly relevant to your Backend API, providing a blueprint for how your 50+ endpoints can handle complex spatial joins (e.g., checking if a claimed parcel overlaps with a Tiger Reserve) with high performance and minimal latency.

Baidu-ERNIE-Team. "PaddleOCR 3.0: High-Performance Document Understanding and Structure Parsing", PADDLE RESEARCH, 2025.

This technical report introduces the PP-StructureV3 and PP-ChatOCR modules, which move beyond simple text transcription to hierarchical document parsing. The authors show that these models can accurately extract tables and key entities from low-quality scanned legal documents. This study validates your choice of PaddleOCR for digitizing the "scattered and non-digitized records" of the FRA, ensuring that the system can automatically populate database fields from old, physical government forms.

Lodha, K. G. "Creating Spatial APIs with FastAPI: Asynchronous Management of Point and Polygon Data", ROTTEN GRAPES GEOSPATIAL, 2025.

This research explores the integration of FastAPI, SQLAlchemy, and Alembic for managing asynchronous database migrations in GIS projects. It details how to serve GeoJSON data efficiently to a frontend interface like React/Leaflet. The study's focus on scalable architecture is critical for your project's WebGIS component, ensuring that the interactive dashboard remains responsive even when multiple users are querying large-scale spatial datasets simultaneously.

Kapoor, A., Esposito, M. "Land Record Management in India and Adoption of Intelligent Frameworks", THE INDIA DIALOG / STANFORD UNIVERSITY, 2024.

This working paper examines the adoption of Machine Learning and Distributed Ledger Technologies in Indian land administration. It argues that high error margins in manual spatial records make them irrelevant in disputes unless supported by AI-driven anomaly detection. The relevance to your project lies in its discussion of Unified Land Parcel Identification Numbers (ULPIN). Your AI-powered Atlas aligns with this modern framework by providing the "error-free, transparent, and tamper-proof" records needed to satisfy the digital standards of the 2026 e-governance era.

III. EXISTING SYSTEM

The existing implementation of the Forest Rights Act (2006) is characterized by a fragmented, paper-centric administrative framework that relies on manual coordination between the Gram Sabha, Revenue, and Forest departments. Under the current regime, forest-dwelling communities submit physical applications that must navigate a multi-tiered bureaucratic hierarchy, which is prone to significant administrative friction and procedural delays. While state-level initiatives like VanMitra or Mo Jungle Jami Yojana have introduced digital tracking, these systems function primarily as static repositories for scanned

PDFs. They lack the intelligent data processing required to handle the millions of legacy handwritten records, leading to high rejection rates due to typographical errors, data inconsistencies, and the loss of physical evidence during inter-departmental transfers.

A critical technical failure of the existing system is the absence of integrated spatial intelligence. Current verification methods often rely on traditional hand-drawn maps or isolated GPS points that do not align with high-resolution, multi-temporal satellite imagery. This spatial "mismatch" makes it nearly impossible to independently verify the legal requirement of land occupation prior to the 2005 cutoff date, leaving claimants vulnerable to subjective administrative bias. Furthermore, the existing data remains trapped in institutional silos, where the lack of a unified, multi-layered "Atlas" prevents officials from identifying overlaps between individual claims, community resources, and developmental projects. Most significantly, the current lifecycle concludes with the mere issuance of a land title, offering no automated Decision Support System (DSS) to link beneficiaries with essential socio-economic welfare schemes. This "Title-Only" approach addresses the legal recognition of rights but fails to provide the data-driven infrastructure necessary for the long-term sustainable development of forest-dwelling populations.

IV. PROPOSED SYSTEM

A. System Overview

The proposed system is an AI-powered Forest Rights Act (FRA) Atlas integrated with a WebGIS-based Decision Support System (DSS) designed to streamline and enhance the implementation of FRA. The system focuses on digitizing and standardizing legacy FRA records, including Individual Forest Rights (IFR), Community Rights (CR), and Community Forest Resource (CFR), using advanced techniques such as Optical Character Recognition (OCR) and Named Entity Recognition (NER). It incorporates remote sensing and satellite imagery to map and analyze key geographical features such as forest cover, agricultural land, water bodies, and settlements. The WebGIS platform provides an interactive interface for visualizing multi-layered spatial and socio-economic data, enabling real-time monitoring of FRA progress at village, district, and state levels. Additionally, the integrated DSS analyzes the collected data to support informed decision-making by recommending suitable government schemes for beneficiaries based on their profiles and location. The system ensures improved transparency, efficient data management, and better accessibility for stakeholders, thereby facilitating effective governance and sustainable development in forest regions.

B. Technology Stack

The Smart FRA Atlas system is developed using a well-structured technology stack categorized across frontend, backend, database, AI, and supporting tools to ensure scalability, performance, and intelligent functionality.

Frontend: The user interface is built using React 19 with Vite, enabling fast rendering and a responsive, component-based architecture. Interactive mapping features are implemented using Leaflet and React-Leaflet, while Tailwind CSS is used for modern, consistent, and responsive UI design.

Backend: The backend is powered by FastAPI (Python), which provides high-performance RESTful APIs, efficient request handling, and seamless integration with machine learning and data processing modules.

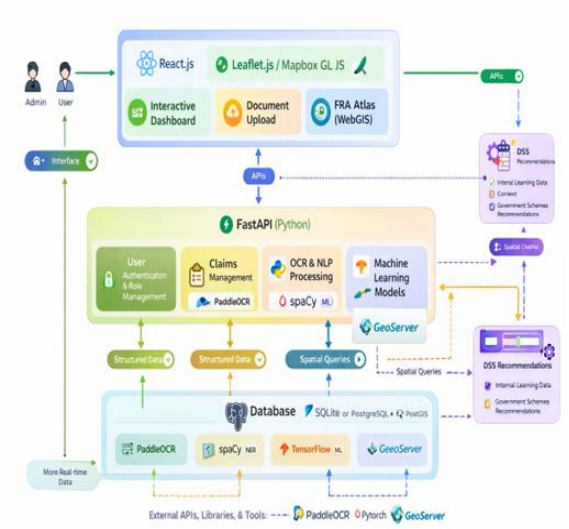
Database: Data persistence is managed using SQLite for lightweight development and PostgreSQL for production-level deployment. PostGIS is integrated with PostgreSQL to support advanced geospatial data storage and spatial queries.

Artificial Intelligence (AI): The system incorporates AI capabilities using PaddleOCR for document digitization and text extraction, and SpaCy for natural language processing and entity recognition. Additionally, Scikit-learn and PyTorch are utilized to develop machine learning models for predictive analysis and decision support.

Algorithms: The Smart FRA Atlas incorporates a range of algorithms to enable automated document processing, intelligent analysis, and geospatial decision support. Optical Character Recognition is performed using PaddleOCR, which applies deep learning-based text detection and recognition models to extract structured data from scanned FRA documents. The extracted text is further processed using Natural Language Processing techniques implemented through SpaCy, including tokenization, part-of-speech tagging, and Named Entity

Recognition to identify key attributes such as names, locations, and claim details. For predictive analytics, machine learning algorithms such as Logistic Regression, Random Forest, and Decision Trees are utilized to analyze historical claim datasets and support classification and decision-making processes. In addition, geospatial analysis is carried out using spatial querying algorithms supported by PostGIS, enabling efficient handling of location-based data, proximity analysis, and map-based visualization. Data preprocessing techniques, including normalization, feature extraction, and data cleaning, are applied to improve model performance and accuracy. These algorithms collectively enhance automation, ensure data accuracy, and provide intelligent insights for effective implementation of the Forest Rights Act.

C. Flow Diagram



The Smart FRA Atlas architecture follows a layered flow where users interact through a React-based frontend for dashboards, document upload, and mapping. The frontend communicates with a FastAPI backend via APIs, which processes requests using modules like authentication, claims management, OCR, NLP, and machine learning. The processed data is stored and managed in a database with geospatial support, enabling real-time analysis, visualization, and intelligent decision-making.

D. Implementation

The implementation of the Smart FRA Atlas system is designed as a modular, scalable, and integrated platform that combines web technologies, geospatial systems, and artificial intelligence to streamline forest rights claim management. The system is structured into multiple functional modules, including user authentication, document upload and OCR processing, claims management, geospatial visualization, approval and verification, and analytics. The user authentication module ensures secure access through role-based login for administrators and users, maintaining data integrity and controlled system interaction. The document upload module enables users to submit claim-related files in various formats, which are then processed using Optical Character Recognition (OCR) algorithms to extract relevant textual information. This extracted data is pre-processed through techniques such as noise removal, tokenization, and normalization to ensure consistency before being stored in the database.

The claims management module acts as the core component, where all extracted and manually entered data are structured and maintained. It supports operations such as claim creation, modification, tracking, and report generation. The approval and verification module incorporates AI-assisted decision-making by analyzing claim data, validating geographical coordinates, and identifying inconsistencies or duplicate entries. Machine learning algorithms, such as classification and anomaly detection models, are employed to assess claim validity and prioritize cases for review. The geospatial visualization module is implemented using WebGIS technologies, enabling the mapping of claims onto an interactive interface. Spatial data processing techniques, including coordinate mapping, layer overlay, and heatmap generation, are used to provide insights into claim distribution and land usage patterns.

The system workflow begins with user authentication, followed by document submission and automated OCR processing. The extracted data is then validated and stored, after which claims are visualized on the GIS interface. Administrators can review claims through the verification module, supported by AI-generated insights, and take appropriate actions such as approval or rejection. The analytics module continuously processes system data to generate reports and visual dashboards, providing stakeholders with performance metrics and trend analysis.

E. Experimental Output

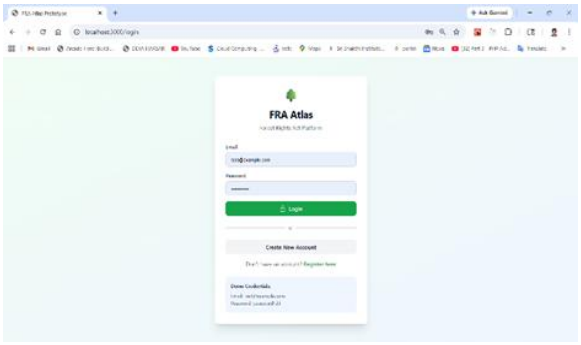


Fig. 1. User Authentication (Login)

This figure shows the secure login interface, allowing users to access the system through authentication mechanisms. It also provides options for account creation and demo access.

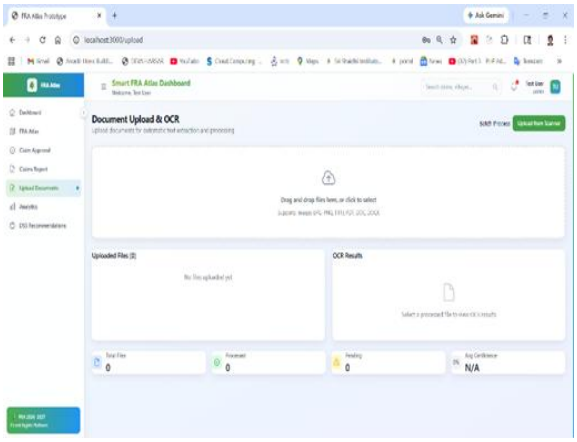


Fig. 2. Document Upload and OCR Processing Module.

This module enables users to upload documents in various formats, which are processed using OCR technology to extract and digitize text data, facilitating easy storage and retrieval of records.

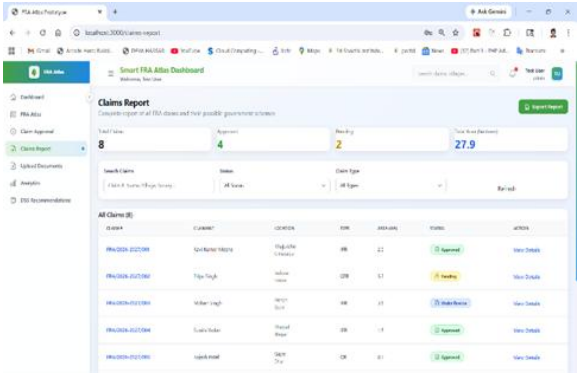


Fig. 3. Claims Report Management System.

This interface provides a comprehensive view of all claims, including their type, status, and area. It supports filtering, searching, and exporting data, enabling efficient report management and administrative control.

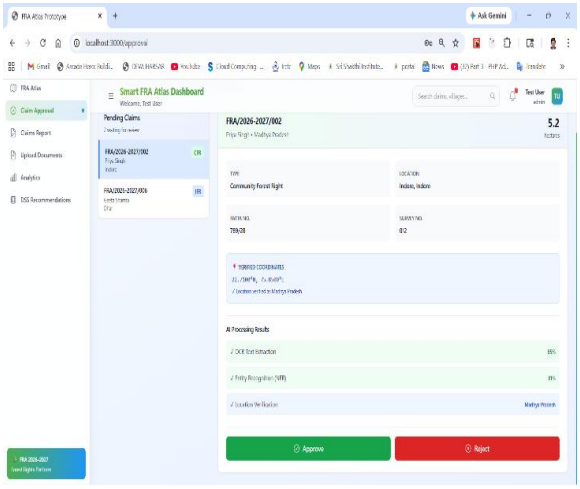


Fig. 4. Claim Approval and Verification Interface.

The claim approval interface allows administrators to review and verify submitted claims. It displays claimant details, geographical coordinates, and AI-generated insights to support accurate and efficient decision-making.

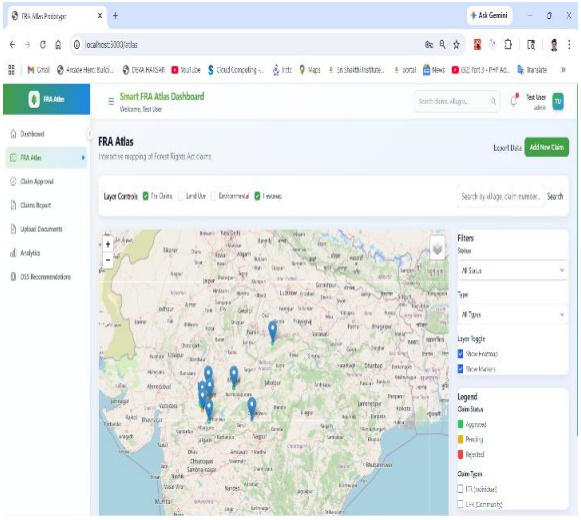


Fig. 5. FRA Atlas Geospatial Visualization Module.

This module presents an interactive WebGIS-based map for visualizing forest rights claims. Users can enable multiple layers such as claim boundaries, land use patterns, and heatmaps to perform spatial analysis and better understand claim distribution.

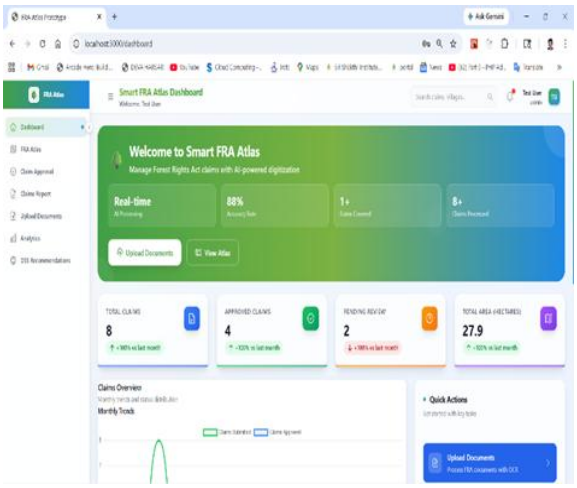


Fig. 6. Smart FRA Atlas Dashboard Interface.

The dashboard provides an overview of the system, displaying key metrics such as total claims, approved claims, pending requests, and total area covered. It also integrates AI processing insights and offers quick navigation to major modules like document upload and atlas visualization.

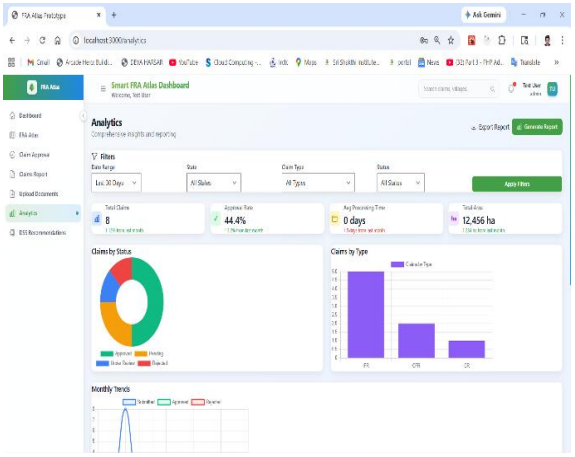


Fig. 7. Analytics and Insights Dashboard.

The analytics dashboard presents graphical representations of claim statistics, approval rates, and processing timelines. It assists stakeholders in monitoring performance and identifying trends within the system.

V. CONCLUSION & FUTURE WORK

The Smart FRA Atlas system provides an efficient and integrated platform for managing forest rights claims through the use of geospatial technologies, AI-based processing, and digital document handling. By combining WebGIS visualization, OCR-based document digitization, and automated analytics, the system enhances transparency, accuracy, and decision-making in claim verification and management. It reduces manual effort, minimizes errors, and ensures a streamlined workflow for stakeholders, thereby contributing to improved governance and sustainable resource management.

Future enhancements of the system can focus on integrating advanced machine learning models for predictive analysis and fraud detection in claims. The inclusion of real-time satellite data and remote sensing technologies can further improve spatial accuracy and monitoring. Additionally, developing a mobile application for field-level data collection, multilingual support for wider accessibility, and blockchain-based record management for enhanced security and transparency can significantly expand the system's capabilities and impact.

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