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Development of Ancient Tea Tree Ecosystem Platform

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----------*ABSTRACT*----------

As an essential component of primitive ecosystems, the ancient tea tree ecosystem possesses irreplaceable value in biodiversity conservation and cultural heritage transmission. However, challenges such as lagging informatization, limited public awareness, and the absence of a unified resource platform hinder its effective protection and management. In response, this study developed a visualization platform for ancient tea tree ecosystems based on the Java technology framework and digital methodologies. By integrating geographical and cultural data from multiple ancient tea tree ecosystems, the platform achieves unified data management and visual representation, offering robust data and technical support for scientific research, conservation decision-making, and sustainable utilization. The findings contribute to enhancing the digital management of ancient tea tree ecosystems and serve as a reference for the digital display of similar ecosystems.

Keywords: *Ancient Tea Trees; Ecosystem; Visualization Platform*

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I. Introduction

tea trees are not only vital resources for the tea industry but also play a critical role in maintaining ecological balance[1]. Predominantly distributed in semi-humid evergreen broad-leaved forests, they form stable ecosystems alongside surrounding vegetation[2]. These trees provide habitats for diverse species, contribute to stable food chains, prevent soil erosion, protect soil structure, and serve as significant carbon sinks—making them integral to climate change mitigation[3]. As both ecological and cultural assets, ancient tea tree ecosystems are vital for biodiversity conservation and tea culture preservation. Yunnan Province houses 97% of China's ancient tea tree resources[4], primarily located in the Lancang River Basin, Gaoligong Mountains, and Ailao Mountains at altitudes ranging from 500 to 3000 meters. This region's complex topography and unique climate foster rich biodiversity. However, increasing human activity has led to ecosystem degradation and other threats.

Current conservation efforts rely mainly on local governments and research institutions through nature reserves, forest closures, and sustainable harvesting practices. Nevertheless, limitations persist, particularly in informatized management. Traditional methods depend heavily on paper records and manual surveys, leading to outdated and incomplete ecological archives. Public awareness remains limited[5], and a unified digital platform is lacking.

To address these gaps, this study proposes and develops a modern digital platform to showcase ancient tea tree ecosystems. The platform integrates location, ecological information, and cultural context, aiming to support conservation and sustainable utilization efforts.

II. System Design

To meet the management and visualization needs of the ancient tea tree ecosystem, the platform adopts a three-tier architecture (as illustrated in Figure 1). The presentation layer at the top is responsible for the user interface and interaction, the business logic layer handles core business processes and system security, and the data layer at the bottom ensures data persistence through database and file storage. This layered architecture significantly enhances the system’s maintainability, scalability, and security.

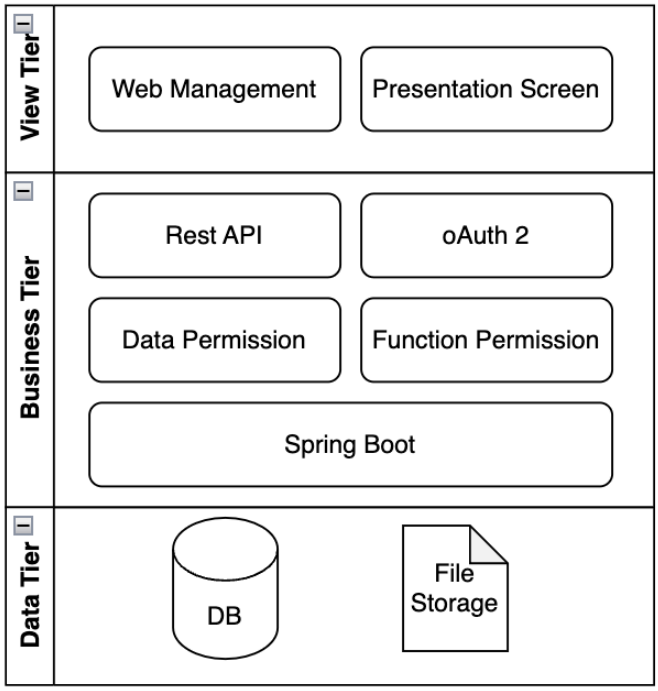

Figure 1 Design and Development of the Ancient Tea Tree Ecosystem Visualization Platform

The Ancient Tea Tree Ecosystem Visualization Platform integrates and displays diverse datasets, including the geographical locations, ages, and growth status of ancient tea trees. It also highlights the cultural significance of these ecosystems through textual and multimedia presentations. Leveraging GIS technology, the platform visualizes spatial data on maps, providing users with a comprehensive and intuitive overview of the ancient tea tree ecosystem.

2.1 System Functional Design

The platform consists of seven core functional modules:

1) User Management: Enables backend operations for adding, modifying, deleting, and querying users, including activation of new users and disabling of inactive accounts.

2) Data and Functional Permission Management: Implements role-based access control (RBAC). Permissions are finely tuned based on roles and attributes, allowing control over entity, attribute, and row-level data visibility. Functional permissions govern user operations such as viewing, creating, editing, and deleting data objects.

3) Ecosystem Change Log: Records modifications within the database, capturing changes made by multiple users. The log includes timestamp, operator, old value, and new value, enabling administrators to audit and track key data changes.

4) Ecosystem Type Management: Supports the creation, deletion, and modification of ecosystem types, including wild, transitional, and cultivated categories.

5) Health Status Management: Classifies ecosystem health levels as excellent, good, average, degraded, or endangered.

6) Ecosystem Maintenance: Systematically manages each ancient tea tree ecosystem's data, including name, description, ecosystem type, and location. It allows multi-point coordinate storage for precise spatial mapping and integrates GIS for visual analysis. Additionally, a narrative module enables the recording of tea culture stories with images to enhance ecological storytelling. The system supports multi-image and multi-video uploads, improving the visual and emotional impact of ecosystem data.

7) Visualization Module: Displays the ecosystems on web pages and large screens based on stored data.

2.2 Technical Architecture

The backend is developed using Java Spring Boot for stability and scalability. The frontend employs Vue.js and Element UI for responsive design. PostgreSQL with PostGIS extensions supports spatial data processing. Redis is used for caching to enhance data access efficiency. Docker and Kubernetes are utilized for containerized deployment, improving maintainability and scalability.

2.3 Database Design

The PostgreSQL database comprises several key tables:

Table 1. Database tables

Table Name	Function	Remarks
EcoSys	Ecosystem Data	Many-to-many relation with file storage (images, videos)
User	User Management	
Role	Role Definitions	
User_Role	User-Role Mapping	
Permission	Data Permissions	
SysFile	File Storage	Secure file management
EntityLog	Change Logs	Tracks all data modifications

III. Implementation of Ecosystem Visualization

3.1 Backend Management

The backend management of the ancient tea tree ecosystem provides efficient and flexible system administration capabilities (as shown in Figure 2), supporting centralized management of core resources such as users, roles, permissions, data, and logs. Through a robust permission control mechanism, administrators can precisely configure access rights for different users, ensuring data security and compliance. The system supports full CRUD operations on critical business data and offers comprehensive log auditing functions to track system activities and data changes. Additionally, it features an advanced search capability with multi-condition filtering, keyword matching, and complex queries, enabling users to quickly locate target data and significantly improve management efficiency. The system also supports data export in Excel format, facilitating offline analysis, report generation, and archival management. Furthermore, backend management integrates system configuration and notification management modules, enhancing operational efficiency, ensuring system stability, and providing reliable data support for frontend visualization.

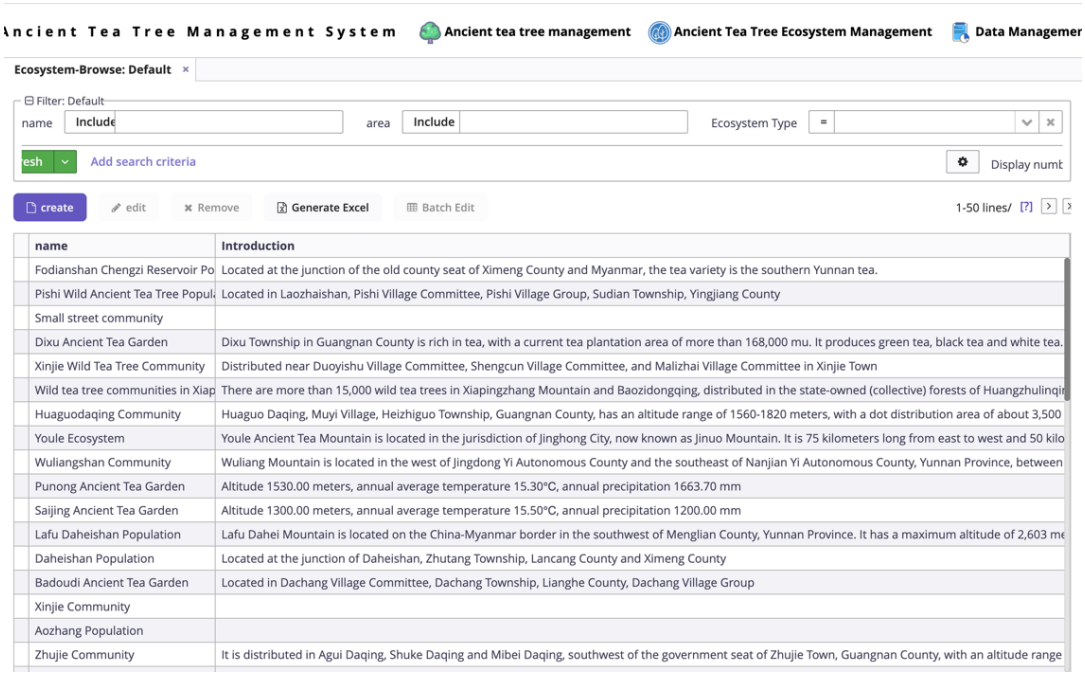

Figure 2. Backend Data Management Interface

The Basic Information page is designed to manage the core data of each ecosystem (as shown in Figure 3-a), including the ecosystem's name, description, coordinate list, health status, ecosystem type, and geographic location. On this page, administrators can input or modify the ecosystem's name to uniquely identify each ecological area. The description section provides a brief overview summarizing the ecological characteristics and significance of the ecosystem.

The coordinate list records the geographical boundaries of the ecosystem (Figure 3-b), supporting spatial selection and visualization. The health status field allows assessment of the ecosystem's current condition—such as good, average, degraded, or endangered—with dynamic updates. The ecosystem type can be categorized as forest, wetland, grassland, or lake to facilitate classification management. The location field specifies the

administrative region (province, city, county, or specific area), enabling regional statistics and large-screen visualization.

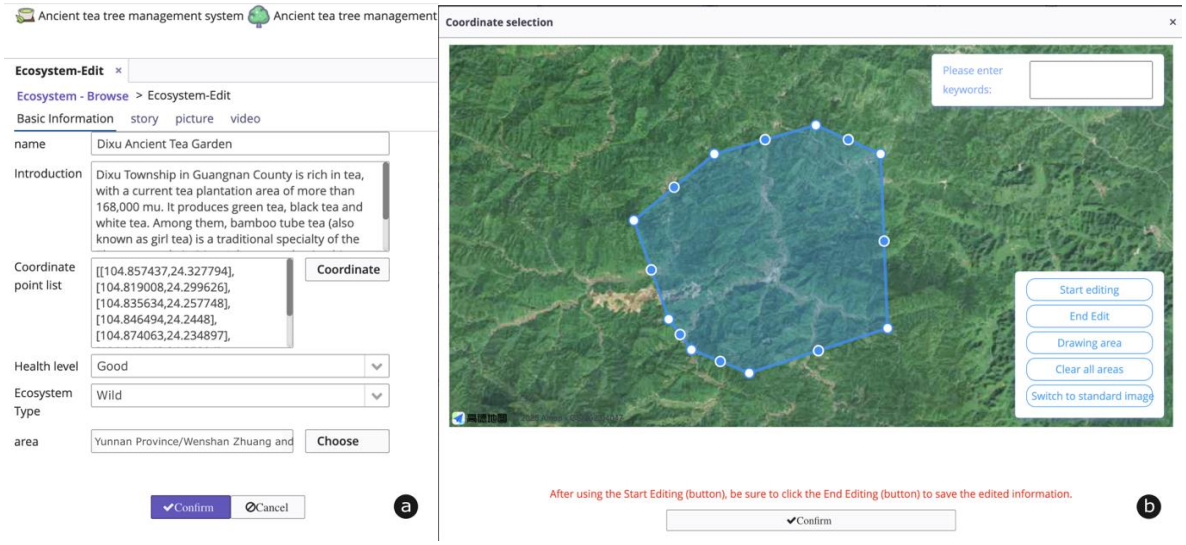

Figure 3. Ecosystem Basic Information Editing Page — a. Basic Information Editing; b. Ecosystem Boundary Coordinate Selection

The Multimedia Display page enriches the narrative presentation of the ancient tea tree ecosystem, incorporating text-image stories, photo galleries, and video displays. The text-image story module supports documenting the ecosystem's history, changes, and conservation measures, with the option to attach images for enhanced readability and communication.

The photo gallery function allows batch uploading and management of ecological photographs, including flora and fauna, landscapes, and ecological restoration results, offering intuitive visual information. Additionally, the video display function supports uploading short videos or embedding online videos, enabling dynamic visualization of the ecosystem's landscape, ecological changes, or scientific research, thereby making management and outreach more vivid and engaging.

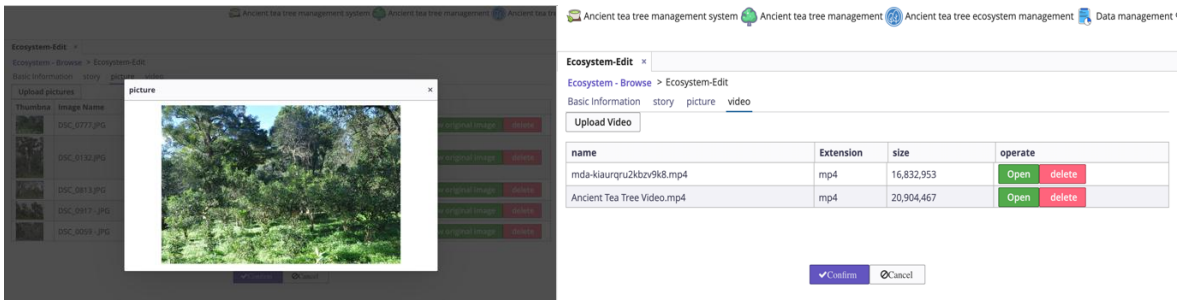

Figure 4. Multimedia display

3.2 Frontend Visualization

The central area of the big data visualization platform adopts an interactive map display (Figure 5), allowing users to zoom in and out freely and providing a flexible spatial data interaction experience. The map integrates spatial analysis functions and automatically adjusts the data display format based on the zoom level. When users zoom to a certain scale, the system aggregates and displays the total number of ecosystems, presenting an overview of their distribution and quantity in the geographic space. As users zoom in further, the system gradually reveals distinct flag markers representing the precise locations of individual ecosystems, complete with detailed geographic coordinates and ecological information. At the highest zoom levels, the map accurately displays each ecosystem's location and associated data. Users can click on each marker to access comprehensive details of that specific ecosystem. This multi-level map visualization enhances the intuitiveness of spatial data while offering flexible user interaction, facilitating in-depth data exploration and visual analysis.

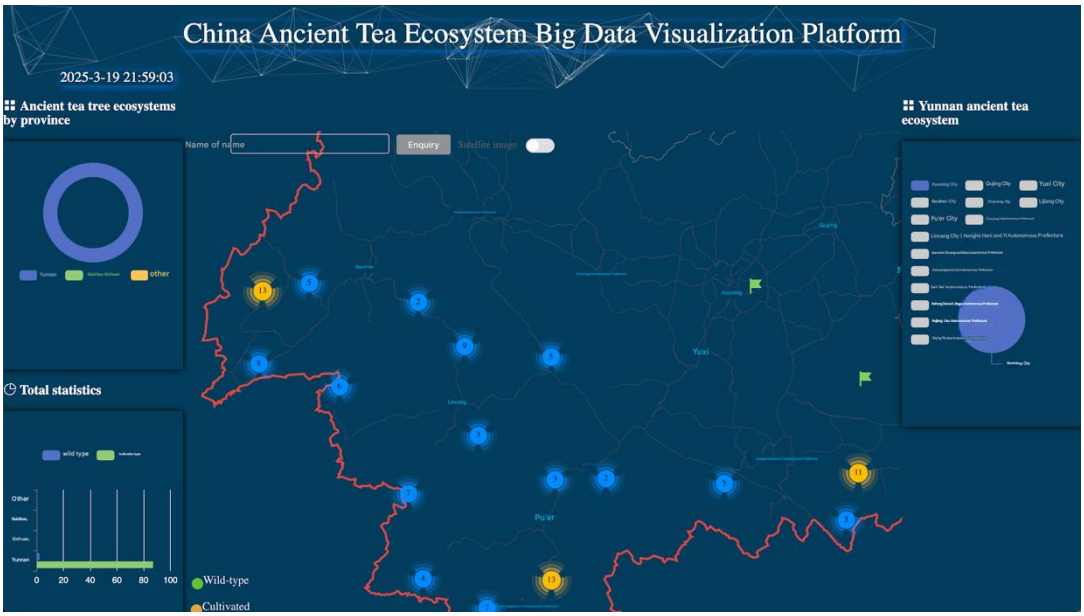

Figure 5. Frontend Large-Screen Display

As shown in Figure 6, clicking on a specific ecosystem marker opens a detailed information window presented in an e-book format. This page consolidates all key ecosystem data, including basic information, ecological stories, multimedia images, and videos. In the basic information section, users can view essential details such as the ecosystem's name, description, health status, type, and location, providing strong data support for understanding its status and significance. The ecological story section presents the history, conservation measures, and ecological changes of the ecosystem through rich text and images, offering users deeper background knowledge. The photo wall displays images of the ecosystem's environment, supporting full-screen automatic playback for an immersive viewing experience. The platform also supports video display, allowing users to select and play multiple videos that dynamically present the ecosystem's evolution, conservation efforts, or scientific research results. This detailed information window is designed to be both user-friendly and interactive, offering rich, intuitive content and multimedia resources that enhance user engagement and learning experiences.

Figure 6. Frontend Large-Screen Display of Basic Information and Photo Wall

On the main page of the platform, interactive pie charts are displayed on the left and right sides, providing statistical information based on region and ecosystem type. The regional pie chart on the left allows users to view the distribution of ecosystems across different areas. Through intuitive graphical representation, users can quickly grasp the quantity and proportion of ecosystems in each region, offering a comprehensive regional overview. The

type-based pie chart on the right illustrates the distribution of different ecosystem types—such as forests, wetlands, grasslands, and lakes—helping users understand the proportion of each type within the overall ecosystem. Both pie charts are interactive, allowing users to click on specific regions or types to view real-time statistical data and related details. These visual charts provide powerful data visualization support, enabling users to quickly understand the spatial distribution and structural characteristics of ecosystems from a macro perspective, and offering intuitive references for data analysis and decision-making.

IV. System Evaluation

Since its launch in June 2023, the platform has recorded 156 ancient tea tree ecosystems, as shown in Table 2, with data collection still ongoing and the number expected to increase. Due to the extensive workload involved, approximately 500 hours have been dedicated to data entry to ensure completeness and accuracy. The current data accuracy has reached 98%, verified against aerial imagery, demonstrating a high level of reliability and credibility. The collected ecosystem data covers 350 hectares, primarily within the Qianjiazhai Nature Reserve, providing essential geospatial data to support ecological conservation and scientific research. Additionally, a total of 1,576 sampling points have been completed, offering detailed spatial distribution information to further support ongoing ecological monitoring and analysis.

Table 2. System data overview

Metric	Value	Remarks
Number of Ancient Tea Tree Ecosystems	156	Data entry ongoing
Data Entry Time	500 hours	
Data Accuracy	98%	Verified against aerial imagery
Data Collection Coverage	350 ha	Major area of Ailao Mountains
Number of Sampling Points	1,576	

The platform has also generated notable social impacts, as detailed in Table 3. Between 2023 and 2024, a total of eight research outputs were completed, including five conservation studies and three technological innovations. In terms of conservation research, the project produced five academic papers and one patent, reflecting both theoretical innovation and practical application in ecological protection. For technological innovation, the project generated six academic papers and three patents, showcasing breakthroughs and advancements in ecological technologies. Overall, the project has significantly contributed to both ecological conservation and technological innovation, providing valuable academic achievements for the scientific community and industry, and further promoting theoretical research and technological application in ecological conservation.

Table 3. Social Impact Generated by the System

Project Type	2023	2024	Total	Research Outputs
Conservation Research	3	2	5	5 papers / 1 patent
Technological Innovation	2	1	3	6 papers / 3 patents
Total	5	3	8	11 papers / 4 patents

V. Conclusion

This study successfully designed and developed the Ancient Tea Tree Ecosystem Visualization Platform, which integrates GIS technology to enable spatial visualization of ecosystem data. Through interactive maps, users can intuitively explore the distribution, quantity, and health status of ancient tea tree ecosystems. In addition, the platform incorporates features such as text-image stories, multimedia displays, and multi-video playback, enriching the forms of ecosystem presentation and enhancing public education and scientific outreach. The system's design not only improves the efficiency of data management and visualization but also promotes interdisciplinary scientific data sharing, providing more accurate support for decision-making. The implementation and application of the platform have significantly advanced the conservation efforts of ancient tea tree ecosystems in the Ailao Mountains. By integrating diverse datasets, the platform has effectively supported both the ecological protection of ancient tea trees and the preservation of tea culture in the region. Practical results demonstrate that the platform plays a positive role in advancing ecological conservation research and technological innovation. It has partially addressed the challenges of low informatization levels and limited public awareness in the management of the Ailao Mountain ancient tea tree ecosystem. Through modern, digital means of visualization and management, the platform enhances the efficiency and transparency of conservation efforts while offering a valuable reference model for the protection of similar ecosystems. Looking forward, with continuous data enrichment and technological upgrades, the platform is expected to be further promoted and applied on a larger scale, contributing more significantly to global ecological conservation initiatives.

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