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Research Progress on GIS-Based Conservation of Ancient and Famous Trees

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Abstract: This article reviews the research progress and practical application of Geographic Information System (GIS) technology in the protection of ancient and famous trees. Leveraging its strengths in spatial data management, visualization, and spatial analysis, GIS has significantly improved the refinement and informatization of ancient tree management. The paper elaborates on its application in four major areas: first, establishing a resource database to achieve digitization and dynamic management of ancient tree information; second, analyzing spatial distribution patterns through methods such as kernel density analysis and spatial autocorrelation to provide a scientific basis for protection strategies; third, integrating multi-source data for pest and disease trend prediction and dynamic monitoring; and fourth, supporting fire risk zoning, fire spot monitoring, and firefighting decision-making in risk management. Research demonstrates that GIS technology has effectively addressed issues such as fragmented data and lagging monitoring in traditional management approaches, substantially enhancing the efficiency and scientific rigor of conservation efforts. It serves as a core technical support in advancing the protection of ancient and famous trees from static management toward dynamic perception and intelligent decision-making.

Keywords: Ancient and Famous Tree Conservation; Geographic Information System (GIS); Resource Database; Spatial Analysis; Pest and Disease Control; Fire Monitoring

1. Introduction

Ancient trees are defined as those over 100 years of age, excluding trees cultivated primarily for timber production in commercial plantations. Famous trees refer to those with notable historical, cultural, scientific, or landscape value, or those bearing important commemorative significance [1]. As valuable ecological resources and historical-cultural heritage, ancient and famous trees have long been a focus of academic research both domestically and internationally [2]. The conservation of these trees is not only crucial for maintaining and enhancing regional biodiversity [3] but also constitutes a significant part of China's ecological civilization construction [4]. China's vast territory, diverse climate, and complex topography have fostered, over millennia, a rich abundance of ancient and famous tree resources. In recent years, the protection and research of these trees have received increasing attention in China [5]. A thematic search of the China National Knowledge Infrastructure (CNKI) database using the keyword "ancient and famous trees" reveals the annual publication trend from 2000 to 2024(*e.g.*, Figure 1).

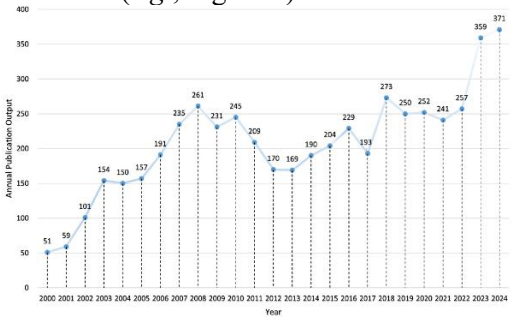

Figure 1. Annual Publication Output (2000 -2024)

The notable rise in the number of papers in recent years reflects growing academic interest and research engagement in this field. Concurrently, at the policy level, China formally promulgated the "Regulations on the Protection of Ancient and Famous Trees" in early 2025. As the first national-level administrative regulation specifically targeting the protection of ancient and famous trees, it systematically standardizes various aspects of conservation and management practices, thereby filling a legislative gap in this

domain.

With the advancement of modern surveying technology, the methods for investigating and studying ancient and famous trees have become increasingly efficient. In particular, the application of Geographic Information Systems (GIS) has provided robust technical support for related research. Currently, the use of GIS technology to assist in the resource investigation and data analysis of ancient and famous trees has become an important research direction and development trend in this field. Keyword co-occurrence analysis can effectively reveal research hotspots and trends in a given discipline [6]. Using "ancient and famous trees" as the subject, relevant literature published between January 1, 2020, and December 31, 2024, was retrieved from the China National Knowledge Infrastructure (CNKI) database. VOSviewer was employed to conduct a keyword co-occurrence analysis, resulting in the co-occurrence map (*e.g.*, Figure2).

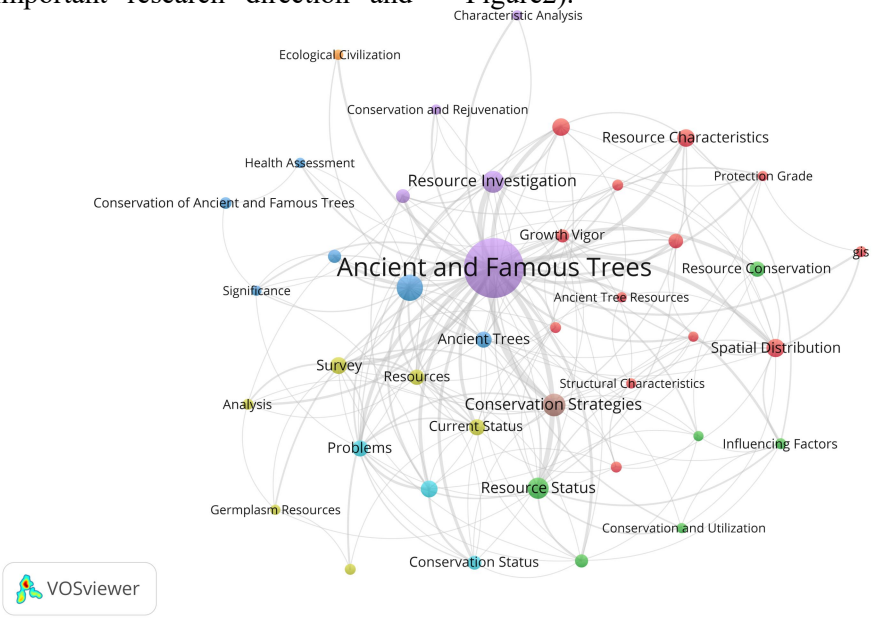

Figure 2. Keyword Co-Occurrence Analysis

The map shows that keywords such as "Spatial Distribution," "Influencing Factors," and "gis" appear frequently in recent studies on ancient and famous trees, indicating that GIS technology has been widely applied in the investigation and conservation of these trees in recent years.

The application of GIS technology in research on ancient and famous trees primarily relies on the integrated use of Remote Sensing (RS) and the Global Positioning System (GPS), collectively referred to as 3S technology. Compared with traditional methods, GIS offers several technical advantages in the protection of ancient and famous trees: (1) It enables integrated management of geographic and attribute data, converting tabular information into visual representations; (2) It provides functions such as zooming, roaming, and geographic attribute querying, facilitating digital browsing of ancient and famous tree resources; (3) It supports spatial analysis functions, allowing assessment of potential impacts from infrastructure such as roads and water systems on ancient trees, and quantifying the effectiveness of conservation measures; (4) It allows for logical condition-based queries, with results displayed in real-time spatial locations; (5) By integrating multimedia technology, it offers an intuitive means of presenting information related to ancient trees.

2. Establishment and Informatized Management of Ancient and Famous Tree Resource Databases

Under the traditional management model for ancient and famous trees, issues such as incomplete data and fragmented information are widespread. This approach hinders the systematic integration of ancient tree resource information, limiting management departments' ability to accurately assess tree growth conditions and conduct statistical analyses, thereby impeding effective conservation and management. Establishing a dedicated resource database for ancient and famous trees can effectively address these shortcomings, enabling the development of a standardized, informatized, and digitalized dynamic management system for

improved monitoring and maintenance [7]. Wang et al. [8] conducted secondary development of a GIS system using VB as the primary tool and applied it to the ancient and famous trees in Xiangshan Park, establishing an information management system with web-based query functionality. As China's first demonstration case applying GIS technology to ancient tree management, this system not only realized digital management of tree resources but also provided key technical references for subsequent research and promotion in the field. Wen et al. [9] adopted component-based GIS technology. They performed secondary development using Map Objects Java Standard Edition (MOJava), successfully constructing an information management system for ancient and famous trees in Zhongshan Cemetery. Their study demonstrated that component-based GIS offers advantages such as cross-platform compatibility, ease of maintenance, and high development efficiency, further improving the management and conservation effectiveness. Nie [10] developed a networked management system based on WebGIS technology using the J2EE architecture and the MapXtreme for Java platform. By publishing ancient tree information online, the system greatly facilitated maintenance personnel in querying relevant data. Notably, the system innovatively incorporated an expert module based on uncertain reasoning, achieving intelligent diagnosis of diseases and pests—a breakthrough that provided important technical insight for subsequent GIS applications in pest and disease control. Bo [11] addressed the inefficiency and data fragmentation issues inherent in traditional paper-based or standalone management models. Focusing on ancient and famous trees in Shanghai and leveraging ArcGIS technology combined with Business Process Reengineering (BPR) theory, she developed an intelligent information management system. By integrating spatial information technology with intelligent recognition and process optimization, the system significantly improved management efficiency. This work introduced BPR into ancient tree management for the first time, offering a replicable methodology and research framework for future studies. Sun and Sun [12] developed a Web-GIS management information system in response to problems such as the absence of dynamic monitoring, unclear conservation responsibilities, and insufficient preventive measures in Beijing's traditional management practices. The system achieved informatized and refined resource management, markedly enhancing both monitoring capabilities and management efficiency. Currently, many cities and parks in China have established ancient and famous tree databases using GIS technology. With ongoing technological advances, these systems continue to integrate new functional modules, effectively improving the efficiency of maintenance, management, and dynamic monitoring, thereby providing solid technical support for refined and informatized conservation.

3. Analysis of Spatial Distribution Patterns of Ancient and Famous Trees

In recent years, with the development of geographic information technology, the analysis of the spatial distribution pattern of ancient and famous trees based on GIS has gradually become a hot topic. Various provinces and cities in China have successively carried out investigations and research in this regard, covering spatial scales such as provinces, cities, counties, and scenic spots.

At present, methods such as Kernel Density Estimation, Buffer Analysis, Spatial Autocorrelation Analysis, Nearest Neighbor Index analysis, and Voronoi Diagrams have been widely applied in the judgment and analysis of the spatial distribution patterns of ancient and famous trees (*e.g.*, Table 1).

Table 1. Spatial Analysis Methods and Applications in Ancient and Famous Tree Studies.

Spatial Analysis Methods	Formula	Application in Research on Ancient and Famous Trees
Kernel Density Estimation,	$f(x) = \frac{1}{nh}\sum_{i=1}^{n} k(\frac{x - x_i}{h})$	Used to identify clustering areas of ancient and famous trees in a given region and to analyze their spatial distribution patterns.
Buffer Analysis	$B_i = \{x: d(x_i, y_i) \leq R\}$	Applied to examine the relationship between the distribution of ancient and famous tree resources and their proximity to features such as rivers, roads, and other infrastructure.
Spatial Autocorrelation Analysis (Moran's I Index)	$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}(x_i - \bar{x})(x_j - \bar{x})}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}}$	Employed to assess the influence of various factors—such as slope, aspect, and human activity—on the spatial distribution of ancient and famous trees.

Nearest Neighbor Index Analysis	$R = \frac{\overline{r_1}}{\overline{r_E}} = 2\sqrt{D}$	Used to determine the spatial distribution pattern of ancient and famous trees within a study area (e.g., clustered, dispersed, or random).
Voronoi Diagrams	$CV = \frac{S}{V} \times 100\%$	Applied to characterize the spatial distribution of ancient and famous trees, often used in combination with Nearest Neighbor Index analysis for validation.

Kernel Density Estimation, as a method for measuring surface density, has a wide range of applications and is often used in the empirical analysis and research of aggregates [13]. The results of Kernel Density Estimation are generally presented through density graphs, where the depth of color can reflect the density level of the research object. This analytical method has been widely applied in disciplines such as urban planning, geology, and forestry. In the study of ancient and famous trees, it is mainly used to determine the aggregation areas of ancient and famous trees in a certain region, and then analyze their spatial distribution pattern [14]. The core idea of Buffer Analysis is: after a set of spatial entities is given, a band-shaped area with a specific distance (that is, buffer radius or width) is demarcated around these entities - that is, buffer polygons - to clarify the range of impact these entities have on the surrounding environment or the service range they can cover [15]. This analysis is often applied in fields such as environmental science, rural tourism, and green space planning. It is often used in the study of ancient and famous trees to explore the relationship between the distribution of ancient and famous tree resources and the distances of river systems, roads, etc. The core logic of Spatial Autocorrelation Analysis is to determine whether there is a correlation or similarity of a certain attribute or feature among adjacent research units in the geographical space by using two key tools, namely the spatial weight matrix and the lag vector [16]. It can be divided into global spatial autocorrelation and local Spatial Autocorrelation Analysis. This analysis is widely applied in the research of human settlement environment, environmental quality, preventive medicine, and agricultural farmland, etc. Moran's I index is a core indicator for measuring spatial correlation. Its core principle lies in combining the spatial position distribution characteristics of the research object with the element values, and accurately identifying its spatial autocorrelation patterns and correlation degrees through comprehensive analysis[17]. Moran's I can analyze and determine whether the spatial distribution pattern of the research object is random, discrete, or aggregated. In the study of ancient and famous trees, the analysis results of spatial autocorrelation can be superimposed and analyzed with various influencing factors (slope, slope direction, population density, etc.), and then the impact of each influencing factor on the distribution of ancient and famous trees can be analyzed and evaluated. The Nearest Neighbor index (R) analysis is often used as a method to determine the spatial distribution pattern of the research object. Its core principle is to conduct statistical analysis on the geographical location information of the research object, thereby clarifying whether its spatial distribution pattern is random, uniform, or aggregated[18]. When R < 1, the distribution is aggregated; when R > 1, the distribution is uniform; when R = 1, the distribution is random. This method is widely applied in the research of agricultural economy, urban planning, environmental science, and other fields. It is often used in the study of ancient and famous trees to analyze and judge the spatial distribution pattern of ancient and famous trees in the research area, and combined with on-site verification and investigation, to analyze the factors affecting their survival from multiple aspects. However, due to the inconsistent criteria for its definition, it is often used in combination with the Voronoi Diagrams in the study of ancient and famous trees, and the analysis results are re-verified[19]. A Voronoi Diagrams is composed of a continuous polygon made up of a set of perpendicular bisectors connecting two adjacent line segments. If any point is selected inside any Voronoi Diagrams, the distance from this point to the control point that generated the polygon will be less than the distance from it to the control points of other Voronoi Diagramss[20]. Voronoi Diagramss use CV values to study the spatial distribution pattern of objects. CV < 0.33 indicates a uniform distribution, CV = 0.33 to 0.64 indicates a random distribution, and CV > 0.64 indicates an aggregated distribution[21]. This analytical method is widely applied in the research of forestry, environmental science, meteorology, and other fields. This analytical method is often

used in the study of ancient and famous trees to analyze the spatial pattern and distribution characteristics of ancient and famous trees in the research area, and is often used in combination with the Nearest Neighbor Index analysis.

Through ArcGIS spatial analysis, the spatial distribution patterns of ancient and famous trees in various regions are analyzed and judged, revealing their distribution patterns. This provides an important theoretical basis and scientific evidence for local governments to formulate targeted protection policies for ancient and famous trees[22].

4. Pest and Disease Control in Ancient and Famous Trees

According to the general pattern of pest and disease occurrence, old and weak plants with poor growth or those with diseases and injuries are the most vulnerable to infection. Therefore, compared with plants in their vigorous growth period, ancient and famous trees are more prone to pest and disease problems. Therefore, pests and diseases are one of the main reasons for the consumption of resources of ancient and famous trees. However, in the current research, there are no reports on the direct application of GIS technology in the prevention and control of diseases and pests of ancient and famous trees. But the research and application of this technology in the fields of agricultural crop and forest plant disease and pest control have achieved quite significant progress at present.

In the work of plant disease and pest control, GIS technology mainly integrates and deeply analyzes geographic information data such as remote sensing data, soil types, climate characteristics, and vegetation to predict and assess the occurrence trends of diseases and pests [23]. With this technology, the occurrence characteristics and spatial distribution of pests and diseases can be comprehensively monitored. Data analysis can be used to predict the outbreak time of pests and diseases, providing a scientific basis for the subsequent formulation and implementation of targeted prevention and control strategies[24]. Since the successful launch of the first Earth resources satellite by the United States in 1972, the application research of satellite remote sensing for monitoring forest pests and diseases has officially begun. For instance, the United States has utilized satellite remote sensing technology to precisely monitor the area and extent of damage caused by gypsies to broad-leaved forests[25]. Gage et al. predicted the occurrence trend of the poisonous moth pest based on GIS technology[26]. With the development and application of GIS technology, research in this field in China has been continuously advancing in recent years. For instance, Chen Guoen deeply integrated GIS technology with the research on the control of pine wood nematode disease, developing a set of information management systems for the control of pine wood nematode disease based on WebGIS and an APP for collecting information on the control of pine wood nematode disease based on mobile GIS. This has effectively enhanced the informatization and scientific level of the control of pine wood nematode disease. And it provided direct spatial data support for prevention and control decisions[27]. In the research on the design of the rice and wheat pest and disease prevention system in Donghai County, Li Hui successfully constructed a GIS-based digital monitoring and early warning system for pests and diseases by using GIS technology, achieving the visualization of the spatial distribution of pests and diseases and the prediction of outbreak trends, and generating control guidelines[28].

To sum up, GIS technology has been initially applied in the prevention and control of diseases and pests in agriculture and forests. We can draw on the experience of applying GIS technology in the prevention and control of diseases and pests in other research fields and apply it to the prevention and control of diseases and pests of ancient and famous trees. This can efficiently predict the occurrence time and distribution patterns of diseases and pests, so as to achieve the principle of "prevention first" in disease and pest control. The strategy of "treatment as a supplement" is adopted to reduce the damage caused by pests and diseases to ancient and famous trees, as well as the pollution of the environment by chemical agents. And with the continuous development of science and technology, by integrating other high-precision and cutting-edge technologies, more precise monitoring can be achieved, enabling dynamic monitoring of individual ancient and famous trees to enhance their survival rate.

5. Fire Monitoring of Ancient and Famous Trees

According to the definition of ancient and famous trees in China[1], the formation of each

ancient tree takes over a hundred years. The occurrence of fire can cause huge damage or even death to ancient and famous trees. Therefore, fire prevention work for ancient and famous trees is the top priority in their protection efforts.

There have been numerous studies and applications of GIS technology in forest fire prevention. We can summarize its experience and apply it to the protection of ancient and famous trees. For instance, the research on forest fire monitoring based on the combination of GIS and satellite remote sensing technology mainly covers: combustible material monitoring, meteorological data monitoring, fire risk and fire point monitoring, forest fire spread trend monitoring, and post-disaster assessment planning[29]. Chen[30]utilized the fuzzy logic and analytic hierarchy process of GIS to generate a high-precision fire risk level zoning map for Yongning County, Hunan Province, to display the fire risk levels of different areas, thereby providing scientific decision support for the deployment of fire prevention forces and the key allocation of fire prevention resources in Yongning County. In addition, GIS technology can also be applied in firefighting operations, such as the analysis of the best firefighting routes and the allocation of rescue personnel and materials.

From this perspective, GIS technology has great potential in the prevention and control of fires involving ancient and famous trees. However, there are currently few research reports in this area. In the future, research in this field can be deepened and combined with other high-precision and advanced technologies to make the technology increasingly mature and accurate, thereby reducing the damage caused by fires to ancient and famous tree resources.

6. Conclusion

This study, in combination with the actual protection of ancient and famous trees, summarizes and analyzes the application of GIS technology in the protection of ancient and famous trees, specifically including the establishment and information management of the resource database of ancient and famous trees, the analysis of spatial distribution patterns, the prevention and control of diseases and pests, and fire monitoring. Integrating GIS technology into the protection of ancient and famous trees is an inevitable direction for future development and an indispensable technical means to achieve scientific and refined management of ancient and famous trees.

However, there are still some problems in the current research, such as the lack of research on the dynamic monitoring of the growth of ancient and famous trees and the early warning of pests and diseases, as well as the precise early warning of fire risks and the classification of fire risk levels. In the future, research in this field can strengthen the deep integration of GIS with RS and GPS technologies, promoting the transformation of the protection of ancient and famous trees from static management to dynamic perception and intelligent decision-making. Provide more solid technical support for China's ecological civilization construction and cultural heritage protection.

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