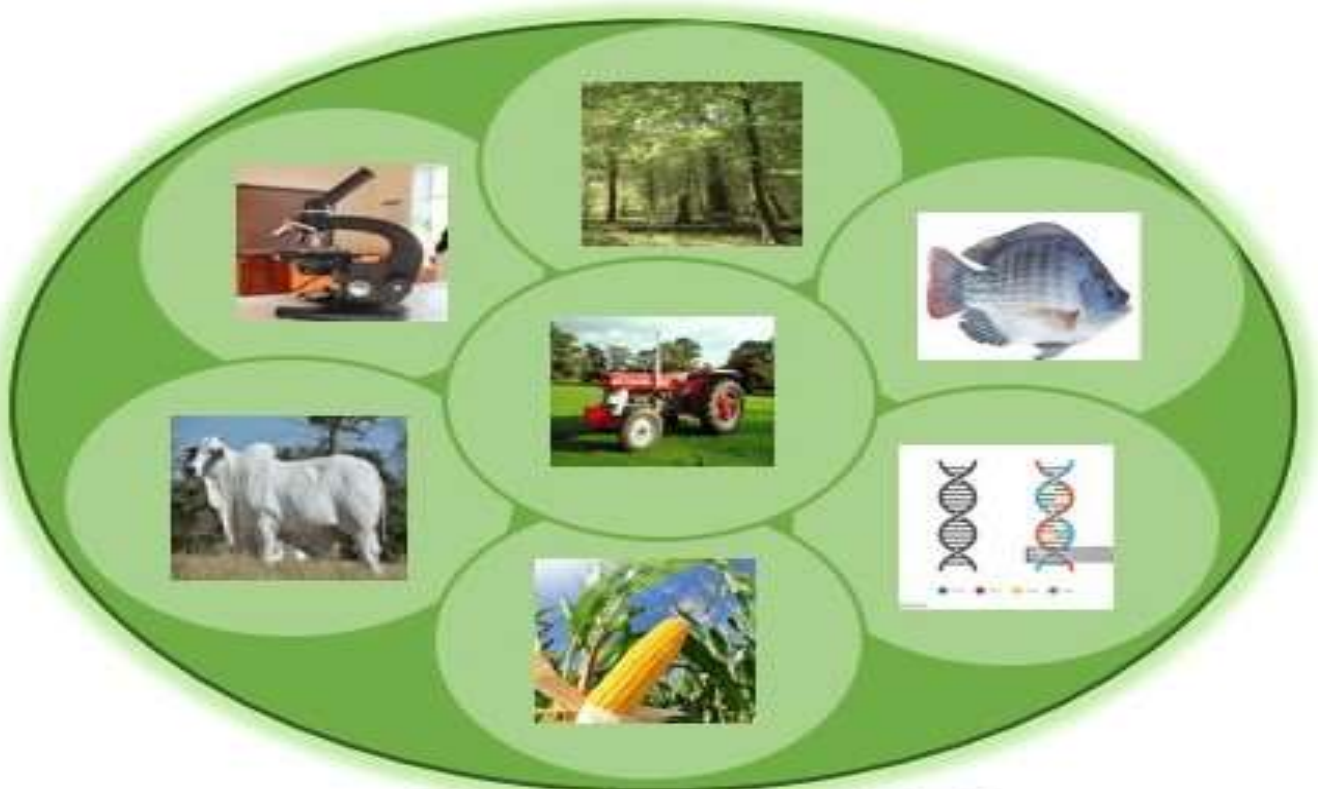




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GEOGRAPHIC INFORMATION SYSTEM (GIS) MODELLING IN FOREST INVENTORY AND MANAGEMENT: A SYSTEMATIC REVIEW

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ABSTRACT

The crucial role that Geographic Information Systems (GIS) modelling plays in forest inventory and management is examined in this systematic study, with a focus on the theoretical underpinnings, conceptual underpinnings, and real-world applications of GIS. The management and inventory of forests are essential elements of sustainable forestry, and GIS offers creative ways to improve these procedures by adding spatial data for better decision-making. GIS's development as a tool for gathering, evaluating, and managing forest data is critically examined in the review, which also emphasises how it integrates other methods used in forest inventories, including remote sensing, tree measuring, and forest composition analysis. The paper highlights the significance of spatial data in supporting precise evaluations of forest resources and demonstrates the tight connection between GIS and forest inventory approaches. Through an examination of several GIS modelling approaches, including terrain modelling, spatial analysis, and predictive modelling, the article explores how GIS helps forest managers monitor species distribution, growth rates, environmental changes, and forest health. This ultimately leads to more effective resource management, which includes biodiversity preservation, conservation, and harvesting. The review delves into the role of GIS modeling in forest inventory and management, examining its theoretical frameworks, conceptual underpinnings, and practical applications. It also critically examines the interrelationships between GIS and forest inventory and forest management, highlighting the ways in which spatial data contributes to sustainable forestry practices. The findings suggest that GIS modeling significantly improves the accuracy and efficiency of inventories and aids in the effective management of forest resources. Finally, recommendations for future research and practical implementation are discussed to encourage further integration of GIS technologies in forest sciences.

Keywords: Modelling; GIS; Inventory; Sustainable and Spatial

Introduction

Forests are essential ecosystems that offer a wealth of social, economic, and environmental advantages. To preserve these advantages, ensure sustainability, and lessen the effects of

climate change, effective forest management is essential. The methodical gathering of information on forest resources, known as forest inventory, is an essential part of forest management. The development of Geographic



Information Systems (GIS) has greatly improved the methods for managing forests and its resources. Accurate and efficient forest assessments are made possible by GIS technology, which facilitates the gathering, processing, and visualisation of geographical data (de By, 2004; Congalton and Green, 2008).

Examining the connections between GIS, inventory, and management techniques, this paper investigates the application of GIS modelling in forest inventory and management. In order to promote sustainable forest management, the study attempts to give a thorough overview of how GIS technology may enable inventory and management, highlighting its potential to enhance the accuracy, efficiency and sustainability of forest practices (Tomppo *et al.*, 2010). To effectively maintain and sustain forest ecosystems in the face of increasing environmental challenges, it is imperative to comprehend the roles that GIS play in forest management (Gardner, 2010).

The promotion of the integration of Geographic Information System (GIS) with other technologies, such as artificial intelligence, remote sensing, and decision support systems, is imperative. By doing this, the GIS will be better able to manage forests and assist the creation of more complex management plans. The use of GIS in forest management should be encouraged by governments and policymakers through the creation of favourable conditions that facilitate the deployment of GIS technology. This includes financing GIS initiatives, creating regulations that promote GIS application in forest management, and sponsoring studies on the subject.

Concept of GIS

The Geographic Information System Computer-based tools for gathering, storing, verifying, and presenting data on locations on

Earth's surface are referred to as geographic information systems, or GISs. An understanding of linkages, patterns, and trends may be gained by using GIS to visualise, analyse, and interpret spatial and geographic data. For gathering, organising, processing, and presenting any kind of spatially related data, the technology combines hardware, software, and data. The use of GIS is broad; it may be applied to resource distribution, disaster management, urban planning, and environmental monitoring (Franklin, 2011). Geographic Information Systems (GIS) are essential to forest management as it helps in resource mapping and analysis, forest cover monitoring, and decision-making assistance. Forest managers may produce precise and in-depth maps of forest regions by using GIS to integrate data from several sources, including aerial photos, satellite imaging, and field surveys. These maps may be used to track the results of management actions, organise conservation initiatives, and evaluate the state of the forests (de By, 2004; Tomppo *et al.*, 2010).

Strong technologies that enable the geographical analysis and visualisation of environmental data are geographic information systems, or GIS. GIS is used in forestry to anticipate potential risks, map forest cover, analyse changes over time and aid in decision-making (Longley *et al.*, 2015). Forest managers can create more successful conservation and management plans by combining GIS with inventory data to obtain a more thorough picture of the health of the forest (Nagendra *et al.*, 2013).

Forest Inventory Concept

Data on forest resources are systematically gathered, analysed, and interpreted as part of the forest inventory process. It entails the measuring and evaluation of forest characteristics, including biomass, density, volume, height, diameter, and species of trees.



Understanding the dynamics, structure, and composition of forest ecosystems is crucial for forest management, conservation, and policy-making. This is made possible by conducting a thorough forest inventory. Field surveys and labor-and time-intensive manual data gathering techniques have been the mainstays of forest inventory in the past. However, the use of GIS technology has changed the methods used in forest inventories, making it possible to gather, analyse, and visualise data more effectively. Remote sensing data and field observations are combined with GIS-based forest inventory methodologies to produce thorough and precise evaluations of forest resources. These evaluations are crucial for planning wood harvests, protecting biodiversity, managing forests sustainably, and tracking changes in the forest cover over time (Congalton and Green, 2008).

Concept of Forest Management

Applying economic, social, and scientific ideas to the management of forest resources is known as forest management. Forest management is to balance the requirements of current and future generations while ensuring the sustainable use and protection of forest ecosystems. This include organising and carrying out projects like harvesting timber, planting new trees, maintaining biodiversity, controlling wildfires, and safeguarding the health of forests (Franklin, 2001; Tomppo *et al.*, 2010).

The structure, dynamics, and function of forest ecosystems must all be well understood in order to practise sustainable forest management. Forest inventory and monitoring, which offer the information required to make wise management decisions, help to acquire this knowledge. Due to its ability to map, analyse, and visualise spatial data, GIS technology is essential to forest management because it helps managers plan and carry out their tasks more efficiently.

Challenges in Inventory and Management of Forests

Despite their significance, forests are threatened by a number of factors, such as habitat fragmentation, deforestation, biodiversity loss, and climate change (Hansen *et al.*, 2013). Maintaining the health of the forest and ensuring sustainable usage are made more difficult by these obstacles, which further complicate forest inventory and management. In order to properly monitor and manage forest ecosystems, more advanced tools like bioindicators and GIS technologies are required, as traditional forest management approaches frequently lack the accuracy required to handle these complex concerns (McRoberts *et al.*, 2010).

Relationships between Inventory and GIS

The accuracy, effectiveness, and comprehensiveness of forest assessments have increased with the use of GIS in forest inventory. The following frameworks may be used to understand the link between forest inventory and GIS:

1. Data Integration and Analysis: GIS makes it possible to combine data from several sources into a single platform, including field survey, aerial photography, and remote sensing. A thorough grasp of the state of the forest is made possible by this integration, which makes it possible to analyse changes in forest resources across both time and space (Congalton and Green, 2008). GIS, for instance, may be used to track the success of management initiatives, evaluate the effects of natural disturbances, and examine changes in forest cover over time.

2. Mapping and Visualisation: Detailed maps of forest regions are made possible by GIS technology and are crucial for forest inventories. A more precise evaluation of forest resources is made possible by these

maps, which may show a variety of forest characteristics including biomass, density, and species distribution of trees. GIS visualisation skills facilitate decision-making by offering understandable and comprehensible depictions of intricate geographical data (Franklin, 2001).

3. Decision Support Systems: To improve forest management, decision support systems (DSS) can use GIS-based techniques for forest inventories. DSS models several management scenarios using GIS data, enabling forest managers to assess the possible results of various management approaches. This promotes rational decision-making and guarantees the sustainable exploitation of forest resources (de By, 2004; Tomppoet *al.*, 2010).

Relationships between Forest Management and GIS

The development and application of successful management plans depend heavily on the link between GIS and forest management. The main areas where GIS aids in forest management are highlighted by the following frameworks:

4. Spatial Planning and Zoning: A GIS is a crucial tool for forest management's spatial planning and zoning. It makes it possible to recognise and distinguish between various management zones—such as those set aside for recreation, conservation, and wood harvesting—within a forest. Based on variables like soil type, slope, and proximity to water bodies, GIS may also be used to evaluate an area's potential for a variety of management operations (Franklin, 2001).

5. Monitoring and Evaluation: The ongoing observation and assessment of forest management operations is made possible by GIS technology. Through the examination of variations in forest cover, biodiversity, and additional forest characteristics, GIS assists forest managers in evaluating the success of management initiatives and implementing

required modifications (Congalton & Green, 2008). GIS may be used, for instance, to track the spread of diseases and pests in the forest, keep an eye on the effectiveness of reforestation projects, and assess the effects of fire management techniques.

6. Risk Assessment and Management: In forest ecosystems, geographic information systems (GIS) are essential for risk assessment and control. It is useful for determining which locations are vulnerable to natural disasters like floods, landslides, and wildfires as well as for creating plans to reduce such risks. The possible effects of climate change on forest ecosystems may also be assessed, and adaptation plans can be created, using GIS-based risk assessment models (de By, 2004).

Resource Allocation and Optimization

The optimisation of resource allocation in forest management is supported by GIS. GIS may be used to analyse spatial data on forest resources and optimise resource allocation for conservation, fire management, and wood harvesting, among other activities. This makes it easier to guarantee that resources are used effectively and that management tasks are completed in an environmentally friendly way (Tomppoet *al.*, 2010).

Conclusion and Recommendations

The accuracy, effectiveness, and sustainability of forest management techniques have been greatly improved by the use of GIS modelling into forest inventory and management. Using GIS technology, it is possible to thoroughly analyse both geographical and temporal data, which facilitates the creation of efficient management plans and well-informed decision-making. For the sustainable use and preservation of forest ecosystems, the linkages among GIS, forest inventory, and forest management are essential (Burroughs & McDonnell, 1998; Franklin, 2001).

To optimize the use of GIS in forest inventory and management, the following recommendations are proposed:

1. **Capacity building:** Forest managers and other stakeholders require GIS technology capacity building. This covers instruction in the use of GIS software, data gathering techniques, and GIS data analysis. Increasing the capability of GIS technology will help forest managers use GIS more effectively in their job and increase their ability to use it (de By, 2004).
2. **Data Availability and Quality:** The quality and accessibility of data determine how useful GIS is for managing forests. Field surveys and sophisticated remote sensing technologies should be used to enhance the quality of spatial data. Enhancing data availability should also be a priority, and this may be done by building user-friendly databases that forest managers and other stakeholders can utilise (Congalton & Green, 2008).
3. **Integration of GIS with Other Technologies:** It is important to encourage the integration of GIS with other technologies, including artificial intelligence, remote sensing, and decision support systems. This will allow the creation of more complex management plans and improve the capabilities of GIS in forest management (Franklin, 2001).
4. **Policy promote:** By fostering an atmosphere that encourages the use of GIS technology, governments and policymakers may promote the application of GIS in forest management. This include sponsoring research on the application of GIS in forestry, creating policies that promote the use of GIS in forest management,

and funding GIS initiatives (Tomppo *et al.*, 2010).

5. **Sustainable Practices:** Adhering to sustainable forestry practices should be the basis for using GIS in forest management. This entails utilising GIS to assist with conservation initiatives, track how management actions affect forest ecosystems, and encourage the wise use of forest resources (Burrough & McDonnell, 1998; Franklin, 2001).

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