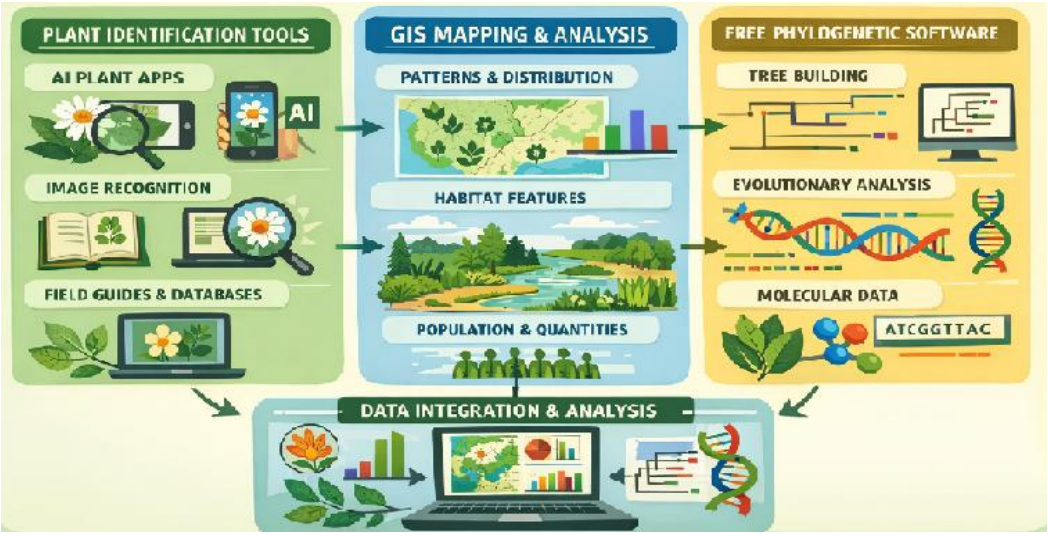
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Tools and Software in Plant Identification, GIS Mapping of Patterns, Features and Quantities, and Free Phylogenetic Software

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Abstract: *Technological advancements in biodiversity informatics, machine learning, and geographic information systems (GIS) have significantly improved plant identification and biodiversity research. Traditional morphological identification methods are increasingly supplemented by automated image-based identification systems, large biodiversity databases, and spatial analysis tools. GIS technologies allow researchers to analyse spatial patterns of plant distribution, ecological features, and biodiversity quantities across landscapes. Additionally, phylogenetic software enables the reconstruction of evolutionary relationships among plant taxa using molecular sequence data. This review discusses major digital tools used in plant identification, GIS mapping of biodiversity patterns, and freely available phylogenetic software. The integration of artificial intelligence, spatial technologies, and molecular phylogenetics has greatly enhanced biodiversity monitoring and ecological research.*



Keywords*:* Plant identification; biodiversity informatics; Geographic Information Systems (GIS); species distribution mapping; spatial pattern analysis; phylogenetic analysis; molecular phylogenetics; bioinformatics software

I. INTRODUCTION

Identifying plants is important for studying plants, protecting nature, checking on ecosystems, and managing the environment.

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Traditionally, people used plant shapes and guides to classify plants. However, these methods need experts and can take a lot of time. New technology like machine learning, digital photos, and computer biology has led to the development of automatic systems that can recognize plant species using images and pattern recognition.

AI and deep learning have made plant identification more accurate.

Deep learning uses computer networks to look at parts of plants like leaves, flowers, and stems to classify them. These systems help track biodiversity and support research in areas where expert botanists are scarce. Studies show that deep learning models trained on plant images can accurately classify plants by learning features like leaf shape, veins, and texture.

Besides automatic systems, GIS has become important for studying how plants are spread out across areas.

GIS helps combine information on where plants live with environmental factors like climate, soil, and land topography to build models that show where plants are likely to grow. These models support efforts to protect biodiversity, predict how ecosystems will change, and assess how suitable an area is for plants to live.

New advances in AI

and computer vision have improved automatic plant identification systems.

Networks trained on big image databases help classify plants accurately and are used more in studying biodiversity and organizing plant knowledge. Recent studies highlight the importance of combining large image databases and observations from people interested in nature to improve these models.

Also, molecular tools help scientists study how plants are related by looking at their DNA.

Software that uses DNA data helps analyze how plants have changed over time and contributes to understanding plant families and the history of life on Earth.

Digital Tools for Plant Identification

Image-Based Identification Systems

New AI has made it easier to automatically identify plants.

Deep learning systems, especially convolutional neural networks, help analyze photos of plant parts to recognize species. These models look at features from images and use them to classify plants correctly.

Studies show that automatic systems can correctly identify plant species in real-time under natural conditions.

For example, deep learning models have been used to identify medicinal plants in the field using photos, showing great potential for tracking ecosystems and protecting plants.

Big image databases and biodiversity databases improve the effectiveness of automatic identification systems.

Machine learning models trained on these databases can detect small differences between species and improve the accuracy of classification. Recent studies also suggest that using a variety of plant features like flower color, leaf shape, and bark texture improves model performance.

Geographic Information Systems (GIS) in Plant Research

Role of GIS in Biodiversity Studies

GIS has become a very useful tool in plant ecology and protecting nature.

GIS technology helps researchers look at how plant species, environmental factors, and landscape features are connected. By combining data from satellite images, weather, and where species are found, GIS can help visualize and model where plants are spread out.

GIS-based models for predicting where plants can grow are widely used to find areas with rich biodiversity and important habitats.

These models help scientists understand how different environmental factors affect where plants live and how they spread across different areas.

GIS helps in ecological research by combining data on where species are found with environmental factors like temperature, rain, and soil.

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These models help predict where plants are likely to live and find important areas for conservation planning. Recent studies say combining GIS with satellite data allows for large-scale tracking of plant changes and patterns of biodiversity across landscapes.

GIS Applications in Ecological Analysis

GIS supports various ecological tasks like mapping plants, assessing where plants can live, studying the environment, and tracking how natural areas are changing.

Spatial modeling techniques help measure biodiversity metrics such as how many plant species are in an area, how dense the vegetation is, and how fragmented the habitats are.

Using GIS with satellite data improves ecological analysis by giving large-scale information about the environment.

These approaches let researchers watch how vegetation changes over time and how climate change impacts plant communities.

GIS Mapping of Patterns, Features and Quantities

Spatial Pattern Analysis

Spatial pattern analysis looks at how plants are spread out on the Earth and finds areas where many species live or where species are found only in certain places.

GIS tools help researchers find where plants are clustered, how their distribution changes across areas, and where biodiversity is high. These studies are key to making good plans for protecting nature and managing protected areas.

Mapping Environmental Features

Environmental variables such as temperature, rainfall, soil properties, and elevation significantly affect plant distribution.

GIS enables researchers to map these environmental factors and examine their associations with plant species occurrences. Understanding these relationships aids in identifying ecological niches and predicting shifts in plant distribution under climate change scenarios (Peterson et al., 2011).

Quantitative Spatial Analysis

GIS also facilitates quantitative assessments of ecological data, including vegetation cover, biomass distribution, and habitat fragmentation.

Spatial statistics assist in quantifying biodiversity patterns and evaluating ecosystem dynamics across time.

Free Phylogenetic Software for Evolutionary Studies

Phylogenetic analysis is a crucial method for understanding evolutionary connections among plant taxa.

Molecular phylogenetics uses DNA sequence data to reconstruct evolutionary histories and estimate species divergence.

Contemporary computational software offers tools for sequence alignment, evolutionary distance calculation, and phylogenetic tree construction.

Software platforms such as MEGA allow researchers to conduct evolutionary analyses using statistical models and molecular sequence datasets.

These tools support the reconstruction of phylogenetic trees through methods like maximum likelihood, neighbour-joining, and Bayesian inference (Tamura et al., 2021). Furthermore, computational environments such as the APE package in R provide flexible tools for phylogenetic analysis, evolutionary modeling, and tree visualization (Paradis & Schliep, 2019).

Advancements in molecular phylogenetics and computational biology have enabled efficient reconstruction of evolutionary relationships among plant taxa.

Modern phylogenetic software allows the analysis of large genomic datasets using statistical models such as maximum likelihood and Bayesian inference (Tamura et al., 2021). Recent developments in bioinformatics have also enhanced

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phylogenetic tree visualization and evolutionary modeling through integrated computational environments (Paradis & Schliep, 2019; Minh et al., 2020).

Integration of Identification, GIS and Phylogenetic Tools

The integration of automated plant identification systems, GIS spatial analysis, and phylogenetic software offers a comprehensive framework for studying plant biodiversity.

Digital identification systems generate species occurrence data that can be integrated into GIS platforms to analyze spatial distribution patterns.

GIS mapping reveals environmental gradients, biodiversity hotspots, and habitat suitability patterns.

Phylogenetic analysis complements these approaches by providing insights into evolutionary relationships among plant taxa. Combining ecological and evolutionary perspectives enables researchers to better understand speciation processes, biogeographic patterns, and biodiversity dynamics (Peterson et al., 2011).

II. DISCUSSION

Technological innovations in biodiversity informatics and artificial intelligence have greatly improved plant identification and ecological analysis.

Deep learning algorithms enable accurate recognition of plant species through digital images, while GIS tools offer advanced spatial analysis capabilities. These technologies enhance biodiversity monitoring and support large-scale ecological research.

However, challenges persist in terms of data quality, taxonomic inconsistencies, and limited datasets for particular regions.

Continued development of global biodiversity databases and machine learning models will further improve automated plant identification systems and ecological modeling approaches (Malik et al., 2022).

III. CONCLUSION

Modern botanical research increasingly relies on digital technologies and computational tools.Image-based plant identification systems, GIS mapping platforms, and phylogenetic software provide powerful methods for studying plant diversity and evolution. These technologies enable researchers to analyze spatial distribution patterns, environmental relationships, and evolutionary histories of plant species. Integrating these approaches will continue to be essential in biodiversity conservation and ecological research.

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