



Digital Agroforestry: GIS, Drones, and Decision Support Systems in Tree-Based Farming

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Digital agroforestry integrates advanced technologies like Geographic Information Systems (GIS), unmanned aerial vehicles (UAVs or drones), and Decision Support Systems (DSS) into traditional tree-based farming systems. These digital tools offer unprecedented insights into land use, tree-crop interactions, soil health, and overall farm productivity. This paper explores how these technologies are revolutionizing agroforestry by enhancing planning, monitoring, and management capabilities, thereby promoting climate-smart agriculture and ecological sustainability.

Introduction

Agroforestry the strategic integration of trees into farms and landscapes—offers multiple benefits such as improved soil health, biodiversity conservation, and climate resilience. However, managing these complex systems across diverse agro-ecological zones remains a challenge. The emergence of Digital Agroforestry addresses this challenge through the deployment of GIS, drones, and DSS. These tools support spatial mapping, real-time monitoring, and data-driven decision-making, empowering stakeholders—from smallholder farmers to policymakers—with actionable intelligence.

Geographic Information Systems (GIS) in Agroforestry

Role of GIS

GIS enables spatial analysis and visualization of agroforestry landscapes. It provides layers of geospatial data, such as:

- Land use and land cover (LULC) maps
- Soil fertility zones
- Slope and elevation (DEM)
- Tree species distribution
- Climate variables (temperature, rainfall)

Applications

- Site suitability analysis for different tree species based on soil, slope, and climate.
- Carbon stock estimation using satellite-based biomass mapping.
- Monitoring encroachment or degradation of agroforestry systems.
- Watershed management through spatial planning of trees for erosion control.

Case Example: GIS tools have been used in India's National Agroforestry Policy to identify potential zones for tree plantation based on agro-climatic zones.

Drones in Tree-Based Farming Systems

Types of Drones Used

- Multispectral drones: Capture data on plant health (NDVI, chlorophyll content).
- LiDAR-equipped drones: Measure tree height, canopy structure, and biomass.
- Thermal drones: Detect water stress and temperature variations.

Applications

- Tree inventory and canopy mapping: Accurately count and classify trees in complex landscapes.
- Pest and disease surveillance: Identify early symptoms through aerial imagery.
- Precision agroforestry: Apply inputs like fertilizers or biopesticides with pinpoint accuracy.
- Monitoring regrowth in reforestation and restoration projects.

Example: In Kenya, drones are used to monitor the survival rate of seedlings in farmer-managed natural regeneration (FMNR) programs.

Decision Support Systems (DSS) for Agroforestry

Components of DSS

A robust agroforestry DSS integrates:

- Geospatial data (from GIS and drones)
- Climatic models
- Crop and tree growth simulators
- Economic models and market data
- Farmer inputs and indigenous knowledge

Functions of DSS

- Species selection guidance based on agroecological zones.
- Productivity forecasting for tree-crop combinations.
- Scenario analysis (e.g., "What happens if rainfall decreases by 20%?").
- Economic planning for long-term tree crop returns.

Software Examples:

- WaNuLCAS (Water, Nutrient and Light Capture in Agroforestry Systems)
- Hi-sAFe (Hybrid Simulation of Agroforestry Ecosystems)
- Agroforestry DSS by ICRAF (World Agroforestry Centre)

Benefits of Digital Agroforestry

Benefit	Description
Precision Planning	Tailored tree planting decisions based on soil and climate data.
Risk Reduction	Early detection of threats like pests, drought, or soil degradation.
Improved Productivity	Efficient resource allocation and reduced input waste.
Monitoring and Evaluation	Real-time progress tracking for restoration or carbon sequestration projects.
Policy Support	Governments can plan incentives and interventions based on data.

Challenges and Limitations

Challenge	Mitigation Strategy
High cost of drones and sensors	Promote cooperative ownership or government subsidies
Limited digital literacy among farmers	Training, mobile apps with vernacular languages
Poor internet connectivity in rural areas	Offline-compatible tools and SMS-based DSS
Data privacy and security	Use decentralized models and ensure farmer consent

Future Directions

- AI + GIS integration for predictive modeling of tree-crop dynamics.
- Blockchain for agroforestry carbon credits verification.
- Edge computing to process drone and sensor data in remote areas.
- Open-source DSS platforms to democratize access to digital tools.

Conclusion

Digital agroforestry is no longer a futuristic concept—it's a practical, scalable approach to modern land management. By combining GIS mapping, drone surveillance, and decision support systems, we can make tree-based farming more data-driven, efficient, and sustainable. As climate uncertainty and land degradation increase, such digital innovations will be vital for building resilient agro-ecosystems and empowering farmers with actionable insights. The integration of these technologies must, however, be inclusive, affordable, and aligned with local ecological and cultural contexts to ensure long-term success.