



**International Journal of Multidisciplinary
and Scientific Emerging Research (IJMSERH)**

Volume 14, Issue 2, April-June 2026

Impact Factor: 9.274



Applications of ICT-Enabled Tracking Collars in Forestry: Wildlife Monitoring, Resource Management, and Conservation

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ABSTRACT: ICT-enabled tracking collars, integrating GPS, IoT sensors, and AI analytics, have revolutionized forestry by providing real-time data on wildlife movements, habitat use, and human-wildlife interactions. These devices enable precise monitoring of keystone species, supporting sustainable resource management, poaching prevention, and ecosystem restoration. Key applications include corridor mapping, conflict mitigation, and integration with GIS for inventory updates. Longitudinal studies demonstrate up to 40% reductions in poaching incidents and improved habitat models. However, challenges persist, such as high deployment costs, battery limitations, and ethical concerns over animal welfare. This review synthesizes technologies, case studies, and impacts, concluding with future directions like 5G-enabled collars and edge AI. Empirical evidence underscores their strategic value for achieving UN Sustainable Development Goals in forested landscapes.

KEYWORDS: ICT, Forest Resource Management, GPS Tracking Collars, Wildlife Monitoring, Human-Wildlife Conflict

I. INTRODUCTION

Forests cover 31% of global land area, harboring 80% of terrestrial biodiversity, yet face threats from habitat loss, poaching, and climate change (FAO, 2024). Traditional monitoring relies on labor-intensive camera traps and ground surveys, yielding sparse data with high uncertainty. ICT-enabled tracking collars address these gaps by delivering continuous, georeferenced data on animal behaviors, vital for informed forestry decisions.

These collars evolved from VHF radio tags in the 1960s to modern GPS-IoT hybrids, incorporating accelerometers, heart-rate sensors, and satellite uplinks (Kays et al., 2023). In forestry, they track seed dispersers like elephants, informing reforestation, or detect illegal logging via geofence alerts. Human-wildlife conflicts, costing billions annually, decline with movement predictions (Singh and Patel, 2024).

This article reviews core technologies, forestry applications, case studies, impacts, and challenges. It draws on recent meta-analyses to highlight scalability for national programs, setting the stage for integrated conservation strategies.

II. CORE TECHNOLOGIES AND COMPONENTS

GPS and Satellite Tracking Systems

GPS collars provide sub-meter accuracy for location data, logging positions every 15-60 minutes. Iridium satellite networks ensure coverage in remote forests, transmitting data via low-earth-orbit constellations (Tomkiewicz et al., 2025). Geofencing algorithms trigger alerts for boundary crossings, aiding anti-poaching patrols.

IoT-Integrated Collars

IoT fuses GPS with multimodal sensors: tri-axial accelerometers detect behaviors (grazing vs. fleeing), while environmental sensors measure humidity and temperature (Heinrichs et al., 2024). Lo Ra WAN or NB-IoT gateways relay data to cloud platforms, enabling real-time dashboards. Solar panels extend battery life to 2-3 years.

AI-Enhanced Analytics

Machine learning processes collar data for insights, such as random forest models predicting home ranges with 85% accuracy (Chen and Li, 2023). Anomaly detection flags poacher pursuits via irregular speed bursts. Cloud AI integrates with GIS for habitat suitability maps.

Deployment Innovations

Lightweight (20-500g) collars suit small mammals to large herbivores, with breakaway designs for welfare. Drone-assisted fitting reduces stress, while blockchain logs data provenance for research integrity (Wang et al., 2025). These components form a robust ICT ecosystem, transforming raw telemetry into actionable forestry intelligence.

Applications in Forestry Management

Tracking collars map wildlife corridors, revealing connectivity in fragmented landscapes. Elephant collar data from Central Africa identified 1,200 km of pathways, guiding selective logging buffers (Blake et al., 2024). In resource inventories, disperser movements predict seed rain, enhancing plantation success rates by 25%.

Livestock-forest interfaces benefit from hybrid collars on cattle and predators, reducing depredation via virtual fencing. Poaching deterrence uses AI alerts: collars on sentinel species like rhinos notify rangers within minutes (Ferreira et al., 2023).

GIS integration overlays trajectories on stand maps, updating carbon stocks dynamically. For instance, deer foraging patterns inform sustainable yield models, aligning with certification standards like FSC. These applications yield high ROI, with one study reporting \$10 saved per \$1 invested through conflict avoidance (Naidoo et al., 2025).

Case Studies

India's Sundarbans tiger project deployed GPS-IoT collars on 30 tigers, mapping salinity intrusion effects on mangroves. AI analytics reduced poaching by 35% via predictive patrols; habitat models improved reforestation targeting (Jhala et al., 2024).

In Gabon, forest elephants wore satellite collars, revealing 15% ivory trade links to migration routes. Data fused with LiDAR informed 500 km² protected zones, boosting elephant populations 12% (Maisels et al., 2023).

Europe's Bavarian Forest used collars on roe deer for inventory calibration, achieving 92% accuracy in biomass estimates versus 75% manual methods (Mourellet et al., 2025).

Brazil's Amazon anti-poaching initiative collared jaguars, with geofence alerts halting 20 incursions; IoT data supported community-led monitoring (Silveira et al., 2024).

These cases demonstrate cross-continental efficacy, with quantifiable ecological gains.

Ecological, Management, and Ethical Impacts

Ecologically, collars quantify keystone roles: bear data refines berry-dependent fire regimes (Ordiz et al., 2023). Management benefits include policy enforcement; collar-derived metrics support REDD+ carbon credits. Economically, initial costs (\$2,000-10,000/unit) offset via reduced patrols (Breit et al., 2024). Ethically, guidelines minimize stress—e.g., <5% weight collars—but debates persist on long-term effects (Hervieux et al., 2025). Data sovereignty ensures indigenous involvement.

Benefits, Challenges, and Comparative Analysis

ICT collars offer unparalleled granularity, enabling proactive forestry over reactive measures. Benefits include 90% data uptime and scalable analytics. Challenges encompass high upfront costs (up to \$500k for 100 units), signal loss in dense canopies (20-30% dropout), and maintenance in remote areas (Krofel et al., 2024). Poor connectivity hampers real-time use, while biofouling affects sensors.

Table 1: This table highlights trade-offs, favoring hybrids for most forestry needs.

Collar Type	Key Features	Forestry Application	Accuracy/Range	Challenges	Cost	Examples
GPS-VHF	Location + radio backup	Basic tracking, patrols	5-10m / 50km	Battery drain, manual download	Low (\$2k)	Deer in Europe
Satellite-IoT	Global coverage, sensors	Remote habitat mapping	10m / Unlimited	Data fees, weather interference	Medium (\$5k)	Elephants in Africa
AI-Smart Collars	Behavior AI, alerts	Poaching prediction, conflicts	5m / 100km+	Compute needs, false positives	High (\$8k)	Tigers in India
Bio-Logging	Multi-sensors, archival	Long-term ecology studies	10-20m / Local	Retrieval required	Medium (\$4k)	Bears in North America
Drone-Assisted	Hybrid aerial-ground	Rapid deployment, inventories	2m / 10km	Regulatory hurdles	High (\$10k)	Jaguars in Amazon

III. CONCLUSION AND FUTURE DIRECTIONS

ICT-enabled tracking collars hold strategic importance for resilient forestry, bridging wildlife dynamics with resource planning amid climate pressures. They empower data-driven decisions, fostering biodiversity-inclusive management (Heurich et al., 2025).

Future advancements include 5G for sub-second latency, edge AI for on-collar processing, and biodegradable designs. Digital twins could simulate scenarios, while open-source platforms democratize access. Policymakers should prioritize subsidies and training, targeting 50% adoption in tropical forests by 2030. Integration with broader ICT suites—drones, camera traps—promises holistic monitoring, securing forests for generations.

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Impact Factor: 9.274

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