The Economic Efficiency of Digital Technologies in Forest Management and Their Implications for Tourism Development

Gadir Mammadov[1] and Najaf Mammadzada[2]

[1]Department of Tourism and Hotel Management, Western Caspian University, Baku, Azerbaijan
[2]Department of Cybersecurity and Computer Engineering, Baku Engineering University, Baku, Azerbaijan

Received: 14.08.2026 Accepted: 01.10.2026 Published:13.10.2026
https://doi.org/10.54414/GUEM3134

Copyright: © 2026 by the authors. Licensee: The Research Journal of Business in Emerging Economics, Western Caspian University, Baku, Azerbaijan. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution 4.0 International License (CC BY 4.0) (https://creativecommons.org/licenses/by/4.0/).

Abstract

Digital technologies are changing the way forests are observed, considered, and watched for, but how useful these technologies are for organizations that hack forests is not clearly defined. The economic efficiency of forest management is attributed to the use of geographic information systems, satellite remote sensing, drones, and artificial intelligence, and to how these technologies influence financial, operational, and institutional factors. Through a critical evaluation of peer-reviewed studies and international reports published primarily from 2021 to 2026, the analysis correlates specific applications, such as satellite-based wildfire monitoring, drone-backed inventory, and digital restoration systems, to economic value mechanisms such as labor savings, better resource allocation, reduced losses, and lower restoration costs. Reported benefits are substantial but conditional. Asset scale, data infrastructure, workforce skills, and interoperable institutional arrangements are key factors in arbitrating returns, while cost-benefit evidence remains limited and sensitive to assumptions. According to the review, digitalization is a worthwhile investment for covering intensity, disturbance risk, and management assets, and it furnishes recommendations for managers, policymakers, and researchers. Good management of digital forestry also assists in observing the landscape in good condition, which is important for forest-based tourism.

Keywords: forest economics; digital forestry; remote sensing; cost-benefit analysis; precision forestry; forest inventory; tourism

1. Introduction

Forests are responsible for timber and non-wood products, conserving soils and water, storing carbon, and supporting tourism and recreation, but their management is typically defined by tight budgets, outdated inventories, and mounting disturbance risks. Economic efficiency in managing forests refers to exercising limited labor, money, and time in a way that observes the value of what the forests furnish at the lowest possible cost. Two pressures make this task harder. Climate-related wildfires, pestilence infestations, and severe storms have led to more frequent and intense disruptions that damage timber value and backwash in higher costs for suppression and restoration (Hope et al., 2024). The sector has been slow to update, as evidenced by the limited adoption of information and communication technologies by forest operators and the scarcity of automation and remote machinery control, according to the United Nations Economic Commission for Europe (UNECE, 2024). Digital technologies propose a way to reduce this limitation by reducing the cost of gathering information. Having accurate and up-to-date information about the condition of trees, any disturbances, and harvest activities assists managers design their work, entrust teams, and

determine where to steep resources more effectively. This reduces the need for frequent trips to the field and minimizes effort. The focus of this research is on how digital technologies can better the economic efficiency of forest management, and what are the financial, operational, and institutional factors that arbitrate whether they hold measurable benefits? The goal is to synthesize the latest information on how digital forestry tools influence the economy, identify when these tools are beneficial, and emphasize what this implies for real-world use and government policies, especially for countries like Azerbaijan that are creating their forest monitoring systems. Instead of presenting primary empirical research as a report, the article serves as a critical, evidence-based analytical review that separates findings from interpretation.

2. Digital Technologies in Forest Management

The main tools habituated in digital forestry contain geographic information systems (GIS), satellite remote sensing, manned aerial surveys, drones, laser scanning, and artificial intelligence (AI) techniques for breaking down data. GIS platforms are accustomed to containing spatial data on areas, roads, land use, and ownership, which aid in spatial planning and resource allocation (UNECE, 2024). A university-cherished forest enterprise in Slovakia developed a web-based GIS portal that evolved the collection, processing, and availability of forestry information and improved collaboration between research and management, showing that even small GIS investments can improve the information base for operational decisions (Zápotocký & Koreň, 2022). Satellite systems proposition regular, affordable observation of big areas. The mapping of defoliation, host species, and disturbance at scales unsuitable for field crews is predicated on free and open data gathered from missions like Sentinel-1 and Sentinel-2 (Bhattarai et al., 2021). AI techniques break down these data streams: a review of 79 studies showed that machine learning and deep learning models, such as convolutional neural networks, usually achieve over 90% accuracy in diagnosing pests and diseases, deforestation and illegal logging, and damage from wildfires (Amoah-Nuamah et al., 2025). The gap between satellites and ground plots is by drones, which furnish high-quality imagery at low prices while minimizing impact on sensitive habitats while also guaranteeing regulatory compliance, data security, and technical constraints (Wang et al., 2025). Beyond monitoring, digitalization extends into operations. Harvesting machines with sensors pack production data almost instantly, which assists in bracketing performance, identifying when equipment might need repair, and automatically marking how much has been reaped. Additionally, a virtual forest simulation permits you to evaluate the costs and types of wood that can be reaped before coinciding with a job (UNECE, 2024). Virtual twins that conjoin remote sensing, weather, and sensor data are being used to support the prevention, response, and post-fire recovery of wildfires (Li et al., 2024). The economics of information in forestry is influenced by these applications, acting as a shift in the marginal cost of assessing the state of a forest, which is the channel for all downstream savings.

3. The Economic Efficiency of Digital Technologies in Forest Management

The reason for exercising digital forestry in economics is predicated on four main benefits: saving money by displacing work that requires a lot of human effort; exercising resources more effectively because of better information; heading off losses by identifying problems earlier; and expending less on disposing of and planting trees. The evidence for each mechanism is more robust in certain scenarios than in others, and the described magnitudes contrast significantly, so the discussion below condenses solely on the figures reported in the mentioned studies. Labor and monitoring costs. Traditional field inventories are one of the biggest ongoing expenses in managing forests. The use of remote sensing is replacing airborne and ground observation for padding plots. In Maine, USA, researchers examined how useful different remote sensing methods are, like satellites and drones, for detecting spruce budworm defoliation, which is the most expensive problem affecting the region's forests (Foster et al., 2024). The substitution of habitual field and aerial survey campaigns with satellite-based observation improves consistency, as AI-backed interpretation typically achieves a classification accuracy of over 90% for pest detection and related tasks, thereby reducing the potential for harvests and mistimed treatments (Amoah-Nuamah et al., 2025). Avoided losses. The most valuable use of digital information is in the management of disturbances, as early detection holds

a disproportionate impact on outcomes. Monte Carlo simulation was used in a cost-benefit analysis of WildFireSat, a Canadian satellite mission for active-fire monitoring, to estimate suppression costs, timber losses, property losses, evacuation costs, and smoke-related health costs (Hope et al., 2024). When comparing the costs and benefits, if we exercise more cautious estimates, the costs were higher than the benefits.But if we exercise more hopeful estimates, the benefits were about 9 to 10 times greater than the costs.The main reason for this big difference was how effective the decision-support tools were, not how much we blinked future costs. This study is instructive in two ways: it papers potentially significant losses that may not have come due to satellite monitoring, and it emphasizes the sensitivity of evaluated estimates to assumptions about the use of information by managers. Restoration and establishment costs. The cost of reforestation can be reduced with the use of digital systems. According to Sasaki and Abe (Sasaki & Abe, 2025), the cost of enforcing traditional labor-predicated planting programs was evaluated at USD 2.00 to 3.75 per tree, while the cost of digital-twin-backed drone seeding systems was evaluated at USD 0.11 to 1.08 per tree. The comparison is predicated on what technology companies and real-world projects have exhibited, not on constrained experiments, so it's more of a general idea.However, the big difference in costs implies that automation can really modify how much money is essential for restoration work, especially in the right kinds of places. Allocation and operational efficiency. Precision forestry combines sensing with machines and planning systems. Harvesters qualified with sensors automatically record yields and assortments, permitting managers to bracket performance across contractors, and the simulation of a virtual forest to evaluate harvesting costs and volumes before disbursement betters negotiation and reduces planning errors. In silviculture, better information degrades the risk of maladaptation by exercising growth models and predictive analytics to halves species, thinning schedules, and harvesting intensity with actual site productivity rather than outdated inventory averages (Wang et al., 2025). Investment and maintenance costs. Along with these advantages, there are big expenses to count: sensors and drones, software licenses, cloud processing, connectivity, and especially highly skilled workers. High implementation costs, system interoperability issues, and digital skill shortages are the primary financial barriers cited in stakeholder surveys in the forestry sector (Damaševičius et al., 2024). The economic feasibility of AI- and LiDAR-predicated forest mapping services is dependent on scalable business models, partnerships, and cost optimization, rather than the complexity of algorithms, as shown by a study of Finnish forest mapping technology (Kordi & Salo, 2025). In actuality, the relevant unit of analysis for an investment decision is a data pipeline, which contains all of its lifecycle costs, rather than just a sensor. Conditions under which digitalization remunerates. When coming across at all the conned evidence, returns are most likely to episode when three specific conditions are caught. The value of the information is in line with the value of the asset, so monitoring that is not cost-effective for a small woodlot may be valuable for a large, high-risk, or high-value company. Second, the risk of disturbances excuses the level of monitoring, because the benefits of heading off losses are most important in areas where there chances actual pressure from wildfires, pests, or illegal logging (Hope et al., 2024; Amoah-Nuamah et al., 2025). The absence of staff capable of processing and construing outputs, connectivity, and compatible systems hinders the acquisition of picked up information, making it difficult for the organization to soak. When these conditions aren't present, options like incremental adoption, participatory services, and open data sources like Sentinel imagery can furnish more affordable ways to get started. Measurement limitations. The evidence base limits the use of indicators such as return on investment and cost-benefit analysis, despite their appropriateness. Avoided losses are not real and are hard to establish because benefit estimates depend on guesses about how well something is working, as exhibited in the WildFireSat analysis (Hope et al., 2024). Many of the cost figures printed are predicated on either technology vendors or single-case deployments (Sasaki & Abe,2025). The scarcity of independent economic analyses on digital forest investments is a result of the lack of technological advancements in the economic literature.

4. Implementation Challenges and Development Opportunities

The literature on implementation identifies a set of limitations that are consistent across different countries and income levels. Small enterprises are unable to prosper due to capital requirements and

uncertain payback; a stakeholder survey in Italy indicates that high investment costs, lack of interoperability, inadequate digital skills, and poor connectivity in rural and mountainous areas are persistent barriers, and training is the primary limiting factor (Corona et al., 2026). At the system level, there are similar constraints such as the absence of data standards, legislative hindrances, data privacy concerns, and stakeholders' reluctance to take action due to concerns about data exposure retarding adoption (Damaševičius et al., 2024). The UNECE has bustling structural reasons as the reason why a significant portion of forest land is cherished by the public and hacked conservatively, while commercial forests are institution in remote areas with poor infrastructure, and forest operations are pacified by small firms with limited investment potential (UNECE, 2024). The lack of data quality in organizations is due to their reliance on drone regulations, photogrammetric processing, and the integration of point clouds into GIS (Corona et al., 2026). The opportunities supervene directly. Due to organizational rather than technical constraints, policies like participating in national platforms, open satellite data, common standards, and training programs run to bring higher returns are tied to hardware subsidies (Kordi & Salo, 2025; Corona et al., 2026). For Azerbaijan, the progress is clear through international projects rather than national data: a project championed by the FAO and GEF, done in 2021 with a budget of about $1.48 million, a system to hack forest resources information, formed a national guide for forest inventory, housebroken planning teams, and helped recreate thousands of hectares of degraded forests and pastures. The project also reports that there was not much experience in inventory work and planning before (FAO, 2021). The National Forestry Programme for 2020-2030 holds a comparable focus on inventory, protection, and restoration (UNECE, 2019). The data show a cautious inference: exercising low-cost, open-data monitoring to build on the new information system chances likely to be a more effective approach than exercising large proprietary platforms, even though there are no published economic evaluations of Azerbaijan's forestry digitalization. Tourism enters as a secondary, downstream implication. Forest-predicated recreation is dependent on landscape quality, safe and accessible trails, and the absence of fire and pest damage; the ecosystem services delivered by sound management contain recreation explicitly (FAO, 2021). Using digital monitoring to rip down on disturbances and direct recreation facilities to stronger, more durable locations assists defended the natural area that brings about in money from tourism. A limited timber-only accounting would command an indirect benefit that strengthens the case for covering investments in forests with economic significance, despite the lack of quantified estimates of this tourism channel in the current literature.

5. Conclusion and Recommendations

Digital technologies improve the economic efficiency of forest management by lowering the cost of information and converting it into better allocation, earlier disturbance detection, and cheaper restoration. The strongest evidence supports three conclusions. The cost of monitoring can be degraded by exercising remote sensing, especially for dogging disturbance across vast stretches (Foster et al., 2024). Another point is that the advantages of avoiding losses through satellite monitoring can be significant, but these benefits depend a lot on how managers choose to exercise the information (Hope et al., 2024). Third, the benefits are only available if certain conditions are met: the size of the assets, the risk of disruptions, the level of skills, the quality of connections, and the existence of compatible institutions (Damaševičius et al., 2024; Corona et al., 2026). For forestry managers, the advice is to commence by coming across at the main decision problem, not just the technology.Identify the monitoring and planning decisions that have the biggest impact on costs and profits. Start by using free satellite data and existing GIS tools. Only introduce drones, LiDAR, or AI services in areas where the risk of mislaid out on benefits is high. Implement these new tools in steps, with small test projects first. Also, plan for ongoing training and maintenance costs for the team over time. Public goods that private adopters do not invest in, such as open data infrastructure, interoperability standards, rural connectivity, and vocational training, are the primary concerns of policymakers. For researchers, the biggest missing piece is clear, habitual evidence about the costs and benefits in different kinds of forests and different-sized organizations; studies that show what actually changes, instead of just what is due, would make all the estimates here more accurate. The well-being of

forests contributes to the sustainability of forest tourism through its scenery, safety, and accessibility, making tourism revenues a part of the overall assessment of forest management performance, even though the economics of the forest detritus is the primary focus in digital investment decisions.

Author's contribution

The sole author is responsible for conceptualizing, collecting, and analyzing data, and writing and editing the manuscript.

Conflict of Interest

The authors declare no conflicts of interest.

Funding

This study received no external funding.

References

1. Hope, E. S., McKenney, D. W., Johnston, L. M., & Johnston, J. M. (2024). A cost-benefit analysis of WildFireSat, a wildfire monitoring satellite mission for Canada. *PLoS one*, *19*(5), e0302699. https://doi.org/10.1371/journal.pone.0302699
2. UNECE. (2024). Trends in digitalization of the forest sector. United Nations Economic Commission for Europe. https://land.unece.org/forests/en/knowledge-hub/forest-information-systems/trends-digitalization-forest-sector
3. Zápotocký, M., & Koreň, M. (2022). Multipurpose GIS portal for forest management, research, and education. *ISPRS International Journal of Geo-Information*, *11*(7), 405. https://doi.org/10.3390/ijgi11070405
4. Bhattarai, R., Rahimzadeh-Bajgiran, P., Weiskittel, A., Meneghini, A., & MacLean, D. A. (2021). Spruce budworm tree host species distribution and abundance mapping using multi-temporal Sentinel-1 and Sentinel-2 satellite imagery. *ISPRS Journal of Photogrammetry and Remote Sensing*, *172*, 28-40. https://doi.org/10.1016/j.isprsjprs.2020.11.023
5. Amoah-Nuamah, J., Child, B., Okyere, E. Y., Adams, O., & Danquah, J. A. (2025). Applications of artificial intelligence in forest health surveillance and management. *Discover Forests*, *1*(1), 56. https://doi.org/10.1007/s44415-025-00061-w
6. Wang, T., Zuo, Y., Manda, T., Hwarari, D., & Yang, L. (2025). Harnessing artificial intelligence, machine learning and deep learning for sustainable forestry management and conservation: Transformative potential and future perspectives. *Plants*, *14*(7), 998. https://doi.org/10.3390/plants14070998
7. Li, Y., Zhang, T., Ding, Y., Wadhwani, R., & Huang, X. (2024). Review and perspectives of digital twin systems for wildland fire management: Y. Li et al. *Journal of Forestry Research*, *36*(1), 14. https://doi.org/10.1007/s11676-024-01810-x
8. Foster, A., Rahimzadeh-Bajgiran, P., Daigneault, A., & Weiskittel, A. (2024). Cost-effectiveness of remote sensing technology for spruce budworm monitoring in Maine, USA. *Forests Monitor*, *1*(1), 66-98. https://doi.org/10.62320/fm.v1.i1.14
9. [Sasaki, N., & Abe, I. (2025). A Digital Twin Architecture for Forest Restoration: Integrating AI, IoT, and Blockchain for Smart Ecosystem Management. *Future Internet*, *17*(9), 421. https://doi.org/10.3390/fi17090421

10. Damaševičius, R., Mozgeris, G., Kurti, A., & Maskeliūnas, R. (2024). Digital transformation of the future of forestry: an exploration of key concepts in the principles behind Forest 4.0. *Frontiers in Forests and Global Change*, *7*, 1424327. https://doi.org/10.3389/ffgc.2024.1424327
11. Kordi, G., & Salo, J. (2025). Business Model Innovation for Sustainable Development: Evidence From the Forest Mapping Technology Sector in Finland. *Business Strategy & Development*, *8*(3), e70214. https://doi.org/10.1002/bsd2.70214
12. Corona, P., Mattioli, W., Brunori, A., Marchi, E., Mori, P., Sacchelli, S., & D'Amico, G. (2026). Digitalization challenges in operational forestry: evidence from a stakeholder survey in Italy. *IFOREST*, *19*(4), 303-310. https://doi.org/10.3832/ifor5233-019
13. FAO. (2021). Forest resources assessment and monitoring to strengthen forest knowledge framework in Azerbaijan (Project GCP/AZE/007/GFF). Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/bitstreams/a1cc6a88-277d-4d21-849e-44c5011ea725/download
14. UNECE. (2019). Azerbaijan presents National Forestry Programme for 2020–2030. United Nations Economic Commission for Europe. https://unece.org/forestry/news/azerbaijan-presents-national-forestry-programme-2020-2030