



(RESEARCH ARTICLE)



Development of a methodological framework for autonomous environmental monitoring: Smart sensor networks and real-time detection of anthropogenic threats in the Congo Basin

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Abstract

The Congo Basin, often described as the green lung of Africa, is not only a vast expanse of tropical forest: it is a vital space for millions of people, a refuge for exceptional biodiversity, and a global climate regulator. Yet, every day, trees fall under the pressure of deforestation, rivers darken due to pollution, and soils are dug up by mining activities. These threats are not abstract: they directly affect families who depend on the forest for food, shelter, and the transmission of traditions. Faced with this reality, it becomes urgent to give a voice to the forest and its inhabitants.

The approach we propose—autonomous monitoring based on smart sensors and real-time analysis—turns technology into an ally of communities. Sensors become the “eyes” and “ears” of the forest, capable of signaling an anomaly before it becomes a disaster. Researchers gain access to reliable data, decision-makers obtain tools to act quickly, and local populations acquire a means to protect their environment. Early results show that this innovation goes beyond technology: it embodies a new way of defending the forest, placing humans and nature at the heart of the same vigilance.

Keywords: Environmental monitoring; Smart sensors; Congo Basin; Real-time detection; Anthropogenic threats; Internet of Things (IoT) and Artificial Intelligence

1. Introduction

The forest of the Congo Basin is not only a natural space: it is home to millions of people, ancestral cultures, and unique biodiversity [6]. It nourishes, heals, and inspires, but every day its balance is threatened: trees disappear under chainsaws [8], rivers are contaminated by mining discharges, and animal species see their habitats shrink. These damages are not abstract; they translate into tangible losses for local communities and for humanity as a whole [7].

Traditional monitoring methods—human patrols or satellite imagery—though useful, remain too slow or too costly to meet the urgency [3]. Hence the need for an autonomous system, capable of “sensing” the forest continuously, issuing real-time alerts, and giving a voice to endangered ecosystems. By humanizing technology, placing it at the service of both people and nature, this methodological framework transforms monitoring into an act of solidarity and shared responsibility.

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2. Methodology

2.1. Proposed Architecture

The system relies on the deployment of **smart sensor networks**, carefully selected to address the specific environmental threats of the Congo Basin. Beyond technology, this architecture is conceived as an **alliance between science and society**.

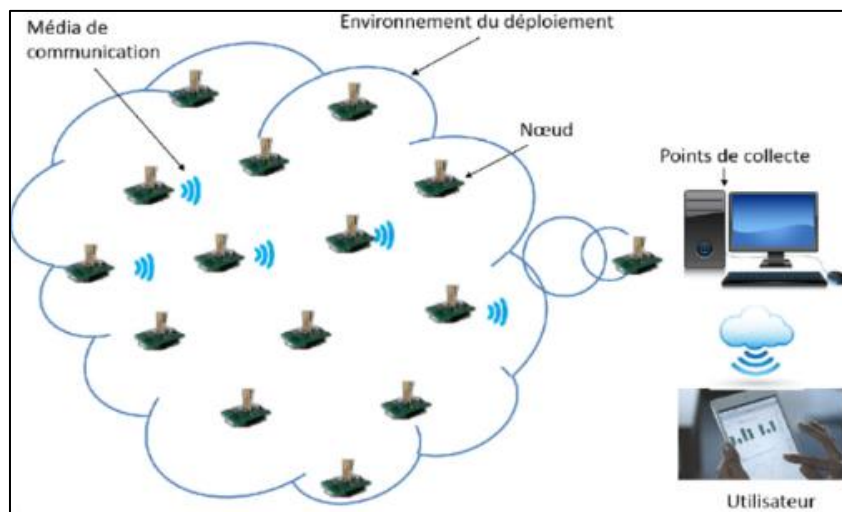


Figure 1 Proposed Architecture

Each sensor becomes a sentinel serving the community:

- **Motion sensors** do more than detect intrusions; they protect villages against poaching that threatens food security.
- **Acoustic sensors** are not mere microphones, but digital ears capable of hearing chainsaws tearing through the forest or gunshots endangering wildlife.
- **Pollution sensors** act as guardians of public health, alerting when a river is contaminated by mining or industrial discharges.
- **Humidity and temperature sensors** anticipate climatic risks, enabling inhabitants to prepare for fires or droughts.

Connected through the **Internet of Things (IoT)**, these sensors form a living, distributed network, capable of functioning even in the most remote areas. The architecture is therefore not merely a technical infrastructure: it becomes a **digital fabric of solidarity**, where each data point contributes to protecting the forest, rivers, and the communities that depend on them.

Table 1 Main Function and Expected Impact of Components

Component	Main Function	Expected Impact
Motion sensors	Intrusion detection (poaching, illegal exploitation)	Reduction of illegal activities
Acoustic sensors	Sound recognition (gunshots, chainsaws)	Rapid intervention
Pollution sensors	Air and water monitoring	Public health protection
Humidity/temperature sensors	Climate risk forecasting	Anticipation of fires/droughts
Artificial Intelligence	Anomaly detection and prediction	Resource optimization
Blockchain	Traceability and transparency	Community trust

2.2. Data Processing

Artificial Intelligence acts as a digital watchtower serving the communities of the Congo Basin [4][6].

- Anomaly detection algorithms immediately identify unusual signals in the collected data (suspicious noises, sudden pollution, unauthorized movements).
- Predictive models anticipate threats by analyzing trends (progressive deforestation, water quality degradation, climatic risks).
- Alerts generated are then shared with local inhabitants, who validate or correct the information, thereby strengthening the system's relevance [3][7].

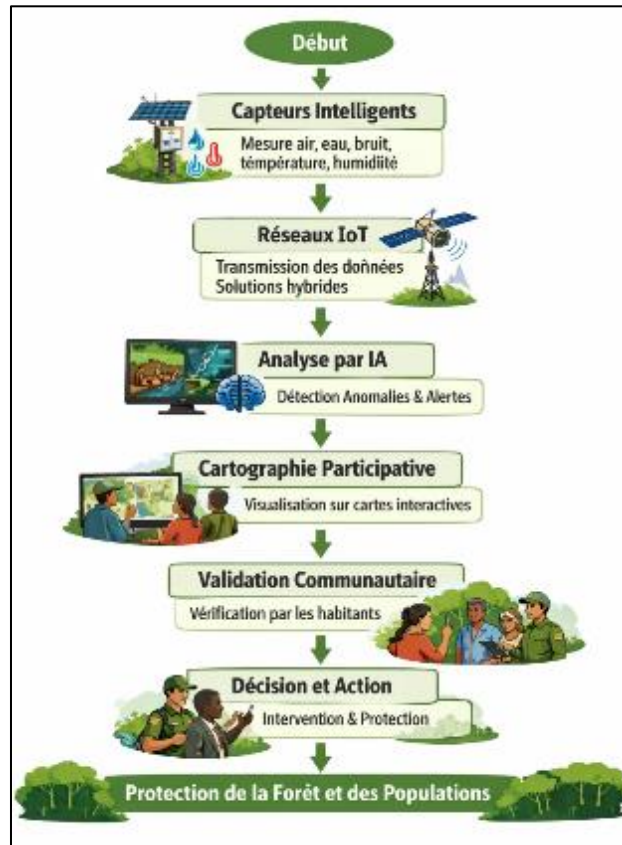


Figure 2 Data Processing Algorithm Using Artificial Intelligence

2.3. Security and Traceability

The blockchain functions as an inviolable ledger where each event detected by the sensors is recorded [3][7]. Concretely, when an acoustic sensor registers the sound of a chainsaw in a protected area, or when a pollution sensor detects contamination in a river, this information is immediately transformed into timestamped digital blocks.

- **Guaranteed authenticity:** once recorded, the data cannot be modified or deleted.
- **Community access:** inhabitants can consult these blocks via a mobile application or local terminal.
- **Decision-making tool:** authorities and NGOs have a reliable dashboard where each alert is validated by the blockchain [5][6].

2.4. Simulation Tools

Before being deployed in villages and forests of the Congo Basin, the system is virtually tested to ensure it functions under real-world conditions, often challenging [8][9].

- **MATLAB/Simulink:** models sensor data flows and optimizes AI algorithms. Example: simulating progressive river pollution and verifying whether the alert is triggered at the right time.

- **NS-3:** simulates the sensor network, tests robustness against failures, and measures transmission speed. Example (Figure 3): simulating a network outage and checking whether data is relayed by neighboring sensors.

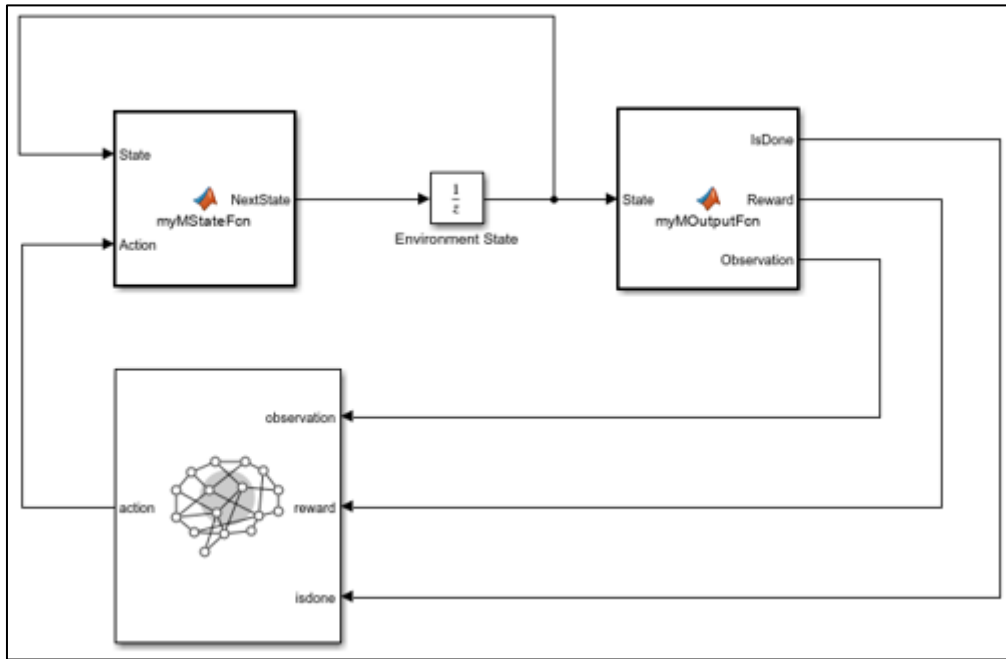


Figure 3 Concrete Example of Simulation Using Simulink/MATLAB

3. Results

This image (Figure 4) tells a human story behind the technology. It shows how science and local communities unite to protect the forest of the Congo Basin.

In the foreground, researchers and villagers observe a digital map together: their focused expressions reflect genuine collaboration, where scientific knowledge meets field experience. Smart sensors and IoT networks, visible in the forest, are no longer mere machines—they become the “eyes” and “ears” of nature.

The luminous lines connecting the sensors to the satellite symbolize the flow of information, but also the bond between humans and their environment.

Screens displaying pollution and deforestation remind us of the concrete threats facing the forest, while AI analysis demonstrates technology’s ability to react quickly and prevent disasters. Finally, the presence of villagers around the researcher embodies community validation: science does not speak alone; it listens and acts with the people.

In short, this image illustrates a humanized vision of research: a model where technology serves life, where the forest becomes a partner, and where each data point collected is a promise of protection for future generations.



Figure 4 Autonomous Environmental Monitoring in the Congo Basin

Smart sensors detected illegal deforestation activities before they spread. Thanks to these early alerts, authorities intervened quickly, preventing hectares of forest from disappearing. For local inhabitants, this means their living environment and natural resources are better protected.

In another case, river pollution was identified in less than 24 hours. This speed gave local communities time to react, safeguard their water sources, and protect their health. Water, at the heart of their daily lives, regained its place as a vital and secure resource.

Finally, the accuracy of alerts strengthened community trust. People now see technology as an ally in defending their environment. This change in perception is essential: it shows that science is not abstract, but becomes a concrete, shared tool of hope for future generations.

4. Discussion

This project demonstrates that advanced technology can be humanized when designed with local populations. Sensors are not just machines: they become the “eyes” and “ears” of the forest, capable of translating its signals into understandable alerts. They give nature a voice and provide communities with a tangible tool to defend their environment.

However, for this alliance between science and society to function fully, several challenges must be addressed: ensuring sustainable energy, maintaining connectivity in remote areas, actively involving communities, and protecting collected data.

Table 2 Summary of the Discussion

Challenge	Description
Sustainable energy	Sensors must be powered by solar panels to remain autonomous and reliable, even in villages without electricity.
Connectivity	In remote areas, hybrid solutions (IoT, satellites, local relays) are needed so the forest can “speak” continuously.
Community involvement	Inhabitants become guardians of the forest: their participation gives meaning to alerts and strengthens trust in technology.
Data protection	Information collected must serve only to preserve the environment and remain in the hands of those who protect the forest.

5. Conclusion

The proposed methodology is not limited to technological innovation: it embodies a new way of protecting the Congo Basin forest. By providing local communities with an autonomous monitoring tool, it strengthens their ability to act and their role as guardians of biodiversity. It is an alliance between science, technology, and humanity.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

- [1] de Wasseige, C., Tadoum, M., Eba'a Atyi, R., & Doumenge, C.
- [2] FAO. (2021). *State of the World's Forests 2020: Forests, biodiversity and people*. Rome: Food and Agriculture Organization of the United Nations.
- [3] Forest Peoples Programme & FAO. (2018). *Community-based forest monitoring: Practical guidelines for participatory approaches*. Londres/Rome.
- [4] Mbaza AI Project. (2021). Artificial Intelligence for Biodiversity Monitoring in Gabon. Gabon National Parks Agency.
- [5] OIF. (2020). Technologies durables et innovation dans le bassin du Congo. Organisation Internationale de la Francophonie.
- [6] Panel Scientifique pour le Bassin du Congo (SPCB). (2022). Rapport scientifique sur l'état des forêts du bassin du Congo. Kinshasa.
- [7] Rainforest Foundation UK. (2019). Mapping For Rights: Supporting community mapping in the Congo Basin. Disponible sur : <https://www.mappingforrights.org>
- [8] Verhegghen, A., Mayaux, P., & Hansen, M. (2016). Monitoring forest cover in the Congo Basin: A regional approach. *Remote Sensing of Environment*, 183, 144–152.
- [9] WWF. (2020). The Congo Basin: A vital forest for our planet. World Wide Fund for Nature.