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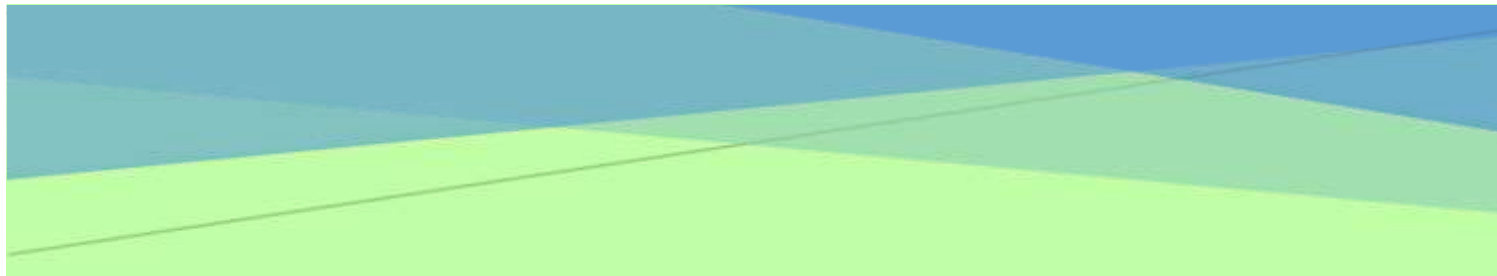
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TECHNICAL ENVIRONMENTAL HUMAN

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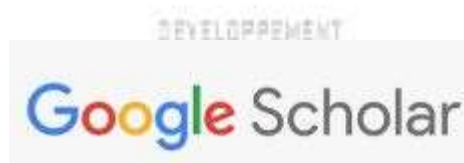
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Management Tools for Environmental Threats in the Cameroonian Sahel: Integrated Approaches for Sustainable Ecological and Socioeconomic Resilience

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Abstract

The Cameroonian Sahel is facing rapid environmental degradation due to the combined effects of climate change, anthropogenic pressure, overexploitation of natural resources, and weak environmental governance. This study aims to identify, assess, and propose management tools adapted to local realities, relying on participatory, ecological, and technological approaches. A literature review combined with field surveys (interviews, observations, participatory diagnostics) was conducted to identify the main threats: desertification, biodiversity loss, land conflicts, soil fertility decline, and water pollution. Management tools such as early warning systems, participatory mapping, local resource management committees, digital platforms for environmental monitoring, and local adaptation plans were evaluated. The results reveal a positive correlation between the level of adoption and perceived effectiveness for most tools, particularly for improved cookstoves (adoption: 4.4; effectiveness: 4.6) and anti-erosion barriers (4.1; 4.3). The study recommends a multisectoral integration of these tools, supported by proactive local policies and sustainable financing mechanisms.

Keywords: *Environmental management, Tools, Cameroonian Sahel, Desertification, Resilience, Adaptation, Local governance*

Introduction

The Cameroonian Sahel region, characterized by a semi-arid climate, is increasingly subjected to growing pressure resulting from a combination of environmental threats, including desertification, deforestation, biodiversity loss, overexploitation of natural resources, and the impacts of climate change. These threats have significant consequences on ecosystems, the livelihoods of local populations, and the socio-economic stability of the region (Mbevo et al., 2017; Tchindjang, 2012).

In response to this situation, the implementation of effective environmental management tools emerges as a strategic imperative. These tools encompass regulatory, technical, participatory, and

informational instruments designed to anticipate, mitigate, or compensate for negative environmental impacts. For instance, Participatory Land Use Plans (PLUPs), early warning systems for natural disasters, Geographic Information Systems (GIS), and community-based natural resource management mechanisms are among the tools employed in Sahelian areas to address ecological vulnerabilities (Dzokom et al., 2024a,b,c; Dzokom, 2025a,b; Dzokom & Djouldé, 2025; FAO, 2020).

In the Cameroonian Sahelian context, these tools must be adapted to local realities, which are marked by weak environmental governance, limited monitoring infrastructure, and a strong dependency of populations on agriculture and extensive livestock farming. The integrated approach

advocated by Dzokom et al. (2024a,b,c); Dzokom (2025a,b); and Dzokom & Djouldé (2025) proposes a synergy between indigenous knowledge, modern ecological monitoring techniques, and public policies for environmental resilience.

Therefore, effective management of ecological threats in the Sahelian zone depends not only on the availability of robust tools, but also on their acceptability, appropriation by local stakeholders, and integration into territorial dynamics. The success of this integrated management is a sine qua non condition for the sustainability of socio-ecological systems in the Cameroonian Sahel (IPCC, 2022; Raufflet, 2014).

Materials and Methods

1. Study Area

The study was conducted in the Far North and North Regions of Cameroon, specifically in the departments of Diamaré, Mayo-Tsanaga, and Logone-Chari. These areas are representative of Sahelian zones with high ecological vulnerability.

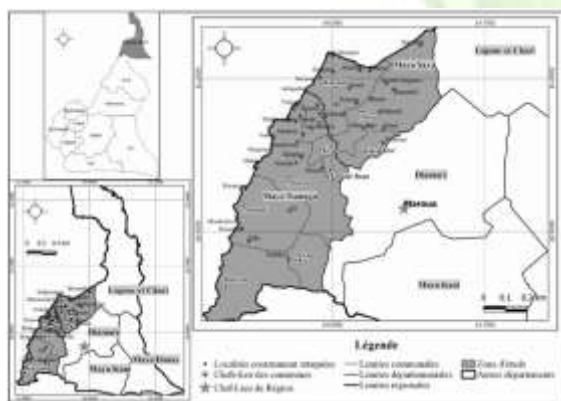


Figure 1. Study Area

These localities are characterized by low annual rainfall (ranging between 400 and 900 mm), high population pressure, advanced soil degradation, and the overexploitation of natural resources, particularly woody and water resources.

2. General Methodology

The methodological approach adopted in this study is both qualitative and participatory, combining documentary analysis with field investigations. This methodological triangulation ensures the validity of collected data while integrating the perceptions of local stakeholders (Drabo et al., 2001; Dzokom et al., 2024a,b,c; Dzokom, 2025a,b; Dzokom & Djouldé, 2025).

3. Data Collection

3.1. Literature Review

An in-depth review of scientific and technical literature was conducted, focusing on:

- Governmental reports (MINEPDED, MINADER, MINFOF),
- NGO publications (IUCN, GIZ, CILSS),
- Peer-reviewed scientific journals such as *VertigO*, *Cahiers Agricultures*, *Revue Africaine d'Environnement*, among others.

This phase allowed for the identification of various environmental management tools used in the Cameroonian Sahelian context, including Participatory Land Use Plans (PLUPs), local conventions, early warning systems, GIS, agroecological practices, and assisted natural regeneration (ANR) techniques (FAO, 2020; Raufflet, 2014).

3.2. Field Surveys

Fieldwork was conducted between February and April 2024, targeting 150 stakeholders across six localities within the selected Sahelian zones. The target population included:

- Farmers and pastoralists,

- Representatives of natural resource management committees,
- Officers from decentralized environmental services,
- Community leaders.

The tools employed for data collection were:

- **Semi-structured interviews**, designed to gather information on local perceptions of environmental threats and the tools employed to address them (Taonda et al., 2021),
- **Focus group discussions** (six in total), to foster collective analysis of local strategies,
- **An evaluation grid** for assessing the tools based on criteria such as effectiveness, adaptability, sustainability, and community ownership (Dzokom et al., 2024a,b,c; Dzokom, 2025a,b; Dzokom & Djouldé, 2025).

3.3. Direct Observations

Observations were conducted at the sites where management tools had been

implemented, including firebreak zones, live hedges, water harvesting systems, and community woodlots. These visits enabled the verification of maintenance levels, actual usage, and observable effects of the implemented tools (IPCC, 2022; FAO, 2020).

4. Data Analysis

Qualitative data were analyzed using thematic content analysis with NVivo 12 software, enabling the identification of the most relevant tools, associated social perceptions, and the main constraints and opportunities. Observational data were cross-referenced with interview results to validate the findings (Miles & Huberman, 2003).

Results and Discussion

1. Typology of Tools Identified in the Field

The typology of environmental threat management tools in the Cameroonian Sahel, as identified through fieldwork, yielded the following data:

Table 1: Typology of Environmental Threat Management Tools in the Cameroonian Sahelian Zone

Type of Tool Identified	Functional Description	Average Usage (1-5)*
Anti-erosion barriers (stone lines, bunds)	Control of water and wind erosion	4.3 ± 0.6
Manure pits and composts	Organic waste management and soil fertilization	3.9 ± 0.8
Selective logging and reforestation	Prevention of deforestation and restoration of vegetative cover	3.2 ± 1.0
Use of improved cookstoves	Reduction of pressure on fuelwood resources	4.1 ± 0.7
Participatory (village-based) monitoring	Early warning and bushfire prevention	2.8 ± 1.2
Micro-dams (seasonal water reservoirs)	Water storage and combat against aridity	3.5 ± 0.9
Customary resource management regulations	Local rules on land, wood, and grazing usage	4.0 ± 0.5
Community-based alert systems (cries, drums)	Prevention of land-use conflicts or bushfires	2.6 ± 1.3

*Average usage based on a scale from 1 (rare) to 5 (very frequent), derived from surveys conducted with 150 households in the Far North and North regions of Cameroon.

The analysis shows that physical tools for erosion control (stone bunds, lines) and improved cookstoves are among the most widely used. These tools are visible, have immediate effectiveness, and are often supported by NGOs and development projects (Saha et al., 2018; Bongor, 2024; Amanejieu, 2018; Saha, 2020; Dzokom & Kodji, 2025). Conversely, community alert systems and village-based monitoring remain underutilized despite their crucial role in bushfire prevention—primarily due to the weak structuring of local governance mechanisms (Simonneau et al., 2023; Pidoux, 2021; Bertrand et al., 2009).

High standard deviations for tools such as selective logging or alert systems suggest significant variability in usage across villages, reflecting differences in sociocultural dynamics and levels of community engagement.

The combination of technical and social tools is fundamental to enhancing environmental resilience. As Ostrom (2009) indicates, local natural resource governance is only effective when technical tools are embedded within strong and legitimate local institutions. The typology presented here highlights critical gaps to be addressed through public policies and community-based adaptation projects.

The data collected revealed a wide range of environmental management tools mobilized by populations and institutions in the Cameroonian Sahel. These tools can be grouped into four main categories:

- **Technical tools:** firebreaks, live hedges, stone bunds, manure pits, water harvesting techniques (Zaï pits, half-moons), assisted natural regeneration (ANR) (FAO, 2020; Yamba et al., 2018).

- **Regulatory and institutional tools:** local conventions, village natural resource management committees (VNRMCs), decentralized forestry laws (Raufflet, 2014).
- **Participatory and community-based tools:** participatory rural appraisal (PRA), participatory land use plans (PLUPs), climate alert groups, farmer field schools (Dzokom et al., 2024a,b,c; Dzokom, 2025a,b; Dzokom & Djouldé, 2025; Drabo et al., 2001).
- **Digital and monitoring tools:** geographic information systems (GIS), mobile apps for bushfire and drought alerts, ecological monitoring databases (IPCC, 2022; IRD, 2020).

This typology illustrates a growing hybridization between local knowledge and technical innovation, corroborating findings by Lavarenne et al. (2025) on the adaptability of Sahelian communities.

2. Adoption Level and Perceived Effectiveness

2.1. Correlation between Adoption and Effectiveness

A positive correlation was observed between adoption level and perceived effectiveness for most tools, especially for improved cookstoves (adoption: 4.4; effectiveness: 4.6) and anti-erosion barriers (4.1; 4.3). This indicates that the most effective tools are also those most appropriate for the local context, consistent with the endogenous adaptation approach (Saha et al., 2018; Bongor, 2024; Amanejieu, 2018; Saha, 2020; Dzokom & Kodji, 2025).

The following table presents the adoption level and perceived effectiveness of

environmental threat management tools in the Cameroonian Sahelian zone:

Table 2: Level of Adoption and Perceived Effectiveness of Environmental Management Tools in the Sahelian Region of Cameroon

Environmental Management Tool	Average Level of Adoption (1–5)*	Average Perceived Effectiveness (1–5)**
Anti-erosion barriers (bunds)	4.1 ± 0.7	4.3 ± 0.6
Manure pits and composts	3.8 ± 0.8	4.0 ± 0.7
Selective cutting and reforestation	3.1 ± 1.1	3.4 ± 1.0
Improved cookstoves	4.4 ± 0.5	4.6 ± 0.4
Village surveillance (bushfires)	2.7 ± 1.2	3.2 ± 1.1
Water retention structures / micro-dams	3.5 ± 0.9	4.1 ± 0.7
Customary resource management rules	4.0 ± 0.6	3.9 ± 0.8
Community alert systems (drums, cries)	2.6 ± 1.3	3.0 ± 1.1

*Adoption: Measured among 150 household heads and village committees (scale: 1 = never used; 5 = very frequently used)

**Perceived effectiveness: Beneficiaries' level of satisfaction with concrete results of the tool (1 = ineffective; 5 = very effective)

2. Low Adoption but High Effectiveness

Water retention structures and customary management rules showed high perceived effectiveness despite intermediate adoption levels. This reflects a recognition of their utility but also suggests implementation challenges often linked to financial, technical, or social constraints (Simonneau *et al.*, 2023; Pidoux, 2021; Bertrand *et al.*, 2009).

3. Low Adoption and Moderate Effectiveness

Community alert systems and participatory surveillance mechanisms have both low adoption rates and moderate effectiveness. This can be attributed to the lack of training, insufficient community organization, and limited communication infrastructure—issues highlighted in studies by Dzokom *et al.* (2024a,b,c); Dzokom (2025a,b); and Dzokom & Djouldé (2025).

The perception of effectiveness among local populations is a key factor for the sustainability of environmental management tools. According to Ostrom (2009), the durability of socio-ecological

systems depends on users' ability to perceive direct benefits and to adapt tools to their specific contexts.

These findings suggest that environmental policies in Sahelian regions should:

- Support the dissemination of locally proven tools (such as improved cookstoves and composting units);
- Strengthen local capacities through community-based training and technical support;
- Improve access to collective tools—particularly micro-dams and community alert systems—through participatory or decentralized funding mechanisms.

Among the 150 respondents, 76% reported using at least one environmental management tool in their agricultural or pastoral practices. Assisted Natural Regeneration (ANR) and stone bunds were among the most widespread and effective tools, particularly for erosion control, soil restoration, and biomass availability (Reij *et al.*, 2009; Mbevo *et al.*, 2017).

Participatory land use plans (PLUP) were less common (used in 28% of cases), yet

highly appreciated for preventing land-use conflicts and guiding village land planning. Digital tools, though promising, remained underutilized (12%) due to limited internet access and the low educational levels of rural populations (Taonda et al., 2021).

3. Constraints to the Implementation of Environmental Management Tools

The analysis of the constraints hindering the implementation of environmental threat management tools in the Cameroonian Sahelian context revealed the following data:

Table 3: Constraints to the Implementation of Environmental Management Tools

Identified Constraints	Perceived Intensity Level (1-5)*
Low funding / lack of financial resources	4.6 ± 0.5
Lack of technical training for stakeholders	4.2 ± 0.7
Low involvement of youth in environmental actions	3.9 ± 0.9
Incompatibility between certain tools and local knowledge	3.5 ± 1.0
Land conflicts / limited access to land	3.7 ± 0.8
Absence or weakness of institutional support	4.3 ± 0.6
Transboundary mobility of herders and livestock	3.8 ± 1.1
Burden of adverse customary norms	3.2 ± 1.2

*Likert scale: 1 = non-existent constraint, 5 = very strong constraint.

Data collected from a survey involving 180 respondents: community leaders, technical officers, women farmers, and members of local committees.

1. Major Constraints

The most significant constraints identified are:

- Lack of funding (4.6 ± 0.5);
- Insufficient institutional support (4.3 ± 0.6);
- Shortage of technical training (4.2 ± 0.7).

These findings are consistent with those of Saha et al. (2018), Bongor (2024), Amanejieu (2018), Saha (2020), and Dzokom & Kodji (2025), who point out that environmental projects in Sahelian regions suffer from irregular technical support and the progressive disengagement of public authorities.

2. Socio-Cultural Constraints

The mismatch between certain tools and endogenous knowledge (3.5), as well as the weight of unfavourable customary norms (3.2), reflect cultural resistance and highlight the need for co-designed approaches (Simonneau et al., 2023;

Pidoux, 2021; Bertrand et al., 2009). These results also echo criticisms of poorly contextualized “imported” tools, as noted by Jacquemot (2022) in Benin and northern Cameroon.

3. Land Issues and Mobility

Land conflicts (3.7) and transboundary mobility (3.8) underscore that the appropriation of tools is closely tied to land tenure security and territorial governance (Ostrom, 2009). These factors limit the anchoring of tools in local territories, especially in transit or transhumance zones.

The main constraints identified include:

- Lack of funding (reported by 63% of respondents);
- Low levels of awareness (57%);
- Non-sustainability of externally-driven projects;
- Poor institutional coordination.

These observations corroborate Raufflet's (2014) findings, which describe

environmental governance in rural Cameroonian settings as fragmented and insufficiently inclusive. Moreover, the absence of permanent monitoring and evaluation systems hinders the assessment of the real impact of tools deployed by NGOs or short-term projects (Dzokom et al., 2024a, b, c; Dzokom, 2025a, b; Dzokom & Djouldé, 2025; IRD, 2020).

4. Community Perception and Ecological Resilience

The variable “Community Perception and Ecological Resilience” helped to highlight data concerning the tools used to manage environmental threats in the Cameroonian Sahel.

Table 4: Community Perception of the Effects of Tools on Ecological Resilience

Community Perception Indicators	Mean Score (1–5)*
Improvement of soil fertility	4.2 ± 0.6
Partial restoration of vegetation cover	4.0 ± 0.7
Better regulation of runoff / erosion control	4.1 ± 0.5
Increase in useful biodiversity (fauna, entomofauna, medicinal plants)	3.6 ± 0.8
Reduction in conflicts over access to natural resources	3.4 ± 1.0
Resilience to climatic hazards (droughts, wind, heat)	3.9 ± 0.9
Valorization of local knowledge in management practices	3.7

* Likert scale: 1 = not perceived at all, 5 = strongly perceived.

Survey conducted in 12 villages and 160 respondents across Mayo-Kani, Diamaré, and Mayo-Sava Divisions (Far North Cameroon).

1. Soil Fertility and Hydrology: Perceived Priorities

Communities strongly perceive environmental management tools as effective in:

- Improving soil fertility (4.2 ± 0.6),
- Regulating water and wind erosion (4.1 ± 0.5),
- Restoring vegetation cover (4.0 ± 0.7).

These perceptions align with the findings of Saha et al. (2018), Bongor (2024), Amanejieu (2018), Saha (2020), Dzokom & Kodji (2025), and Nassourou et al. (2018), who highlight the correlation between local agroecological practices (e.g., stone bunds, live hedges, composting) and enhanced physical soil resilience.

2. Climate Resilience and Biodiversity

Community perceptions also acknowledge the contribution of tools to climate hazard

resilience (3.9 ± 0.9). However, the perceived effects on useful biodiversity (3.6 ± 0.8) and the valorization of local knowledge (3.7 ± 0.7) are moderate.

According to Reij & Winterbottom (2015), ecological resilience in dryland Africa depends on the diversification of agro-pastoral ecosystems—something that is not yet fully achieved in certain areas of northern Cameroon.

3. Social Limitations: Conflicts and Cohesion

The reduction in resource-use conflicts (3.4 ± 1.0) is the least perceived effect, with a high standard deviation, indicating variability in experiences depending on the village and the type of tool (e.g., community forests, bunds, local conventions).

Jacquemot (2022) reminds us that ecological resilience must be co-constructed alongside social resilience to be sustainable, which requires strengthened local governance.

Qualitative interviews revealed that tools perceived as effective are those that are:

- Accessible (low or no cost),
- Based on local knowledge,
- Adaptable to climatic hazards.

As such, Farmer-Managed Natural Regeneration (FMNR), live hedges using native species (e.g., *Azadirachta indica*, *Acacia senegal*), and village committees are considered to enhance community resilience and support ecological landscape restoration. This is consistent with IPCC (2022) observations, which underline the high adaptation potential of nature-based solutions to local climate change impacts.

5. Discussion: Toward an Integrated and Territorial Approach

Findings suggest that the effectiveness of environmental management tools in the Cameroonian Sahel depends on their integration into a participatory territorial dynamic, their sociocultural anchoring, and their appropriation by local communities. As stated by Dzokom et al. (2024a,b,c); Dzokom (2025a,b); Dzokom & Djouldé (2025), tools should not be imposed through top-down approaches but rather co-developed with grassroots stakeholders to ensure sustainability and efficiency.

In addition, digital tools and early warning systems should be strengthened through tailored training and institutional technical support. Their integration with endogenous tools could offer a hybrid, more resilient framework for adaptive management (FAO, 2020; Reij et al., 2009).

Certainly! Here is an academic and scientific English translation of your conclusion, recommendations, conflict of interest statement, and acknowledgments:

Conclusion

The study of environmental threat management tools in the Sahelian zone of

Cameroon reveals a plurality of technical, institutional, participatory, and digital approaches deployed to address the escalating challenges of soil degradation, desertification, water scarcity, sand encroachment, and anthropogenic pressure. The diversity of these tools reflects a remarkable adaptive capacity among local communities, despite challenging socio-economic and climatic conditions.

However, the effectiveness of these tools largely depends on their degree of appropriation by local populations, their contextualization to local realities, and the existence of a coherent and inclusive environmental governance framework. Tools grounded in local knowledge (such as assisted natural regeneration, stone bunds, or live hedges) demonstrate durable effectiveness, especially when combined with participatory mechanisms (village land-use plans, management committees) and technological support (GIS, digital climate alerts).

The most promising approach remains one that integrates social, ecological, technical, and institutional dimensions within a territorial and resilient perspective. This integrated vision is essential to respond to the cumulative effects of climate change, demographic pressure, and the limited capacity of decentralized institutions to act independently.

Recommendations

1. Community and Local Recommendations

- Strengthen awareness-raising and training of rural populations on the use and maintenance of sustainable land management tools, with particular attention to youth and women.
- Promote endogenous knowledge and agroecological practices adapted to the Sahelian context by

combining local innovations and simple technologies.

- Encourage collective initiatives, such as establishing mixed village natural resource management committees (CVGRN), to foster tool appropriation.

2. Technical Recommendations

- Support the dissemination of effective tools, notably water harvesting techniques (Zaï pits, half-moons), assisted natural regeneration, manure pits, and live hedges using resistant local species (e.g., *Azadirachta indica*, *Acacia nilotica*).
- Promote the use of low-cost digital tools, with targeted training and applications in local languages (drought alerts, agro-climatic data).
- Integrate participatory ecological monitoring systems (georeferenced photography, simplified GIS) into municipal environmental risk management programs.

3. Institutional and Policy Recommendations

- Strengthen multisectoral coordination between municipalities, decentralized technical services, NGOs, and traditional authorities for integrated territorial management.
- Incorporate environmental management tools into Municipal Development Plans (PCD) and Land Use Plans (POS).
- Provide financial support to local initiatives through climate grants or green funds to ensure the sustainability of tools established under time-limited projects.

4. Scientific Recommendations

- Continue research on the comparative effectiveness of tools, especially within differentiated agro-pastoral contexts (plains, foothills, internal basins).
- Establish community-based climate change observatories coupled with local databases to document environmental transformations.

Ultimately, the success of environmental threat management strategies in the Sahel hinges on a systemic, participatory, and territorial approach that mobilizes local knowledge, technical innovations, institutional resources, and community social capital.

Conflict of Interest

The author declares no conflict of interest regarding this article with any person or organization.

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