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Field-Based Environmental Vigilance Profiles Associated with Rural Activities in the Pool Department, Republic of the Congo

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Abstract

Local environmental planning requires diagnostic tools capable of identifying areas and activities that may place pressure on soils, fragile environments and water resources before these pressures become measurable deforestation or forest degradation. This study characterises environmental vigilance profiles associated with rural activities in seven localities of the Pool Department, Republic of the Congo, using 178 completed field-observation records collected in 2024 by the doctoral researcher and subsequently checked and verified by Ifo Suspense Averti. The analysis is restricted to environmental and territorial records describing activity types, localities, proximity to rivers or water points, field-recorded indicators affecting fragile environments and water bodies, soil instability and potential conflicts. No respondent-level social or perceived-risk data and no direct biophysical measurements of erosion, soil compaction or water quality were used. Agriculture dominates most localities, whilst Mindouli displays a mixed agro-pastoral profile, Koubola a distinctive pastoral profile, and Yalavounga, Yangui and Linzolo very high hydrological sensitivity. Field-recorded indicators affecting fragile environments and water resources are especially frequent in Missafou, Yalavounga and Linzolo. The paper proposes a qualitative environmental vigilance typology distinguishing multi-activity hydrological-risk, agricultural-riparian/hydrological, mixed agro-pastoral and pastoral profiles. This screening typology offers a practical basis for

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prioritising local monitoring, riparian protection and agroecological land-use planning, but it should not be interpreted as a measured probability of environmental damage.

Keywords: Environmental vigilance; rural activities; water resources; agriculture; livestock; Pool Department; Republic of the Congo

Introduction

Rural landscapes in Central and West Africa are increasingly affected by agricultural expansion, livestock keeping, domestic wood use, growing accessibility and competition for land and water resources. These processes do not only result in forest loss; they also generate localised environmental risks, including soil disturbance, riverbank degradation, vegetation fragmentation and pressure on riparian ecosystems. Long-term land-cover studies in West Africa have shown that human-dominated land-cover classes, particularly croplands and settlements, have expanded at the expense of natural vegetation (Vittek et al., 2014; Barnieh et al., 2020; Herrmann et al., 2020).

The Pool Department, located in southern Republic of the Congo, is particularly relevant for such an analysis. It is characterised by a forest-savannah mosaic, gallery forests, secondary forest patches, agricultural lands and hydrological networks that support rural livelihoods. Previous botanical and ecological studies in the Pool and neighbouring Congolese landscapes have shown the importance of secondary forests, degraded forests, savannahs and riparian formations for biodiversity, soil-water regulation and ecosystem functioning (Kimpouni et al., 2009; Ndzai et al., 2022; Gomat et al., 2024).

At the Congo Basin scale, small-scale agriculture, villages, roads, fuelwood demand and other components of the rural complex remain central to forest disturbance, especially in fragmented and secondary forests (Mayaux et al., 2013; Ernst et al., 2013; Tegegne et al., 2016; Tyukavina et al., 2018; Shapiro et al., 2023).

The problem addressed in this paper differs from an analysis of perceived drivers of deforestation. The empirical question is: which locality-level environmental vigilance profiles emerge from the observed distribution of rural activities, hydrological proximity and recorded indicators affecting fragile environments and water resources? This diagnostic perspective is important because environmental pressures are not distributed uniformly across space. Evidence from West African floodplain and wetland studies and from Congo Basin landscape assessments shows that agricultural expansion, settlement growth and livestock pressure may affect vegetation, soils and water resources differently according to local ecological settings (Nsor et al., 2019; Barnieh et al., 2020; Shapiro et al., 2023).

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The general objective is to identify and compare environmental vigilance profiles associated with rural activities in surveyed localities of the Pool Department. The specific objectives are to: (i) describe the frequency distribution of recorded rural activities by locality; (ii) assess observed hydrological proximity; (iii) identify and compare locality-specific profiles of recorded indicators affecting fragile environments and water resources; and (iv) propose monitoring and rural land-use planning priorities adapted to each locality.

This article draws on the environmental and territorial component of the field database assembled for the doctoral thesis of Makaya Helischa Audrey, entitled "Suivi de la dynamique des écosystèmes forestiers du Département du Pool de 1990 à 2020". The present analysis is distinct from the thesis component based on community perceptions of forest decline.

Materials and methods

Study area

The study was conducted in localities of the Pool Department in southern Republic of the Congo: Missafou, Linzolo, Mindouli, Koubola, Yalavounga, Yangui and Niangui. The department is a rural and peri-urban landscape where agricultural land, savannahs, gallery forests, secondary forest patches and hydrological networks interact. The physical geography of the Pool is marked by plateaux, hills and plains, with hydrographic systems that support rural livelihoods and create ecologically sensitive riparian environments (Vennetier, 1966; Monographie du departement du Pool, 2011). Figure 1 presents the general location of the study area. The database did not include a geospatial land-use layer permitting calculation of the relative area occupied by agriculture, settlements or other rural land uses in each locality. Consequently, the study does not estimate area-weighted exposure or the proportional impact of the recorded indicators on rural livelihoods.

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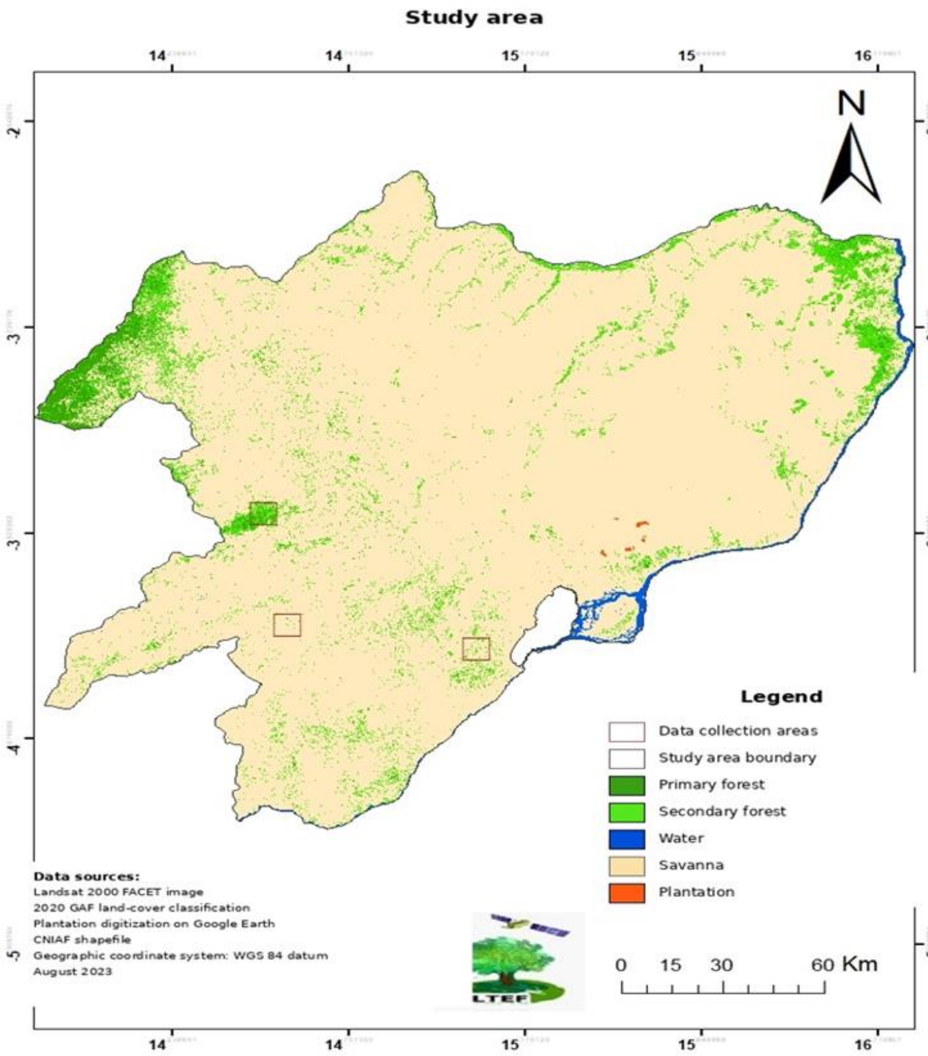

Figure 1: General location of the study area in the Pool Department

Data and analytical scope

The data were drawn from 178 completed environmental and territorial observation records collected in 2024 by Makaya Helischa Audrey during her doctoral fieldwork. The same structured field-screening form was used across the seven localities. All records were subsequently checked and verified by Ifo Suspense Averti before analysis. The retained variables describe localities, activity types, proximity to rivers or water points, field-recorded indicators affecting fragile environments and rivers or lakes, soil or geological instability, and observation-level flags for potential conflicts or inequalities. Variables relating to sub-projects and direct beneficiaries were excluded to

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keep the analysis focused on environmental and territorial screening indicators.

The analytical unit was a completed environmental observation record, not an individual respondent. A record was retained as completed when it passed the verification step, contained an identifiable locality and provided usable entries for the environmental variables required for the relevant analysis. The structured form recorded locality, activity type, proximity to water and the presence or absence of predefined environmental indicators. Each indicator was coded as present (1) or absent (0) only when the corresponding field had been explicitly completed; missing entries were treated as unavailable rather than recoded as zero. Consequently, the tables present frequency counts of valid observation records or recorded occurrences, and not responses from individual residents. The hydrological-proximity variable is an observed screening field rather than a direct measurement of discharge, water quality, bank erosion or flood probability.

This article does not use the community-perception database associated with the thesis survey. This methodological choice maintains a distinct analytical angle: the paper examines environmental vigilance profiles derived from field-screening records rather than perceived causes of forest decline. No respondent-level social dataset was analysed; the potentially social variables available in the source database were outside the analytical scope of this paper. The analysis is descriptive and does not claim statistical causality or a validated quantitative risk assessment.

The bibliographic framework of this article was purposefully strengthened with studies from West Africa and Central Africa that address land-cover transitions, riparian vegetation change, soil-water dynamics, savannah-forest mosaics and environmental monitoring. This choice reinforces the environmental-diagnostic orientation of the paper and distinguishes it from the companion manuscript centred on community perceptions and perceived drivers of deforestation. This comparative framing is consistent with land-cover and ecoregional assessments that document agricultural expansion, vegetation transitions and rural landscape change in West Africa (Tappan et al., 2004; CILSS, 2016; Tappan et al., 2016; Cotillon & Mathis, 2017).

Data processing

Locality names were harmonised to group spelling and administrative variants. Activities were classified into five categories: agriculture, livestock, trade, fish farming and other activities. After collection, the records were screened for completeness and internal consistency, category labels were harmonised, and frequency tables were recalculated following verification by Ifo Suspense Averti. Because one doctoral researcher collected the field data,

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no inter-observer reliability statistic was applicable; consistency was addressed through the use of a single structured form and supervisory verification. Activity data and field-recorded environmental indicators were summarised as absolute frequency counts; hydrological proximity was expressed as the percentage of valid observation records indicating the presence of a river, stream or water point. The analysis led to a qualitative environmental vigilance typology based on combinations of activity structure, hydrological proximity, recorded indicators and data completeness.

Potential vigilance levels were assigned through an explicit rule-based qualitative screening matrix. A very-high level was assigned when hydrological proximity reached at least 90% of valid records, or when a diversified activity structure coincided with the largest total of field-recorded environmental indicators. A moderate-to-high level was assigned when agriculture and livestock were nearly balanced and hydrological proximity ranged from 65.0% to 74.9%. A moderate level denoted a livestock-dominant or otherwise localised pressure profile with hydrological proximity below 65% and fewer recorded indicators. Niangui was classified as indeterminate because only two valid records were available. Table 5 reports the decision rule for each profile family. These levels are relative screening priorities; they are not additive risk scores, probabilities, effect sizes or results of physical risk measurement.

Results

Distribution of observed activities

Table 1: Frequency counts of recorded activity mentions by locality

Locality	Agriculture (n)	Livestock (n)	Trade (n)	Fish farming (n)	Other (n)	Environmental profile
Missafou (Mindouli)	35	15	11	8	5	Diversified, agriculture-dominated
Linzolo (Goma tse-tse)	24	6	10	0	3	Agricultural-commercial and hydrological
Mindouli	11	10	3	0	2	Mixed farming-livestock
Koubola (Goma tse-tse)	7	9	4	0	1	Pastoral pressure on soils
Yalavounga (Kinkala)	12	2	2	0	1	Sensitive agricultural-riparian
Yangui (Kinkala)	10	5	0	0	0	Agricultural with strong hydrological proximity
Niangui (Kinkala)	2	0	0	0	0	Agricultural, limited data
Total activity mentions	**101**	**47**	**30**	**8**	**12**	**198 mentions**

Note: Counts are activity mentions in valid field observation records, not respondent totals; one record could include multiple activities.

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Table 1 and Figure 2 show that the distribution of activities is dominated by agriculture in most localities. Missafou is the most diversified, combining agriculture, livestock, trade and fish farming. Linzolo combines agriculture and trade, whereas Mindouli shows a mixed agriculture-livestock profile. Koubola differs from the other localities because livestock is relatively dominant, which calls for a specific interpretation of risks associated with grazing routes, soil trampling and watering points.

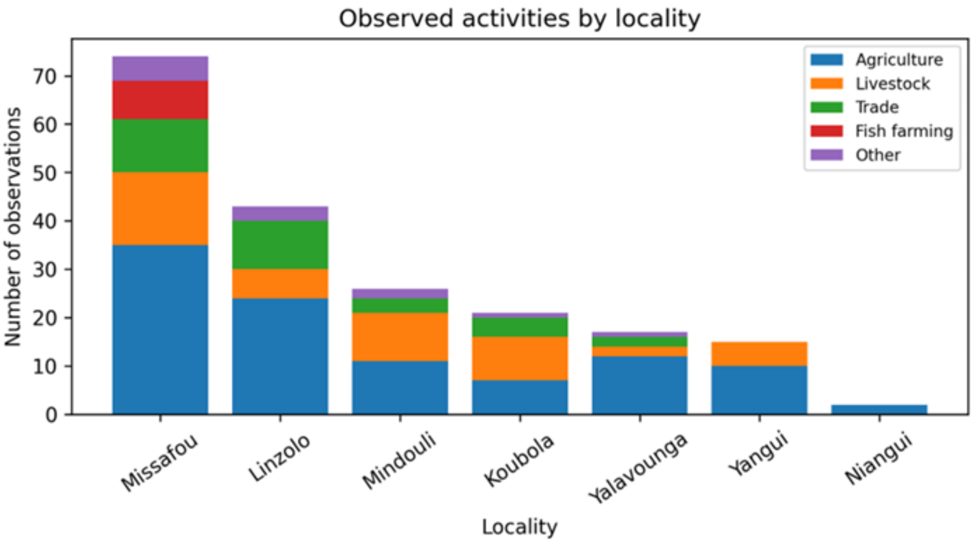

Figure 2: Distribution of observed activities by locality in the environmental database

Hydrological sensitivity of localities

Table 2: Frequency and percentage of field records indicating hydrological proximity

Locality	Records close to water (n)	Valid records indicating proximity (%)	Sensitivity level
Missafou (Mindouli)	49	66.2	Moderate to high
Linzolo (Goma tse-tse)	30	90.9	Very high
Mindouli	14	70.0	Moderate to high
Koubola (Goma tse-tse)	11	64.7	Moderate
Yalavounga (Kinkala)	17	100.0	Very high
Yangui (Kinkala)	14	93.3	Very high
Niangui (Kinkala)	2	100.0	Very high, to be interpreted cautiously
All localities (descriptive total)	**137**	**77.0 (137/178)**	**Not a departmental risk score**

Note: Percentages use records with a completed hydrological-proximity field. The pooled value of 77.0% is descriptive of the 178 records and is not an area-weighted risk estimate for the Pool Department.

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Table 2 and Figure 3 show that Yalavounga, Yangui, Niangui and Linzolo have the highest proportions of observations close to water. Niangui should be interpreted cautiously because the number of observations is low. Hydrological proximity is a central vigilance indicator because rural activities near watercourses may affect riverbanks, gallery forests, water quality and soil stability.

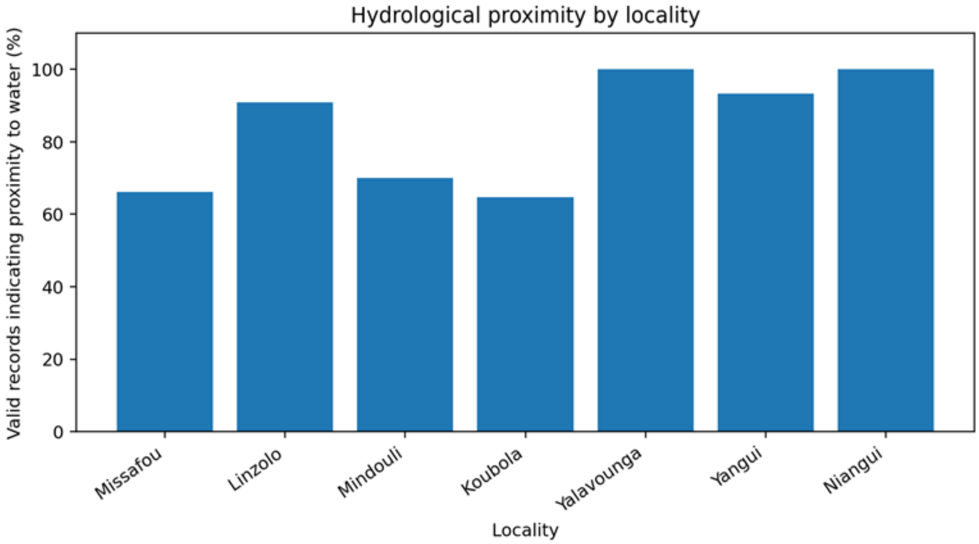

Figure 3: Proportion of observations indicating proximity to a river or water point

Recorded risk indicators for fragile environments and water resources

Table 3: Frequency counts of recorded environmental indicators by locality

Locality	Fragile areas (n)	Rivers/lakes (n)	Soil instability (n)	Conflict flags (n)
Missafou (Mindouli)	17	21	0	3
Linzolo (Goma tse-tse)	10	6	1	1
Mindouli	2	6	1	1
Koubola (Goma tse-tse)	5	1	1	1
Yalavounga (Kinkala)	11	7	2	0
Yangui (Kinkala)	3	6	1	0
Niangui (Kinkala)	0	0	0	0
Total recorded occurrences	**48**	**47**	**6**	**6**

Table 3 and Figure 4 show that field-recorded environmental indicators are particularly frequent in Missafou, Yalavounga and Linzolo. Missafou has the largest total of recorded occurrences (41), followed by Yalavounga (20) and Linzolo (18). Missafou combines the highest numbers

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of occurrences relating to fragile environments and rivers or lakes. Yalavounga combines very strong hydrological proximity with frequent indicators affecting fragile environments. Linzolo also presents a sensitive profile because agriculture and trade occur in a context of strong proximity to water points. These totals are counts of field-recorded occurrences, not measured damage rates.

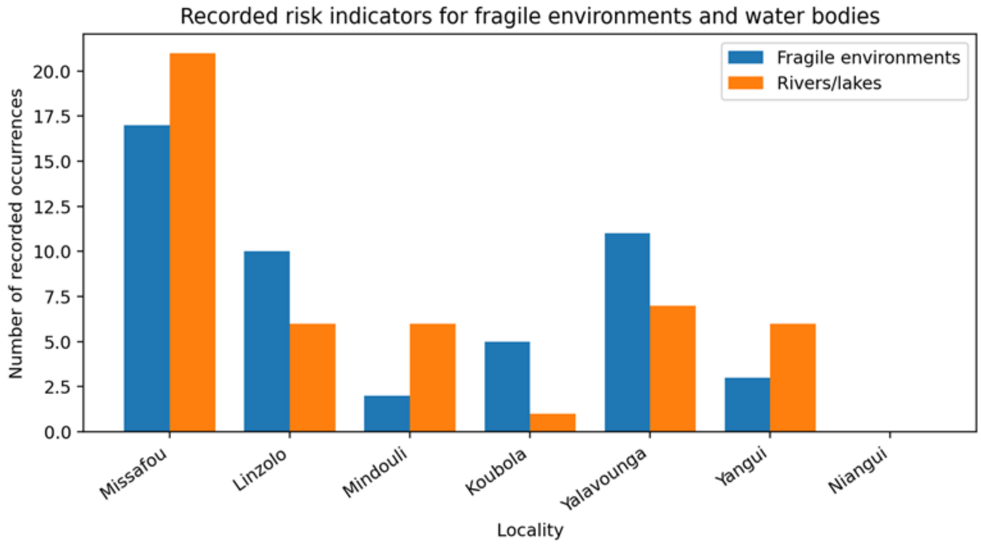

Figure 4: Recorded risk indicators for fragile environments and rivers/lakes

Environmental vigilance typology

Table 4: Locality-level environmental vigilance typology and potential vigilance level

Locality	Vigilance profile	Monitoring priority	Potential vigilance level
Missafou	Multi-activity hydrological-risk profile	Integrated agriculture-livestock-fish-farming planning and riparian protection	Very high
Linzolo	Agricultural-commercial hydrological profile	Control of riparian clearing and monitoring of water points	Very high
Mindouli	Mixed agro-pastoral profile	Combined management of cropping areas, grazing routes and soils	Moderate to high
Koubola	Pastoral profile	Management of grazing routes, watering points and compacted soils	Moderate
Yalavounga	Highly sensitive agricultural-riparian profile	Strict protection of riverbanks and fragile areas	Very high

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Yangui	Agricultural profile with strong hydrological proximity	Vegetated buffer strips and limitation of burning	Very high
Niangui	Limited-data profile	Additional field investigation required	Indeterminate (limited data)

Table 4 presents the locality-level profiles and their qualitative potential vigilance levels. Table 5 consolidates these locality-specific labels into four main profile families: multi-activity hydrological-risk, agricultural-riparian/hydrological, mixed agro-pastoral and pastoral. Niangui is retained as a separate limited-data category and is not counted as a fifth main profile. This typology makes it possible to prioritise monitoring measures according to local context rather than applying a uniform strategy to the entire department.

Table 5: Decision rules for the four principal environmental vigilance profiles

Main profile family	Defining combination / decision rule	Localities	Potential vigilance level
Multi-activity hydrological-risk	At least four activity categories; 66.2% water proximity; highest indicator total (41).	Missafou	Very high
Agricultural-riparian/hydrological	Agriculture dominant; water proximity at least 90%; recurrent riparian or fragile-area indicators.	Linzolo, Yalavounga and Yangui	Very high
Mixed agro-pastoral	Agriculture and livestock nearly balanced; water proximity 65.0-74.9%; lower indicator total.	Mindouli	Moderate to high
Pastoral	Livestock exceeds agriculture; water proximity below 65%; localised grazing, compaction and watering-point indicators.	Koubola	Moderate

Note: These are qualitative screening priorities, not measured probabilities or validated physical risk scores. Niangui remains an indeterminate limited-data category.

The purposive locality sample and unequal numbers of valid records do not support calculation of a single quantitative risk status for the entire Pool Department. At the screening level, however, the findings indicate that vigilance should be highest where rural activities coincide with strong hydrological proximity and recurrent fragile-environment or water-resource indicators, particularly in Missafou, Linzolo, Yalavounga and Yangui. Mindouli and Koubola diverge from the strongest hydrological-risk pattern because their profiles are driven more by the composition of activities—mixed agro-pastoral in Mindouli and relatively pastoral in Koubola—and by fewer

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recorded water-related indicators. This divergence does not imply an absence of pressure; it indicates a different pathway requiring soil, grazing-route and watering-point management.

Discussion

Vigilance profiles rather than declared drivers of deforestation

The originality of this paper lies in its focus on environmental vigilance profiles rather than on declared drivers of deforestation. This distinction is important for submission as a separate diagnostic study. While many studies in the Congo Basin focus on forest-cover loss or on the rural complex, this article uses field-based environmental variables to classify localities according to recorded conditions requiring environmental vigilance. This regional framing is supported by Congo Basin studies showing that smallholder clearing and the rural complex - including small-scale agriculture, settlements, roads and wood extraction - remain major sources of disturbance, particularly in fragmented forests (Ernst et al., 2013; Tegegne et al., 2016; Tyukavina et al., 2018; Shapiro et al., 2023). This approach is closer to applied environmental monitoring and land-use diagnosis, as recommended in long-term land-cover assessments across West Africa (Brink & Eva, 2009; Vittek et al., 2014; Herrmann et al., 2020).

The results confirm that agriculture structures most local profiles, but agriculture does not create the same risks everywhere. In Yalavounga and Yangui, agricultural observations coincide with very high hydrological sensitivity, whereas Missafou combines agricultural, livestock, commercial and fish-farming activities. This supports the conclusion that environmental diagnosis should be spatially differentiated. Similar findings have been reported in West Africa, where land-use transitions are location-specific and depend on the interaction between human activities, ecological context and water-resource conditions (Barnieh et al., 2020; Nsor et al., 2019).

Riparian environments as a central component of environmental diagnosis

The high proportion of observations close to rivers or water points indicates that riparian environments should be central to environmental monitoring in the Pool Department. Studies from West African floodplains and wetlands show that agricultural encroachment, grazing, fuelwood extraction and settlement expansion can transform floodplain vegetation, reduce surface-water area, increase bare ground and intensify erosion and sedimentation (Nsor et al., 2019). In the Pool Department, recent work on degraded forest and savannah soils at Mayitoukou also highlights differences in rainwater infiltration and soil moisture dynamics between degraded forest and savannah ecosystems (Gomat et al., 2024).

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The profiles of Yalavounga, Yangui and Linzolo indicate that rural activities should be accompanied by basic rules for riverbank protection: maintenance of vegetated buffer strips, limitation of riparian clearing, control of organic waste, improved management of fish ponds and prevention of trampling around water points. These measures fall under a preventive approach to degradation rather than a purely corrective response after forest loss has occurred.

Specificity of pastoral and agro-pastoral profiles

Koubola and Mindouli show that environmental vigilance cannot be reduced to agriculture alone. Livestock may generate localised impacts on soils, riverbanks and grazing areas. The Koubola profile is especially important because ecological work conducted in the secondary forest of Koubola confirms the conservation value of local secondary formations and the need to avoid further simplification of habitats (Ndzai et al., 2022). Evidence from Miombo landscapes in the Democratic Republic of Congo also shows that savannahs, degraded open forests and anthropised zones often form connected ecological units under pressure from slash-and-burn agriculture, fuelwood exploitation, bushfires and demographic pressure (Kalawu et al., 2023).

Implications for local environmental monitoring

An effective environmental monitoring strategy in the Pool Department should be based on local profiles. Departmental environmental, forestry and agricultural services should work with district authorities, extension agents and village committees to implement and document the recommended measures. Missafou and Yalavounga should receive the first integrated field checks because they combine the highest recorded-indicator totals with diversified activities or very high hydrological proximity. Linzolo and Yangui should follow for riparian monitoring, while Mindouli requires combined cropping, grazing and soil management, Koubola requires targeted grazing-route and watering-point management, and Niangui requires additional data collection before a vigilance level is assigned.

A minimum routine monitoring set should record: (i) the number and type of activities occurring near rivers or water points; (ii) the presence and continuity of vegetated riparian buffers; (iii) visible riverbank erosion or riparian clearing; (iv) bare ground and soil compaction around grazing and watering points; (v) visible changes in water condition; and (vi) conflict or inequality flags associated with access to land and water. Repeated recording of these indicators would permit the preliminary profiles to be updated and would identify where direct soil and water measurements are most urgently needed.

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The value of this field-screening approach is strengthened when it is linked to spatial indicators. Congo Basin research has shown that condition-based metrics combining forest-cover history, fragmentation and biomass-related information can improve the prioritisation of conservation and management interventions (Shapiro et al., 2021).

Limitations of the study

This study does not directly measure deforestation and does not use community perceptions of its causes. It therefore does not attribute forest loss to specific actors or practices. Its contribution is operational: it identifies where environmental vigilance should be prioritised from structured field-screening records. A critical limitation is the absence of direct biophysical measurements of erosion, soil compaction, water quality, pollutant loads, vegetation condition or hydrological processes. The recorded indicators depend partly on observer judgement and may be affected by uneven record completeness and unequal numbers of observations among localities. Moreover, the database did not permit calculation of agricultural or rural land-area proportions, and the purposive sample does not support statistical extrapolation to the whole Pool Department. The qualitative vigilance levels are therefore preliminary screening categories, not measured probabilities, causal effects or validated physical risk scores. Future research should combine the present typology with standardized soil and water measurements, GPS-referenced observations, land-cover mapping, repeated surveys and independent ecological validation.

Conclusions

With the analysis restricted to environmental and territorial field-screening records, this paper identified environmental vigilance profiles associated with rural activities in several localities of the Pool Department. The profiles are defined by combinations of activity structure, hydrological proximity and recorded environmental indicators rather than by respondent perceptions or direct physical risk measurements. Agriculture dominates most localities, but the configurations differ: Missafou has a diversified multi-activity hydrological-risk profile; Yalavounga and Yangui have agricultural-riparian/hydrological profiles; Linzolo combines agricultural-commercial activity with high hydrological sensitivity; Mindouli has a mixed agro-pastoral profile; and Koubola has a relatively pastoral profile.

The main contribution of the paper is a qualitative environmental vigilance typology that can guide local monitoring and rural land-use planning. Its policy implication is that a uniform departmental strategy would be inappropriate. Departmental services and local authorities should prioritise integrated field checks in Missafou and Yalavounga, riparian protection in

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Linzolo and Yangui, coordinated cropping and grazing management in Mindouli, and grazing-route, soil and watering-point management in Koubola. Niangui requires additional observations before ranking. Routine monitoring should at minimum document activities near water, riparian-buffer condition, visible erosion, soil compaction, water-condition changes and land- or water-access conflict flags. Because the study does not quantify physical risk or deforestation, the proposed levels should be used to prioritise further measurements and preventive action rather than as definitive risk scores.

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Author contributions: MAKAYA Helischa Audrey contributed to field data collection, data organisation and description of the surveyed localities. IFO Suspense Averti contributed to study conceptualisation, methodological supervision, analysis, interpretation of results and critical revision of the manuscript. Both authors read and approved the final manuscript.

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