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Local knowledge of gully erosion in Kinshasa, Democratic Republic of Congo: the case of the avenue sikama mega-gully in the commune of Kisenso

Connaissance locale de l'érosion des ravines à Kinshasa, République Démocratique du Congo : le cas de la méga ravine de l'avenue sikama dans la commune de Kisenso

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Abstract

One of the current environmental challenges facing tropical cities is the sustainable management of gully erosion. Indeed, gully erosion in a built-up environment causes the loss of infrastructures, homes and human lives. This has devastating socio-economic and socio-psychological effects. This study analyses the local knowledge around the Avenue Sikama mega-gully in Kisenso, one of Kinshasa's municipalities, about the gullies according to the zone of location in relation to the gully (upstream zone, critical zone, downstream zone). Surveys were carried out with a random sample of 82 respondents in each of the three zones considered, covering the causes of erosion, erosion control proposals, and assessment of perceived level of risk exposure (nr) on an increasing scale from 1 to 10. The contingency tables of causes and control proposals for the three zones considered were subjected to correspondence factorial analysis, and the nr data to analysis of variance. In the upstream and downstream zones, respondents rated their risk as medium (nr = 4.3 and nr = 5.2 respectively). In the upstream zone, they cited technical and financial causes, and proposed plot management, while in the downstream zone, they cited a lack of community spirit as a cause, and proposed community mobilization. In the critical zone, respondents rated their risk as high (nr = 9.6). They cited the lack of spatial organization as the cause and called for help. Local knowledge of erosion therefore remains calibrated not by the landscape perspective of the problem but by the local experience of the immediate environment.

Keywords: Perception, gully erosion, gully control, local knowledge.

Résumé

L'un des défis environnementaux actuels auxquels sont confrontées les villes tropicales est la gestion durable de l'érosion en ravin. En effet, l'érosion dans un environnement bâti entraîne la perte d'infrastructures, d'habitations et de vies humaines. Cela a des effets socio-économiques et socio-psychologiques dévastateurs. Cette étude analyse les connaissances locales sur le ravinement autour du méga ravin de l'avenue Sikama à Kisenso, une des communes de Kinshasa, en fonction de la zone de localisation par rapport au ravin (zone amont, zone critique, zone aval). Des enquêtes ont été menées auprès d'un échantillon aléatoire de 82 répondants dans chacune des trois zones considérées, portant sur les causes de l'érosion, les propositions de lutte antiérosive et l'évaluation du niveau perçu d'exposition au risque (nr) sur une échelle croissante de 1 à 10. Les tableaux de contingence des causes et des propositions pour les trois zones considérées ont été soumis à une analyse factorielle des correspondances, et les données relatives au nr à une analyse de variance. Dans les zones amont et aval, les personnes interrogées ont évalué leur risque comme moyen (nr = 4,3 et nr = 5,2 respectivement). Dans la zone amont, ils citent des causes techniques et financières et proposent l'aménagement des parcelles, tandis que dans la zone aval, ils citent le manque d'esprit communautaire comme cause et proposent la mobilisation de la communauté. Dans la zone critique, les personnes interrogées évaluent leur risque comme étant élevé (nr = 9,6). Ils citent le manque d'organisation spatiale comme cause et appellent à l'aide. La connaissance locale de l'érosion reste donc calibrée non pas par la perspective paysagère du problème, mais par l'expérience locale de l'environnement immédiat.

Mots clés : Perception, ravin, lutte antiérosive, connaissance locale.

1. Introduction

The strong urbanization expected in Africa is predominantly expressed through pe-ri-urbanization (Bogaert and Halleux, 2015). In developing cities, the latter unfortunately rhymes with environmental imbalance, accentuating habitat precariousness and land-scape degradation (Secretariat of the Convention on Biological Diversity 2012). Coupled with climate change in areas with poorly cohesive soils, (peri-) urbanization promotes gully erosion, among other things (Tchotsoua 1994; Kayembe Wa Kayembe 2015). This is precisely the case in the city of Kinshasa, particularly in its hilly area (Van Caillie 1990; Lopanza et al. 2020). Indeed, the city is home to an increasing number of mega-gullies, especially in hillside municipalities such as Kisenso (Miti Tseta and Aloni Komanda 2005; Makanzu Imwangana 2010; Makanzu Imwangana et al. 2015; Lopanza et al. 2020).

To date, numerous scientific studies detail the causes and consequences of the in-tra-urban gully phenomenon (Miti Tseta and Aloni Komanda, 2005; Wouters and Wolff 2008; Makanzu Imwangana 2010; Makanzu Imwangana et al. 2015). In this respect, it has been established that social causes are the most preponderant, at least as far as the city of Kinshasa is concerned (Kayembe Wa Kayembe and Wolff 2015). For this same city, the various solutions implemented to treat gullies are also well documented (Lelo 2008; Makanzu Imwangana 2010; Lutete et al. 2023). However, it is clear that most of the anti-erosion solutions envisaged are ad hoc and temporary. They take little account of the landscape scale or the drainage basin scale, which is necessary to sustainably address the problem. In addition to being largely defensive rather than dealing with nature, under-stood here as the natural conditions of the environment, most of these solutions end in failure (Makanzu Imwangana 2010; Lutete et al. 2023). As a result, the sustainable treatment of gullies as part of the more global problem of environmental imbalance remains an entirely separate issue in Kinshasa.

Faced with the environmental challenges in cities, it is now accepted that urban planning must be based on the principles of an "ecology of the city" (Gauzin-Müller 2001; Da Cunha 2015). In this context, bioengineering is increasingly in demand, defined as an "art of biodiversity" aimed at combining conventional engineering with ecology to rebuild living spaces by preserving biodiversity and optimizing ecosystem services (Rey et al. 2015). This art has led to the development of "eco-technics" or, in a broader sense, "ecotech-nologies" inspired by nature, which are often inexpensive, relatively easy to apply and therefore sustainable (Stokes et al. 2008). It is also recognized that, for any development project to succeed, the perceptions, representations and uses of the site must be taken into account (Moser and Weiss 2003; Charpentier et al. 2004). This is even truer for problems of which the main causes are social, such as intra-urban gullying.

In order to provide knowledge to better integrate the landscape scale and socio-cultural factors into gully treatment approaches in Kinshasa, it is important to deter-mine the knowledge that populations experiencing the problem have of it. Miti et al. (2005) have addressed this issue in the district of Kisenso under the term "population percep-tion". The results of their studies are well reported by Lelo Nzuzi (2008), who asserts that "people perceive the phenomenon as a punishment from God because of sins, a work of sorcerers jealous of the town's development, and a punishment from the Teke-Humbu customary chiefs". Such a perception is mixed with what Ngub'usim Mpey-Nka (1992) and Katunga Nijikap (2018) call "idio-cosmognosies", i.e. mental representations or images that individuals make of their environment or their life, most often in relation to the gods. This perception is strongly out of phase with the scientific causes of the phenomenon and encourages fatalism and inac-tion. However, since these studies were carried out, numerous interventions have been carried out, suggesting a probable change in people's perceptions.

Moreover, as gullying is a spatial problem, it is reasonable to assume that proximity to the gully may influence people's knowledge. In addition, a good grasp of people's perceptions of a phenomenon is essential to guide interventions and environmental education. In order to meet this challenge, we need to provide a clear picture of local knowledge of gully erosion. In this context, the aim of this study is to determine people's current knowledge of gully erosion. More specifically, this study aims to (i) assess local knowledge on the causes of gully erosion, (ii) understand people's perception of their level of exposure to the risks associated with gully erosion, and (iii) study the anti-erosion solutions they envisage. The investigation is carried out in Kisenso, one of Kinshasa's municipalities heavily affected by the phenomenon, based on the hypothesis that (i) people's knowledge of the causes of gully erosion varies according to their location in relation to the gully; (ii) people upstream and downstream of the gully underestimate their level of exposure to the risks associated with gully erosion; and (iii) people's knowledge of the possibilities for erosion control is not very eco- technical and also varies according to their location in relation to the gully.

2. Materials and Methods

2.1 Study environment

The study was conducted in Kisenso, one of 24 municipalities in the city of Kinshasa, the capital of the Democratic Republic of the Congo (DRC) located between 4°-5° S and 15°-16° E (Figure 1).

With 386,151 inhabitants over an area of 16.6 km², Kisenso comprises 17 districts (Commune report 2022). Like all municipalities settled in the upper town, Kisenso is built on sandy-loam soils covering tertiary sands laid on soft clayey sandstones of secondary age. These fine sandy soils with almost zero cohesion are easily eroded (Van Caillie 1997). This fragility is accentuated by uncontrolled urbanization and the destruction of the original plant cover (Kayembe Wa Kayembe and Wolff 2015). The municipality has at least 52 erosion heads (Shomana 2003), in a total of 600 for the city as a whole (World Bank 2018). The municipality's climate is AW4 according to the Köppen-Geiger classification (Peel et al. 2007).

We note that the survey was carried out particularly around the commune's most extensive ravine, known in Lingala, the local vernacular language, as "libenga Sikama", which in French means "Sikama avenue ravine". The ravine extends into three districts: Bikanga, Kitomesa and Mission (Figure 1).

2.2 Gully mapping

To carry out the study, we first digitized the current extent of the gully through Google Earth with corrections following field visits. We then determined the boundaries of the gully's drainage basin (Makanzu Imwangana et al., 2014) in ArcGis 10.1, using the ArcSWAT tool, based on a Shuttle Radar Topography Mission (SRTM) at 30 m resolution of the town, obtained from the Central African Forest Satellite Observatory (OSFAC). Subsequently, on the basis of the hydrographic network and the geomorphology of the drainage basin, we distinguished three zones around the ravine (Figure 1). These are (i) the upstream zone: located upstream of the gully - the zone from which all the water flowing into the gully is mobilized; (ii) the critical zone: made up of the gully bed itself and its immediate surroundings, this is the zone directly affected and threatened by gullying; and (iii) the downstream zone: located downstream of the gully, this is the outlet for runoff from the gully. In geomorphological terms, these zones correspond respectively to the plateau, the flank (sloping zone), and the plain of the watershed.

2.3. Sampling and data collection

Data were collected by interviewing a total random sample of 246 people, i.e. for comparison purposes, 82 respondents in each of the three zones considered around the gully studied (upstream zone, critical zone, and downstream zone). The size (n) of the total sample is obtained using the normal approximation of the binomial distribution (Dagnelie 1998), the formula for which is given below:

$$n = \frac{U_{1-\alpha/2}^{2} \times p(1-p)}{d^{2}} \quad (1)$$

In equation 1, U_(1-α⁄(2))= 1.96, is the value of the normal random variable for an α risk equal to 5%; d is the margin of error for estimating parameters from the survey set at 5% and p, is the average proportion of people aware of the existence of the gully studied. This proportion is estimated at 80% following an exploratory survey of 30 people throughout the gully's drainage basin. This size of 30 is generally accepted as the minimum required for good population representativeness (Dagnelie 1998).

The data collected includes the known causes of gullying, possible solutions, and an estimate of perceived level of exposure to the risks (nr) associated with gullying for each area considered, on an increasing scale from 1 to 10. The respondent gives a value of 1 to nr, if he considers his level of exposure to risk to be negligible. On the other hand, he will give a value of 10 if his level of exposure is very high.

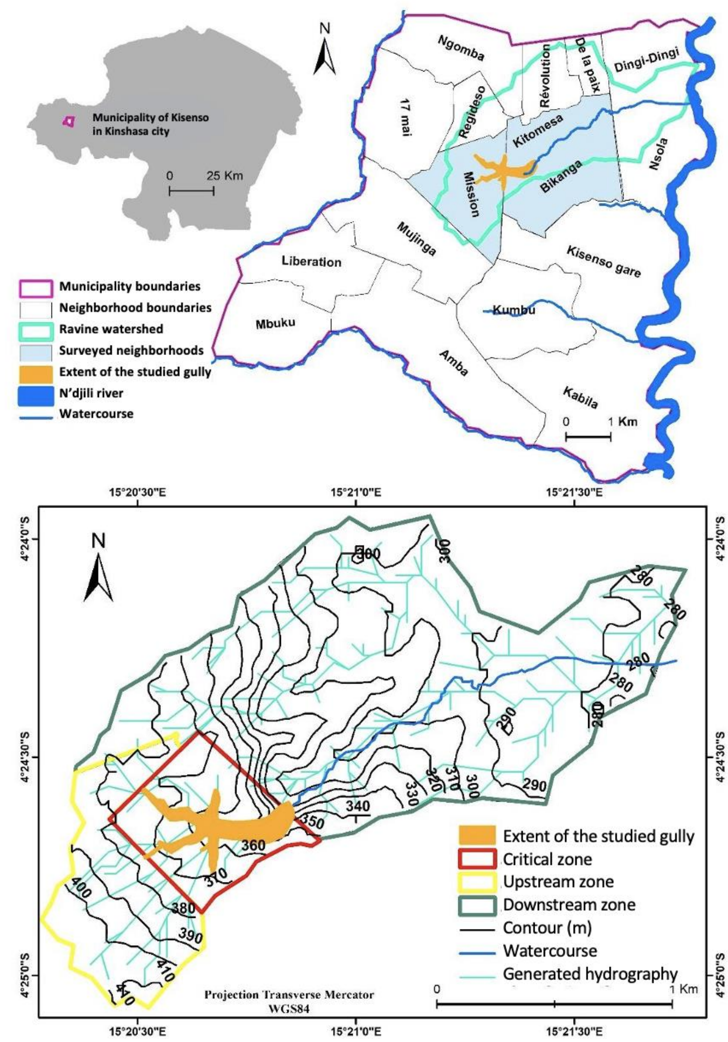

Figure 1. Location and geomorphological details of the studied gully and surveyed area.

2.4. Data analysis

First, we grouped all the causes of gullying and possible solutions listed by the respondents into as many categories as possible. Then, for each category of causes and solutions, we determined the absolute and relative citation frequencies, both overall and for each zone considered.

Total relative frequencies have been used to construct the corresponding illustrative histograms. Absolute frequencies by zone are used to construct the corresponding contingency tables. These were then subjected to a Correspondence Factorial Analysis (CFA) to account for variations in local knowledge of the causes of gully erosion on the one hand, and of possible solutions on the other hand, depending on the gully zone. The CFA is performed using the FactoMineR package (Husson et al. 2013).
Estimates of the level of gully risk exposure for each of the three zones were analyzed using one-factor analysis of variance (ANOVA) with Tukey post hoc comparison test. All analyses were performed using R software version 3.4.4.

3. Results

a. Local knowledge of the causes of gully erosion

Respondents mentioned a total of 15 causes of gully erosion (Figure 2). The results of the Correspondence Factorial Analysis applied between these causes and the gully zones, indicate a breakdown into three groups of the causes cited, each corresponding to one of the gully zones (Figure 2). This breakdown shows that leaving aside the likely "non-scientific" causes, respondents upstream of the gully are more likely to cite causes linked to a lack of technical and financial support. On the other hand, those in the critical zone spoke more of a lack of spatial organization, and those in the downstream zone of a lack of community spirit. Furthermore, we note that respondents, especially those in the upstream zone, always link the gully to evil spirits (sorcerers) or, as they say in Lingala, the local vernacular, bisimbi (plural) or kisimbi (singular).

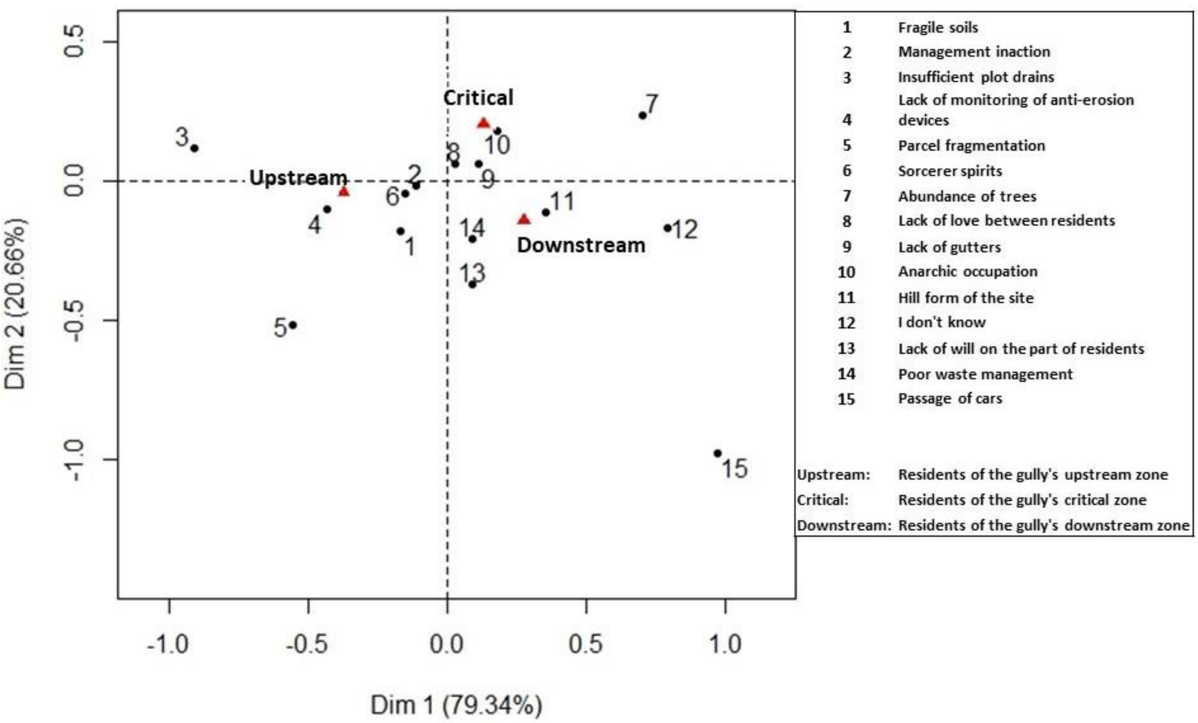

Figure 2. Results of Correspondence Factorial Analysis between gully zones and causes cited by respondents. The first two factorial axes summarize 100% of the information.

b. Estimating people's exposure to the risks associated with gullying

The results of the estimation of the level of exposure to gully-related risks (nr) on a scale of 1 to 10, reveal an underestimation for the upstream and downstream zones (Figure 3). Indeed, there was unanimous agreement among respondents that the critical zone is clearly at a high level of risk exposure (nr = 9.6). The same is true for the upstream zone, where the level of exposure is considered relatively average (nr = 4.3). Conversely, for the downstream zone, respondents from other zones set their level of exposure at an average level (nr = 5.2), while respondents from the same zone considered it to be relatively very low (nr = 2.1).

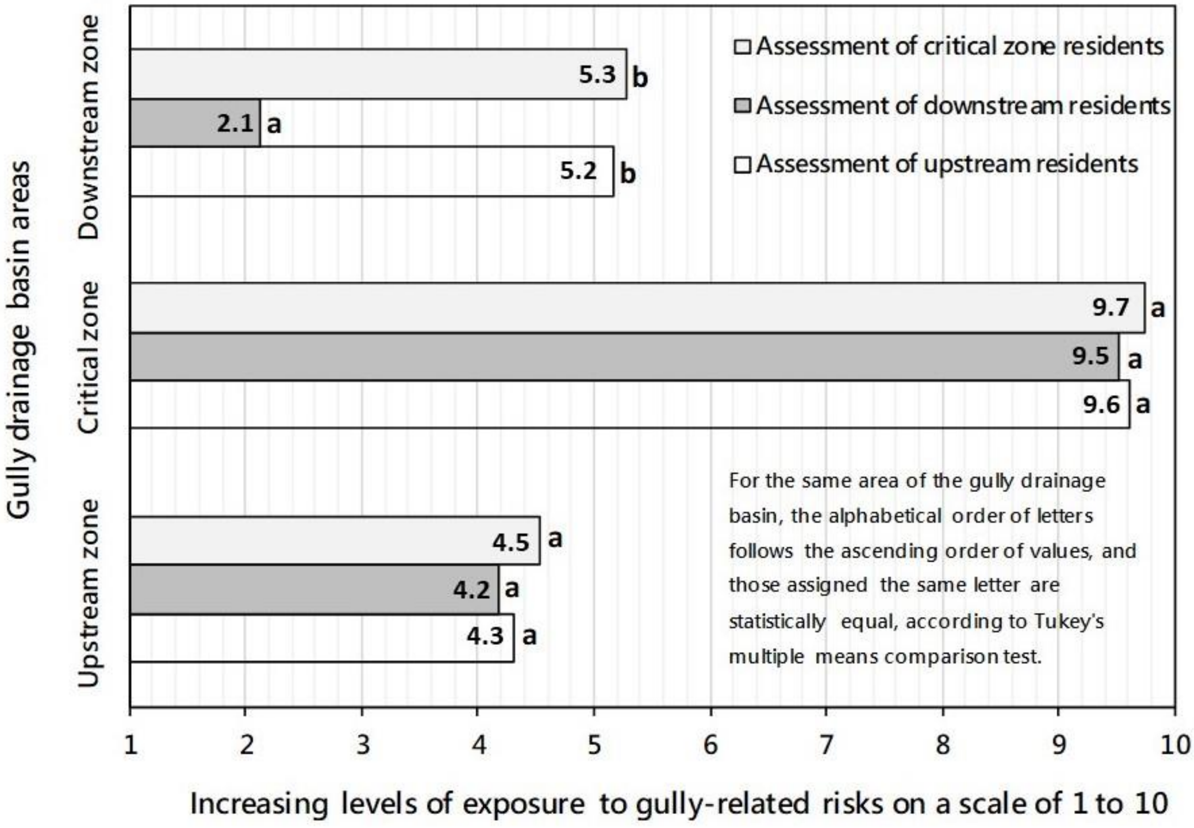

Figure 3. Estimated levels of exposure to gully-related risks by respondents.

c. Local knowledge of erosion control solutions

Respondents put forward a total of 14 proposals for erosion control (Figure 4). Four, or 29%, of these proposals were eco-technical, i.e. based on respect for the environment. These included proposals to build retention basins, plant trees, install plot drains and de-velop eco-citizenship by mobilizing local residents.

The results of the Correspondence Factorial Analysis carried out on the contingency table of erosion control proposals ac-cording to the gully zone, show a breakdown into three groups corresponding to the three gully zones. In the upstream zone, the proposed solutions focus more on plot development and management. As for the critical zone, it is marked by both fatalism and a call for help, while respondents in the downstream zone call for the mobilization of local residents and various upstream developments.

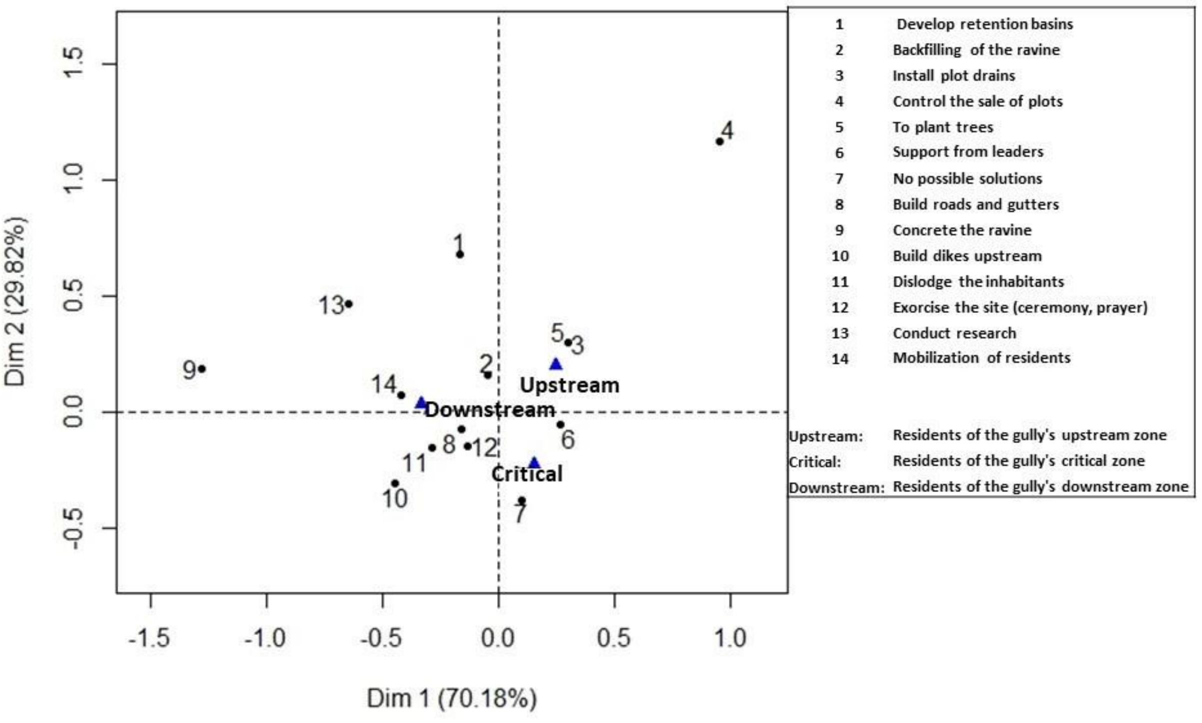

Figure 4: Results of Correspondence Factorial Analysis between gully zones and gully control solutions cited by respondents. The first two factorial axes summarize 100% of the information

4. Discussion

a. Methodology approach

This study of loacal knowledge about mega-ravines was based on a survey approach. This is an approach very often used for this type of study (Miti Tseta 2005; Miti Tseta and Aloni Komanda 2005; Ngatse 2021). It makes the most of the combination of quantitative and qualitative approaches. Although the survey involved a large sample of 246 respondents, it was based on a single gullied site. While this enabled an in-depth analysis of the case study, the prospect of a study taking several sites into account is encouraged.

b. Local knowledge on gully causes, level of risk exposure and gully control according to location in relation to the ravine

This assessment of local knowledge of gully erosion is part of a systemic approach to environmental education. This approach aims to take a better account of Man's relationship with his living environment in its cultural context (Moser and Weiss 2003). It is this ambition that Berque (2014) gives to mesology, the science of environments, the environment being the result of the interpretation of the environment by the being or the relationship of society to space and nature. As such, he distinguishes the milieu from the raw data of the environment. In the same vein, Moser (2009) clearly demonstrates the importance of environmental psychology in revealing the relationship between man and his living space, which is essential in architectural and urban operations.

Our results reveal a spatial variation in local knowledge of the causes and solutions to gullying, depending on the three geomorphological zones that make up the gully drainage basin studied. This variation can be justified by the fact that the physical manifestations of the phenomenon differ according to the zone considered.The upstream zone is where the gully is extended by successive head retreat or col-lapse.

It is also from this zone that all the run-off water excavating the gully originates. As a result, this zone is the focus of most erosion control operations, which are limited in time. Accustomed to support, the inhabitants of this area consequently cite causes linked to the lack of technical and financial support. What's more, apart from the inhabitants who are at the hinge between the upstream and critical zones, it is easy to observe a lack of maintenance of the anti-erosion plot drains in the field. One of the reasons for this is that they underestimate their level of exposure to the risks associated with gully erosion, as shown by the value recorded (nr = 4.3).

As for the critical zone, it is the site of major physical damage caused by the deepen-ing of the channel and the collapse of the flanks, with the loss of plots of land and houses. Inhabitants of this zone often have no choice but to relocate. This is one of the reasons why the erosion problem in this area seems fatal, and is more closely linked to the lack of spa-tial organization. In the downstream zone, the gully is not physically present. This is undoubtedly why people living in this area underestimate their level of exposure to gully erosion (nr = 2.1). However, this area is directly affected by water erosion through sedimentation due to sand masses washed away with runoff water. This is also one of the causes of flooding in the N'Djili valley. In addition, if downstream settlements don't allow run-off volumes to drain properly, there will be greater rises in water levels in the ravine, leading to more collapse damage. Clearly, for the inhabitants of this area, erosion is mainly due to a lack of ade-quate upstream precautions. The role of the downstream zone seems less important to them.
Moreover, the diversity of the solutions proposed testifies of the spirit of creativity and innovation that characterizes Kinshasa's peri-urban inhabitants (Trefon and Kabuyaya 2015; Lutete et al. 2023). However, these solutions are largely defensive with regard to envi-ronmental conditions. They also summarize the various anti-erosion interventions carried out by various actors (non-governmental organizations, individuals, politicians and local churches) (Makanzu Imwangana 2010). We also note that most of the solutions envisaged are either simply inappropriate (filling in the gully, etc.), or effective only for a limited period of time.

Furthermore, the problem of gully erosion is still the subject of a divination. As a result, the ravines that cut into the amphitheaters of springs and concave slopes are seen as cursed places, havens for bisimbi (witch spirits), even though they play a part in the natu-ral evolution of the landscape. Indeed, in certain regions, such as Hamilton in New Zealand, some residents see gullied valleys as a source of wealth, and consequently develop them with a view to landscaping and conserving biodiversity (Jay and Stolte 2011). As a result, they derive a number of ecosystem benefits and services.

c. Implications for mega-gully treatment

This study's assessment of people's knowledge of gully erosion reveals that local experience of this phenomenon strongly calibrates the relationship with the living environment. Better still, the landscape or large-scale perspective of the phenomenon seems less present in the minds of the surveyed inhabitants. As a result, the solutions envisaged so far remain local and of limited effectiveness over time. It is therefore now necessary to change the paradigm and adopt a forward-looking approach, rather than simply reacting to events in the present (Lhémery 2006). Such an approach will ensure the resilience of gullied slopes.

5. Conclusion

This study reveals the complex nature of the problem of gully erosion, which is in fact linked to a number of other issues, including waste and flood management. Local knowledge of the causes and possible solutions remains diverse and fragmentary, as it is calibrated not by the landscape or systemic perspective of the problem, but by the local experience of the immediate surroundings. Although it is normal for residents to be primarily concerned with the protection of their individual plots, it should be noted that in risk zones such as the one studied, all developments should take into account the fragility of the site as a whole. This calls for a paradigm shift towards a forward-looking, holistic approach. This approach should take into account the landscape dimension and the complexity of the problem, draw on the intrinsic strength of the population (endogenous eco-citizen practices, development of community spirit) and build on the strengths and weaknesses of the environment so as to ensure the long-term resilience of gullied slopes and transform them into areas of opportunity rather than curse.

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