

Operationalizing epistemic justice: Participatory 3D Modelling in conservation practice

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Academic Editor: Martin A. Nuñez

Abstract

This article examines the transformative potential of Participatory 3-Dimensional Modeling (P3DM) as a tool to operationalize epistemic justice in conservation, focusing on its application in the Itombwe Nature Reserve, Democratic Republic of Congo. Epistemic justice demands the recognition, inclusion, and equitable treatment of marginalized knowledge systems, particularly Indigenous and local epistemologies, in environmental sciences. Drawing on conservation governance literature on community participation, existing studies on Participatory 3-Dimensional Modeling, and political ecology's focus on epistemic justice, this study evaluates the extent to which Participatory 3-Dimensional Modeling bridges power asymmetries through the promotion of traditional ecological knowledge. Through participant observation during a pilot P3DM exercise in 2016, constant engagement with the process aftermaths over four years, and a follow-up mission in 2020, the article highlights the dual promise and pitfalls of participatory approaches. Using criteria for epistemic justice (recognition, procedural equity, redistributive justice, and reflexive justice), this study critically assesses Participatory 3-Dimensional Modeling as an opportunity to foster inclusive conservation governance. Our findings reveal that Participatory 3-Dimensional Modeling facilitated indigenous knowledge recognition, intergenerational information transfer, and the identification of culturally and ecologically significant areas. However, systemic barriers—including unequal power dynamics, insufficient follow-up, and logistical constraints—limited its transformative potential. This article contributes to advancing participatory conservation governance by illustrating the practical and ethical challenges of bridging diverse knowledge systems in a contested landscape. It underscores the need for long-term investment, robust governance frameworks, and sustained collaboration to ensure participatory tools deliver equitable ecological and social outcomes. By situating Participatory 3-Dimensional Modeling within broader efforts to decolonize environmental sciences, this study provides actionable insights for making sustainability science more inclusive and justice-oriented.

Keywords: *Participatory 3D Modelling (P3DM), traditional ecological knowledge (TEK), epistemic justice*

Citation: Gauthier M. Operationalizing epistemic justice: Participatory 3D Modelling in conservation practice. *Academia Environmental Sciences and Sustainability* 2025;2. <https://doi.org/10.20935/AcadEnvSci7663>

1. Introduction

How we understand and relate to nature shapes how we govern and protect it. In an era where conservation efforts are increasingly scrutinized for their exclusivity and reliance on top-down approaches [1–3] the recognition of indigenous and local knowledge systems and worldviews has become a critical pathway toward equity. Can the inclusion of diverse knowledge systems redefine conservation as an act of shared stewardship? This question lies at the heart of global efforts to bridge epistemic divides in environmental science. As a response to these historical challenges, participatory methodologies and adaptive management in conservation have been developed approaches that actively involve Indigenous peoples, local communities, and other stakeholders in the decision-making, implementation, and evaluation of conservation projects [4]. These methodologies aim to combine scientific and local knowledge to address conservation challenges dynamically, empowering communities by recognizing their right to, knowledge systems of, and contributions to biodiversity management [5]. These approaches rely on tools such as community mapping, co-management agreements, and inclusive monitoring and evaluation

systems to emphasize collaborative governance models that evolve over time [6]. Recent global frameworks, such as the Convention on Biological Diversity (CBD) and the Sustainable Development Goals (SDGs), underscore the need for inclusive tools that integrate diverse worldviews into conservation governance.

Within this context, participatory 3-Dimensional Modeling (P3DM) has emerged as a particularly relevant tool for integrating indigenous spatial knowledge with modern geospatial technologies in order to co-create solutions for sustainable futures. Unlike conventional participatory mapping, which often relies on 2D representations, GIS data, or paper-based sketch maps, P3DM uses a three-dimensional, tactile approach. This enhances engagement for communities with limited literacy or formal cartographic training, while challenging Western cartographic traditions and spatial governance models [7, 8]. P3DM applications have been particularly notable in land-use planning, conflict resolution, and environmental management. However, the transition from documentation and validation of traditional ecological knowledge

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(TEK) to governance shifts remains underexplored. This leads to suspicions of epistemic tokenism, where Indigenous perspectives are included symbolically but do not influence policy [9, 10]. Other scholars have developed structured methodological frameworks which would enhance the useability of the collected data and hence foster change [11, 12]. Locally, such an exercise leads to expectations of empowerment. If not followed with governance shifts, P3DM risks functioning as an extractive exercise where mapped knowledge remains controlled by external actors rather than empowering local decision-making [13]. Looking at the translation process from knowledge to action challenges simplistic participatory narratives and proposes a structurally embedded, long-term research approach to P3DM in conservation governance.

Epistemic justice offers an interesting framework to look at the translation of knowledge to political change. Epistemic justice is concerned with fairness in knowledge production, dissemination, and utilization while promoting more inclusive knowledge creation and credibility for marginalized voices [14]. It calls for dismantling knowledge hierarchies to ensure that Indigenous and local epistemologies are treated as foundational rather than supplementary, and, when applied in conservation governance, critically examines who retains control over how knowledge is applied in management arrangements [15, 16]. Specifically, it enables the recognition, procedural equity, redistributive justice, and reflexive justice of local and Indigenous knowledge systems in conservation governance. As global conservation efforts grapple with the twin crises of biodiversity loss and climate change, epistemic justice provides a vital framework for addressing historical exclusions and asymmetrical governance structures. The present article investigates two intertwined questions: Does the implementation of P3DM fulfill the criteria of epistemic justice? Does P3DM allow for broader epistemic justice objectives to be achieved within the conservation project? If not, what structural barriers are to be overcome to fully unleash its transformative potential?

The relationship between epistemic justice and participatory methodologies is analyzed through the case of P3DM in the Itombwe Nature Reserve, in the East of the Democratic Republic of Congo. The case study covers a P3DM pilot exercise led in 2016 and the evolution of the protected area as the project sought to involve Indigenous and local communities in redefining the Reserve's boundaries and management arrangements. This study happened through two main field works in the Itombwe Reserve in 2016 (during the exercise) and 2020 (follow-up observations), through a combination of participant observation as well as focus groups and interviews with participants and local actors in this biodiverse and contested region of the Democratic Republic of Congo. This analysis operationalizes epistemic justice by assessing P3DM's impact on four dimensions: (1) recognition (whether Indigenous and local ecological knowledge is acknowledged as equally valid to scientific knowledge); (2) procedural equity (whether communities have fair access to the process and meaningful roles in subsequent decision-making) (3) redistributive justice (whether the tool leads to shifts in governance authority over and within conservation objectives); and (4) reflexive justice (whether participatory tools enable new mechanisms of long-term community control over land-use decisions). By applying these criteria, the study moves beyond a technical evaluation of P3DM's implementation to engage with deeper questions of knowledge legitimacy, recognition, and redistribution in conservation governance.

This study aligns with a growing body of literature that explores the role of participatory mapping in conservation governance. By doing so, it interrogates how power dynamics and historical injustices shape the governance of natural resources, foregrounding the structural inequities that participatory methodologies aim to address [17, 18]. Weaving together environmental science debates on participatory conservation governance and political ecology discussions on epistemic justice, this study contributes to a growing interdisciplinary dialogue advocating for more inclusive and equitable forms of environmental management. This article makes a dual contribution by both advancing the conceptual framework of P3DM and examining its practical application in a contested conservation landscape. This study not only expands theoretical discussions on epistemic justice in participatory conservation but also provides one of the few empirical assessments of the impact of P3DM's long-term governance in Central Africa. In addition, this study provides original field data from an underexplored region of the Democratic Republic of Congo, where land tenure conflicts, Indigenous rights, and conservation governance intersect. Beyond conceptual and empirical findings, this research offers policy-relevant insights into the long-term sustainability of P3DM outputs. By critically assessing institutional barriers, follow-up gaps, and ongoing power asymmetries, it highlights to what extent participatory mapping may be a transformative governance tool rather than a one-time exercise or a symbolic inclusion mechanism. These insights are particularly relevant for conservation practitioners, policymakers, and organizations seeking to align sustainability science with principles of justice and inclusivity.

P3DM has been widely studied in environmental sciences as a tool for integrating local and indigenous knowledge into spatial decision-making. Participatory mapping refers to a broad set of spatial data collection and visualization techniques that involve community stakeholders in mapping processes. It is widely used to document local knowledge, assert land claims, and enhance participatory decision-making [19]. P3DM, first implemented in 1987, is a specific subset of participatory mapping that integrates GIS technology with tactile, three-dimensional models, allowing communities to visualize their landscapes and assert spatial claims [11]. Geographic features—such as land use and land cover—are depicted by the environment users on the model using painted areas for polygons, pushpins for points, and yarns for linear elements. Once completed, the model is overlaid with a scaled, georeferenced grid to facilitate the extraction, digitization, and plotting of data [7]. Unlike general participatory mapping, P3DM is not just a data collection tool but a governance mechanism, particularly in conservation contexts where land use, ecological knowledge, and power relations are contested [20]. Implementations and advocacy uses have been documented in watershed land-use planning in Panama [21], in ecosystem services assessments in Suriname [20], in marine resources management policies in Europe [22], in disaster risk reduction in the Philippines [23] as well as in climate adaptation decision-making in the Solomon Islands [24].

The effectiveness of P3DM has been debated among scholars. The above-mentioned case studies demonstrated its advantages as a more straightforward way for participants to engage with the mapping process, given that we all naturally experience the space around us three-dimensionally. P3DM has been proven to facilitate a richer exchange of knowledge by physically representing features such as elevation, water flow, and land-use patterns, which are more

challenging to conceptualize in 2D formats. It has the advantage of collecting georeferenced data from a large area without the need to utilize GPS in sometimes difficult-to-access areas, saving both time, money, and being less demanding technologically, especially for communities for whom the use of a GPS may be a challenge at first. The collaborative process of constructing the model also reinforces collective ownership, enhancing trust and solidarity among participants. P3DM may then lead to more context-specific and equitable conservation strategies, as empowered communities may better assert their rights and influence decision-making [25]. More recently, acknowledging that 3DPM is still in its infancy, researchers proposed structured methodological and analytical frameworks in order to enhance the useability of 3DPM's collected data and enable the tool to go beyond mere knowledge exchange [11, 12]. Such contributions advance 3DPM as a transformative tool, which not only provides data but is central to environmental planning and management. Yet, critics have pointed at the lack of impact of such a participatory tool, with the final decision-making power over mapped data remaining with external conservation institutions [26]. In order to move beyond this debate, examinations of the sustainable development dynamics over the years are necessary. Environment Science researchers often focus on technical aspects and examinations of the long-term impacts of participatory mapping, particularly 3DPM, remain scarce. The political implications of P3DM on conservation governance remain underexplored, particularly in contested landscapes such as the Itombwe Nature Reserve.

Academic literature on conservation governance has heavily debated power dynamics, looking at how conservation interventions govern and affect peoples and ecologies [27]. Historical exclusions and colonial legacies have been documented as shaping the foundation of protected area management, later fostering the need for corrective participatory tools. Several geographers and historians have critiqued how international conservation perpetuates eco-colonialism by imposing Western conceptions of wilderness that marginalize local land claims [28, 29]. Guides on protected area governance, such as WWF's Guide to Inclusive, Equitable and Effective Implementation of Target 3 of the Kunming-Montreal Global Biodiversity Framework, highlight some of the best practices in co-management (WWF and IUCN WCPA. 2023. A Guide to Inclusive, Equitable and Effective Implementation of Target 3 of the Kunming-Montreal Global Biodiversity Framework: Version 1, August 2023). Yet these models often fail to institutionalize community decision-making beyond consultation phases. On the other hand, some scholars have rightly cautioned against participatory processes, which are too often viewed as "acts of faith" [30]. While they hold promise, they may be inherently messy, imprecise, and yield unpredictable outcomes. Empirical studies show that community participation can enhance conservation legitimacy, but also demonstrate that participatory mechanisms frequently operate within restrictive governance regimes [31]. Despite this growing body of literature, there is a notable gap in empirical research regarding how specific transformative tools, such as P3DM, interact with governance constraints—especially in the context of land dispossession and conservation-related conflicts in Central Africa. Research on conservation governance in Central Africa, and particularly in Itombwe, remains limited. Scientific biodiversity assessments were key drivers of conservation planning in Itombwe and portrayed the reserve's participatory framework and TEK inclusion as a supplementary knowledge system rather than a foundational framework for governance [32]. In contrast, this

research aims to interrogate epistemic hierarchies, data ownership, and the performativity of participation. As studies have shown, participation does not necessarily lead to governance transformation unless accompanied by legal recognition, political will, deconstruction of entrenched power asymmetries, and sustained financial commitments [26]. To address these constraints, it is crucial to integrate analytical frameworks from political ecology and epistemic justice, allowing for a deeper exploration of the power dynamics, knowledge inequalities, and governance challenges inherent in conservation practices.

Political ecology is an interdisciplinary framework that examines the power-laden nature of environmental governance. By integrating insights from political economy, anthropology, and geography, political ecology challenges conventional narratives of environmental stewardship and promotes a reflexive analysis of how participatory conservation tools like P3DM operate within pre-existing knowledge hierarchies. Brockington et al. argued that while participatory conservation frameworks have gained traction, governance remains highly centralized, with State and NGO actors retaining authority [1]. Political ecology scholars critique how conservation governance often prioritizes global biodiversity narratives over community land rights, positioning Indigenous knowledge as supplementary rather than foundational [17, 18, 33]. The political ecologies of mapping further demonstrate that participatory tools can serve as mechanisms of both inclusion and control—potentially reinforcing hegemonic conservation agendas [34]. In the context of P3DM, political ecology helps interrogate to what extent these participatory tools truly redistribute epistemic authority or remain constrained by dominant power and knowledge structures [35]. Escobar [36] built on Miranda Fricker's foundational text, "Epistemic Injustice: Power and the Ethics of Knowing" [15], to critically engage with the politics of knowledge production in environmental governance, highlighting how conventional conservation practices can marginalize local epistemologies. More recent studies in the realm of environmental political theory, such as those by Katherine Whyte [37] on indigenous climate change studies, further explore how power dynamics in environmental governance often privilege certain forms of knowledge over others. Collectively, these works articulate how epistemic justice can be a valuable lens in political ecology—challenging entrenched knowledge hierarchies and promoting a more inclusive, decolonized approach to understanding environmental issues. Although P3DM asserts a commitment to inclusive knowledge, its transformative potential remains largely unexamined, as the epistemic justice framework has yet to be applied.

The present article builds on the literature of Participatory P3DM, participatory approaches in conservation governance, and political ecology. These bodies of work provide valuable contributions by demonstrating effective data integration, fostering collective ownership, and challenging conventional conservation practices, yet they leave gaps regarding long-term power dynamics, the political implications in contested landscapes, the redistribution of epistemic authority, and the transformative potential of P3DM. The present article will contribute to this field of study by (1) analyzing the methodology of P3DM in light of governance constraints and the context of land-related conflicts in Central Africa, (2) integrating political ecology and epistemic justice frameworks to critically assess power/knowledge dynamics in P3DM, and (3) evaluating P3DM's role not just as a procedural mechanism but as a potential tool of epistemic transformation in conservation governance.

2. Materials and methods

2.1. Background: the Itombwe Nature Reserve

The Itombwe Massif in South Kivu, spanning over 7000 square kilometers, showcases a complex interplay between ecological and cultural richness, social and environmental threats, and armed conflict (**Figure 1**). It is located in the Democratic Republic of Congo's (DRC's) rainforest, located in the heart of the Congo Basin, which represents 10% of the world's tropical rainforests. The Itombwe Massif is recognized as a key biodiversity hotspot within the Albertine Rift, supporting high levels of endemism and species diversity across multiple taxonomic groups [38, 39], including the notable presence of Grauer's gorilla (*Gorilla beringei graueri*). Studies indicate that historical forest refugia and geographic isolation have played a role in species diversification and generated the massif's function as an evolutionary refuge [40, 41]. The territory is characterized by a sub-montane equatorial climate, with annual precipitation ranging from 2000mm to 3000mm. The Itombwe reserve is spread over four administrative districts: Mwenga, Uvira, Fizi, and Shabunda, each of which has distinct socio-economic and ecological characteristics. Several studies emphasize the region's importance for biodiversity conservation while addressing the socio-political complexities of resource governance [42, 43].

Itombwe's biodiversity hotspot is also a home of cultural diversity. Itombwe's social composition is deeply shaped by historical migrations, ethnic governance structures, and socio-economic inequalities. The region hosts approximately 60,000 people, composing a complex mosaic of ethnic groups, including the Bantu-speaking Bashi, Balega, Bafuliro, Babembe, and Bayindu. These communities have long-established traditional land tenure systems, yet their access to land and resources has been increasingly threatened by conservation policies and economic transformations [44]. Additionally, records from the Belgian colonizers also noted the presence of "Watutsi" (Tutsi) and "Bahutu" (Hutu) in the region [45]. Some Tutsi communities are known as the Banyamulenge (predominantly Tutsi pastoralists), while some Hutu communities have been designated Banyabwisha [46]. Further waves of migration due to the Rwandan genocide and the region's instability brought other peoples, both from neighboring countries and from DRC, further complicating an already ethnically polarized situation [47]. Lastly, the Batwa people, an Indigenous group residing in the Great Lakes region of Central Africa, inhabit the Itombwe Massif [48]. They have historically relied on forest-based livelihoods, hunting, gathering, and spiritual traditions tied to their ancestral lands. Their deep ecological knowledge and customary practices have long contributed to sustainable forest management, yet they have faced systematic marginalization due to social and economic discrimination, development and conservation policies, land dispossession, and legal-political exclusion [49].

Local communities perceive forest ecosystem services differently based on ethnicity and livelihood strategies. Hunter-gatherer groups, such as the Batwa, show stronger attachment to places and consider the forest as integral to their cultural identity [50]. Studies on ethno-governmentality in South Kivu further illustrate how ethnicity has been instrumentalized in governance since colonial times, often reinforcing divisions between groups and exacerbating conflicts over land and political representation [51, 52]. However, the massif remains an area where deep ecological knowledge and spiritual connection to the land underpin subsistence practices

and cultural identity. Research on Balega and Batwa customary practices has documented how spiritual beliefs, seasonal hunting restrictions, and sacred sites shape resource use, forming a locally embedded conservation ethic [53]. Workshops conducted with traditional knowledge holders in Basile, Wamuzimu, and Lwindi revealed that TEK is transmitted orally through rituals and apprenticeship systems, ensuring the intergenerational continuity of sustainable hunting, fishing, and forest management practices. Socio-cultural changes, ongoing conflicts and conservation policies that restrict access to ancestral lands threaten the persistence of these practices.

The Itombwe Massif has been subject to rapid changes over recent decades. Economic development, international demand for natural resources, and prolonged conflicts have destabilized the region. Conflicts in the Itombwe region are deeply intertwined with historical tensions and resource competition, creating a volatile security landscape. Armed groups, active since the Second Congo War (1998–2003), have sought refuge in the forests, disrupting livelihoods and contributing to resource exploitation. Competing claims over land, customary governance, taxation practices, artisanal mining, charcoal production and cattle-based economies, exacerbated by broader regional dynamics of militarization, have led to frequent violent clashes [54]. This protracted conflict has severe humanitarian and environmental consequences, displacing thousands of people and contributing to food insecurity, ecological degradation, and the erosion of traditional livelihoods [55]. Mining concessions pose an additional threat, as large portions of Itombwe's forests are allocated for resource extraction, complicating conservation planning and enforcement [56]. Artisanal mining and bushmeat hunting are identified as major threats to wildlife, but they are also deeply linked to local economies, with many communities reliant on these activities for their livelihoods [42]. Climate change and habitat degradation further complicate conservation strategies. Projections indicate that rising temperatures and shifting precipitation patterns will significantly impact species distributions—and subsequent food availability—with many endemic species at risk of severe range contractions [56].

In 2006, a ministerial decree established the Itombwe Nature Reserve, initially spanning an extensive 15,000 square kilometers (see **Figure 1**). The creation of the reserve aligned with the DRC government's objective to designate 17% of its territory as protected areas by 2020. However, this decree was created without consulting local and Indigenous communities, leading to widespread resistance. Conservation strategies often struggle to reconcile environmental goals with socio-economic realities, leading to conflicts over land use and access to resources [42]. Communities feared displacement, loss of access to ancestral lands, and restrictions on traditional activities. Some inhabitants of the Itombwe Massif reported during interviews conducted between 2016 and 2020 that they had been displaced from the nearby Kahuzi-Biega National Park, which has been the site of waves of forced expulsions in the 1970s and the 1980s, and subsequent removals in the 2010s. This neighboring park has been at the center of an ongoing and intense conflict between conservation actors and Indigenous Batwa communities, with conservation enforcement leading to violent evictions, land dispossession, crimes, and violent reoccupation initiatives by the Batwa [57]. Militarized conservation approaches, such as the deployment of eco-guards, have fueled distrust and resistance among local populations, particularly given past human

rights violations in other protected areas of the Democratic Republic of Congo [42]. In Itombwe, early protests and mistrust toward conservation actors prevented the reserve’s effective implementation.

Recognizing the need for inclusivity, the Congolese Institute for Nature Conservation (ICCN), in collaboration with international

organizations such as WWF and WCS and local NGO Africa-capacity, initiated the Joint Framework in 2008. This innovative platform brought together conservation actors, civil society, and community representatives to redefine the reserve’s boundaries and governance model. The framework prioritized participatory methodologies, including consultations with communities, training local cartographers, and developing scenarios for land use. Key

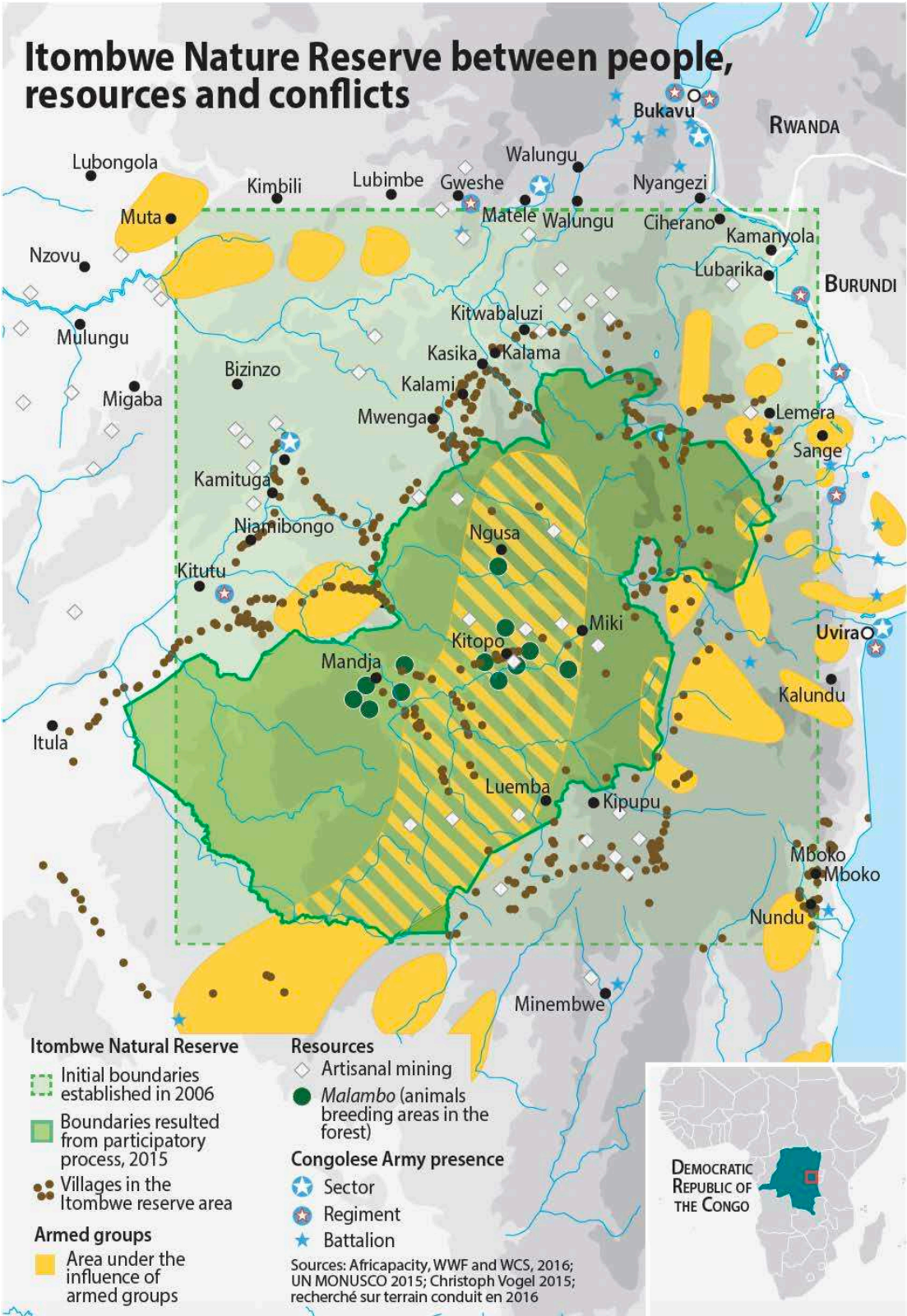


Figure 1 • Itombwe Nature Reserve between people, resources, and conflicts. Source: Riccardo Pravettoni and The Rainforest Foundation Norway [58].

objectives included participatory border delineation, zoning that respected community needs, and establishing community-based management. The corrective participatory process, which engaged 550 villages and approximately 200,000 people in resource-use mapping, consultations, and zoning exercises, led to different scenarios for the reserve. In 2016, a provincial decree formalized the reserve's new boundaries, which were reduced to 5732 square kilometers, based on community input [32]. This event marked a significant shift in conservation governance. In 2017, a Management and Development Plan for the Itombwe Nature Reserve was defined by an external consultant, based on consultations conducted with local communities. This plan envisions the gradual empowerment of these communities, ultimately leading to genuine co-management of the reserve between the ICCN and local communities. Between 2016 and 2020—and up until now—the Itombwe Massif remained an area of volatile insecurity, with armed groups controlling sections of the forest and local populations caught between conservation actors, government forces, and non-State armed actors. At the same time, conservation initiatives continued to reshape territorial governance. Conservation organizations have focused on wildlife monitoring, enforcement of conservation laws, and community-based awareness programs to reduce poaching and habitat destruction [42]. Despite an innovative process, funding constraints and the need for long-term financial sustainability have remained recurring concerns.

Within this process, P3DM emerged as a governance tool rather than merely a technical exercise in spatial data collection. Introduced through the Joint Framework, a pilot P3DM exercise was planned in Mwenga (see **Figure 1**). The Mwenga Territory spans 11,172 km² and is located within the Itombwe Massif, making it a key site for the pilot exercise and for this study's fieldwork. Access was also a central criterion contributing to Mwenga's selection, as it is the most accessible part of the reserve from Bukavu, South Kivu's provincial capital. The P3DM exercise was co-led by Jean de Dieu Wasso, Director of Africapacity, a member of the Joint Framework and Bukavu-based local Civil Society Organization (CSO) engaged in supporting communities' claims from 2004, and by Barthelemy Boika, Director of IRDAC, a Congolese GIS consultancy. Local communities were invited to engage in mapping internal reserve zones and identifying ecologically and culturally significant areas. The application aimed to allow communities to visually assert their land-use claims and document their rights, uses and knowledge in ways that could be recognized in governance negotiations. By facilitating a shared understanding of territorial dynamics, P3DM was promoted as a platform for dialogue between conservation actors and communities and a way to empower participants by making their spatial knowledge visible in conservation decision-making. This approach aligns with broader efforts to integrate conservation with Indigenous rights and priorities, illustrating a shift away from coercive conservation models and toward participatory governance mechanisms. Further activities were planned in the following years in order to use P3DM as a basis to initiate adaptive co-management of the Reserve.

2.2. Epistemic justice as a conceptual framework

Epistemic injustice was introduced by Fricker to define unfair treatment of individuals and groups in knowledge-related and communicative practices [42]. In reaction, epistemic justice refers to the equitable recognition and treatment of different knowledge

systems. In environmental governance, epistemic justice entails recognizing Indigenous and local knowledge as legitimate and ensuring that it holds decision-making authority alongside Western scientific paradigms [16]. Epistemic justice in conservation governance is inherently intertwined with the four dimensions of environmental justice [59]. The specific articulation of epistemic justice in environmental science has evolved through subsequent scholarly debates, from recognition [60] and procedures [61] to redistribution [37] and reflexivity potential [62, 63].

To assess to what extent P3DM advances epistemic justice, hereby serving as a transformative mechanism in conservation governance, the present study applies the following analytical criteria:

1. Recognition—do Indigenous and local knowledge systems receive equal status alongside Western scientific approaches in conservation governance? Are they acknowledged as legitimate and foundational rather than supplementary?
2. Procedural Equity—do local actors have fair, meaningful and sustained opportunities to share their knowledge influence land-use decisions through P3DM, or is their participation constrained by structural barriers?
3. Redistributive Justice—does P3DM shift epistemic authority by redistributing decision-making power to marginalized groups, or does it merely serve as a consultative tool within pre-existing governance structures?
4. Reflexive Justice—do conservation institutions and practitioners critically engage with their own biases and histories, ensuring that participatory mapping does not merely extract local knowledge but actively challenges power hierarchies in the long term?

By examining its implementation in a contested conservation area in the Democratic Republic of Congo (DRC), this research evaluates whether P3DM can serve as an epistemic justice intervention—redistributing authority over conservation knowledge and land-use governance. This study employs a qualitative approach, incorporating observation, informal discussions, and semi-structured interviews to examine the operationalization of P3DM in the Itombwe Nature Reserve. The fieldwork was conducted over two periods (2016 and 2020), allowing for a longitudinal perspective on how P3DM evolved within conservation governance and community participation frameworks. Between the fieldwork, regular email and phone contact, as well as document analysis, allowed me to engage with the subject continuously. The methodology is rooted in critical participatory research, aiming to document not only how P3DM was implemented but also how it was perceived and negotiated by various stakeholders, particularly Indigenous and local communities. Lived experiences served as a cornerstone of this study, providing a nuanced understanding of the socio-political dynamics surrounding P3DM. This method involved immersive engagement in all stages of the process, from the construction of the physical model to community discussions about its implications and, four years later, the aftermath of the exercise. Observations were particularly focused on the participatory dynamics, examining the roles and interactions of facilitators, the engagement of various community groups—including women, elders, and youth—and the articulation and integration of local knowledge into

the mapping process. Through this approach, participant observation revealed how historical inequities and trust deficits influenced participation, as well as how logistical challenges shaped the outcomes of the exercise. The relational aspects of participant observation resonate with the ethics of care, emphasizing empathy, mutual accountability, and the validation of marginalized knowledge systems [64, 65]. The method provided a lens to assess how trust and collaborative relationships were built, as well as how epistemic justice was enacted through the recognition of community priorities and concerns. This focus on relationality underscores the importance of centering community voices in conservation governance and contributes to the broader goal of achieving epistemic justice. Participant observation thus bridged the technical and social dimensions of the P3DM exercise, enabling an integrated understanding of its impacts.

2.3. Fieldwork overview and research engagement

2.3.1. Pre-fieldwork engagement (2012–2015)

Before formal research began, I traveled to South Kivu two to three times per year between 2012 and 2015 as part of my work with an international NGO. These trips provided important background knowledge on conservation governance, land disputes, and community dynamics. During this period, I met with administrative and traditional authorities, civil society organizations, conservation actors, and community members. I engaged in formal and informal discussions that helped establish trust and contextualize the power dynamics shaping conservation interventions.

2.3.2. Fieldwork 1 (2016)—initial P3DM exercise

In 2016, I participated as an observer in the first ever P3DM exercise in the Itombwe Nature Reserve. This exercise took place during three weeks at Mwenga administrative center, with the participation of approximately 70 Indigenous and local communities, conservation actors, and CSO representatives. My role was to document the process, observe interactions, and analyze how different actors engaged with the mapping exercise. The key research activities were as follows:

- Participant observation of the two-week P3DM modeling process (Figure 2), focusing on who participated, who led discussions, and how community knowledge was incorporated in Mwenga administrative center;
- Visits conducted over a the space of a week to villages that the participants came from and which were represented on the map (Kamituga, Bionga, Lwindi, Basile, and Wamuzimu);
- Interviews with community members on the exercise, their lived experience of the reserve, and their perceptions of P3DM;
- Engagement with local CSO staff, conservation NGOs (WWF, WCS), and conservation authorities to understand their perspectives on participatory governance.

These observations enabled me to assess the P3DM methodology, and laid the groundwork for my return in 2020 to observe how the situation had evolved.

The following steps were followed:

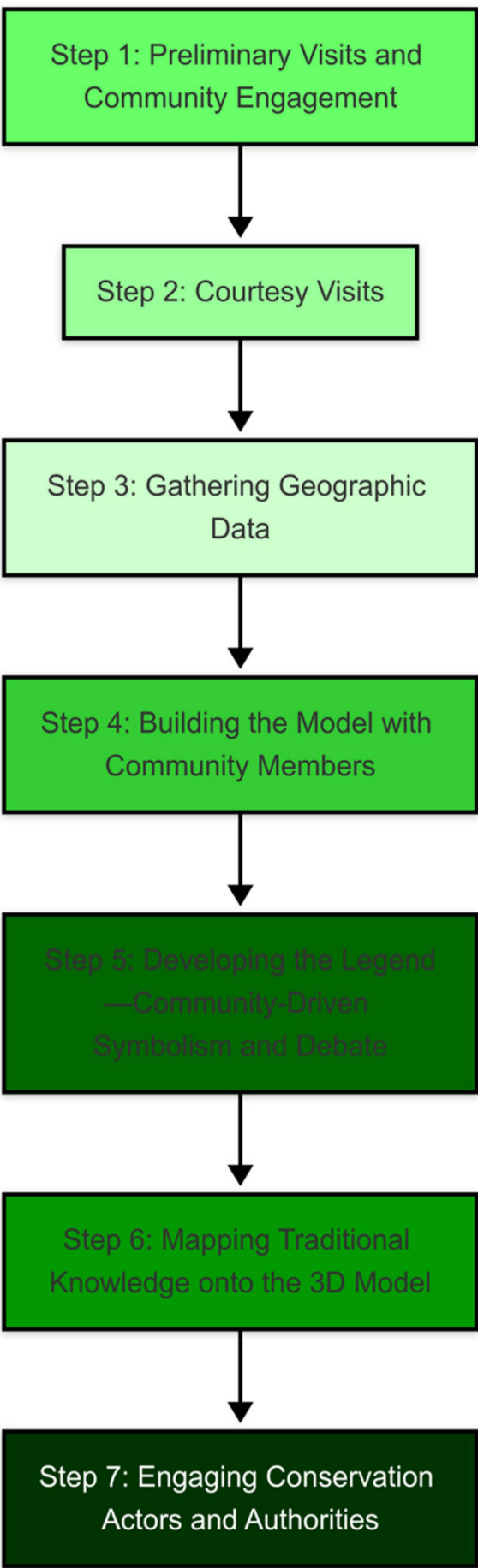


Figure 2 • Flow diagram of P3DM methodological steps. The steps are color-coded from light green (least connected) to dark green (most connected) based on their alignment with epistemic justice principles.

A month before the P3DM exercise began, preliminary visits were conducted to participating villages to explain the objectives, methodology, and intended outcomes. These visits were led by trusted local civil society organizations (CSOs), such as Africa-capacity, who played a critical role in mediating discussions and addressing initial skepticism. Sessions were open to all community members, and participants were encouraged to express concerns and ask questions, ensuring that participation was voluntary and fully informed.

Before initiating the P3DM exercise, courtesy visits were conducted to seek approval and symbolic validation from administrative, traditional and religious leaders. These visits involved meetings with *mwami* (traditional chiefs), village elders, and respected knowledge holders, who were consulted as sources of authoritative knowledge. Given the cultural and political importance of hierarchical structures in decision-making, these visits were essential in ensuring that the exercise was recognized as legitimate by all authorities. While these meetings provided formal approval for the mapping process, they also served as key moments to clarify objectives, address potential concerns, and reinforce the participatory nature of the initiative.

Before engaging with the communities, GIS technicians collected topographical and geospatial data to define the physical parameters of the 3D model. Contour lines (**Figure 3**) were extracted from satellite imagery, and previous GIS datasets related to land use and environmental zoning were reviewed. However, a deliberate decision was made by cartographers from Congolese national NGOs to withhold certain external GIS layers—such as industrial concessions and prior conservation maps—during the initial community engagement phase. This exclusion aimed to prevent external data from shaping local knowledge contributions and to ensure that participants engaged with the landscape based on their lived experiences rather than predefined conservation or mining boundaries. The horizontal scale was set at 1:10,000, a decision made by GIS specialists to ensure accurate georeferencing while accommodating logistical constraints.

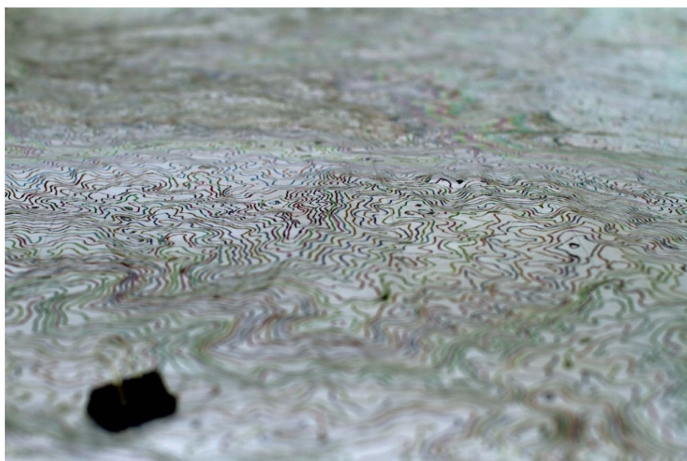


Figure 3 • Topographic base map used during the P3DM process, showing contour lines and elevation details. Source: Riccardo Pravettoni and The Rainforest Foundation Norway [58].

Community members physically constructed the 3D model using locally available materials such as foam, glue, and white paint (**Figure 4**). The model was built layer by layer, following topographic contours, with elders and knowledge holders contributing

ecological and cultural insights, while youth engaged in the physical assembly. While the horizontal scale was set, the vertical exaggeration was left to participants' discretion, allowing communities to highlight summits and landforms they considered culturally or ecologically significant. This resulted in a model that reflected not only topographical accuracy but also the symbolic and lived geographies of the participants.



Figure 4 • Community members collaboratively build up the 3D relief model by stacking and gluing layers of cardboard according to contour lines. Source: Riccardo Pravettoni and The Rainforest Foundation Norway [58].

Once the physical 3D model was completed, participants gathered to develop a shared legend, defining how landscape features such as hunting grounds, sacred forests, rivers, and biodiversity hotspots would be visually represented (**Figure 5**). This process involved intense discussions over colors, symbols, and markers, with community members debating how best to depict different territorial elements.



Figure 5 • The model is enriched with color codes, pins, and labels following a legend collectively defined by community members. Source: Riccardo Pravettoni and The Rainforest Foundation Norway [58].

Once the legend was established, community representatives transferred their knowledge onto the model, marking territorial boundaries, resource zones, and culturally significant areas (**Figure 6**). This process involved negotiating land-use claims, overlapping access rights, and areas designated for conservation

or restricted entry. Facilitators intentionally refrained from interfering, ensuring that the process remained entirely community-driven.



Figure 6 • Participant adds information to the completed 3D model to represent local knowledge, land use, and culturally significant sites. Source: Riccardo Pravettoni and The Rainforest Foundation Norway [58].

Once the model was finalized, a presentation meeting was organized in Mwenga, the administrative center of the territory. All relevant authorities and conservation actors were invited, and community members presented the model in their language, explaining land-use priorities, challenging existing conservation restrictions (**Figure 7**). Presenters advocated for a co-management approach. Other neighboring communities came to attend and listen. During this meeting, community members and CSOs presented 3DPM as a step towards a co-management framework for the Itombwe Reserve, to be implemented over the following years.



Figure 7 • The completed model is presented by community members to local authorities and conservation actors. Source: Riccardo Pravettoni and The Rainforest Foundation Norway [58].

2.3.3. Fieldwork 2 (2020)—observing the evolution of co-management

The second fieldwork period in 2020 focused on how P3DM had influenced the governance of the Itombwe Nature Reserve over

time. Given that P3DM was part of a broader effort to establish participatory conservation governance, the research examined the integration of P3DM outputs into conservation governance frameworks, the role of community-based monitoring groups—one of the key demands that had emerged in 2016—in ongoing land-use decision-making, community perceptions of whether their participation in P3DM translated into real influence over conservation policies, and challenges to co-management, including conflicts over zoning and restrictions on resource access. This fieldwork happened through the following measures:

- Focus groups and interviews in Mwenga and Basile conducted over a one-week period;
- Observation of 3 days of meetings and training sessions between the ICCN and community members in Burhinyi;
- Participation in a week of community patrols in the surroundings of Burhinyi.

2.4. Key considerations

2.4.1. Respect for local ethics

I followed strict ethical and cultural considerations. No visits were made to sacred areas or places restricted by gender norms—in Basile for instance, no women could be part of the community patrols because some of the local forest areas are forbidden to them—to respect local customs and leadership structures. I conducted formal courtesy visits to the local administrator, the traditional chief (*mwami*), and the village pastor, recognizing the interwoven nature of traditional, religious, and administrative authority in governance structures. However, I also resisted the pressure for local religious leaders to be present at all interviews and focus groups, ensuring that dissenting voices could express themselves freely.

2.4.2. Language and translation

My ability to communicate was partially facilitated by my knowledge of French, which allowed me to engage directly with Congolese CSO workers, local authorities, and some community members such as primary school teachers. However, deeper engagement with most community members required reliance on translation, as I have only basic proficiency in Swahili. My primary translators were two local CSO workers with whom I had worked with since 2012. One of them is from Itombwe himself, and both had worked extensively in the region, which meant community members trusted them. Because I was presented as these locals' partner, and because they presented me as "*an ally*" (all quotations in this article are derived from the author's fieldwork conducted in 2016 and 2020), engagement with participants was facilitated. This long-term engagement was crucial in ensuring that translations captured not only words but also cultural and political nuances. With the participants' consent, I also recorded and filmed our exchanges. This enabled me to go through the recordings and re-translate at a later stage of my research, instead of solely relying on the immediate on-site translation.

2.4.3. Reciprocal approach in interviews and focus groups

A key methodological principle was to ensure reciprocity in the research process. Interviews and focus groups were not one-directional—participants were encouraged to ask questions in return. One particularly significant moment occurred when a woman from a focus group in Burinyi asked me: *“It’s the third time we see you here. You come and go, come and go. Concretely, what are we getting from all the information we give to you?”* This question highlighted the ethical tensions in research conducted in historically marginalized communities, where outside actors—whether they be researchers, conservationists, NGO workers, or government representatives—are often seen as extracting information without contributing tangible benefits. Addressing her question was key in order to find common solutions not for extracting information and reproducing epistemic injustices, but rather to embed the research in a mutually satisfactory process.

To address these concerns, the following approaches were implemented:

- Findings were shared back with communities, rather than only being used for external reporting—I wrote a report in French, which was shared with the local French speakers, who committed to share it in Swahili and other relevant dialects with community members. They envisioned this report as an advocacy tool which they could use in their future land-use discussions.
- Conversations were framed as collaborative discussions, not just interviews. Apart from a few long interviews held at Mwenga administrative center, most discussions happened through informal exchanges, as I was staying with the community in their villages or in tents in the forest while conducting both sets of field work.
- Community members were informed about who I was and the broader purpose of the research. I was also careful to distinguish myself from conservation organizations and government actors, as park staff or conservation NGO workers (*“les parcs”*) were associated with paramilitary conservation enforcement. This distinction was necessary to build trust and clarify that my role was to listen, document, and amplify community voices, not to enforce conservation policies.

2.4.4. Community consent and power dynamics

Consent was a central ethical concern, especially in light of the fact that this research was conducted in a region where communities have historically been excluded from land governance decisions. The Itombwe Massif’s history of dispossession and forced conservation policies meant that Free, Prior, and Informed Consent (FPIC) was not just an ethical requirement but a political necessity. In practice, this had the following implications:

- Local CSOs visited villages a month before the P3DM exercise to inform people about the research, discuss logistical arrangements, and allow communities to decide how and when they wanted to engage in the exercise and the research (see step 1).

- Community members had full autonomy in choosing whether to participate in interviews, focus groups, and mapping exercises.
- Women, youths, and marginalized groups were actively sought out for interviews, in recognition of the fact that community leadership structures often prioritize male voices.

2.4.5. Addressing researcher positionality

As a white female researcher from the Global North, my presence required careful navigation of local perceptions and expectations. My introduction by trusted local CSO staff facilitated engagement, but my presence inevitably brought with it enduring cultural images and preconceptions. This influenced how people addressed me. While the funding opportunity was soon disregarded, many continuously saw me not as a researcher but as a potential advocate for their concerns: *“you have to note this”*, some insisted when discussing a certain point, while others requested, *“You will tell people about our situation”*. This dynamic shaped the research process in significant ways, as I could see how community members framed their narratives around advocacy and resistance to conservation policies. It also shaped my own engagement, as I felt a responsibility to be accountable. This situation motivated me to write articles in mainstream European newspapers about Itombwe [66] to convey the messages I had received. Addressing my positionality in this research also meant actively engaging with local scholars and integrating work from Congolese researchers in my literature review and engaging with often under-cited African scholarship, ensuring that local academic perspectives were central to the analysis rather than marginal additions. Despite these considerations, I remained acutely aware of the limitations of my role in bridging these perspectives, recognizing that my involvement could never fully translate or represent the complexities of local experiences and struggles. Additionally, the tension between my roles as researcher and opportunistic advocate continues to challenge me, demanding constant reflexivity and critical engagement to maintain critical distances with the participants’ discourses.

2.4.6. Extent of participatory and decolonial methodology

While the methodology incorporated participatory elements, its decolonial impact was constrained by structural realities. P3DM itself was implemented as part of a structured conservation program, meaning that community participation was not entirely free from external influence. Ethical challenges arose when it came to balancing research objectives with community expectations, particularly regarding what concrete outcomes they could expect from participating in the study. Lastly, it was not always possible to record the participants, which meant I had to rely on my own notes and their potential biases during the research process. Despite these constraints, the research process prioritized community agency, aiming to document governance power struggles rather than impose external knowledge frameworks. The back-and-forth travel between immersion, interviews, notes, and theoretical work over four years allowed the epistemic justice analytical framework to emerge incrementally. Specifically, a link with epistemic justice was made by hearing the iteration of references to the value of traditional knowledge versus scientific knowledge of *“the parks”* in community discourses. Community members repeatedly asserted

their expertise with statements like, “*we are the ones who know the forest*”; “*where the animals go is our knowledge*”, “*we taught the parks and now they want to teach us*”, “*We have learned from the forest from our ancestors*”, and “*Only those like us who were born here truly understand the forest*”.

3. Results

3.1. Methodological insights into Participatory 3D Modeling (P3DM)

The P3DM exercise in Mwenga provided an opportunity to examine the operationalization of epistemic justice in conservation governance. This activity was not merely a mapping exercise but a governance-driven move that facilitated the negotiation of territorial claims, the exchange of ecological knowledge, and discussions over power asymmetries in protected area management. The exercise involved representatives from multiple communities of the Mwenga Territory, prioritizing the inclusion of historically marginalized voices, particularly Indigenous Batwa peoples. Below, each methodological step taken during the exercise is assessed in relation to epistemic justice.

Step 1: Preliminary visits and community engagement

This step was essential for establishing trust and ensuring epistemic justice in knowledge production. By prioritizing community voices in early discussions, the process actively challenged top-down conservation practices and valued Indigenous and local knowledge as central rather than supplementary. Engaging local facilitators instead of external conservation actors helped counteract extractive research dynamics, ensuring that participants were not just informed but had space to negotiate the terms of their engagement. The consent process was clearly understood, as reflected in participant interviews, with one Batwa woman from Ilibo village, Albertine, stating, “*At first, we were unsure about participating because we have seen outsiders come and go without real change*”. Given the historical association of white researchers with conservation enforcement, initial skepticism was expected, but clear communication about the research aims and its advocacy focus ensured that participants understood my role as distinct from conservation authorities. This distinction was crucial, as expressed by a participant from Wamuzimu who noted, “*We have seen many visitors who come to tell us what to do with our forest. But this time, we are asked to show what is important to us*”.

Step 2: Courtesy visits

Community governance structures were informed and engaged from the outset. Recognition was granted not only to formal authorities but also to informal governance figures, acknowledging their historical role in land stewardship and conflict mediation. Procedural equity was reinforced by ensuring that these visits were consultative rather than coercive, allowing community leaders to discuss their concerns openly and preventing a top-down imposition of conservation mapping efforts. The courtesy visits were successful in securing broad community support, as evidenced by the active participation of village elders, traditional leaders, and respected local figures in subsequent stages of the exercise. While

these leaders provided essential validation, their presence did not overshadow the participation of ordinary community members, particularly women, whose engagement increased in later phases of the mapping process. While the exercise was primarily community-led, local State officials were also informed. The administrateur de territoire, as a representative of the State, highlighted the importance of these preliminary visits in maintaining transparency amid the ongoing conflict in the region, stating, “*With the ongoing conflict, it is particularly important that NGOs do not engage in activities without the State being duly informed*”. These engagements helped counter the elite’s skepticism, ensuring that P3DM was perceived as a community-driven initiative rather than an externally imposed conservation project.

Step 3: Gathering geographic data

This step was primarily technical, ensuring that the model and any subsequent maps were georeferenced and spatially accurate. However, contrary to the principles of epistemic justice, TEK did not serve as the foundation of the mapping process at this stage—only pre-existing scientific datasets were used. While ensuring technical precision, this implicitly reinforced epistemic hierarchies by prioritizing GIS expertise over local spatial understandings at this early phase. The decision to exclude industrial concession limits—despite the presence of mining operations in the area—was made solely by cartographers, raising questions about the selective application of external datasets and its implications for power dynamics within the exercise. Participants were not involved nor informed about this phase, which had a significant influence on the mapping process. While they engaged freely with the landscape representation during the following stages, the initial reaction to the base map of contour lines was one of curiosity, but also incomprehension. The technical sheet filled with isopleths appeared abstract and disconnected from daily experiences, creating an asymmetry between GIS experts and community members—a dynamic of “knowers” vs. “non-knowers” that shaped early interactions. Tambwe, a local cartographer from Bukavu and a CSO worker trained in GIS, shared, “*We provide the initial basic topographic knowledge to make their knowledge transferrable*”. One significant challenge emerged when participants pointed at places they considered part of their territory, only to realize that these areas fell outside the predefined mapping frame set by GIS technicians. While communities conceptualized space in a fluid and relational manner, the exercise imposed strict spatial limits, revealing tensions between participatory aspirations and predefined technical constraints. This limitation underscores the challenge of ensuring that preliminary technical steps do not impose rigid structures that constrain the process from the outset.

Step 4: Building the model with community members

The hands-on involvement of community members in physically shaping the model ensured an equal opportunity for participation for all: “*another advantage is involving young people who may not have had extensive knowledge of territorial history because they participate in constructing the model by tracing contour lines, cutting the materials, and assembling the model like a puzzle*”, shared Tambwe. Recognition was embedded in the process, as participants were able to define elevation features based on their

own lived experience rather than strictly adhering to standardized cartographic norms. This approach reflects a decolonial perspective on mapping, where local ways of understanding space and landscape are prioritized over imposed scientific representations. This participatory process strengthened local ownership of the mapping exercise, particularly for younger generations, who were actively involved despite not being the primary bearers of traditional ecological knowledge. While GIS facilitators ensured structural accuracy, their role remained secondary to the community-led definition of landscape representation. One striking example of the community asserting their knowledge was when a specific mountain was made significantly higher than others due to its cultural importance, rather than its actual elevation. Barthelemy, a Congolese GIS technician from Kinshasa and technical coordinator of this exercise, shared the following statement: *“Miniaturizing the natural environment allows even those with little formal education to orient themselves. They can see their mountains, locate their villages, and use this as a basis for discussion. It presents reliable data because it links satellite imagery, topography, SRTEM, images, and cartographic software to geoprocess these images, forming the foundation for building a georeferenced 3D model. And all of this is combined with community knowledge”*.

Step 5: Developing the legend—community-driven symbolism and debate

This phase ensured that communities determined how their environment would be depicted, reinforcing TEK as central to the exercise rather than imposing external classifications. Community members decided what to represent and how. They also decided what not to share on the map, demonstrating that trust was not granted. Reflexivity emerged through contentious debates, revealing how different community members valued landscape features differently. The negotiation of symbolic meanings made the process more than just a technical exercise—it became an opportunity for communities to assert their own ways of categorizing and relating to their land. Certain color choices sparked debate, demonstrating the tension between standardized cartographic conventions and local perceptions. For instance, a GIS technician initially suggested using blue for rivers, aligning with international cartographic norms, but this was quickly dismissed by participants, who argued, *“But our rivers were never blue, they are brown”*. The group laughed at the proposal, reinforcing the idea that representation should match lived experience rather than imposed conventions. Similarly, deforested areas were marked in shades of brown, as participants pointed out that when trees are gone, the soil becomes visible. These discussions highlighted deep ecological knowledge and ensured that the final 3D model was not only spatially accurate but also culturally meaningful. As Barthelemy highlighted, *“Communities possess an enormous amount of geographical knowledge, a vast body of traditional environmental knowledge that must be valued. But often, elites do not care about this knowledge. They arrive with their own plans, telling communities what to do, forgetting that communities are the only ones who truly know their geography and resources. The goal is to value this knowledge”*. By allowing the community to self-determine how their environment was visually represented, this phase reinforced the importance of integrating Indigenous perspectives into conservation governance.

Step 6: Mapping traditional knowledge onto the 3D model

Redistributive justice was reflected in how epistemic authority was actively centered on local actors, rather than external conservation priorities. Procedural equity was ensured by opening the mapping process to all community members, particularly those historically excluded from land governance discussions. This was the longest phase of the exercise, as participants engaged in collaborative problem-solving, particularly in cases where overlapping land-use is claimed to be addressed. Each community member provided complementary information about their own uses and knowledge. Hunters showed the *malambo* (sites where animals give birth, seen as sacred natural sanctuaries, where it is forbidden to hunt) and designated them as key conservation areas to be included in the strictly protected zone. Women identified cultivation zones, foraging areas, and spaces essential to their households' daily subsistence. This led to debates over whether the reserve should be limited to *malambo* only or whether broader areas needed to be granted conservation status. Another crucial aspect was defining culturally restricted areas, including ritual initiation forests. Entry to these places is forbidden to outsiders, and communities were clear that they do not want any forest guard to violate them. Many community members were reluctant to share all artisanal mining sites, which could pose issues in their discussions with the reserve's management. Conservationists classify these sites as environmental threats, whereas communities classified them as livelihood sources. Discussions over claims between villages were peaceful, thanks to earlier participatory land-use discussions in Itombwe. Similar experiences in other regions of the country has shown that such discussions can generate disputes which may last for weeks or even months [58], illustrating the importance of establishing pre-existing land governance structures to ensure smoother participatory processes. The geography of Itombwe, with its clear mountain ranges and valleys, also helped to facilitate land delineation, as territorial extents were naturally bounded. Additionally, this phase reinforced intergenerational knowledge transfer, as elders, younger participants, and women collectively contributed to defining which areas held ecological, cultural, or economic significance. By mapping spatial knowledge in this way, the process ensured that TEK was embedded in conservation planning, rather than being treated as anecdotal or informal knowledge. It was a highly empowering moment which also allowed development issues to be discussed; these are rarely dealt with profoundly in conservation initiatives. Mabulayi, a female cultivator and mother of five from the village of Kigogo, noted, *“It allows us to show our villages, how our activities take place, our hills, our mountains, our home. We drew this to teach what is important and what should be left to us. We also showed our difficulties—the lack of schools for our children, the absence of a health center, and all the problems we have—they are on the map”*.

Step 7: Engaging conservation actors and authorities

Recognition was achieved as TEK was physically embedded in conservation discussions, compelling external actors to engage with Indigenous spatial knowledge on equal footing with scientific data. As they were talking, and administrative authorities were silent, a young man turned to me and said with pride, *“wanasikiliza”*

(“they listen”). A sense of reflexive justice seemed to be initiated in this reversal of roles. Community members were teaching their reality to the authorities. The 3D model presentation successfully created a platform for dialogue, but higher-level conservation authorities, particularly international NGOs involved in the reserve’s management, did not attend. This reflected a broader challenge of institutionalizing participatory governance, as external conservation actors remained disengaged from community-led initiatives. However, political and administrative authorities did attend, recognizing the mapping process as a credible tool for land-use planning. Despite these limitations, the physical representation of TEK created a lasting advocacy tool, which communities could continue using for ongoing land negotiations and conservation planning. The fact that the model remained in the community’s possession was particularly important, as it ensured that the knowledge documented through P3DM was not extracted and appropriated by external actors. Mabulayi spoke during the conference: *“We want to remain responsible for this forest; we do not want it to be taken from us. We want to manage it ourselves because all our activities are here. This is where we find our medicines, our fruits, our food, where we cultivate, where we find the wood we use for cooking. And if, in the future, we find forest guards who do not know our lives and our difficulties, it will cause us great problems”*.

Active participation was strong throughout different phases of the exercise, with approximately 70 participants attending, and up to 100 in key moments, reflecting a diversity of age groups and origins within the Mwenga territory. Women were present and engaged, despite being a little underrepresented and more silent in the initial phases. However, in more informal moments, such as small group discussions or when recounting daily subsistence practices, women’s contributions were more pronounced, revealing extensive ecological knowledge. Participants debated, discussed, and often did not want to stop the exercise when the night was falling. This level of engagement and reluctance to end the sessions demonstrate that participants not only valued the process but also believed in its relevance and potential impact on their communities and land rights. However, while the P3DM process succeeded in recognizing and documenting local knowledge, and in involving the larger community in a rather equal manner, its effectiveness in shifting conservation governance remained uncertain. In addition, the following section critically evaluates the extent to which P3DM achieved epistemic justice in practice, particularly in relation to power asymmetries and long-term accountability.

4. Discussion

The P3DM exercise in Itombwe was envisioned by CSOs as a mechanism to integrate local communities and indigenous peoples into conservation governance. It was perceived by the communities as potentially challenging historical knowledge hierarchies, empowering them in land governance. Using the four epistemic justice criteria—recognition, procedural equity, redistributive justice, and reflexive justice—this evaluation critically examines P3DM results over the following years. Fieldwork conducted in 2020 provided new insights into the long-term effectiveness of the process, revealing both successes and structural limitations that shaped its potential as a transformative tool.

4.1. Recognition: was local knowledge legitimized in conservation governance?

One of P3DM’s strongest achievements was its ability to validate and spatially represent local ecological knowledge in a way that had never been officially acknowledged before. Through participatory mapping, community members documented sacred sites, hunting grounds, and resource-use zones, reinforcing the legitimacy of Indigenous knowledge alongside scientific conservation data. The 2016 decree that legalized the community-defined boundaries of the Itombwe Nature Reserve was a historic milestone—a formal recognition of customary land-use knowledge that contrasts with the usual top-down conservation practices in Central Africa. However, the extent of this recognition was limited in practice. While TEK was integrated into the 3D model, conservation institutions did not institutionalize it into formal governance frameworks.

Only eight months after the exercise, the Terms of Reference for recruiting a consultant to develop the Management Plan for the Itombwe Nature Reserve showed backlash. Rather than incorporating insights from the P3DM exercise, the document focused solely on scientific data regarding fauna and flora, omitting local indigenous perspectives such as customary prohibitions, positive local practices, and inputs from traditional leaders like the *Mwami*. Local CSOs noted that the subsequent 2017 Management Plan overlooked community concerns about the conservation value of critical tree species—such as *“Katugwetugwe”*, *“Musela”*, and *“Mushiishi”*—which locals argued were endangered by logging and charcoal production. These omissions represent a clear failure to uphold the recognition criterion of epistemic justice, marginalizing the rich, locally grounded insights that could have informed a more inclusive and effective conservation strategy. Moreover, the document lacked mechanisms for inclusive engagement at the village level; its governance sections did not include provisions for village-level meetings or the incorporation of traditional village structures, instead merely stating that some governance bodies should include community representatives—erroneously equating participation with decision-making power. Finally, the knowledge management sections emphasized “Development and promotion of scientific research” and “Establishment of a scientific council for the Reserve”, while ignoring other forms of knowledge. Communities were only referenced under capacity-building activities, thereby implying a top-down knowledge transfer from the ICCN to the local actors.

Four years later, the second fieldwork project included observing one of these capacity-building activities. The park authorities were training community members on biodiversity monitoring. The top-down knowledge transfer was fueled by epistemic injustice features: written PowerPoints in French shown to non-francophones and, in many cases, illiterate participants; no opportunity for dialogue, questions; and no discussion on how local knowledge of animal behavior, seasonal patterns, or traditional conservation practices could complement technical monitoring efforts. ICCN trainers taught community members how to use GPS devices for wildlife tracking, demonstrating standardized data collection techniques that did not incorporate TEK into species identification or ecological assessments. Community knowledge became sidelined while technical expertise was given primacy,

leading to the continued marginalization of Indigenous ways of knowing. A woman from the community of Burhinyi expressed her frustration: *“These people have studied, they have real knowledge”*. This moment illustrated the process of epistemic erasure, through the undermining of community confidence in their own knowledge systems, which often lead to the erosion of traditional forms of knowledge. During the following field patrol in the hills, far from ICCN members, several community members proudly demonstrated their extensive local knowledge to me, insisting on teaching me about the local environment. One participant exclaimed, *“We know every hill, every plant, every watershed here”*, underscoring their deep, lived understanding of the landscape. This moment stood in stark contrast to the top-down training sessions and their muted attitude, highlighting the untapped potential of indigenous expertise that remains largely unrecognized in official conservation practices.

One of the most pressing challenges highlighted by P3DM in Itombwe is the issue of knowledge ownership. While communities co-produced the maps and contributed their knowledge, they ultimately lost control over the outputs. In 2020, the physical 3D model remains in the ICCN office, effectively under State control. The digital maps (Figure 8), processed by GIS technicians and a cartographer, are held by international conservation NGOs. Even if local communities have direct access to their mapped knowledge, this raises serious concerns about data sovereignty and epistemic justice. One participant in Basile, reflecting on this loss, stated, *“We made this map, but now it belongs to them. What did we get in return? We are still waiting”*. These concerns align with broader critiques of extractive participatory research, where local knowledge is documented but remains inaccessible to those who

generated it [67]. While P3DM was designed to empower communities, the failure to embed knowledge sovereignty protections has instead reinforced external control over conservation data. The Itombwe case also highlights the risk of sensitive knowledge disclosure. During the mapping process, some community members deliberately withheld information about key grounds and activities due to fears that external actors might use these data to impose further restrictions on their land-use practices. *“We did not show everything. If we tell them everywhere we hunt, one day they might tell us not to go there anymore”*, shared a Batwa hunter. P3DM balances knowledge sharing with community protections, making provisions for TEK not to be used against the very people who provide it.

4.2. Procedural equity: who was able to participate meaningfully?

The dynamic nature of P3DM mirrors the fluid nature of TEK, which is too often misrepresented as a fixed, unchanging body of knowledge. Tambwe testified about this crucial aspect of P3DM: *“3D modeling is a dynamic production, unlike static mapping. With 3D, communities can continuously add data and enrich the model”*. The interactive, iterative, and participatory nature of P3DM should allow for the continuous refinement and updating of spatial knowledge, reinforcing the idea that TEK is not a static relic of the past but a living, adaptive system of knowledge production shaped by generational learning, environmental changes, and socio-political transformations [5]. In dominant conservation discourses, TEK is frequently framed as a static, pre-modern system of knowledge, in contrast with Western scientific epistemologies, which are perceived as dynamic and progressive [68]). This false

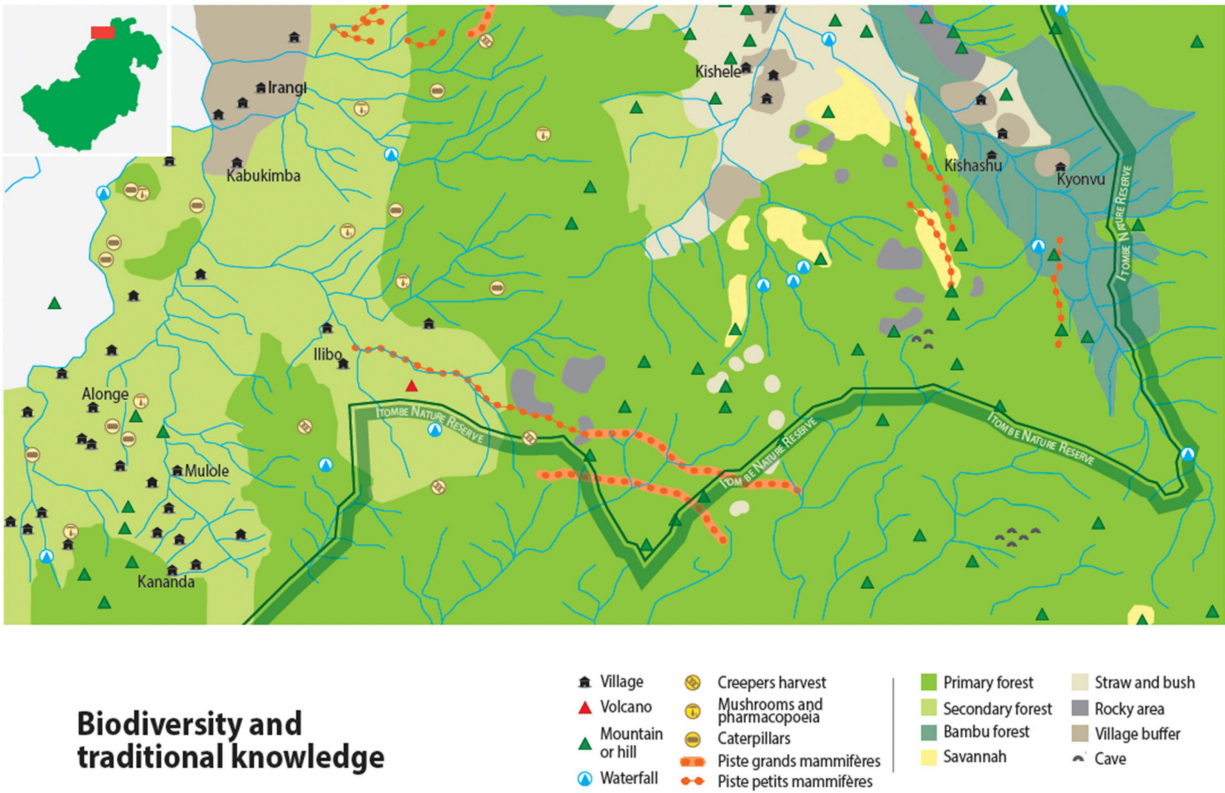


Figure 8 • Digitalized map from data collected on the 3-D Model in Mwenga, 2016. Source: Riccardo Pravettoni and The Rainforest Foundation Norway [58].

dichotomy often reduces Indigenous knowledge to an object of preservation rather than a framework for active environmental governance. Such perceptions have led to tokenistic incorporations of TEK into conservation policies, where it is acknowledged only insofar as it aligns with pre-existing scientific frameworks, rather than as a co-equal epistemology [37]). Procedural Equity should hence have meant continuous engagement and enrichment of the 3D model. In practice, no modification was made over the four years of this study. P3DM, despite its potential, did not challenge dominant conservation paradigms that have historically treated Indigenous knowledge as something to be archived rather than applied [69].

The limited engagement with the P3DM process can be attributed to several interlocking factors. First, the physical model was housed at the ICCN office rather than within the community, which significantly curtailed local access and ownership, thereby inhibiting ongoing contributions. Additionally, chronic underfunding of the reserve meant that there were insufficient resources to support regular participatory updates, nor even to extend the “pilot” study to the four other areas of the reserve. Finally, conservation actors displayed a clear lack of motivation—evidenced by their nonattendance in the presentation meeting in 2016, and the absence of reference to the knowledge generated through P3DM in the Management Plan design—resulting in minimal institutional support for integrating TEK into active management practices. The oversight may lie in the lack of preliminary agreement among all concerned outlining the model’s intended use. As one conservation actor shared, *“This was an initiative we welcome, but did not include in our planning. The organizations who led this initiatives had their own interests in mind. We have our own priorities”*. Other factors that hindered progress over these four years included high staff turnover at ICCN, the kidnapping of NGO workers by an armed group, and subsequent death of the Deputy Site Manager in charge of research and biomonitoring—which unsettled international funders—the volatile security situation, an Ebola epidemic, and a decline in international funding for the region. Together, these factors undermined the dynamic, iterative process that is central to achieving procedural equity in participatory mapping.

An opportunity to operationalize procedural justice was also associated with the ability to have the community members participate in the reserve’s management procedures—a key demand during the 2016 exercise. When we met in 2020, community members still talked about co-management, community empowerment, and a future of self-determination. But the shift was timid: only a few community patrols had been trained, with no means to actually patrol. Communities had demanded the ability to patrol their own forests, or at least that eco-guards would be hired among them. These requests were mostly ignored due to legal and financial constraints. ICCN communicated that sixty ICCN eco-guards had been hired from the communities, but the lack of funding had restrained them from allowing official postings and material. Community patrols had been gathered and trained, but were left underfunded and without enforcement authority. Some participants had expected to be employed after the trainings—but no formal jobs materialized, leading to frustration and disappointment. *“We were trained in 2018, and have never patrolled since. We thought our work would be to know the forest and to sensitize the community to protect it. We expected to be hired, to have a job after this training”*. This reveals how participatory initiatives can raise expectations without

ensuring actual power redistribution—leaving communities disillusioned rather than empowered.

4.3. Redistributive justice: did the process shift power over land governance?

Redistribution of power over land management was a clear expectation from Batwa participants. As Albertine said while transferring her knowledge to the map, *“this mapping is different—it is about what we see and know about our land. Now, we are going to manage our forest as we have shown on the map”*. Four years after the exercise, the advocacy message from the 3DPM exercise remained consistent but unachieved. Baati Gozi Irangi, a primary school teacher from the Irangi village, who participated in the mapping process, reaffirmed, *“What we want is to manage this forest ourselves. We absolutely do not want the State to take control of it. No, and no”*. Mapping made knowledge visible, but it did not transfer power over land-use decisions. Communities were asked to document their landscapes but not to define conservation policies or monitoring strategies. The ICCN retained control over biodiversity monitoring and enforcement, demonstrating that “recognized” knowledge was still subordinate to externally imposed conservation frameworks. The maps visually reinforced community land claims, supported zoning decisions, but ultimate decisions were still made by the ICCN and international NGOs. The multi-use zoning agreements remained fragile, as there were no legal guarantees that community-defined areas would be protected from future conservation restrictions. One of the biggest limitations of P3DM in Itombwe are the geopolitical tensions surrounding land use and land control. The State has agreed, since 2006 and since the formation of the initial local resistance movement, to decentralize knowledge production, redefining the reserve’s boundaries based on communities’ inputs, and agreeing to the use of P3DM. Achieving co-management was part of the initial agreement of the Joint Framework. However, in 2016, facing no positive evolution of the complicated security situation in the Itombwe Massif and more broadly in the Kivus, the State did not decentralize governance power in the reserve. The Joint Framework, where decisions are taken on the future of the reserve, has always been based in Bukavu, controlled by the provincial head of the ICCN, who acts under the national Ministry of the Environment.

For participatory methodologies like P3DM to move beyond symbolic recognition of TEK, they must be linked to governance frameworks that grant communities meaningful decision-making power. Currently, mapped knowledge does not equate to governance influence—communities have demonstrated their expertise in land-use planning, yet conservation authorities and external NGOs continue to dictate final zoning and enforcement policies. A critical step toward epistemic justice is formalizing the role of TEK within conservation law, ensuring that maps generated through participatory processes hold legal weight in land-use planning. This would prevent scenarios where community-defined land-use zones remain mere suggestions rather than enforceable conservation strategies. Future conservation initiatives in Itombwe must shift from consultation to legal integration, guaranteeing that participatory processes translate into governance frameworks rather than stand-alone projects. *“Our concern is to see this protected area fulfill the mission for which it was created—namely, the shared governance of natural resources. We want to ensure the*

effective empowerment of local communities and Indigenous peoples living in and around this reserve. We want the competent authorities to actively engage in the sustainable management of the Itombwe Nature Reserve by equipping it with all the necessary legal tools, primarily through its national decree recognizing communities' inputs, which will facilitate the implementation of its management and development plan", stated Jean de Dieu, Africapacity's Director, in 2020.

For P3DM to become a transformative tool, it must be embedded in governance frameworks that prioritize institutional change. This requires the following measures: (1) Institutional commitments to integrating TEK into conservation law and governance frameworks. (2) Sustained funding and long-term engagement to avoid short-term participatory exercises that fail to produce lasting change. (3) Mechanisms that ensure data sovereignty, preventing TEK from being appropriated without community control. (4) Recognition of community patrols and governance structures, so participation extends beyond mapping and into decision-making authority. Without these reforms, participatory conservation risks reinforcing structural inequalities rather than dismantling them.

4.4. Reflexive justice: was there follow-up and structural change?

Itombwe's P3DM process suffered from a lack of follow-up mechanisms to ensure its long-term impacts. The P3DM process demonstrated that TEK was dynamic and valuable, but by 2020, a shift back toward Western conservation paradigms was evident. While the mapping exercise was hailed as an innovative participatory success, its institutionalization into conservation governance remained weak. The ICCN and international conservation NGOs framed P3DM as a successful exercise in community engagement, yet no formal commitments had been made to integrate its outputs into governance frameworks. As a result, they did not feel accountable to use it to transform the way they engaged with communities' knowledge. Africapacity and IRDAC were constrained by the lack of funding to pursue the exercise in the whole reserve and to use its results. They shifted their accountability towards their funders, who were not ready to further support this work, who in return had only signed a one-year renewable agreement. No one had formally committed to anything. By 2020, four years after the participatory zoning agreement was formalized, local communities observed that their land-use decisions had limited enforcement power, as external conservation actors continued to control key decision-making processes. One participant expressed growing skepticism: *"We made the map, and we are proud to have done it, but what comes next?"* This sentiment encapsulated the gap between the promise of participatory mapping and its practical impact on conservation governance.

The challenges of institutionalizing participatory conservation in Itombwe reflect the broader conservation governance struggles in the region today. Science-based conservation narratives had framed the Itombwe Massif as an ecological priority long before community rights were considered. P3DM, as a corrective exercise, could not challenge the conservation paradigm without higher political accountability. Like in other protected areas of the sub-region, conservation approaches remained top-down, with community involvement limited to sensitization programs rather than active participation in governance. A recent publication by ICCN on the habitats and dominant species of Itombwe, present on the

3D model, makes absolutely no mention of the pre-existence of this information or of local knowledge apart from *"local residents of the RNI contributed to confirming the vernacular names of the plants collected in the field at Kisiru and Rubanga"*. Communities are instead mentioned in the "threat" section; for instance, they are mentioned for their *"Excessive harvesting of non-timber forest products (NTFPs) (...) for use in traditional medicine"* [70].

5. Conclusions

The findings from Itombwe highlight both the potential and limitations of participatory methodologies in conservation governance. While P3DM offers a means to visually integrate local ecological and cultural priorities into conservation planning, its application in Itombwe reveals critical gaps between participatory intent and governance outcomes. Although P3DM validated traditional ecological knowledge (TEK), it did not fundamentally alter decision-making structures, nor did it significantly challenge the epistemic hierarchies that continue to favor external conservation actors. This case study demonstrates the urgent need to move beyond performative participation and critically reassess the structures of conservation governance, the control of spatial knowledge, and the epistemic foundations of conservation planning. Adaptive co-management is often limited by institutional inertia, power asymmetries, and short-term project funding cycles, all of which are evident in the Itombwe case, where P3DM produced participatory data but failed to translate into sustained governance shifts. Future research should explore how P3DM could be better integrated into adaptive governance frameworks, ensuring that participatory knowledge is not only documented but also continuously revisited and institutionally embedded to avoid performative participation.

5.1. Beyond knowledge validation: a critical engagement with epistemic justice

While epistemic justice is often framed in participatory conservation as the inclusion and validation of Indigenous knowledge, this conceptualization is limited if it does not address power structures in knowledge production and governance. The Itombwe case study demonstrates that recognizing TEK in participatory mapping does not inherently shift epistemic authority; rather, it often functions as a supplementary layer to Western scientific frameworks, rather than as an equal and autonomous system of knowledge. Epistemic justice should not be reduced to integration into pre-existing structures but must involve a fundamental transformation of whose knowledge shapes conservation governance. In Itombwe, scientific biodiversity assessments remained the primary justification for conservation, while TEK, despite being mapped, did not lead to shifts in enforcement practices or conservation policy. This reflects a broader pattern in conservation, where participatory approaches remain structured within epistemic frameworks that reinforce Western scientific authority. Achieving epistemic justice in conservation requires more than mapping knowledge—it necessitates a shift from inclusion to authority, from consultation to governance power.

5.2. Alternative epistemologies: challenging the dominance of scientific mapping

The reliance on spatial representation in participatory methodologies such as P3DM assumes that mapped knowledge is the

most legitimate and actionable form of environmental governance. However, many Indigenous and local knowledge systems operate through non-cartographic means, such as oral histories, customary decision-making processes, and relational ecological understandings. In Itombwe, knowledge about land is embedded in ritual practice, seasonal patterns, and generational transmission, yet participatory conservation remains anchored in mapping as the dominant epistemic framework. This raises the following question: what forms of knowledge are excluded by the participatory turn in conservation? While P3DM provides an important advocacy tool, it does not necessarily accommodate spatial ontologies that are not dependent on Cartesian mapping. A truly transformative approach would require rethinking participatory methodologies beyond GIS-compatible formats, incorporating narrative mapping, oral land histories, and customary spatial logics. Such approaches could help resist the colonial legacy of conservation mapping, which has historically functioned to delineate, regulate, and control space rather than empower communities.

5.3. Rethinking participation: alternative governance structures

Participation in conservation governance is often conceptualized within existing institutional frameworks, such as NGOs, State conservation agencies, and international conservation organizations. However, as the Itombwe case demonstrates, these institutions often remain reluctant to relinquish governance power, even when participatory processes are introduced. The NGO-led, donor-dependent model of participatory conservation frequently limits communities to a consultative role rather than an authoritative one. Moving forward, participatory conservation must be decolonized, shifting from externally validated processes to community-driven governance models. In Itombwe, the exclusion of communities from decision-making post-mapping highlights the structural limits of current participatory methodologies. A truly decolonial approach would invert existing governance models, ensuring that conservation is defined and led by local communities rather than imposed by external actors. This could take the form of Indigenous-managed conservation areas, legal recognition of customary land governance structures, or long-term, community-led biodiversity monitoring programs that are independent of external conservation institutions.

5.4. Power struggles over knowledge and data control

A critical but often overlooked aspect of participatory methodologies is who controls the knowledge produced in these processes. In Itombwe, the spatial data generated through P3DM were retained by ICCN and international NGOs, limiting community access to and control over their own documented knowledge. This reflects a broader struggle over the control of conservation data, where communities provide knowledge, but external actors maintain authority over its application. As conservation increasingly integrates digital mapping technologies, data sovereignty must become a central concern in participatory methodologies. The Itombwe case highlights that even when communities are involved in knowledge production, they do not necessarily gain governance power over that knowledge. This raises urgent questions about data justice in conservation: Who owns conservation data? Who decides how these data are used? Can participatory methodologies genuinely

redistribute knowledge power if the final decision-making authority remains external? Without addressing these questions, participatory methodologies risk becoming another form of knowledge extraction, reinforcing rather than dismantling conservation hierarchies.

5.5. Theoretical Vs. Practical realities: the limits of P3DM in Itombwe

While P3DM is often framed as a tool for local empowerment, the Itombwe case study underscores the practical barriers to its realization. Theoretically, P3DM should support community-led conservation governance, institutionalize TEK, and provide communities with decision-making power over land use and conservation planning. In practice, however, several structural barriers prevented this from happening in Itombwe:

- External conservation actors maintained control over governance decisions, limiting the ability of participatory mapping to translate into policy change.
- Legal and institutional structures did not integrate TEK beyond consultation phases, ensuring that scientific knowledge remained the dominant framework for conservation management.
- Financial and logistical constraints prevented long-term engagement, leading to community disillusionment and the perception that participatory mapping was a one-time exercise rather than an ongoing governance tool.

This highlights the broader challenge of implementing participatory conservation within institutional frameworks that were not designed for community governance. Without legal mechanisms to enforce community sovereignty over conservation data, governance structures, and resource control, participatory methodologies risk functioning as performative exercises rather than transformative interventions. Future research should critically assess not just the effectiveness of participatory methodologies but also the institutional conditions necessary for their success.

5.6. Final reflections and future research

The Itombwe experience illustrates both the potential and the limits of participatory conservation methodologies. While P3DM provided a platform for validating Indigenous ecological knowledge, it did not fundamentally alter governance power or conservation enforcement structures. The case study demonstrates that participation alone does not guarantee justice—instead, it must be embedded within larger shifts in governance authority, knowledge control, and conservation frameworks. Future research should explore the following considerations:

1. How alternative epistemic frameworks beyond mapping can be integrated into conservation governance.
2. How legal mechanisms can ensure community sovereignty over conservation decision-making.
3. How participatory methodologies can be decolonized to prioritize community-led, rather than NGO-driven, conservation models.

By engaging with these questions, conservation scholars and practitioners can begin to move beyond the limitations of performative participation and develop truly transformative approaches to environmental justice and biodiversity governance.

Acknowledgments

I extend my deepest gratitude to the Indigenous communities of Mwenga, Irangi, Burhinyi, Basile, Ilibo, Kigogo, and Kitamba for their invaluable contributions to this study. Their knowledge, insights, and collaboration were central to the participatory process and the findings presented here. In striving to uphold epistemic justice through my work, I have sought to center the voices and knowledge systems of Indigenous and local communities, recognizing them as equal partners in conservation science and practice. I hope this article helps amplify their perspectives and catalyze more inclusive and equitable environmental governance. I also sincerely thank Africapacity (Jean de Dieu Wasso, Tambwe Musimbi) and IRDAC (Barthelemy Boika) for their expert facilitation and unwavering commitment to fostering inclusive dialogue. My appreciation goes to Rainforest Foundation Norway for funding and supporting participatory approaches in forest governance in the DRC, as well as for enabling this P3DM exercise, the subsequent mission, and the inclusion of visual material (pictures and maps) in this publication. Finally, I am infinitely grateful to Riccardo Pravettoni for his invaluable support in visually documenting the process, and for creating the digitalized maps and visual materials that enrich this research. All maps and photos included in this article are his work, funded by the Rainforest Foundation Norway.

Funding

Field work was funded by the Rainforest Foundation Norway.

Author contributions

The author confirms sole responsibility for this work. The author approves of this work and takes responsibility for its integrity.

Conflict of interest

The author declares no conflicts of interest.

Data availability statement

Data supporting these findings are available within the article, at <https://doi.org/10.20935/AcadEnvSci7663>, or upon request.

Institutional review board statement

Ethical review and approval were waived for this study due to the nature of the research and the absence of a formal Institutional Review Board process in the local context. However, the study was conducted in accordance with the Declaration of Helsinki and in compliance with ethical guidelines established by Africapacity, the local facilitator, based on previous agreement with the participating communities. Ethical oversight was provided through

a community-led Free, Prior, and Informed Consent (FPIC) process, ensuring alignment with principles of respect, beneficence, and justice in research involving human participants. Key ethical considerations included securing FPIC from all participating communities, maintaining transparency in research objectives and methods, and addressing potential risks related to the collection and use of sensitive data. Special care was taken to respect the cultural and intellectual property rights of Indigenous and local communities, ensuring that their knowledge and contributions remained central to the research outcomes.

Informed consent statement

Explicit informed consent was obtained from all subjects involved in the study.

Additional information

Received: 2024-12-31

Accepted: 2025-04-07

Published: 2025-04-25

Academia Environmental Sciences and Sustainability papers should be cited as *Academia Environmental Sciences and Sustainability* 2025, ISSN 2997-6006, <https://doi.org/10.20935/AcadEnvSci7663>. The journal's official abbreviation is *Acad. Env. Sci. Sust.*

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