

Mapping Social Cohesion in Restoration Landscapes: Evidence from Western Rwanda

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ABSTRACT

Social cohesion is increasingly recognized as essential for effective ecosystem restoration, yet it remains underexplored in practice. We mapped social relationships in restoration landscapes of Western Rwanda. Using Net-Map-based interviews and participatory workshops, we evaluated horizontal and vertical cohesion. Restoration approaches strengthened trust, collaboration, and communication within communities, key drivers of knowledge exchange and collective action, offering scalable models for advancing broader restoration initiatives in Rwanda and similar contexts. We also found weak community–government relationships driven by top-down governance, underscoring the need for inclusive, equitable restoration policies. For such inclusion to be meaningful, communities must be empowered to actively influence restoration decisions, which would likely foster sustainable, long-term outcomes. This study underscores the value of combining quantitative and narrative methods when using Net-Map to understand relationship quality and power dynamics among actors in socioecological restoration networks.

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Introduction

Globally, landscapes are rapidly degrading due to deforestation, biodiversity loss, and soil erosion, affecting nearly one-quarter of the terrestrial area and more than one-third of the global population (Stanturf 2021). In Sub-Saharan Africa (SSA), over 60% of agricultural land is degraded due to poor land management, erosion, and declining soil fertility, among other factors, ultimately threatening food security (Barbier and Hochard 2018; Zingore et al. 2015). In response, various approaches and initiatives at

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the local to global scale have emerged to restore degraded landscapes (Stanturf 2021). At the global level, Forest Landscape Restoration (FLR) has become a leading framework in the context of ecosystem restoration, underpinning the Bonn Challenge, which aims to restore 150 million hectares of degraded land by 2020 and 350 million hectares by 2030. More than 34 countries in SSA have aligned with this framework through the African Forest Landscape Restoration Initiative (AFR100), pledging to restore over 100 million hectares (AFR100 2025). FLR enhances ecosystem services, supports livelihoods, and promotes community well-being (Hampson et al. 2017; Stanturf 2021), conflict resolution (Moluh Njoya et al. 2025; Ullah 2024), and social cohesion (SC) (Ullah 2024).

Despite these advances, the social dimension dynamics are often overlooked in governance frameworks for restoration landscapes (RL) projects (Chazdon et al. 2021; Mansourian et al. 2025). This neglect stems from the traditional focus on technical expertise (Higgs 2005), sidelining social dimensions of ecological restoration (Fischer et al. 2021). This gap between science and practice may lead to stakeholder conflicts (Dickens and Suding 2013; Höhl et al. 2020), leaving practitioners feeling that researchers overlook their needs and constraints (Dickens and Suding 2013). Thus, restoration projects may deliver technically sound but socially unsustainable outcomes (Clewell, Aronson, and Winterhalder 2004). In many SSA countries, restoration is implemented through multistakeholder governance approaches that engage communities, civil society, NGOs, and the private sector (Akinnifesi 2018, 88). While such approaches are recognized as effective for RL (Bixler, Jedd, and Wyborn 2018; Jeffery and Vira 2001), persistent power imbalances and top-down decision-making often marginalize local actors (Okereke and Stacewicz 2018; Reed et al. 2010). Dominant stakeholders may impose strategies that lack local ownership and alignment with community priorities (Barnaud and Van Paassen 2013), weakening collaboration and threatening the sustainability of restoration outcomes (Nsikani et al. 2023). Similarly, the limited inclusion of marginalized groups can erode trust and SC within RL (Chazdon et al. 2021; Nchanji, Ramcilovic-Suominen, and Kotilainen 2021). Limited financial mechanisms and resources, weak private sector engagement (Tuyizere et al. 2025), and competing interests further undermine actors' relationships and constrain FLR benefits (Kabirigi et al. 2025; Owusu, Kimengsi, and Giessen 2023). Fundamentally, neglecting human dimensions and contextual realities risks the failure of FLR initiatives (Desta et al. 2025; Gitonga and Likhoto 2025; Keddie et al. 2013; Mansourian et al. 2025). Yet the roles and influence of different actors on FLR outcomes remain understudied (Owusu, Kimengsi, and Giessen 2023).

This study investigates SC in Western Rwanda, a region characterized by numerous restoration projects and ambitious restoration goals. Our objective is to map SC levels within the context of RL initiatives in Western Rwanda. We ask: (1) Who are the key restoration actors in Western Rwanda? and (2) How strong are relationships of trust, collaboration, communication, and resource flow among restoration stakeholders? To identify restoration actors and analyze their interrelations based on resource flow, collaboration, communication, and trust, this research employed Net-Mapping. By understanding stakeholder interaction patterns, potential imbalances between actors are revealed, and societal aspects are better considered in restoration policies and practice. This study advances understanding of power dynamics in multistakeholder

restoration governance and contributes to debates on inclusive governance and related policies, offering insights for policymakers and practitioners in Rwanda and similar post-conflict contexts. It also highlights the value of integrating quantitative and qualitative narrative analysis when applying Net-Map.

Theoretical Framework

SC has gained prominence across disciplines to address societal challenges (Chan, To, and Chan 2006). In natural resource management, including biodiversity conservation and ecosystem restoration, SC is increasingly seen as a leverage point for long-term success (Cebrián-Piqueras et al. 2023). It plays a crucial role in promoting sustainable resource management by facilitating collective action and shared stewardship (Löhr et al. 2021). While Ostrom (2009) and Schiefer and Van der Noll (2017) argue that strong SC enhances the effectiveness of environmental initiatives by fostering cooperation, trust, and common goals among stakeholders, there is some empirical evidence that suggests otherwise in some contexts. Idrissou et al. (2011, 2013), for instance, indicate that cohesion does not necessarily guarantee sustainable resource management, as trust deficits can emerge and trigger conflicts among stakeholders. Cui et al. (2021) reveal that ecological restoration can still succeed even with limited community participation. Jeffery and Vira (2001, 15) conclude that participatory approaches, though valuable, are only one element of long-term solutions to resource degradation in developing countries.

Despite its growing prominence across disciplines, SC lacks a standard definition, with measurement varying across academic disciplines (Delhey, Dragolov, and Boehnke 2023; Walle 2022). Broadly speaking, SC is the “glue” that binds members of society together (Leininger et al. 2021). It is characterized by trust, a sense of inclusive identity, and a willingness to cooperate for the common good. Chan, To, and Chan (2006) distinguish between horizontal cohesion, which refers to relationships among individuals and groups within society, and vertical cohesion, which concerns the relationship between the state and its citizens or civil society. Specifically, horizontal level, this involves trust, cooperation, and shared identity among citizens (subjective) as well as social participation and civil society engagement (objective). The vertical level encompasses trust in institutions (subjective) and political participation (objective). For a society to be cohesive, both horizontal and vertical levels must be balanced (Leininger et al. 2021). In the context of restoration, it is key to look at both levels carefully as we assume a difference to exist with implications on implementation and future policies and practices.

Vertical and horizontal cohesion have distinct yet complementary impacts on societal relations (Chatterjee, Gassier, and Myint 2023; Kamatsiko 2021). Strong horizontal cohesion fosters community resilience, collective action, and a sense of belonging, which enhance social inclusion and cooperation, key to stability and problem-solving (Chan, To, and Chan 2006). Conversely, vertical cohesion strengthens governance by promoting legitimacy, trust in institutions, and compliance, reducing conflicts and encouraging civic engagement (Aall and Crocker 2019; Sisk 2020). When both are strong, societal relationships are marked by mutual trust within communities as well as between communities and the state. These dynamics foster grassroots belonging and empowerment while enhancing institutional accountability and responsiveness (Jenson 2010). Conversely, the absence of either level of cohesion can heighten divisions and inequalities, undermining

peace and development efforts (Sisk 2020). Adopting an inclusive approach to ecosystem restoration can enhance horizontal cohesion (Ullah 2024), whereas neglecting inclusivity and societal relations risks fostering conflict and unintended negative outcomes (Löhr et al. 2021). Exclusive restoration governance can lead to resistance, protests, and mistrust toward the state and restoration organizations, potentially provoking backlash against conservation authorities and undermining implementation and long-term restoration efforts (Kashwan 2013). Inadequate inclusive governance can fuel conflicts and mistrust among community members (Fox and Cundill 2018). However, communities may still exhibit a high degree of SC without being included in or benefiting from equitable decision-making processes (Holzer and Baird 2026). Despite the potential benefits that could be obtained by paying attention to SC in RL, few studies have empirically mapped cohesion dynamics in restoration contexts, particularly in SSA (Bayala 2024; Djenontin, Zulu, and Richardson 2022; Eilola et al. 2021; Nzyoka et al. 2021).

Landscape Degradation, Restoration, and Social Cohesion in Rwanda

Rwanda's history is marked by political instability, ethnic division, and civil war, which culminated in the 1994 genocide against the Tutsi. This tragedy stemmed from a complex interplay of factors, including colonial rule, the influence of international financial institutions and the international community, poor governance, and demographic pressure, all of which intertwined with landscape degradation. Belgium's colonial rule entrenched ethnic divisions by privileging Tutsis as "alien Hamites" and defining Hutus as indigenous Bantu, linking ethnicity to political and economic power. These policies laid the groundwork for subsequent conflict (Moodley, Gahima, and Munien 2011; Purdeková and Mwambari 2022), as disputes over land tenure and access increasingly became major sources of tension from 1959 onward (Musahara and Huggins 2005). Ethnic competition for power and resources fueled political instability, leading to successive coups, civil war, the 1994 genocide, and mass displacement. In addition, Melvern (2024, 11–12) highlights the role of global economic pressures, pervasive poverty, and Western indifference to the events of 1994. Similarly, Pottier (2002, 9) points to demographic pressures, including rapid population growth and exclusionary land governance, which left many people landless and vulnerable to manipulation. These conditions enabled elites to mobilize young people to commit violence against Tutsis and appropriate their land. Rothe, Mullins, and Sandstrom (2008) further argued that in postcolonial Rwanda, the International Monetary Fund and World Bank imposed structural adjustment policies, though not intended to cause harm, exacerbated fragile economic conditions and social instability, indirectly contributing to the environment that enabled genocide.

Following the issues mentioned above, post-genocide Rwanda has faced profound social and ecological challenges. The societal fabric remains marked by eroded trust among individuals and communities, alongside weakened norms and values that once sustained cooperation and collective action for the common good (Colletta and Cullen 2002). At the same time, the country's ecosystems have suffered extensive degradation due to habitat fragmentation during the civil war and genocide, overexploitation of natural resources, biodiversity loss, pollution, and the killing of endangered species (Kanyamibwa 1998; Ordway 2015). Refugees and militia settlements near protected areas further accelerated deforestation, with some regions losing up to two-thirds of

their historical vegetation cover (Kanyamibwa 1998), as seen in the loss of the Gishwati Forest (Clay 2019). Armed conflicts compounded these problems, leading to increased poaching, the loss of conservation personnel, and reduced funding for environmental protection (Plumptre et al. 2001). In response, Rwanda has committed to restoring 80% of its terrestrial land under the Bonn Challenge (Nash et al. 2020; Tuyizere et al. 2025). These restoration efforts engage a wide range of actors, including government institutions, civil society, NGOs, donors, bilateral organizations, and local communities (Buckingham et al. 2021; Frietsch et al. 2024). However, community members often report feeling unsupported, limited access to resources and information, and minimal private sector participation (Buckingham et al. 2021; Tuyizere et al. 2025).

Methods

Study Area

This study focused on the Rutsiro and Ngororero districts in western Rwanda, both mountainous areas. Although the 1994 genocide against the Tutsi affected the entire country, western Rwanda was particularly impacted. The region experienced refugee settlements and subsequent militia incursions from the DRC, which further destabilized communities, eroding trust and weakening social norms that once supported cooperation and collective action (Colletta and Cullen 2002; Kanyamibwa 1998). Refugees' reliance on local resources for firewood and food also intensified habitat fragmentation, biodiversity loss, deforestation, and land degradation (Clay 2019; Ordway 2015). Topographically, Rutsiro lies at an average elevation of 2,400 m and experiences heavy rainfall, while Ngororero, at about 1,500 m, is traversed by the Nyabarongo River. Both districts face severe erosion, with Rutsiro losing an estimated 41 million tons of soil annually, ranking third nationally, and Ngororero ranking second (Macháček 2020). They include parts of Gishwati–Mukura National Park, and residents depend primarily on subsistence agriculture and mining for their livelihoods. Rutsiro contains 3,706.5 ha of natural forest, whereas Ngororero covers 68,103 ha, 67% of which is used for agriculture. Demographic pressure and intensive land use (Frietsch et al. 2024; Ndayizeye et al. 2026) further compound restoration challenges in both districts.

Three villages were selected in each district (Figure 1): Shyembe, Rwamiyaga, and Gisunzu in Rutsiro District, and Kabuga, Kagarama, and Bereshi in Ngororero District. These villages were chosen because their communities are interconnected through restoration landscape projects led by the Albertine Rift Conservation Society (ARCOS) and Tubura, the two key international nongovernmental organizations (INGOs) involved in restoration. Furthermore, the six villages represent a diverse range of landscape restoration types, including broadly representative opportunities for community participation and benefits.

The Net-Map Tool

We applied the Net-Map methodology, an interview-based participatory social network mapping tool designed to visualize implicit knowledge and analyze the intricate interplay of formal and informal networks, power dynamics, and the goals of various actors

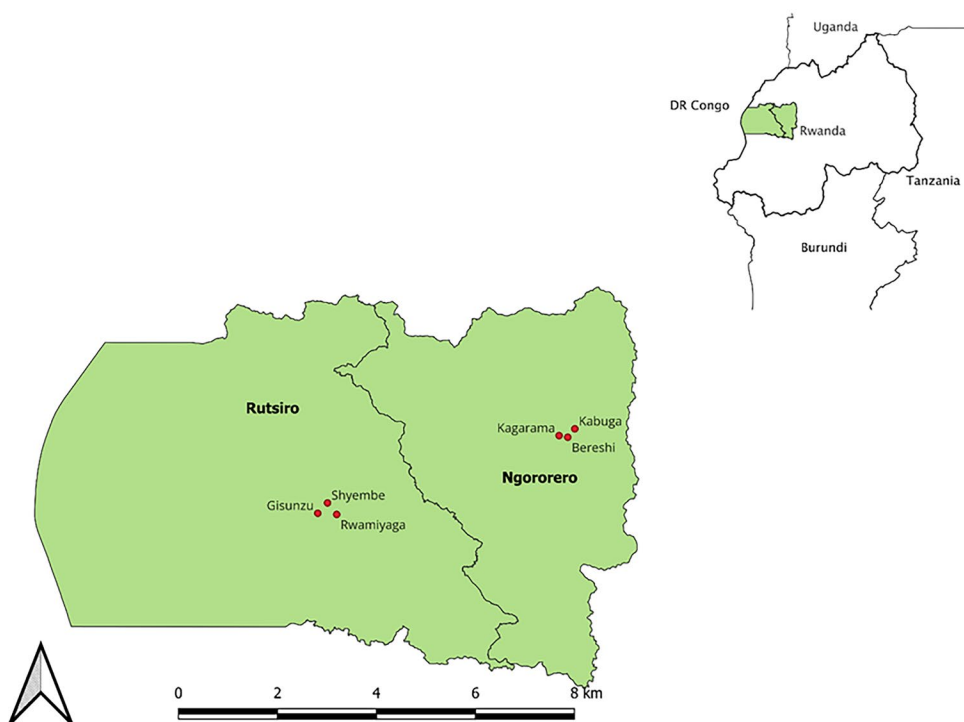


Figure 1. Map of Rwanda highlighting the six villages (red dots) selected for this study. Map produced by Valery Ndagijimana.

(Schiffer, Hauck, and Andreini 2002). Net-Map identifies sources of conflict and opportunities for collaboration, facilitates knowledge-sharing and learning processes, and helps develop shared visions and strategies to achieve common objectives (Schiffer and Hauck 2010). The tool illustrates how power, influence, and connections can impact outcomes. By employing Net-Map, stakeholders are identified, roles clarified, relationships evaluated, and levels of influence or support assessed. Net-Map generates both qualitative and quantitative data (Schröter et al. 2018), enhancing understanding by going beyond a purely structural approach to combine structural metrics with measures of actors' attributes, particularly regarding their perceived influence and goals (Hauck and Schiffer 2012).

Data Collection

Individual interviews and participatory workshops were combined within a mixed-method approach and conducted from 4 to 27 June 2024. Key interviewees were identified through snowball sampling, beginning with ARCOS and Tubura, the two leading restoration actors in the region, who helped identify other connected actors, including village heads. According to the Rwanda Governance Board (RGB) policy, every actor operating within a district is required to register with the district office to facilitate collaboration, access necessary support, and participate in the Joint Action Development Forum (JADF). Therefore, as part of our interview process, we interviewed the district

officials, which gave us the opportunity to ensure all key actors operating in the districts were mapped. Furthermore, village heads were also interviewed as they work closely with different actors who are active in their village and know all the farmer groups active in the selected areas. The village heads put us in contact with farmer group leads, and here we put an emphasis on making sure women were included among those they recommended.

In Rutsiro, 20 Net-Map interviews were conducted, including five women and 15 men. In Ngororero, 15 interviews were conducted, comprising three women and 12 men. Interviewees ranged from local stakeholders, including community members, government representatives, and companies, to international and local NGOs. Each interview lasted between 90 and 120 min and was recorded to support the creation of network maps. Ethical clearance was obtained beforehand, and before the interview process began, the terms and procedures were explained, with questions on data protection and confidentiality clarified.

In each interview, participants were first asked to write the names of actors involved in restoration within their villages on multi-colored cards. Each type of actor was assigned a specific card color: government actors on red, INGOs on light green, local nongovernmental organizations (NGOs) on dark green, farmers on blue, companies on yellow, donors on orange, and bilateral organizations on pink.

After all relevant actors were identified, participants arranged their cards on a flip chart to illustrate the relationships between them in the next step. Interviewees then drew links to represent various types of interactions between actors. A red arrow indicated resource flow, a blue arrow signified collaboration, a green arrow represented communication, and a black arrow depicted trust. Resource flow specifically emphasized knowledge sharing and funding, along with the provision of farming tools and tree seedlings.

The influence of various actors on restoration outcomes was evaluated based on their areas of expertise and authority, such as involvement in policymaking, the scale of restoration interventions, and financial contributions. Each interviewee was asked to identify the most significant actors within the network by allocating bottle caps as influence markers. The number of caps represented the strength of each actor's influence on restoration efforts, with more bottle caps indicating greater influence. Actors with no influence received no bottle caps. Next, the interviewee explained the source and extent of influence of the actor with the fewest bottle caps, as well as potential conflicts if two equally influential actors disagreed, particularly when their influence stemmed from similar grounds. Discussions also explored the nature of such conflicts and reasons for disparities in influence. Network maps were photographed for subsequent analysis.

After the Net-Map interviews, participatory one-day workshops were conducted in each village to validate the interview data and collaboratively map a common network for each district. Using the district's official list of actors, we invited both men and women through phone calls to the workshop through village heads. Participants included farmers (10), farmer group leaders (12), village heads (6), cell-level and district government extension officers (6), and NGO and companies' representatives (7). Village heads were also encouraged to nominate an additional female representative when farmer groups were led by men. In Rutsiro, the workshop included 21 male and

six female participants. In Ngororero, the workshop consisted of nine male and five female participants. Data was systematically recorded using audio devices, while key points were diligently noted. Following each workshop, we photographed the network maps (Supplementary Sample Network Maps).

Data Analysis

All audio files were manually transcribed, and notes were reviewed and written up for further data analysis. All transcripts were then translated from Kinyawanda to English for further processing in the team. However, as team members are fluent in both, it was always possible to get back to the original files in case of uncertainty. UCINET software was used to perform quantitative data analysis (Borgatti 2002), whereby first, we extracted all actors' names stated during the interviews and topologized them, differentiating: government actors, community actors in pink, international NGOs (INGOs), local NGOs, donors, bilateral organizations, and companies. Next, we analyzed key actors' positions within the network using centrality metrics, including degree, betweenness, closeness, and eigenvector centrality (Freeman 2002; Hawe, Webster, and Shiell 2004; Levkoe et al. 2021). Degree measures the number of connections an actor has, reflecting their activity or popularity. Betweenness captures an actor's role as a bridge or gatekeeper, identifying those in strategic positions to facilitate relationships and control resource flow in uneven collaborative networks. Closeness centrality reflects an actor's efficiency or independence in reaching others; actors with high closeness can rapidly disseminate information and are less reliant on others. Eigenvector centrality highlights actors connected to highly influential peers, identifying potential change-makers who can shape network dynamics. We also assessed overall network cohesion with a focus on network diameter, connectedness, compactness, fragmentation, breadth, k-core approach, network density, reachability, reciprocity, and transitivity (Borgatti et al. 2022). produced qualitative visualizations of the networks. Network visualization complements quantitative analysis by revealing patterns often overlooked by numerical methods (Borgatti et al. 2022, 120). By translating complex interactions into visual formats, network diagrams help diverse audiences grasp relational dynamics more intuitively (Tabassum et al. 2018). This approach makes findings accessible to stakeholders unfamiliar with network science (Freeman 2000). A network diagram consists of nodes representing actors and ties denoting relationships (Borgatti et al. 2009). Nodes were scaled by degree centrality, indicating the number of connections an actor has, while tie width reflects relationship strength. Actor categories are distinguished by color: government actors in red, community actors in pink, INGOs in green, local NGOs in grey, donors in burgundy, bilateral organizations in olive, and companies in orange. Tie direction and reciprocity were visualized, with nonreciprocal ties shown as red lines and reciprocal ties depicted with blue lines.

Interview data were further used for a better in-depth understanding of actors' relations and SC-restoration relations, using inductive qualitative content analysis in MAXQDA 2018. The transcript was carefully reviewed alongside field notes to gain familiarity with the data and identify key emerging ideas (Kalpokas and Hecker 2025). Subsequently, codes and sub-codes were developed that helped to systematize and analyze the data. Codes included: If codes turned out too similar, for example, limited

consultation and acceptance of top-down decisions, they were merged into a lack of participation in decision-making. Themes were then identified by clustering related codes and comparing data segments to ensure consistency and maintain grounding in the narratives (Mustika and Wardah 2021). The systematized data helped to better understand actors' maps, especially a deep understanding of the quality of actors' relations, such as examples of collaboration, conflicts, and measures that foster trust building. Illustrative quotes were selected to highlight participants' perspectives and to explain further patterns observed in the network maps. While we aimed for gender balance, gender-specific analysis was deemed unnecessary due to similar responses from the few female and male participants.

Results

Key Actors in Restoration Landscapes

Through Net-Map interviews, 51 actors were identified in Rutsiro and 40 in Ngororero (Table S1). These actors were grouped into seven categories: community organizations, government actors, companies, local and international NGOs, donors, and bilateral organizations. Government actors dominate both districts, with 15 in Rutsiro and 12 in Ngororero. Rutsiro has 12 INGOs compared to eight in Ngororero. Community organizations include four actors in Rutsiro and nine in Ngororero. Six bilateral organizations operate in Rutsiro and four in Ngororero. Rutsiro also has four donor actors and seven local NGOs, while Ngororero has two each. Finally, there are three companies in Rutsiro and one in Ngororero.

The diversity and types of actors across categories influence restoration efforts and stakeholder relationships. Rutsiro surpasses Ngororero in the number of government entities, INGOs, bilateral partners, and donors, reflecting greater investment, resource mobilization, accountability, and community engagement opportunities. This higher actor count also points to Rutsiro's stronger capacity to attract external support, enabling more diverse, well-funded, and innovative restoration approaches. Increased participation often accompanies actor diversity, suggesting strong potential for collaborative restoration in Rutsiro compared to Ngororero. In contrast, Ngororero's fewer actors indicate lower institutional capacity and weaker collective action, making resource mobilization more difficult. However, Ngororero's strength in community organizations highlights strong grassroots capacity and promising prospects for sustainable, locally driven restoration.

Key actors in both districts include government actors and INGOs. Community actors such as farmers and farmer groups also play crucial roles. This structure enables top-down resource and policy support, but gaps in communication and power asymmetries can marginalize community actors. Still, channels for bottom-up feedback allow communities to share successes and challenges. However, top-down approaches risk creating policy-practice gaps and community disengagement.

Each district also has distinct actors contributing uniquely to restoration success. In Rutsiro, academic institutions like the University of Rwanda (UR) and IPRC support local capacity through research and training, with student involvement promoting knowledge transfer in restoration. In Ngororero, organizations such as NUDOR and

NCDA emphasize social inclusion, which is vital for equitable restoration. Mapping revealed that community members largely recognized local actors but had limited awareness of broader restoration networks. Besides smallholders, government institutions working directly with farmers were the most visible at the local level.

In terms of influence, government actors, especially the districts emerged as the most prominent, followed by INGOs like ARCOS and Tubura, and then community actors, particularly farmers (Figure 2). The districts played key roles in implementing decentralized government initiatives, while RAB, REMA, and RFA acted as key facilitators. INGOs contributed critical resources, including seedlings and tools. Overall, influence mapping revealed strong top-down state control, which supports policy and funding alignment but limits adaptability to local needs, resulting in weaker vertical cohesion.

Relationships between Actors

Resource Control and Flow Patterns

In both districts, resource flow follows a top-down pattern, as shown in the network maps (Figure 3). Peripheral actors, such as donors and bilateral organizations, channel funds to intermediary actors, mainly government agencies and INGOs, which acted as facilitators. These intermediaries then distribute resources, primarily financial, to community members like farmers and farmer groups. Participants noted that central government institutions, including the Ministry of Environment (MoE) and the Ministry of Agriculture (MINAGRI), allocate funds either directly to districts or through agencies such as RFA and RAB. While these agencies work with districts and INGOs on restoration, their presence at the community level remains limited. INGOs often use their own extension groups to deliver resources and capacity-building directly to farmers.

Government actors scored highest in degree, closeness, eigenvector, and betweenness centrality (Tables 1 and 2), underscoring their pivotal role in securing and distributing resources. Community actors followed as key recipients for restoration implementation,

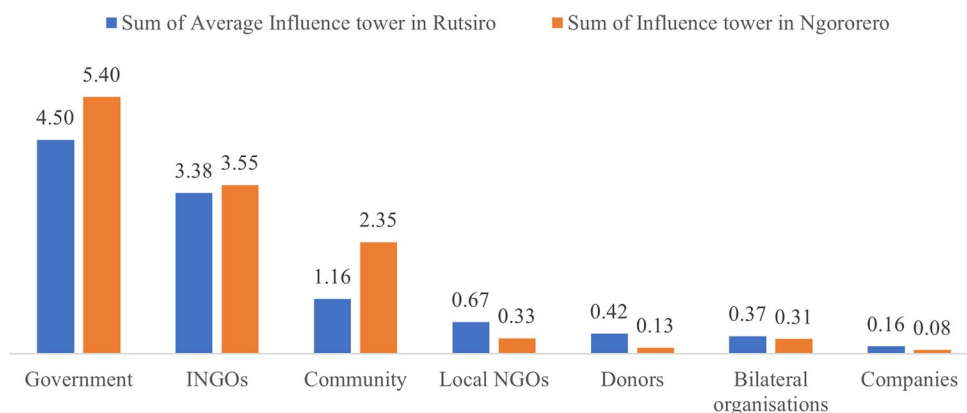


Figure 2. Average influence tower of actors in Rutsiro and Ngororero districts.

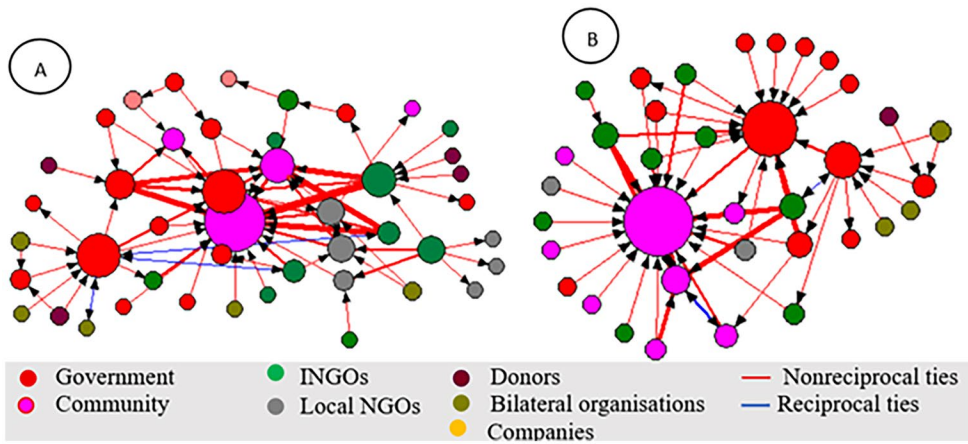


Figure 3. Resource networks map (A Rutsiro District, B Ngororero District).

while INGOs provided complementary funding and supported community-based efforts. Other actors primarily facilitated restoration activities.

In Rutsiro, government actors were the most influential, whereas in Ngororero, community actors played a more central role in resource networks. This decentralized structure in Ngororero facilitated rapid scaling of activities such as terracing but often lacked strong local ownership, risking sustainability once external support diminishes. Rutsiro's network was more cohesive, with a greater number of nodes (51), ties (79), and a higher K-core index (4), benefiting from substantial donor and bilateral funding that fostered stronger community cohesion. However, a high dependency sum (283) highlighted Rutsiro's reliance on external resources and centralized control. In contrast, Ngororero demonstrated greater self-reliance but faced limitations in attracting external funding, potentially missing opportunities for sustainable restoration. While donor engagement in Rutsiro enhanced capacity, poor coordination risked exclusion of local actors. Ngororero's self-reliant model promoted ownership but required broader resource access to sustain restoration outcomes.

Collaboration

Collaboration among restoration actors was evident, with Rutsiro exhibiting relatively higher levels than Ngororero as observed in actors' ties (Figure 4) and centrality scores (Tables 1 and 2). However, in both cases, ties between communities and government actors remained weak, indicating that horizontal cohesion outweighs vertical cohesion in both districts. Communities demonstrate stronger horizontal cohesion, stemming from farmer-to-farmer interactions and collaboration among farmer groups. Despite higher centrality scores (Tables 1 and 2) and dense connections among government actors, INGOs, and communities, which would suggest vertical cohesion, farmers expressed mixed perceptions of participation. While some felt represented by the district, others felt excluded from decision-making processes.

As one female farmer in Rutsiro explained, "Yes, we accept what the district proposes; they know what is best for us" (FGD1, June 2024). Conversely, a male farmer from Kabuga village, Ngororero district, remarked, "I do not think we have a say in what

Actors' relationships, and their centrality metrics

Actors' category	Factors relationships and trust: certainty metrics																	
	Resource flow						Collaboration						Communication					
	Degree	Closeness	Eigenvector	Betweenness	Degree	Closeness	Degree	Closeness	Eigenvector	Betweenness	Degree	Closeness	Degree	Closeness	Eigenvector	Betweenness	Degree	Closeness
Community	33	415	1.04	605.81	55	377	0.63	252.6	47	393	0.64	159.36	55	377	0.63	252.6		
Government	52	1667	1.74	534.65	160	1325	1.88	653.86	142	1423	2.15	807.73	160	1325	1.93	653.86		
INGOs	32	1169	1.01	457.86	124	1201	1.6	320.84	86	1179	1.48	190.83	124	1169	1.6	324.93		
Bilateral	7	670	0.26	0	32	670	0.44	4.11	10	720	0.24	0	32	670	0.44	4.11		
Donors	5	549	0.15	0	6	466	0.09	0	6	330	0.16	0	6	466	0.09	0		
Companies	3	320	0.04	2.67	13	331	0.1	2.87	9	308	0.2	0	13	331	0.1	2.87		
Local NGOs	18	790	0.54	199.03	46	674	0.58	111.73	42	689	0.76	138	46	674	0.55	111.73		

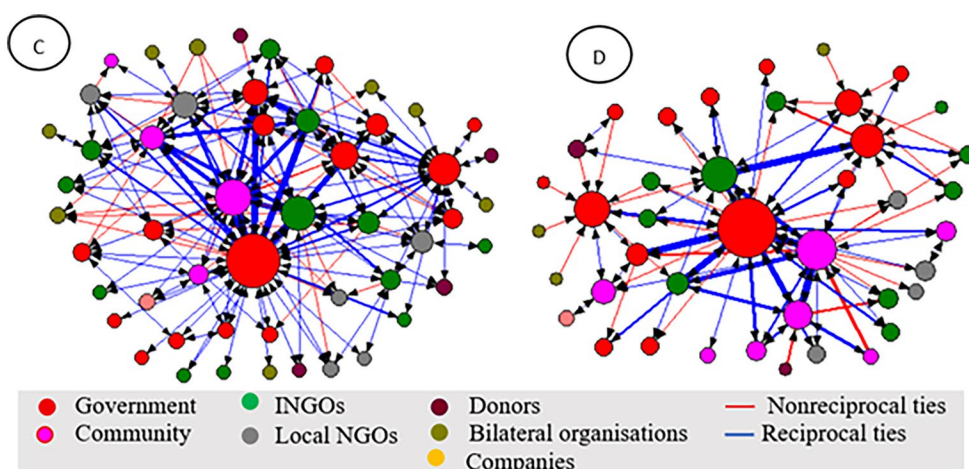


Figure 4. Collaboration networks map (C Rutsiro District, D Ngororero District).

is to be done; we just accept what we are requested to do by the district” (Individual interview 1, June 2024). A male district official stated: *“From my point of view, a simple farmer does not find himself in JADF”* (Individual interview 2, Rutsiro, June 2024). This shows that despite the official directory to include each actor group in the JADF, farmers were still not represented. This stands in stark contrast to the government’s core principles of promoting citizens’ involvement in development initiatives through enhanced community participation and inclusiveness, collaboration and partnership, and transparency (Table S2).

Communication

Communication among actors is largely top-down, reflecting weaker vertical cohesion and dominated by government actors who serve as key information hubs (Figure 5). Although communities exhibit horizontal connections, vertical governance arrangements restrict farmers to a largely passive role, functioning mainly as recipients of information from other stakeholders. Rutsiro exhibited more reciprocal ties and higher centrality scores than Ngororero (Tables 1 and 2). The dense community connections and higher centrality scores largely reflect instances of reporting back or requesting information, rather than actively shaping it. This pattern was also evident in interviews from Rutsiro. As one male farmer explained, *“I have the cell agronomist’s phone number, and I call her. For other restoration activities, I get information from my group lead farmer”* (Individual interview 8 in Rutsiro, June 2024).

Nationally, restoration actors exchange information through the Sector Working Group, and at the district level through JADF meetings, both of which exclude farmers. Subsequently, parent NGOs transmit information to their affiliated farmer groups. This farmer–NGO relationship shapes farmers’ understanding of restoration, aligning it with their respective NGOs’ core values (Table S3). For example, Tubura-affiliated groups view restoration through a business lens, emphasizing income generation. In contrast, ARCOS-affiliated self-governed groups focus on conservation, referring to themselves as *“friends of Nature.”*

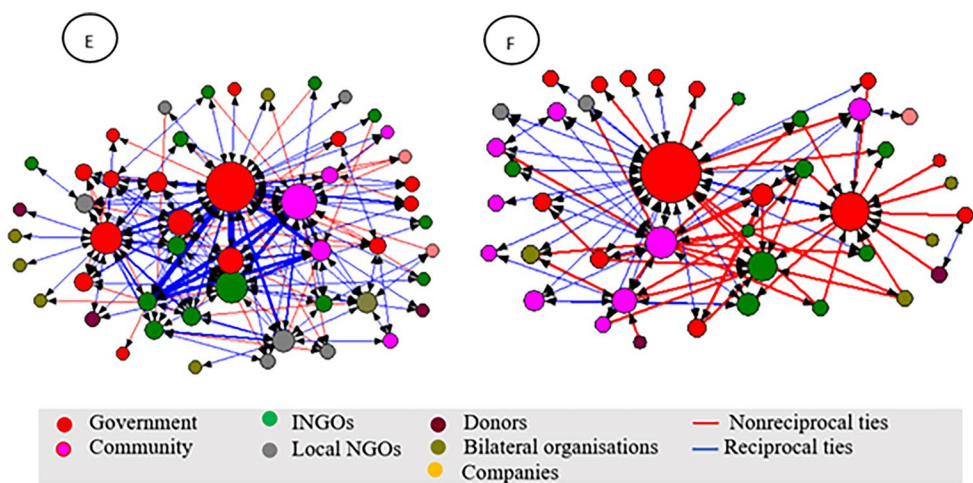


Figure 5. Communication networks map (E Rutsiro District, F Ngororero District).

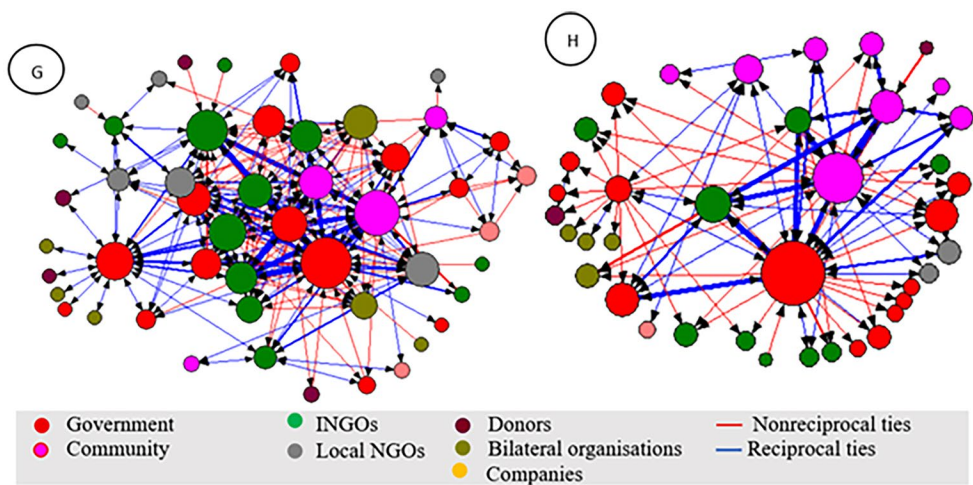


Figure 6. Trust networks map (G Rutsiro District, H Ngororero District).

Trust

Network actors established trust, with government actors, INGOs, and farmers benefiting the most. The network map (Figure 6) showed trust relationships among actors in both districts. In Rutsiro, the district actor overlaps significantly with farmers, indicating a strong connection. The district is the most connected actor, followed closely by farmers. Reciprocal ties in Rutsiro highlight mutual trust among actors. In Ngororero, farmers are the most trusted, also with reciprocal ties. Both districts have established trust among diverse actors, including donors, to secure resources. A male official from Ngororero District noted, “Any organization operating in this district, its presence equates to trust in our district” (Individual interview 1 in Ngororero, June 2024). Nevertheless, Rutsiro’s cohesive network shows more actor diversity and interaction than the fragmented structure of Ngororero network (Tables 1 and 2). Again,

while Rutsiro's network reflects horizontal cohesion among farmers, Ngororero's larger number of community actors, particularly farmer groups, indicates a more interactive grassroots network and greater social trust. In terms of centrality, government actors in Rutsiro recorded the highest scores, positioning them as the most trusted and influential in restoration, reflecting a centralized trust structure. In Ngororero, government actors ranked highest in closeness and betweenness centrality, underscoring the trust placed in them to connect actors and facilitate information flow across the network. Lastly, the higher degree and eigenvector scores of community actors demonstrate the trust they command from many other actors, including key stakeholders such as NGOs.

Overall Network Cohesion

When assessing the overall network (Table 3), Rutsiro demonstrates strong SC, marked by balanced influence, high connectivity, and significant reciprocity, fostering collaboration. In contrast, Ngororero's network is fragmented and reliant on a few key actors, resulting in weaker cohesion and limited resource flow. This suggests Rutsiro is more diverse and supportive of sustainable restoration, while Ngororero risks inequitable, short-term outcomes. Rutsiro exhibits high density across resource, collaboration, communication, and trust ties, enhancing cohesion and facilitating resource and

Table 3. Social cohesion in Rutsiro and Ngororero explained by network-level statistics.

District	Rutsiro and Ngororero							
	Resource		Collaboration		Communication		Trust	
Network-level statistics								
# Of nodes	51	40	51	40	51	40	51	40
# Of ties	79	56	347	56	301	139	347	122
Avg degree	1.549	1.4	6.804	1.4	5.902	3.475	6.804	3.05
Indeg H-index	4	4	11	4	9	5	11	6
K-core index	4	3	12	3	7	4	12	4
Deg centralization	0.334	0.521	0.467	0.521	0.714	0.722	0.467	0.619
Out-centralization	0.132	0.095	0.412	0.095	0.675	0.698	0.412	0.604
In-centralization	0.356	0.542	0.432	0.542	0.634	0.645	0.432	0.341
Indeg Corr	0.217	0.388	0.104	0.388	0.41	0.542	0.104	0.377
Outdeg Corr	0.133	0.112	0.06	0.112	0.396	0.565	0.06	0.441
Density	0.031	0.036	0.136	0.036	0.118	0.089	0.136	0.078
Components	47	38	9	38	4	8	9	17
Largest component	4	2	43	2	48	32	43	23
Component ratio	0.92	0.949	0.16	0.949	0.06	0.179	0.16	0.41
Connectedness	0.106	0.1	0.811	0.1	0.922	0.809	0.811	0.556
Fragmentation	0.894	0.9	0.189	0.9	0.078	0.191	0.189	0.444
Transitivity/closure	0.243	0.222	0.54	0.222	0.337	0.198	0.54	0.252
Avg distance	2.048	1.885	2.213	1.885	2.115	2.124	2.213	2.232
Prop within 3	0.099	0.097	0.785	0.097	0.912	0.799	0.785	0.541
SD distance	0.87	0.808	0.757	0.808	0.617	0.594	0.757	0.716
Diameter	4	4	5	4	4	4	5	4
Wiener index	553	294	4578	294	4974	2681	4578	1935
Dependency sum	283	138	2509	138	2622	1419	2509	1068
Breadth	0.937	0.936	0.575	0.936	0.516	0.582	0.575	0.716
Compactness	0.063	0.064	0.425	0.064	0.484	0.418	0.425	0.284
Mutuals	0.003	0.003	0.101	0.003	0.102	0.069	0.101	0.053
Asymmetrics	0.056	0.067	0.07	0.067	0.032	0.04	0.07	0.051
Nulls	0.941	0.931	0.829	0.931	0.866	0.891	0.829	0.896
Arc reciprocity	0.101	0.071	0.744	0.071	0.864	0.777	0.744	0.672
Dyad reciprocity	0.053	0.037	0.592	0.037	0.76	0.635	0.592	0.506

information flow. Many actors are interconnected, directly or indirectly. Balanced centralization promotes shared roles and reduces dependency. A high K-core index (12) for collaboration highlights a strong core of mutual support.

Low fragmentation in Rutsiro's collaboration and trust networks indicates a well-connected system. High transitivity in collaboration ties fosters trust and resilience. High reciprocity reflects balanced exchanges and shared goals. Conversely, Ngororero shows low density across all ties, limiting connectivity and flow. Low connectedness results in isolated clusters. High centralization in communication ties creates vulnerabilities. A lower K-core index reflects fewer tightly connected groups, weakening resilience. High fragmentation and low largest component ratios further restrict communication and collaboration. Low transitivity and reciprocity reduce trust and collective engagement.

In summary, based on the network-level statistics, the Rutsiro network appears more cohesive than the Ngororero network. Consequently, the Rutsiro network is more effective in facilitating resource flow, collaboration, information exchange, and trust among local actors. However, the higher centrality scores of government actors in both networks indicate weaker vertical cohesion, reflecting limited integration between local communities and higher-level institutions. Overall, both cases reveal the predominance of top-down governance approaches in the restoration systems of the two districts, underscoring the limited integration of local perspectives in decision-making.

Discussion

Patterns of Weaker Vertical and Stronger Horizontal Cohesion

Our findings revealed stronger horizontal than vertical cohesion in landscape restoration across both districts, spanning resource flow, collaboration, communication, and trust. Governance remained top-down, shaped by power hierarchies, with government and INGOs dominating. The community had limited influence except within Rutsiro's trust network. Many NGOs have established farmer groups through which they implement their restoration activities. This approach not only facilitates restoration initiatives but also strengthens social ties among community members. As Sentama (2017) observed, community members who were once antagonistic are unlikely to collaborate effectively unless their relationships are restored or strengthened. The role of community-based restoration in strengthening horizontal cohesion is further supported by Ullah (2024), who found that community participation in the forest landscape approach enhanced SC among participants.

The weaker vertical cohesion can be potentially explained by the absence of effective restoration governance and policy incoherence. Van Oosten, Uzamukunda, and Runhaar (2018) noted that while Rwanda has made ambitious land restoration pledges, implementation has remained highly centralized and often conflicts with agricultural policies. The rapid enforcement of the Land Law and agricultural specialization policies has destabilized subsistence farmers' livelihoods by promoting monocropping and increasing market dependence. At the same time, beyond these substantive conflicts, a procedural conflict has also been noted, limited space for incorporating local experience, which

has led to frustration among farmers (Uzamukunda 2016). Many farmers view restoration as a government duty and feel excluded from programme design and decision-making (Van Oosten, Uzamukunda, and Runhaar 2018). Although national policies promote community participation (Protik et al. 2018), such involvement remained largely procedural, with little substantive engagement in planning or priority setting (Umuziranenge 2019). Some farmers have also lost land to restoration activities, while others expressed dissatisfaction with the tree species chosen for restoration (Van Oosten, Uzamukunda, and Runhaar 2018). Buckingham et al. (2021) stressed the mismatches between national policy goals and community needs, compounded by farmers' limited access to restoration information. As a result, farmers often view NGOs, despite their temporary presence, as more reliable and collaborative than government institutions.

Implications for Policy and Practice

For restoration efforts to be sustainable, vertical and horizontal cohesion must both be balanced, as they influence restoration outcomes in different ways, and misalignment between them can undermine intended goals and long-term success. Vertical cohesion strengthens linkages across governance levels, promoting legitimacy, compliance, trust, and conflict reduction, key factors for effective and accountable restoration governance (Aall and Crocker 2019; Sisk 2020). Likewise, when restoration is inclusive, relationships between communities and policymakers are strengthened, which promotes the scaling up of restoration efforts (Holl 2017), enhances effectiveness, and is vital for achieving sustainable and locally owned outcomes (Löfqvist et al. 2023). In contrast, Verling et al. (2025) argue that top-down restoration initiatives that exclude community participation risk creating a disconnect between decision-makers and local stakeholders, undermining the success and legitimacy of restoration efforts. Browne (2013) similarly notes that overly top-down approaches, reflecting weak vertical cohesion, can stifle democratic engagement and erode grassroots connections. Such systems often exclude certain groups, fostering inequities and conflicts (Nat 2000), while power imbalances exploit vulnerable communities and marginalize local voices (Kamatsiko 2021). Excluding communities from development initiatives can also provoke resistance, weaken implementation, and jeopardize long-term sustainability goals (Kashwan 2013; King 2013).

Horizontal cohesion fosters social ties, solidarity, shared identity, trust, reciprocity, and cooperation, which enhance collective action and knowledge exchange (Kamatsiko 2021; Nunan et al. 2018). This, in turn, supports socially inclusive, sustainable, and locally owned restoration outcomes, leading to lasting socioecological impacts across landscapes (Favretto et al. 2022). Horizontal cohesion also sustains social memory during times of change, provides buffering capacity in cases of loss, and reinforces a sense of belonging that underpins collective resilience (Bodin, Crona, and Ernstson 2006). In contexts such as Rwanda, where local ecological knowledge of native species and their management has diminished, strong horizontal cohesion enables intergenerational knowledge sharing, helping to preserve and integrate traditional ecological practices into contemporary restoration strategies. Thus, horizontal cohesion provides a valuable foundation for restoration practitioners to build upon restoration initiatives.

Building on the above, policymakers must ensure that smallholders are effectively represented in decision-making processes to achieve sustainable and long-term restoration success (Fox and Cundill 2018). This should include their active participation in national and district platforms such as the JADF. Drawing inspiration from Rwanda's gender policy, which mandates women's representation in governance (Burnet 2011), a similar framework should guarantee farmer representation across all restoration forums. However, since representation does not necessarily translate into influence (Burnet 2008), we argue that practitioners place greater emphasis on empowering farmers through targeted training and capacity building for both farmers and farmer group leaders. Such efforts should strengthen their ability to renegotiate their rights and actively influence decisions, both in reclaiming representation and once included in decision-making platforms, thereby enhancing local actors' negotiation power. Capacity building should also prioritize trust-building, effective communication, and collaboration between farmers and government actors (Leventon et al. 2019). Once empowered, farmers can advocate for addressing power imbalances and improving their access to resources and information, as recommended by Buckingham et al. (2021), while also effectively influencing other restoration-related policies. Sylvère and Emmanuel (2017) also proposed establishing a coordination body to reduce state dominance and improve community and NGOs' access to resources. We further emphasize the need to introduce and reinforce accountability mechanisms to ensure that governments promote legitimate, participatory restoration programs (Loos et al. 2024). These changes can transform degraded landscapes (declined in health and functionality) into sustainable systems that balance ecological, social, and economic needs. Ultimately, practitioners should build on existing trust and solidarity within communities and invest in farmer-to-farmer exchanges and demonstration plots that incorporate traditional practices to ensure sustainable, long-term restoration outcomes. Such peer learning fosters local innovation, enhances community engagement, and helps preserve traditional knowledge (Borowski 2010; Kueper, Sagor, and Becker 2013; Schusler, Decker, and Pfeffer 2003).

Study Contribution, Limitations, and Future Research Directions

This study contributes to understanding power relations in a multistakeholder restoration governance by highlighting the value of combining narrative and quantitative analyses when using Net-Map to map SC levels among restoration actors. It further contributes to the existing literature on ongoing power dynamics and inclusive restoration governance, as well as to related policy debates, offering valuable insights for policymakers and practitioners in Rwanda and other similar post-conflict contexts. However, our findings reflect the context of Rwanda's restoration governance and the methodology used and should thus be generalized to other similar contexts with caution. It is important to note that although Net-Map is a valuable tool for visualizing social networks, it relies heavily on participants' subjective perceptions. This reliance can introduce bias, as individuals may overlook or misinterpret connections (Schiffer and Hauck 2010) or lack a full understanding of broader network structures (Schröter et al. 2018). Careful interpretation of Net-Map data is therefore essential. Furthermore, given the limited sample size and diversity of participants, particularly limited number of key government actors

such as RGB and marginalized groups such as women, repeating the exercise with a broader range of stakeholders across different provinces and with balanced representation, or replicating it in a similar country context, would help reveal policy gaps and practices underlying existing power imbalances. Further research is also needed on how to design effective capacity-building initiatives that empower communities to renegotiate their inclusion in restoration governance and to identify mechanisms through which governments can better align local needs with policy design for sustainable, long-term restoration outcomes. Ultimately, balancing horizontal and vertical cohesion is essential for achieving Rwanda's ambitious restoration goals and for advancing similar efforts in other contexts.

Conclusion

This study mapped key actors in Western Rwanda's restoration landscapes and empirically analyzed cohesion dynamics, an often-overlooked dimension of restoration initiatives. Our study found higher trust, collaboration, and communication within restoration communities, in contrast to weaker social relationships between communities and government actors. For practitioners, the observed strong horizontal cohesion highlights the value of approaches that build trust, solidarity, knowledge exchange, and mutual support among community members, conditions essential for scaling up restoration and sustaining collective action. At the same time, it also creates close attention to questions of power and negotiation capacity in order to facilitate more just and equal participation by diverse actors. Here, tools such as Net-Map can help to identify not only actors but also learn about actors' (power) relations. For policymakers, the weaker social relationships point to the need for genuine community participation in policy design so that local priorities are balanced with national restoration goals. Policies that ensure quotas for farmers in decision-making platforms, gender inclusive strategies, and an empowered community to influence restoration decisions are vital to transforming landscape restoration not only at the ecological but also social scale.

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Ethical Approval

Ethical approval was granted through the research permit, which was issued by the National Council of Science and Technology of Rwanda (NCST). All participants provided written informed consent before participating in the study.

Author Contributions

CRedit: **Valery Ndagijimana**: Conceptualization, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing; **Barbara Schröter**: Methodology,

Writing – review & editing; **Apollinaire William**: Investigation, Validation, Writing – review & editing; **Jacqueline Loos**: Writing – review & editing; **Stefan Sieber**: Supervision, Writing – review & editing; **Joern Fischer**: Supervision, Writing – review & editing. **Katharina Löhr**: Conceptualization, methodology, supervision, validation, Writing - review, and editing, funding acquisition, project management.

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