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RESEARCH ARTICLE

Ecosystem services provision through nature-based solutions: A sustainable development pathway to environmental stewardship as evidenced in the Protecting Lake Hawassa Partnership in Ethiopia

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Abstract

The imperative to foster environmental stewardship amidst escalating challenges has driven the adoption of nature-based solutions (NBS) for landscape restoration. This paper explores the implementation and impacts of ecohydrological NBS interventions within the context of sustainable development, focusing on restoring locally valued ecosystem services and catalyzing environmental stewardship to drive environmental, economic, and social sustainability. It posits that if development interventions effectively deliver ecosystem services valuable to stakeholders, impacted communities are likely to support local environmental protection. Ethiopia's Protecting Lake Hawassa Partnership (PLHP) employed a participatory approach guided by the Natural Resources Risk and Action Framework (NRAF) to engage a diverse network of local stakeholders in restoring and protecting the watershed. Implemented ecohydrological NBS enhanced ecosystem functionality in targeted hillslopes, gullies, and degraded farmlands. Multiple ecosystem services addressing soil erosion, water scarcity, and agricultural productivity were delivered, including productivity enhancement, flood regulation, land preservation, co-benefits from plantation, and moisture conservation. Landscape Functionality Analysis (LFA) revealed significant improvements in ecosystem stability, infiltration, and nutrient cycling. Qualitative assessments of the communities' perception of ecosystem services emphasized the importance of aligning development project outcomes with local needs. Results underscored the robust nexus between NBS, ecosystem services, and environmental stewardship, highlighting the role of perceived benefits in fostering community engagement. The study advocates that environmental management practices, including NBS, which tangibly improve ecosystem services prioritized by local communities, drive stewardship and, therefore, the long-term sustainability of improved environmental protection. Further research is warranted to explore the scalability and cost-effectiveness of NBS interventions in diverse socioeconomic contexts, and to enhance understanding of trade-offs and synergies between economic development, ecological conservation, and social equity in development projects.

Keywords Ecohydrology · Nature-based solutions · Ecosystem services · Environmental stewardship · Landscape restoration

1 Introduction: Environmental challenges in the Anthropocene - Reconciling human activities and natural systems

The contemporary Anthropocene era is characterized by discord between human activities and natural systems, exacerbating environmental challenges linked to sustainable development (Sookram 2013, p. 1). Escalating human activities pose threats of abrupt and potentially irreversible environmental transformations, jeopardizing ecological services crucial for economic activities, human health, and significant cultural and spiritual value. The global ecological footprint, now estimated at 1.75, highlights humanity's

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unsustainable demands on Earth's ecosystems, indicating a looming tipping point (Steffen et al. 2015, p. 736). To reverse this trajectory, urgent action is required to (re)establish harmonious relationships with nature (Buergelt and Paton 2018, p. 201). Society must acknowledge its role as steward of the planet, irrespective of individual preferences or motivations (Sanderson et al. 2022, p. 902). Many societies struggle to harmonize with the natural world (Bradshaw et al. 2021), leading to ecosystem degradation, loss of ecosystem services, and hindering the transition to sustainable pathways. A failure to grasp fundamental ecosystem characteristics (Lorimer 2012, p. 601) and adequately consider the socioeconomic dimensions (Sanborn and Jung 2021, p. 6) of ecosystem degradation further impedes efforts. Harmonizing human–environment interactions is crucial in achieving sustainable development goals, especially amid challenges like climate instability, biodiversity loss, heightened poverty, and inequality, which undermine development achievements (IPBES 2019; WWF 2020). Rural communities in developing countries face heightened vulnerability to ecological shifts due to their direct reliance on ecosystems and their services (Suich et al. 2015).

1.1 Defining environmental stewardship and its potential for local empowerment

There are significant opportunities to deepen our understanding of socio-ecological system structures, interactions, and dynamics (Messerli et al. 2019; Scholz and Binder 2011). Environmental stewardship, defined by Bennett et al. (2018, p. 606) as proactive earth-keeping and responsibility for environmental protection and preservation, is crucial for achieving sustainability (Steffen et al. 2011; Preiser et al. 2017). Though dynamic as a concept (Turnbull et al. 2020), environmental stewardship, as an action-oriented framework, promotes socio-ecological sustainability (Chapin et al. 2010) and signifies a shift in resource management philosophy from reactive responses to proactive governance that guides change toward sustainability and anticipates future challenges (Chapin et al. 2009).

Environmental stewardship is emerging as a pivotal approach, promoting enhanced human–environment interactions and catalyzing improved environmental management and social welfare (Díaz et al. 2015). Given the urgent need to foster a proactive and positive human-nature relationship (Bennett et al. 2018), stewardship serves as a valuable mechanism for achieving this objective among local actors, reconnecting individuals with nature and fostering resilience within socio-ecological systems (Preiser et al. 2017, p. 84). Enhancing stewardship within communities requires understanding how to create incentives that effectively engage diverse community members with sometimes conflicting perceptions and priorities (Coley et al. 2021, p. 3), encompassing moral considerations (Gill 2014, p. 267), values (Szucs et al. 2009), practices (Pant et al. 2004), services (Penker et al. 2013, p. 55), and outcomes (Plummer et al. 2008, p. 56).

1.2 Understanding stewardship dynamics and motivations

Recent research highlights the potential virtuous feedback-loop of stewardship (Richards et al. 2022). Understanding stewardship dynamics involves examining the individuals or groups initiating and propelling local stewardship initiatives (Sayles and Baggio 2017). Stewardship hinges on intrinsic factors, such as worldview, values, and beliefs (Worrell and Appleby 2000), and extrinsic factors including goals, perceived benefits, and outcomes (Bennett et al. 2018), as well as the capacity to take action (Bennett et al. 2018, p. 606). In developing countries, where environmental projects often target rural communities characterized by low incomes, multidimensional poverty, and high rates of ecosystem degradation, understanding the motivating factors and capacity for environmental stewardship is of paramount importance. Understanding the unique intrinsic and extrinsic factors of these communities is crucial for designing contextually relevant solutions that address specific socioeconomic concerns and foster buy-in and positive impact (Richards and Gutierrez-Arellano 2022, p. 609).

1.3 Case study: The Protecting Lake Hawassa Partnership

Ecosystem services form the ecological foundation of environmental stewardship (Chapin 2017), thriving where people feel connected to nature (Lokocz et al. 2011). Community awareness and perceptions of ecosystem services significantly influence attitudes and behaviors toward environmental stewardship (Willock et al. 1999). This paper argues that aligning incentives with solutions motivates stewardship (Chapin III et al. 2011), and conversely, that ecosystem services crucially drive community engagement in environmental protection (Langemeyer et al. 2018). It contextualizes environmental stewardship as grassroots efforts by local communities and resource users to sustain their immediate environment. Conducted under the framework of the GIZ Natural Resources Stewardship program (GIZ-NatuReS) since 2017, this study illustrates the iterative relationship between community engagement in nature-based solutions (NBS) implementation and enhanced stewardship within the

Lake Hawassa catchment through the examination of the case of the Protecting Lake Hawassa Partnership (PLHP) in Ethiopia.

1.4 Hypothesis and assumptions

The study argues (see Fig. 1) that ecohydrological NBS effectively deliver ecosystem services, thereby enhancing stakeholder engagement in natural resource stewardship. The hypothesis asserts that NBS for landscape restoration, particularly ecohydrological practices in the Lake Hawassa Catchment, strengthen or restore ecosystem services (*Outcome 1*), and foster environmental stewardship *(Outcome 2*). We name the conceptual framework highlighting these interlinkages the "landscape-ecosystem services-stewardship nexus" (see Fig. 1). The paper posits that initiatives generating multiple ecosystem services are more likely to increase stewardship of natural resources. Assumptions include the trust-building capacity of NBS among partners and communities through collaborative environmental efforts, and the comparative effectiveness of NBS over mechanistic solutions in promoting stewardship.

2 Methodology

2.1 The case study area

The Lake Hawassa catchment covers an area of 143,651 hectares situated in the central North-East region of the Ethiopian Rift Valley Basin (see Fig. 2). It encompasses five sub-catchments: Dorebafena-Shamena, Wedesa-Kerama, TikurWuha, Lalima-Wendo Kosha, and Shashemene-Toga. The geographical coordinates of the sub-basin range from 6°45' to 7°15'N latitude and from 38°15' to 38°45'E longitude.

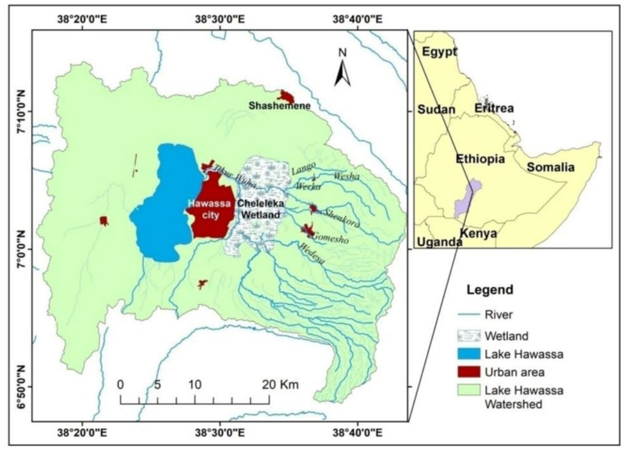


Fig. 2 Location of the study area (*Source*: Degife et al. 2021)

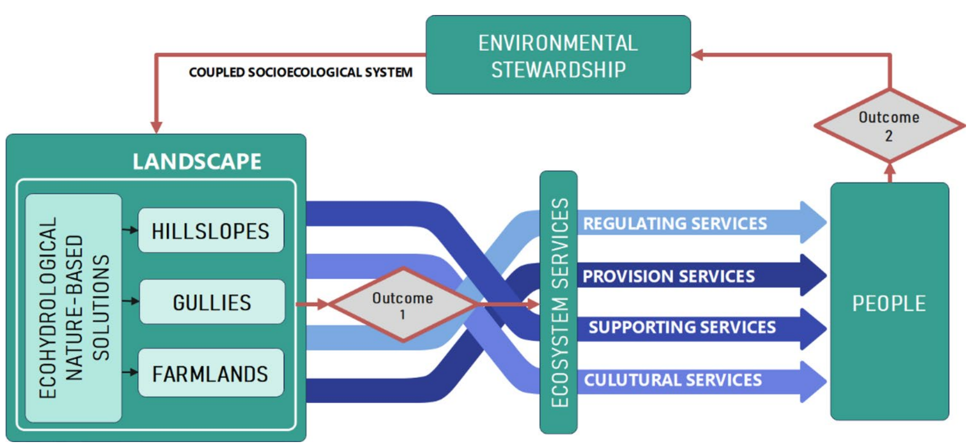
2.2 Protecting Lake Hawassa Partnership (PLHP)

The PLHP is a comprehensive, multi-stakeholder collaboration established in 2017 and facilitated by the GIZ-NatuReS program. Its primary objective is to enhance water security for residents, businesses, and the environment in Hawassa, encompassing both the lake and its sub-catchment area. This partnership brings together private, public, and civil society organizations to enhance water security for the communities and businesses situated around Lake Hawassa by collectively addressing shared risks associated with natural resources (see Eiblmeier 2023, p.2).

2.3 NRAF methodology and implementation

To effectively involve the community in conceiving, assessing, planning, executing, and managing activities aimed at protecting Lake Hawassa, the project adopted the Natural Resources Risk and Action Framework (NRAF) (Cáceres and Fernández 2021). The PLHP case study adhered to the

Fig. 1 Conceptual framework for landscape-ecosystem services-stewardship nexus



NRAF methodology in both the creation and execution of its stewardship partnership.

The NRAF methodology comprises five phases: prepare, assess, commit, act, and scale & exit (see Fig. 3). Practical tools facilitate each stage of partnership creation and execution (see Table 1). The framework includes 27 tools designed to guide a stewardship initiative from preparation to conclusion. Utilizing the NRAF process, stakeholders engaged in stewardship activities across the framework's five phases, informing the data collection methodology employed for this study.

2.4 Ecohydrological nature-based solutions

Ecohydrological NBS for landscape restoration emerged as a significant initiative within the PLHP, following a participatory and multi-sectoral methodology. Approximately 50 active partners from civil society, private entities, and public actors engaged in this process, facilitated by the NRAF framework and its associated tools. The project's design and implementation involved collaborative efforts with Hawassa University, the Ministry of Water and Energy, and GIZ-NatuReS.

Two primary areas of interventions for ecohydrological NBS are briefly outlined below:

2.4.1 Hillslope and gully resource conservation

As noted by Belete (2023, p. 71), the fundamental resource-conserving attributes of hillslopes are linked to a 'source' and 'sink' system (see Fig. 4), which regulates the flow of water and energy across landscapes. This system transfers water and sediments from bare source areas to vegetated patches known as sinks. This process maximizes resource utilization, leading to pulses of enhanced vegetation growth and increasing the capacity of these patches to capture surface resource fluxes, thereby promoting water and soil conservation at the landscape level (Schlesinger et al. 1990, p. 1044). Implemented in the study area, this system provided multiple ecosystem services.

2.4.2 Agro-ecosystem water management

Agro-ecosystems provide and rely on essential ecosystem services (Zhang et al. 2007, p. 254). Among these services, the availability of water, in terms of both quantity and quality, is crucial for agriculture. In most natural ecosystems and rain-fed agroecosystems, vegetation and food production rely on green water from soil moisture (Falkenmark and Rockström 2004). This study implemented an ecohydrology-based overland flow regulating system (see Fig. 5) (Belete 2022, p. 98) in farmlands to provide multiple ecosystem services including increased water availability and nutrient retention.

2.4.3 Landscape Functionality Analysis (LFA): Monitoring the bio-physical impact of the NBS

Monitoring landscape's capacity to capture and regulate critical resources is essential for assessing its progress toward self-sufficiency and functional efficacy. However, many restoration programs lack adequate monitoring systems (Machmer and Steeger 2002). Responding to the global need for cost-effective research and monitoring tools (Read et al. 2016), this study applied landscape functionality theory and the associated Landscape Functionality Analysis (LFA) methodology developed by Tongway and Hindley (2004). Three functionality parameters—stability, infiltration, and nutrient cycling—serve as surrogates for ecohydrological function and ecosystem function (Maestre and Cortina 2004, p. 495). The LFA methodology facilitates calculation of landscape functionality using a prescribed spreadsheet. These parameters were derived from 11 field indicators (see Table 2 and Fig. 6).

Fig. 3 Natural Resources Risk and Action Framework (*Source*: adapted from Cáceres and Fernández 2021, p.20)

Table 1 The NRAF tools (*Source*: compiled from Cáceres and Fernández 2021)

	The NRAF tools	Purpose of the tool
Phase 1: Prepare	1 Stakeholder analysis	Identifying key players and all other partners to be considered to make the partnership a success
	2 Market scan tool	Identifying relevant companies with natural resources-intensive business, including their natural resources risks and locations, and planning for their engagement
	3 Determine stakeholder representation	Building legitimacy and credibility, and avoid conflicts and capture through balanced stakeholder engagement
	4 Participants due diligence investigation	Identifying potential past unethical behavior by any participant, in order to determine proper next steps and avoid conflicts
	5 Problem butterfly	Providing an overview of your risks, including an analysis of their causes, effects and affected groups
	6 Value proposition	Demonstrating which benefits the partnership provides to different stakeholders and how it performs uniquely well
	7 Partnership Action Plan	Mapping the major steps/activities for the partnership to achieve its desired outcomes, including the required resources to implement them
	8 Assign suitable roles and responsibilities	Ensuring the right people are performing the correct roles in a partnership, and no person or organization is given a role that might lead to conflicts of interests or illicit practice
	9 Letter of intent	Formalizing the general objectives of the partnership and express a convergence of will among them
Phase 2: Assess	10 Risks and opportunities assessment	Identifying the typical damages resulting from impacts on natural resources in the area as well as identifying of opportunities
	11 Assessment on risk of capture	Identifying red flags in the partnership and mitigate
	12 Cost–benefit analysis	Determining the socioeconomic feasibility of the planned interventions
	13 Checklist of potential beneficiaries	Compiling an inventory of groups affected by natural resources risks that could benefit from measures and projects to reduce these risks
	2 Market scan tool	Identifying stewards and plan for their engagement
	4 Participants due diligence investigation	Identifying potential past unethical behavior by any participant, in order to determine proper next steps and avoid conflicts
	5 Problem butterfly	Providing an overview of risks, including an analysis of their causes, effects and affected groups
	6 Value Proposition	Demonstrating what benefits partnership will provide to different stakeholders and how it will be performed uniquely well
	7 Partnership Action Plan	Mapping the major steps/activities for the partnership to achieve its desired outcomes, including the required resources to implement them
Phase 3: Commit	14 Business concept	Enabling partners understand and appreciate the importance of the partnership, especially as in how it generates benefits
	15 Business case	Estimating and analyzing so that the financial feasibility of the partnership is ascertained
	16 Develop optimal structure of vehicle	Designing project implementation to reach the goals of the partnership, including its legal entity
	17 Identify skills needed	Identifying the right skills needed to deliver the goals of the partnership, and assessing who among the partners has them and which capacities need still to be built
	7 Partnership action plan	Mapping the major steps/activities for the partnership to achieve its desired outcomes, including the required resources to implement them
	18 Develop sustainability strategy	Defining the idea of what success looks like; a plan of when and how to terminate, hand over, or transform the partnership; and provisions for the withdrawal of participants
	19 Negotiation practices	Enhancing capacity of partnership facilitators/initiators to reach compromises or agreements with diverse stakeholders, avoiding argument and dispute
	20 Memorandum of understanding	Legally binding the defined partnership governance, roles and responsibilities of participants, targets (beneficiaries), budget and partners' contributions

Table 1 (continued)

	The NRAF tools	Purpose of the tool
Phase 4: Act	21 Identify experts	Selecting experts who can help build capabilities and who can advise on selected subjects within the implementation
	22 Capacity building	Planning ways to fill the identified gaps, and corresponding training, workshops, and coaching sessions are carried out to build capabilities
	23 Communication strategy	Developing communication strategies for all partnerships
	7 Partnership action plan	Mapping the major steps/activities for the partnership to achieve its desired outcomes, including the required resources to implement them
Phase 5: Exit	24 Feedback session	Acquiring feedback from all the different partners confirms that the expectations were met and if not indicates where they were not
	25 List of lessons learnt	Documenting and disseminating the factors that led to success or failures in meeting the partnerships objectives
	7 Partnership action plan	Mapping the major steps/activities for the partnership to achieve its desired outcomes, including the required resources to implement them
	26 Decision-making matrix for scale-up	Analyzing if and how to scale up the partnership
	18 Develop sustainability strategy	Clarifying what success looks like; a plan of when and how to terminate, hand over, or transform the partnership; and provisions for the withdrawal of participants
	27 Final handover	Transferring the management/ coordination responsibilities to the right/ selected people within the partnership

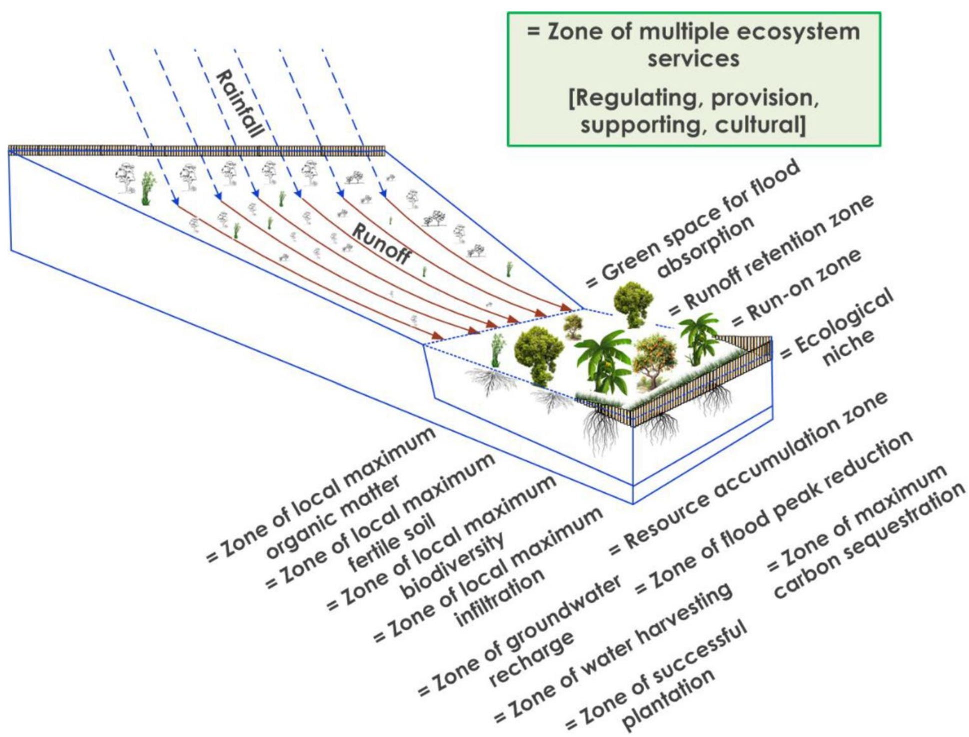


Fig. 4 Runoff-Runon system on hillslopes with multiple ecosystem services (*Source*: Modified from Belete (2022, p. 71)

2.5 Qualitative Approach: Community engagement and perception of the diverse ecosystem services derived from NBS

In addition to assessing the biophysical impact of the interventions, this study aimed to capture the communities' perceptions of the multiple ecosystem services generated. This approach was based on the understanding that local communities are more inclined to monitor services that hold significance to them (Cuni-Sanchez et al. 2019; Hartel et al. 2014; Leonard et al. 2013). A total of 60 households, who were direct beneficiaries of the intervention, participated in focus group

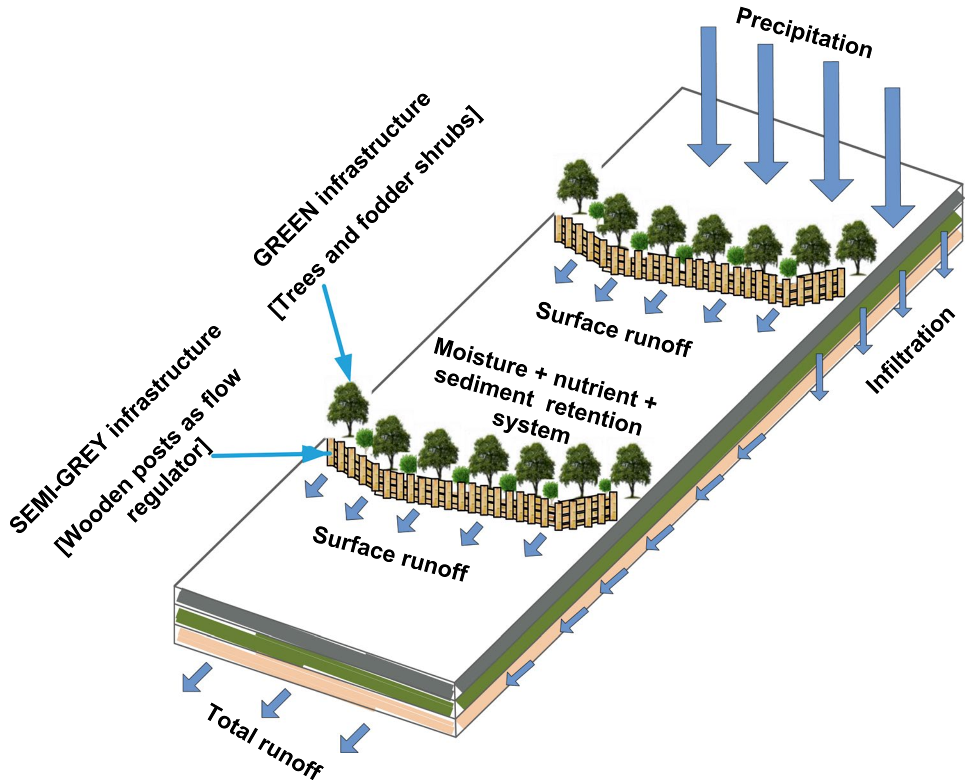


Fig. 5 Ecohydrology-based overland flow regulating system on farmlands with multiple ecosystem services (*Source*: Modified from Belete (2022, p. 98)

Table 2 Summary of the 11 indicators of soil biogeochemical properties and processes with their purposes and scoring ranges

	Indicators	Surface features assessed	Score low–high
1	*Rainsplash protection/soil cover*	The degree to which surface cover and projected plant cover ameliorate the effect of raindrops impacting on the soil surface; the susceptibility to erosion	1–5
2	*Perennial basal/vegetation cover*	The basal cover of perennial grass and/or the density of tree and shrub canopy cover; the potential nutrient biomass	1–4
3	*Litter cover*	The amount, origin, and degree of plant litter decomposition; the soil organic matter component and degree of incorporation	1–10
4	*Cryptogam cover*	The cover of cryptograms (algae, fungi, lichens, mosses, liverworts, and mycorrhizas) visible on the soil surface as a positive indicator of surface stability	1–4
5	*Crust broken-ness*	Crust stability and susceptibility to erosion; the extent of breakage of the surface crust	1–4
6	*Soil erosion type and severity*	The type and severity of recent/current soil erosion	1–4
7	*Deposited materials*	The nature and amount of alluvium transported to and deposited on the query zone	1–4
8	*Soil surface roughness*	Surface roughness, indicating capacity to capture and retain mobile resources such as water, propagules, topsoil, and organic matter	1–5
9	*Surface nature*	The ease with which soil can be mechanically disturbed to yield material suitable for wind or water erosion	1–5
10	*Slake test*	Soil coherence when wet, indicated by the texture of the surface soil and related to permeability	1–4
11	*Soil texture*	Surface soil texture class, indicating impact on infiltration	1–4

discussions (FGDs), open dialogues (ODs), and field observations. Data were framed into likely categories of ecosystem services and corresponding stewardship signals, with the attainment of saturation serving as a criterion for discontinuing data collection and analysis in alignment with qualitative research principles. Participants articulated their perceptions during the FGDs and ODs, expressing perceived importance, preferences, needs, and/or demands. These articulations were transcribed, coded, and categorized into sets of ecosystem

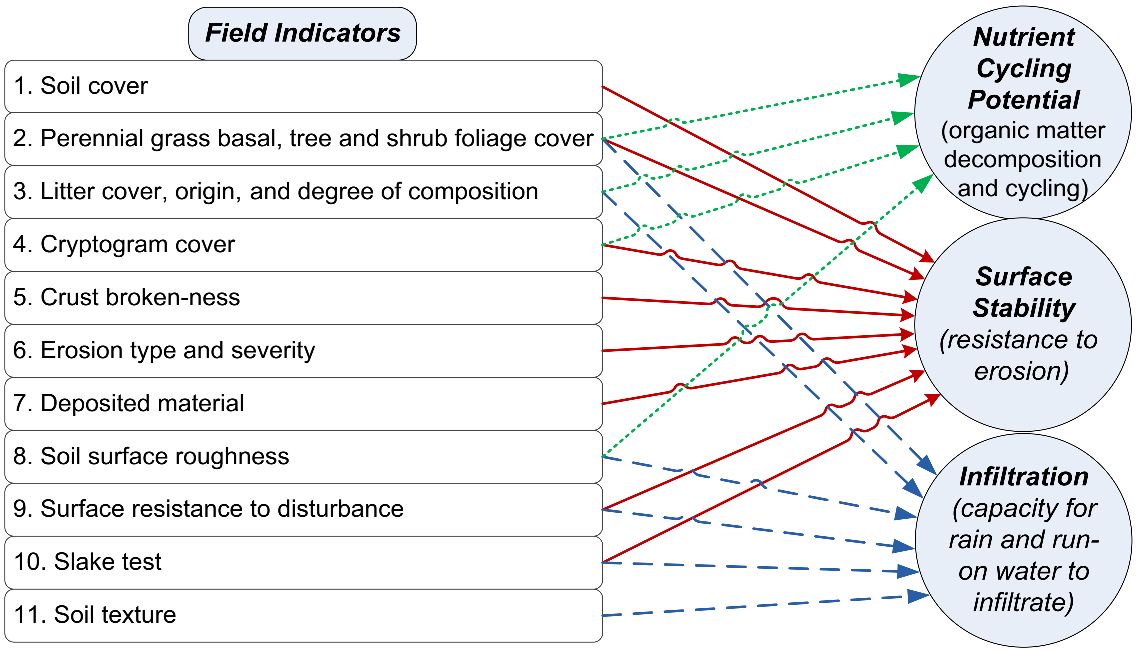


Fig. 6 Derivation of the main functional parameters from field indicators (*Source*: Modified from Tongway and Hindley 2004, p. 111; Belete (2022, p. 82))

services grouped into four categories as suggested by MEA (2005).

Data collection methods included open-ended interviews, field observations, desktop reviews of formal reports by partners, and discussions with sector offices (such as the Rift Valley Lakes Basin Administration Office, Hawassa University, PVH, SIWI, GIZ, and AFLaH—Association of Friends of Lake Hawassa). The central themes of the FGDs and interviews focused on (1) identifying differences in the ecosystem services delivered by conventional techniques vs. NBS, and (2) assessing the level of environmental stewardship before and after the delivery of beneficial ecosystem services by the interventions. Partnership documents provided supplementary documentation.

3 Results

3.1 Landscape Functionality Analysis (LFA): Measure of biophysical status of the landscape

The combination of Table 3, Fig. 7, and Fig. 8 illustrates the results of LFA. *Site-1* represents an abandoned hillslope suffering from extreme degradation, while *Site-2* depicts an extensively gullied landscape beyond its self-rehabilitation capacity. The findings demonstrate an enhancement in ecosystem functionality toward self-sustainability at both sites.

The indices, ranging from 0 to 100%, reflect the functionality of the ecosystem, with 100% representing fully functional systems. At *Site-1,* there was an improvement in stability from 44.4% before intervention to 58.3% after intervention, infiltration potential from 10.4 to 25.1%, and nutrient cycling from 10.5 to 25.6%. Similarly, *Site-2* exhibited enhancement in stability from 30.6 to 47.2%, infiltration potential from 24.7 to 32.6%, and nutrient cycling from 10.5 to 22.5%. Overall, the results affirm that landscape restoration efforts using ecohydrological NBS contribute to improved physical, biological, and ecological impacts, thereby facilitating the subsequent delivery of relevant ecosystem services.

3.2 Identification of ecosystem services delivered by ecohydrological NBS as perceived by the community

After transcription and analysis of FGDs and interview recordings, eleven major ecosystem services were identified (see Fig. 9). These services, valued by the farmers, were considered benefits of the NBS. Participants compared the new approach with conventional terracing (bunding) practices. The identified ecosystem services can be viewed as advantages gained from the new ecohydrological techniques implemented in this NBS. The ecosystem services resulting from the intervention were classified into groups, with the results indicating that NBS interventions addressed the four

Table 3 Raw data of the Landscape Functionality Analysis (LFA)

LFA indicators	Site -1 (Abandoned land)		Site -2 (Extremely gullied landscape)	
	Value of indicators before intervention	Value of indicators after intervention	Value of indicators before intervention	Value of indicators after intervention
Rain splash protection/soil cover	1 [No splash protection]	5 [> 50% vegetation cover]	1 [No splash protection]	4 [30–50% vegetation cover]
Perennial basal/vegetation cover	1 [< 1% basal and canopy cover]	2 [1–10% basal and canopy cover]	1 [< 1% basal and canopy cover]	2 [1–10% basal and canopy cover]
Litter cover	1ln [< 10% plant litter cover; no sign of transport; slightly decomposed]	2ls [10–25% plant litter cover; no sign of transport; slightly decomposed]	1ln [< 10% plant litter cover; no sign of transport; slightly decomposed]	2ts [10–25% plant litter cover; transported litter; slightly decomposed]
Cryptogam cover	1 [< 1% cryptogam cover]	2 [1–10% cryptogam]	1 [< 1 cryptogam cover]	2 [1–10% cryptogam cover]
Crust broken-ness	4 Crust present but intact, smooth	3 Crust present but slightly broken	1 Crust present but extensively broken	1 Crust present but extensively broken
Soil erosion type and severity	1 [Scalding]	3 [Slight sheet erosion]	1 [Rills and gullies]	3 [Slight sheet erosion]
Deposited materials	4 [None or small amount of material present]	3 [5% to 20% deposited material present]	4 [None or small amount of material present]	3 [5% to 20% deposited material present]
Soil surface roughness	1 [Little or no retained materials]	3 [Moderately visible resource retention]	1 [Little or no retained materials]	3 [Moderately visible resource retention]
Surface nature (resistance to disturbance)	4 [Barren, hard scald surface]	3 [Moderately hard surface]	2 [Easily broken surface]	2 [Easily broken surface]
Slake test	0 [No coherent fragments available]	0 [No coherent fragments available]	0 [No coherent fragments available]	0 [No coherent fragments available]
Soil texture	1 [Very slow infiltration rate]	1 [Very slow infiltration rate]	3 [Moderate infiltration rate]	3 [Moderate infiltration rate]

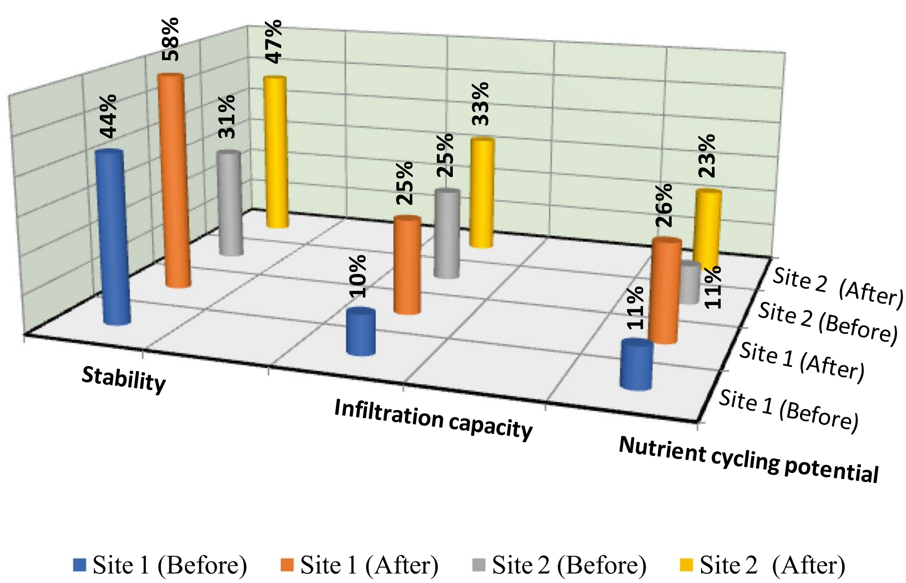


Fig. 7 Graphical presentation of the LFA results (before and after the interventions)

	Site 1: Ecohydrologic rehabilitation of abandoned land	
Before treatment ***(Baseline condition)***		LFA result for site-1 (former mining site) before management action (baseline indices) (reference points): Stability = **44.4%** Infiltration capacity = **10.4 %** Nutrient cycling potential = **10.5 %**
After treatment		LFA result for site-1 (former mining site) after one year of management action: Stability = **58.3%** Infiltration capacity = **25.1 %** Nutrient cycling potential = **25.6 %**
	Site 2: Ecohydrologic rehabilitation of extremely gullied landscape	
Before treatment ***(Baseline condition)***		LFA result for extremely gullied landscape (site-2) before management action (baseline indices) (reference points): Stability = **30.6%** Infiltration capacity = **24.7 %** Nutrient cycling potential = **10.5 %**
After treatment		LFA result for extremely gullied landscape (site-2) after one year of management action: Stability = **47.2%** Infiltration capacity = **32.6 %** Nutrient cycling potential = **22.5 %**

Fig. 8 Sceneries of before and after the interventions and their LFA results (*Source*: Belete (2022, p. 76) and Belete (2023. p. 5))

categories of ecosystem services (MEA 2005) as follows (see Fig. 9):

Supporting services: Underlying ecosystem functions essential for the production of other services.

- Efficient silt trapping
- Slim flow regulating structure to preserve productive lands
- Reclamation of formerly abandoned farmlands
- Minimal earthwork
- Creation of favorable condition due to better accumulation of vital resources

Provisioning services: The products obtained from ecosystems.

- High impact on productivity
- Generating co-benefits from plantation

Regulating services: Contributions to natural production and resilience of habitats and ecosystem processes.

- Improved hydraulic performance during extreme flood events
- Enhanced moisture conservation

Cultural services: Non-material benefits people obtain from the ecosystem.

- Better integration with the existing farming system
- Resilient to cattle trampling

3.3 Community engagement and environmental stewardship signal analysis

Stewardship involves caring for what we value (Palmer 2006, p. 65), encompassing all "efforts to create, nurture and enable responsibility in landowners and resource users

Fig. 9 The diverse ecosystem services acknowledged by the community (stewards) in positively influencing the socioeconomic system (*Source*: self)

to manage and protect land and its natural and cultural heritage” (Brown and Nora 2000). Farmers’ buy-in is considered one of the indicators of environmental stewardship. The qualitative data analysis revealed that due to the innovative approach to land management taken in this intervention, the community perceived their concerns were valued by other partners, thereby enhancing their stewardship to the environment.

Figure 10 illustrates five identified dimensions of volunteer commitment:

- Facilitating the transport to tree seedling afforestation, along with volunteering for plantation.
- Applying organic manure to the seedlings.
- Installing live fencing to protect against cattle trampling.
- Erecting indigenous safeguarding system to protect structures against possible dismantling, particularly valuable for the green-(semi) gray structures.
- Hoeing the surroundings to dislodge weeds.

4 Discussion

In this Anthropocene Era, reconciling the relationship between society and nature is of paramount importance. Environmental stewardship is rooted in the principles of sustainable development and conservation (Jin 2023, p1). Understanding barriers that hider community from acting as stewards of the environment is part of the broader sustainable development picture. This paper demonstrates the proven potential of successful NBS as a pathway to achieve harmony by shaping human-nature interactions and establishing pathways of change. This study focuses on low-income, less educated communities in a developing country that exhibited responsibility over development interventions delivering locally perceived and valued ecosystem services. In this context, ecosystem services act as incentives to engage individuals and communities. The results suggest that delivering multiple ecosystem services through development interventions encourages positive environmental actions, representing a realistic investment in fostering local environmental stewardship in developing countries and beyond. Within socio-ecological systems, active environmental stewardship is a critical pathway

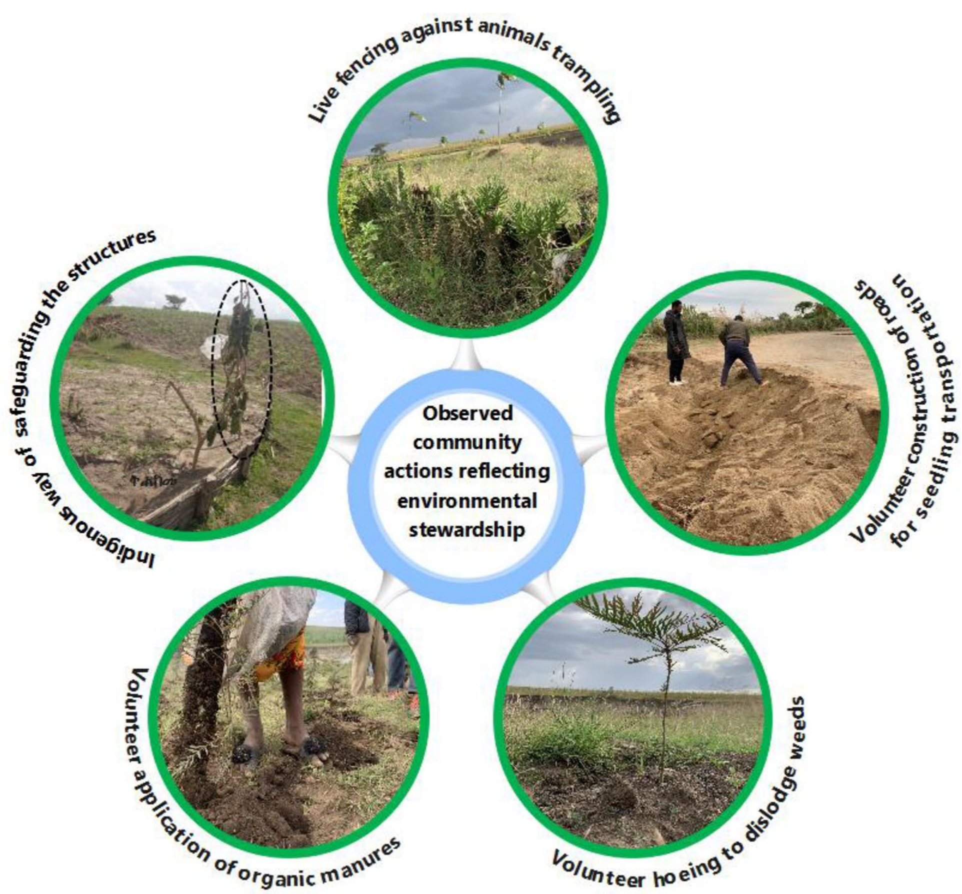


Fig. 10 Observed volunteer commitment by the community to safeguard the ecosystem services by the NBS practices (*Source*: self)

toward achieving sustainable development, underpinning the theory of change.

The study highlights the robust nexus between NBS, ecosystem services, and stewardship. Development practitioners worldwide should consider these linkages in the design and implementation of development projects. Interdisciplinary, evidence-based monitoring, evaluation, and learning efforts should center on these concepts. Recognizing landscapes as socio-ecological systems and acknowledging the delivery of essential ecosystem services as primary outcomes of interventions are crucial. Ecosystem services not only serve as incentives but also as stepping stones toward achieving ultimate environmental stewardship. This understanding can form the basis for future environmental management interventions in the face of challenges such as climate change and biodiversity loss.

As a limitation, this study acknowledges that comprehensive analysis of environmental stewardship may require broader assessment beyond the scope covered. Given the novel interdisciplinary nature of this action-research, which tested stewardship as a pivotal concept illustrating the iterative relationship between community engagement and sustainable livelihood-oriented NBS, future research should focus on the scalability of such approaches. Comparative studies on the costs of implementing NBS versus the economic benefits realized by the local population post-implementation could provide valuable insights. Additionally, while this paper aimed to connect nature and humanity through environmental stewardship and ecosystem services, it acknowledges the broader meanings and scope of these concepts beyond the specifics covered in this research.

Further conceptualization of stewardship can facilitate deeper interdisciplinary methodologies leveraging multi-sectoral actors to address sustainability trade-offs, particularly in balancing economic, ecological, and equity imperatives in development pathways.

5 Conclusion

This paper acknowledges that stewardship does not arise in isolation; development interventions should yield tangible benefits in the form of ecosystem services to foster environmental stewardship, particularly in developing countries where subsistence life predominates. These benefits lead to community stewardship toward the environment, as evidenced by the voluntary commitments of community members to safeguard and contribute to NBS interventions. We observed feedback loops that foster synergies among various place-based stakeholders, including actors, enablers, facilitators, and civil society at large.

The stewardship approach supported by the NRAF has been applied in over 40 different partnerships worldwide in the past decade. Examples include projects in Saint-Lucia, Pakistan, Uganda, South Africa, Kenya, Zambia, and Tanzania, addressing water resources risks, plastic pollution, and other natural resources risks (Natural Resources Stewardship Programme (n.d.)). Additionally, the GIZ-NatuReS programme has implemented multi-sectoral risk-based stewardship partnerships in urban contexts (e.g., Kampala and Lusaka), economic zones, industrial parks, circular economy initiatives (specifically for plastics), and water catchments.

In conclusion, this paper effectively bridges disciplines and connects development practice with research. Often, development initiatives led by international agencies are short-term, with little impact analysis conducted after the intervention's closure. However, by designing financially sustainable stewardship partnerships that are less dependent on external organizations, there is a genuine opportunity to address the tragedy of the commons and achieve long-term positive outcomes.

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Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no confict of interest in this project.

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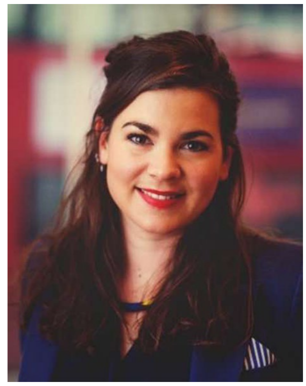

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