A Social-Ecological Approach to Enhance Tree Diversity in Farmland with Application to a Cultural Landscape in Ethiopia

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1. Summary

Landscape multifunctionality is beneficial for biodiversity and local livelihoods in many agricultural landscapes of the Global South, and hence, benefits social-ecological resilience. In this regard, a diversity of woody vegetation throughout farming landscapes, which is used for many different purposes (both material and immaterial benefits to people and nature), is a central aspect of such landscape multifunctionality. However, driven by "green revolution" policy agendas, agricultural intensification threatens woody vegetation and its management, and thereby, landscape multifunctionality, in many rural landscapes of the Global South. It appears therefore that maintaining biodiversity-oriented landscape multifunctionality and social-ecological system (SES) resilience is of paramount importance for both nature and human wellbeing in those cultural landscapes. Sustainable woody vegetation management and SES resilience building can be enhanced by understanding the intimate connections between people and ecosystems, and this perspective is termed a "social-ecological systems" perspective. This process, in turn, can be assisted by embracing systems thinking. Systems thinking is an analytical perspective to study and manage the emergent behaviour of complex and interlinked social-ecological system elements. Systems thinking and its uses can be accelerated by adopting social-ecological resilience principles generated by Biggs et al. (2012).

To contribute to this, the **overall goal** of the project is to investigate how social-ecological resilience principles can be applied to woody vegetation management and thereby identify how landscape multifunctionality can be maintained to generate synergies between biodiversity conservation and local livelihoods in southwest Ethiopia and beyond in the Global South.

With this, the project has the following specific objectives:

- To generate a template for how to improve smallholder farming landscape multifunctionality and social-ecological resilience via promoting sustainable management and maintenance of trees and shrubs in the landscape; and
- To begin to apply this template in southwestern Ethiopia.

To achieve these specific objectives, the project has four work packages:

- **Work package 1** assess and elaborate the obstacles and opportunities from the point of view of various stakeholders for an increase in multifunctionality in the landscape.
- **Work package 2** assess how different stakeholders perceive and applies existing principles to woody vegetation management and strengthen socio-ecological resilience specifically of the ecosystem service multifunctionality of agricultural landscapes.
- **Work package 3** transfers the results of work packages 1 and 2 into a clearly described guide or template, which is intended to be used in the form of a small book, especially in Ethiopia, but also in agricultural landscapes around the world.
- **Work package 4** pilots the project's template in a selected municipality in the study region, which begins to implement the results of the project.

The project was implemented successfully and achieved the following results that can be applied in the study region and beyond, particularly other similar SES in the Global South:

- It identified barriers and opportunities for resilience building and multifunctionality maintenance in the context of wood vegetation management in smallholder farming landscapes;
- It uncovered empirical and theoretical evidence on the significance of all resilience principles, including places of intervention in systems across levels of systemic depth, i.e., from the relatively shallow levels of parameters and feedbacks to the deeper levels of system design and intent, to improve wood vegetation management;
- It produced a useful manual for how to enhance resilience in the context of woody vegetation management in local language (Afaan Oromo) and in English for the study region and beyond; and
- It accomplished multistakeholder workshops and field days, and thereby, started the implementation of resilience principles in the study region.

2. Introduction

Biodiversity is the variability among living organisms, including diversity within species, among species and of ecosystems. Biodiversity provides numerous benefits to humanity and nature, including provisioning (e.g., food, timber, fuelwood), regulating (e.g., climate and water regulation), cultural (e.g., spiritual experiences, recreation, education) and supporting (e.g., nutrient cycling and primary production) ecosystem services (MA, 2003; Díaz et al., 2018).

More specifically, the diversity of trees or woody vegetation – including diversity in species identity, traits, composition and configuration – provides multiple direct and indirect benefits to people (e.g., see Fischer et al., 2010; Wu, 2013; Rivers et al., 2022). For example, trees can provide house construction wood, fuelwood, medicine and timber, as well as providing cultural services such as spiritual and educational uses (Maarif, 2015; Shumi et al., 2019; Pehou et al., 2020). They also help to fertilize and protect soils and regulate our climate and water (Bayala et al., 2014; Gitz et al., 2021; Shumi et al., 2021). Furthermore, trees serve as a home and a source of food for many other species and contribute prominently to local biodiversity conservation – for instance, about half of the world's animals and plant species rely on trees for their survival. Forests harbour about 75% of bird species, 68% of mammal species, 80% of amphibian species and around 10 million invertebrate species (Mayfield and Daily 2005; Gove et al. 2008; Engelen et al. 2017; Rivers et al., 2022). Such diversity, in turn, underpins ecosystem integrity and is valuable for crop pollination, environmental cleansing, pest and disease regulation (Barrios et al., 2018). In agricultural settings, trees are an important part of a multifunctional landscape, and help to ensure food security and nutrition, particularly in the Global South, where people fundamentally rely on nature (Rahman et al. 2015; DeClerck et al. 2016; Manning et al. 2018; Gitz et al., 2021).

In many regions of the Global South, however, woody plant diversity – and landscape multifunctionality – is threatened by top-down agricultural intensification policy following a "green revolution" discourse. Particularly land use changes such as intensification and expansion of conventional agriculture, deforestation and land degradation endanger the existence and management of woody vegetation and its associated ecosystem services in many smallholder farming landscapes of the Global South (e.g., see Akinnifesi, 2016; Rasmussen et al., 2018; Grass et al., 2020; Hickel et al., 2022; Santiago et al., 2022). These changes often not only devastate nature, but also marginalize local communities and force them to abandon their complex traditional ecological knowledge systems, cultures, ethical and spiritual values and experiences that might be essential for sustainable social and ecological system management (Arora, 2019; Lyver et al., 2019; Fernández-Llamazares et al., 2021; Hartel et al., 2022). As a consequence, many smallholder farming landscapes are vulnerable to turn into monocultures for short-term profit (Curtis et al., 2018; Rasmussen et al., 2018; Appelt et al., 2022; Kastner et al., 2022), and thereby, may lose their long-term resilience – that is, their ability to buffer shocks and to continue functioning as a system (Altieri, 2008; Folke et al., 2010; Lyver et al., 2019; Nyström et al., 2019). The ongoing loss of diversity driven by landscape commodification could have major negative ramifications for humanity and ecosystems in many landscapes of the Global South.

Given these considerations, it appears that maintaining biodiversity-oriented landscape multifunctionality and social-ecological system (SES) resilience is of paramount important for both nature and human wellbeing. This can be achieved by understanding the intimate connections

between people and ecosystems, and such perspective is termed a "social-ecological systems" perspective. A social-ecological systems perspective recognises that agricultural landscapes need to not only generate short-term incomes, but that their long-term sustainability is also important for both people and ecosystems (Fig. 1). As such, heterogeneous land uses, small and large forest patches, scattered trees, agroforestry, hedgerows, and wetlands, for example, all play important roles in the landscape. Such systems thinking and social-ecological resilience within a multifunctional agricultural landscape could be strategically enhanced through key resilience management principles distilled by Biggs et al. (2012) (see Table 1 for details). Resilient and multifunctional landscapes via sustainable woody vegetation management, in turn, can contribute to the United Nations Sustainable Development Goals (SDGs; UN 2015), for instance, via improving the provisioning of multiple ecosystem services including food supply (SDG1, SDG2 and SDG3), fuelwood supply (SDG7), improved water regulation (SDG6 and SDG9) and carbon sequestration (SDG13), habitat provision for native species (SDG14 and SDG15), as well as enhancing better social relations and learning (SDG3, SDG4, SDG5, SDG10) (UN 2015; DeClerck et al. 2016; Singh et al. 2018).

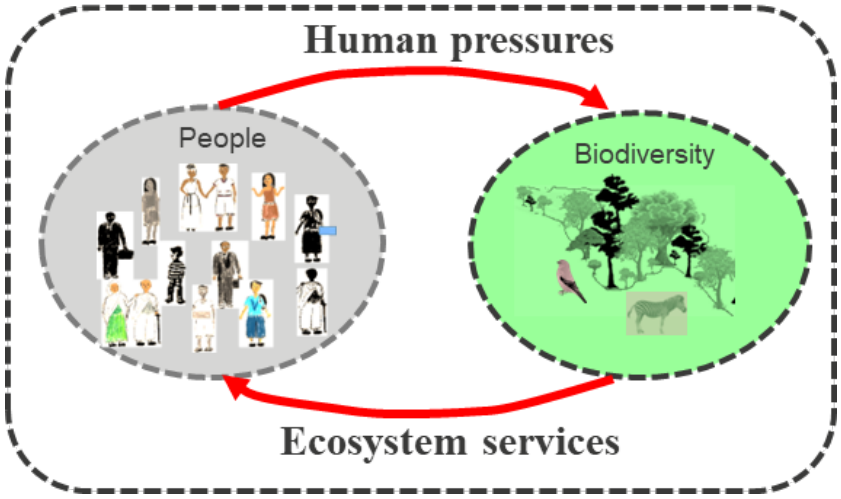

Fig. 1. People and biodiversity influence one another within a social-ecological system (SES).

To contribute to this, the **overall goal** of the project was to investigate how social-ecological resilience principles can be applied to woody vegetation management and thereby, how landscape multifunctionality can be maintained to generate synergies between biodiversity conservation and local livelihoods in southwest Ethiopia and beyond in the Global South.

The project had the following specific objectives:

- To generate a template for how to improve smallholder farming landscape multifunctionality and social-ecological resilience via promoting the management and maintenance of trees and shrubs in the landscape; and
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To achieve these specific objectives, the project has four work packages:

- **Work package 1** assesses and elaborates the challenges and opportunities from the point of view of various stakeholders for an increase in multifunctionality in the landscape.
- **Work package 2** assesses how different stakeholders perceive and apply existing principles to woody vegetation management in order to strengthen socio-ecological resilience specifically with respect to the multifunctionality of agricultural landscapes.
- **Work package 3** transfers the results of work packages 1 and 2 into an easily accessible guide or template in the form of a small book, which can be used especially in Ethiopia, but also in agricultural landscapes around the world.
- **Work package 4** pilots the project's template in a selected municipality in the study region, and thereby begins to implement the results of the project.

Table 1. Contemporary principles for building resilience of SES, and their relation to the management of woody vegetation. E = primarily ecological aspects; S = primarily social aspects. E and S were differentiated for some principles for ease of discussion with local stakeholders; we are acutely aware that E and S aspects are tightly interrelated (Adapted from Biggs et al. (2012)).

P1. Maintain diversity and redundancy	P1E: Maintaining ecological diversity and redundancy Diversity refers to diversity of woody plant species, habitats and ecosystems. Redundancy is functional replication of species in SES that can provide options for responding to change and adapting to uncertainty, thereby building resilience.
	P1S: Maintaining social diversity and redundancy Diversity refers to diversity of social actors. Redundancy relates to the functional replication of social actors in SES and can provide options for responding to change and adapting to uncertainty, thereby building resilience.
P2. Manage connectivity	P2E: Managing ecological connectivity Ecological connectivity – that is, the way in which resources e.g., seeds disperse, species migrate or interact with each other across patches, habitats or ecosystems – helps to maintain diversity and is key for resilience.
	P2S: Managing social connectivity Social connectivity – that is, the way in which multiple social actors interact with each other and collaborate across social structures and domains – helps to maintain diversity and is key for resilience. Notably, too much connectivity can cause rigidity.
P3. Manage slow variables and feedbacks	P3E: Managing ecological slow variables and feedbacks Managing ecological, slowly changing variables as well as the feedbacks that influence the configuration and dynamics of a given SES is important to avoid crossing possible thresholds into undesired states.
	P3S: Managing social slow variables and feedbacks Managing social, slowly changing variables as well as the feedbacks that influence the configuration and dynamics of a given SES is important to avoid crossing possible thresholds into undesired states.
P4. Foster an understanding of SES as complex adaptive systems Complex adaptive systems thinking helps to make sense of SES dynamics and to manage SES for multiple ecosystem services in an integrated way, across multiple temporal and spatial scales.	
P5. Encourage learning and experimentation The uncertain and dynamic nature of complex SES requires continuous learning via adaptive management, co-management and collaborative governance.	
P6. Broaden participation Active participation of stakeholders in the management and governance process enhances collective action for resilience.	
P7. Promote polycentric governance systems Governance systems in which various interacting governing bodies have autonomy to make and enforce rules can enhance resilience by improving connectivity, participation and adaptive learning.	

3. Project implementation: work steps and methods

Initially, because of the COVID-19 pandemic, it was unfortunately not possible for us to meet the planned time frame. Like many researchers during this time, we had to get creative and adapt our plans so that we could achieve as much as possible despite adverse circumstances. With this in mind, this chapter presents the details on project implementation, including activities, work steps and methods step by step.

First, we started with writing of a conceptual review paper. In our review, we aimed to combine resilience framework insights with insights on woody vegetation management particularly in the Global South and thereby, distil key lessons to enhance the resilience of smallholder landscapes via improved woody vegetation management. Specifically, the focus of this work was to review literature on how to apply seven existing principles to woody vegetation management and building social-ecological system resilience in smallholder farming landscapes. In doing so, we highlighted existing perspectives, challenges and opportunities for applying each principle to woody vegetation management and SES resilience building. This manuscript is now in review with the *Journal of Environmental Management* for consideration for publication. This work creates a solid foundation for all other work packages.

Second, we implemented work packages 1 and 2 — that is, we collected empirical data on how different stakeholders perceive and apply existing principles, including perception of the current situation, and challenges and solutions of applying resilience principles in the context of woody vegetation management in Jimma Zone, southwestern Ethiopia (Fig. 2) — despite strict travel restrictions. For this to happen, together with our project partner in Addis Ababa and based on previous contacts from our previous work in Ethiopia, we subcontracted two young researchers in Ethiopia. We prepared data collection protocols in the local language (Oromifaa) and in English, as well as COVID-19 protection guidelines or safety rules, and posters that helped to guide and conduct focus group discussions with various stakeholders, including local stakeholders at different places (Fig. 2). We first systematically selected relevant stakeholders —from local to zonal levels— and grouped them based on their likely similar backgrounds, shared experiences, ages and wealth or social status. During data collection, we also closely monitored the data collection processes and procedures online. This way, the researchers conducted 17 main focus group discussions from February to April 2021. The collected data were translated from local language to English and transcribed, and then, coded deductively (based on resilience principles) and inductively (additional coded categories were developed for each principle based on discussants' responses). Then, we conducted quantitative content analysis.

We also combined the generated codes — empirical data obtained via a social-ecological system perspective — with a leverage points perspective (Meadows 1999) to better understand places of interventions in systems acting on different levels of systemic depth, i.e., from the relatively shallow levels of parameters and feedbacks to the deeper levels of system design and intent (Abson et al. 2017). This further facilitated to identify potential interventions that could help bring about transformative change to sustainability via resilience management (Fischer and Riechers, 2019). To this end, we classified the coded categories of challenges and solutions of each resilience principle across levels of systemic depth, namely system parameters, feedbacks, design and intent (see Table 2 for system characteristics and specific leverage points) and generated Sankey

diagrams to visualise resilience challenges and solutions associated with each level of systemic depth. We also assessed whether different stakeholder groups noted challenges and solutions differently at different levels of system depth and produced histograms to visualise the results. Finally, using all findings of this work package, we wrote a research paper entitled "Resilience principles and a leverage points perspective for sustainable woody vegetation management in a social-ecological system of southwestern Ethiopia". The paper is currently in review with the journal of *Ecology & Society*. The findings of this work are also an excellent input for the implementation of work packages 3 and 4.

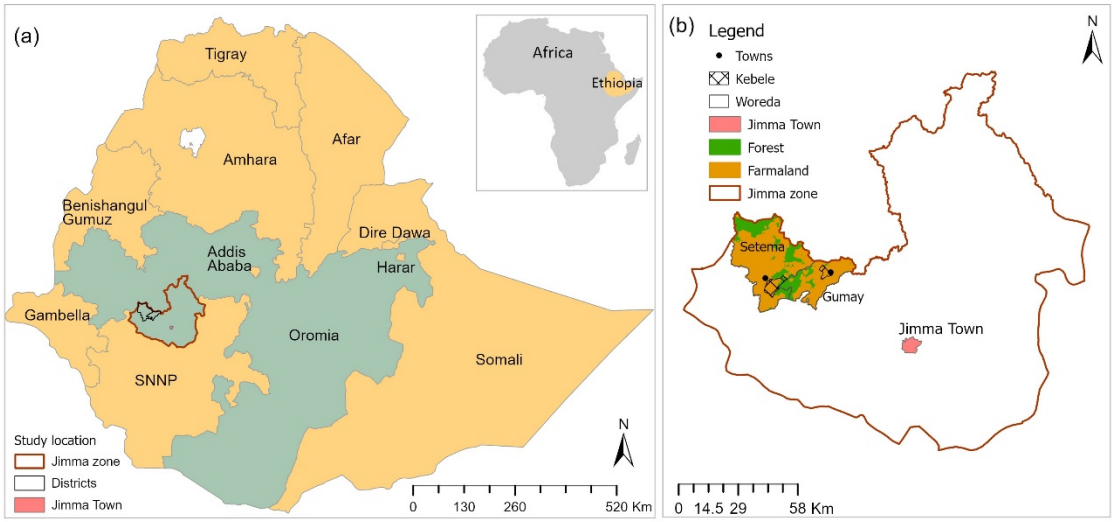

Fig. 2. Location of (a) study area in Ethiopia, Oromia Regional State, Jimma Zone; (b) the two kebeles (Gido Bere in Setema district, Kuda Kofi in Gumay district), two district towns (black dots, namely Gatira in Setema district and Toba in Gumay district), and Jimma town.

Table 2. System characteristics as defined by Abson et al. (2017) and leverage points by Meadows (1999), with increasingly deep (i.e., influential) leverage points towards the bottom of the table.

System characteristics			
Effectiveness	**Type**	**Description**	**Leverage points**
Shallow leverage points	Parameters	The relatively mechanistic characteristics or physical elements typically targeted by policy makers (or environmental managers in our case)	12. Constants, parameters, numbers (such as subsidies, taxes, standards) 11. The sizes of buffers and other stabilising stocks, relative to their flows 10. The structure of material stocks and flows (such as transport networks, population age structures)
	Feedbacks	Interactions between elements within a system that drive internal dynamics	9. The lengths of delays, relative to the rate of system change 8. The strength of negative feedbacks, relative to the impacts they are trying to correct against 7. The gain around driving reinforcing feedback loops
Deep leverage points	Design	The social structures and institutions that manage feedbacks and parameters	6. The structure of information flows (who does and does not have access to what kinds of information) 5. The rules of the system (such as incentives, punishments, constraints) 3. The power to add, change, evolve, or self-organise system structure
	Intent	The underpinning values, goals, and worldviews of actors that shape the emergent direction to which a system is oriented	3. The goals of the system 2. The mind-set or paradigm out of which the system – its goals, structure, rules, delays, parameters – arises 1. The power to transcend paradigms

Third, we implemented work package 3 – that is, we produced a general toolkit – a template in both the local language of the study region (Afaan Oromo) and in English – on how to apply resilience principles to woody vegetation and thereby, enhance landscape ES multifunctionality and SES resilience. This manual or small book draws on our empirical work as well as the literature review work presented above. More specifically, in our non-technical manual, we elaborated how each principle is related to woody vegetation management and provided examples of tangible activities that help to operationalize each principle in smallholder farming landscapes of southwestern Ethiopia and other similar SES in the Global South. Tangible activities were identified and prioritized specifically from perceived resilience challenges and solutions that occurred at different levels of systemic depth, i.e., from the relatively shallow levels of parameters and feedbacks to the deeper levels of system design and intent. The printed versions of the manual are currently on their way from the publisher to us; the final PDF versions are attached as appendices to this final report. The booklets will be distributed in the study area in June.

Fourth, we implemented work package 4 – that is, we organized and conducted collaborative multi-stakeholder workshops and field days to kick-start the implementation of some of tangible activities prioritised by local and district stakeholders for of each resilience principle. The workshops and field days were conducted at two kebeles, namely Gido Bere and Kuda Kofi and at the two district offices that these two kebeles are located within, namely Gumay and Setema

(see Fig. 2 above for location of these two kebeles and districts; and Appendix 1: Multi-stakeholders' workshops and filed days report for their details). For this to happen, we subcontracted one local facilitator from Ethiopia, and Dr. Girma Shumi Dugo went on a trip trip to Ethiopia. We systematically selected participants from different sectors within each district. Similarly, we systematically selected local participants, but grouped them into G1 – Women; G2 – Elders; G3 – Low-income farmers; and G4 – Model farmers, development agents, students and teachers at each kebele. At each district, we started the workshop with a briefing of our research findings and elaborated examples of tangible activities of each resilience principle. We also provided draft books (text finalized but not yet with professional layout) and posters prepared as outreach materials. Then, we facilitated district participants to lead the workshop, and thereby, to identify tangible activities and prepare a local action plan that suited the specific context of each district.

At the kebele level, we also started the workshop with a briefing of our research findings and elaborated examples of tangible activities of each resilience principle to local participants. Here we guided the participants of each group to select tangible activates they were most interested in and asked them to elect their group representatives. Then, we went back to the district together with representatives of each local community group and conducted a workshop that resulted in the harmonization of the actions envisaged by district stakeholders and those envisaged by representatives of local communities. This workshop enabled the inclusion of tangible activities prioritised by local groups into the final action plan that was adopted by the district. Finally, we conducted collaborative multi-stakeholder field days and piloted the implementation of parts of the action plan, as prioritised and agreed upon by all stakeholders. We also provided seed money to the representatives of local stakeholders in presence of district leaders, to enable them to own and continue the implementation of the action plan (for details see Appendix 1: Multi-stakeholders' workshops and filed days report).

4. Results – presentation of achieved results

From the literature review, we collated evidence and highlighted the relevance of all seven resilience principles to woody vegetation management in the Global South. However, we also found widespread absence of the application of resilience principles – that is, widespread obstacles to sustainable woody vegetation management, such as top-down and sectoral policies of agricultural and natural resource management, deep-rooted power dynamics and asymmetries, and the marginalisation of local people and their knowledge systems. Indeed, we learned that smallholder landscapes are rarely seen as SES and managed in a way that enhance SES resilience.

Empirically, all discussant groups agreed on the existence and benefit of various direct and indirect ecosystem services of diverse tree and shrub species (P1E) (Table S1). Similarly, a large majority of groups (16 or 94%; and 13 or 77% respectively) perceived benefits from the existence of connectivity among different habitats (P2E) via vegetation strips/corridors and stepping stones in the landscape (Table S1). However, almost all groups noted an absence of application related to many of the resilience principles to woody vegetation management in the study region (Table S1). The discussants identified 37 different challenges that could hinder the application of at least one resilience principle. The identified challenges were most numerous particularly for P6 – broadening participation (24 challenges); P1S – managing social diversity and redundancy (22 challenges); P7 – encouraging polycentric governance (22 challenges); and P5 – continuous learning and experimentation (20 challenges) (Table S2). Box 1 summarises key challenges that need attention in the study area and beyond.

Box 1. Key challenges (in decreasing frequency of total mentions summed across all individual groups and principles) that hinder the application of resilience principles to the management of woody plant diversity in smallholder faming landscapes of southwestern Ethiopia (cf. Table S2, for complete list of challenges).

1. Individualism and absence of commitment, responsibility, care and respect
2. Lack of awareness and experience sharing
3. Weak government performance and policy implementation
4. Failure to recognise and prioritise local people and their needs and experiences
5. Deforestation/tree clearing for land-use expansion and intensification, and overutilisation
6. Lack of or weak monitoring
7. Lack of or fake participation–only for political/reporting purposes
8. Corruption
9. Absence of or weak trees/forest planting, management, maintenance and governance
10. Predominance of inequality and unfairness
11. Lack of or weak support and supply of materials (e.g., seedlings)
12. Predominance of human–wildlife conflict
13. Dependency on or waiting for government for tree/forest management
14. Lack of or fake collaboration – connectivity among stakeholders across scales
15. Lack of or weak local social network and collaboration in trees/forest management
16. Lack of coordination or predominance of diverging values, knowledge, needs and interests
17. Lack of responsible unit or institution
18. Loss of local social norms, values, cultures, institutions and bylaws (customary laws)
19. Power of political elite – local people are afraid to stand up for their rights
20. Predominance of mistrust/doubt, and absence of interest, motivation and willingness in trees/forest management

Discussants also identified 44 different types of solutions or opportunities that could facilitate the application of at least one of the resilience principles (Table S3) in the context of woody vegetation diversity management. Box 2 lists most prominently suggested solutions for better resilience management in the study region and beyond.

Box 2. Suggested solutions (in decreasing frequency of total mentions summed across all individual groups and principles) that could help facilitate the application of resilience principles to the management of woody plant diversity in smallholder faming landscapes of southwestern Ethiopia (cf. Table S3, for complete list of suggested solutions).

1. Enhance awareness creation and experience sharing
2. Enhance connectivity among stakeholders across units and levels
3. Enhance adaptive co-management and governance of trees/forest
4. Enact and enhance local social network and collaboration legally
5. Enhance genuine participation or local self-mobilisation
6. Strengthen government structures and policy performance
7. Enhance equity and roles of stakeholders, particularly local groups
8. Avoid individualism, and enhance care, responsibility and respect
9. Restore and enhance local cultures, norms, values, institutions and bylaws
10. Empower local people and their social networks/institutions
11. Enhance support and supply of materials (e.g., seedlings)
12. Recognise and prioritise local people, their needs and experiences
13. Enhance NGOs/projects and their performance
14. Enhance family planning services
15. Enhance law, legislation and proclamation as well as its enforcement
16. Enhance monitoring
17. Recognise local people trees/forest ownerships and use rights
18. Enhance soil and water conservation practices
19. Enhance transparency and freedom of speech or expression
20. Enhance job creation/suitable poverty reduction strategy
21. Stop corruption

As to the occurrence of resilience challenges and solutions across system depth, relatively few resilience challenges and solutions were associated with the shallow levels of system parameters (Fig. 3) and feedbacks (Fig. 4). In contrast, many perceived resilience challenges and solutions occurred at the deeper levels of system design (Fig. 5) and intent (Fig. 6). Furthermore, administration staff, expert, researcher and model farmer stakeholder groups articulated resilience challenges and solutions that occurred across all system levels, including shallow levels of system parameters and feedbacks (Fig. S1, S2, S3 and S4). In contrast, local stakeholder groups, including low-income farmers, perceived resilience challenges and solutions that occurred predominantly at the deeper levels of system design and intent (Fig. S3 and S4).

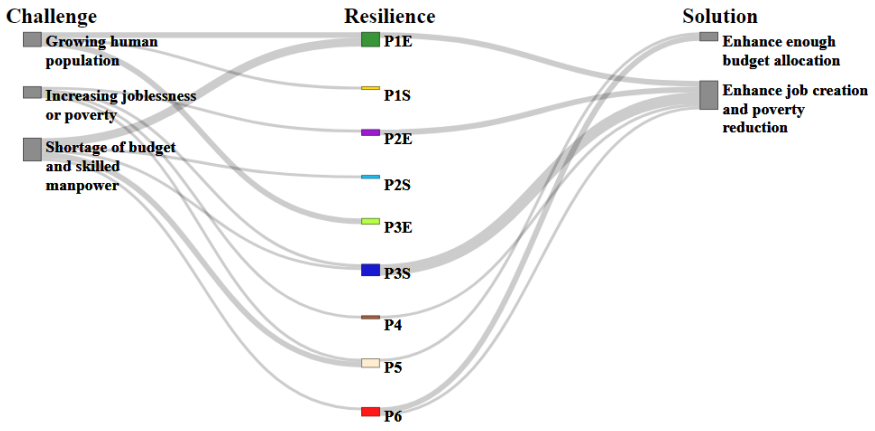

Fig. 3. Sankey diagram of perceived challenges for and solutions to resilience, at the systemic level of parameters. The width of lines in the diagram denotes the number of stakeholder groups asserting the challenge or solution. For details of resilience principles, see Table 1.

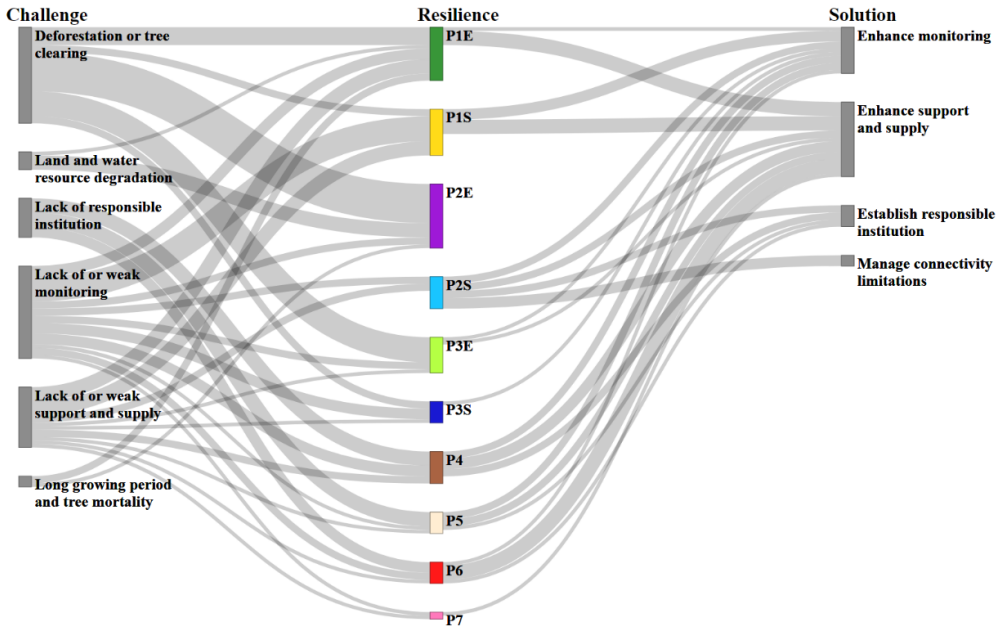

Fig. 4. Sankey diagram of perceived challenges for and solutions to resilience at the systemic level of feedbacks. The width of lines in the diagram denotes the number of stakeholder groups asserting the challenge or solution. For details of resilience principles, see Table 1.

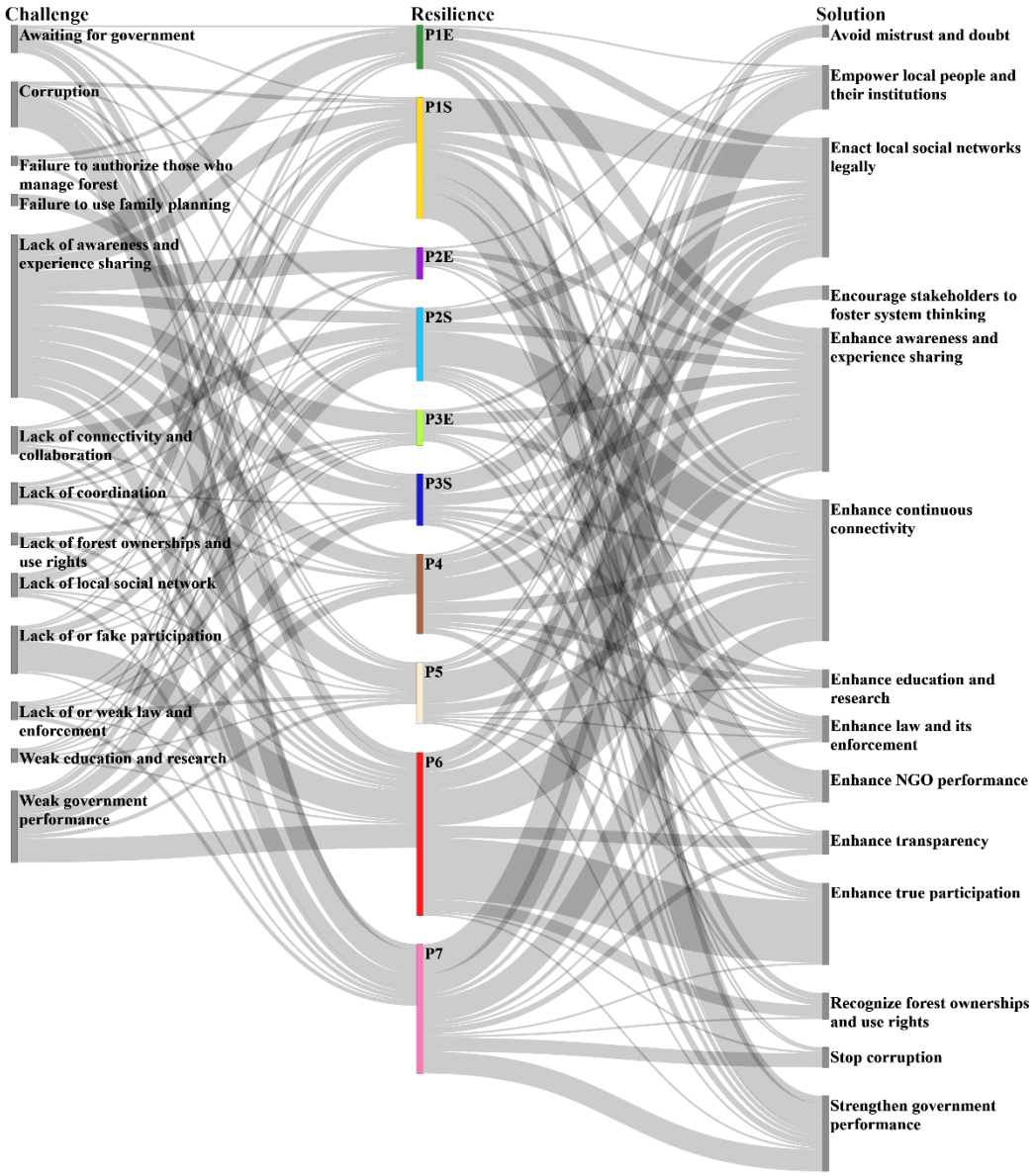

Fig. 5. Sankey diagram of perceived challenges for and solutions to resilience at the systemic level of design. The width of lines in the diagram denotes the number of stakeholder groups asserting the challenge or solution. For a complete list of perceived challenges for and solutions to resilience for the design system level, see Tables S2 and S3. For details of resilience principles, see Table 1.

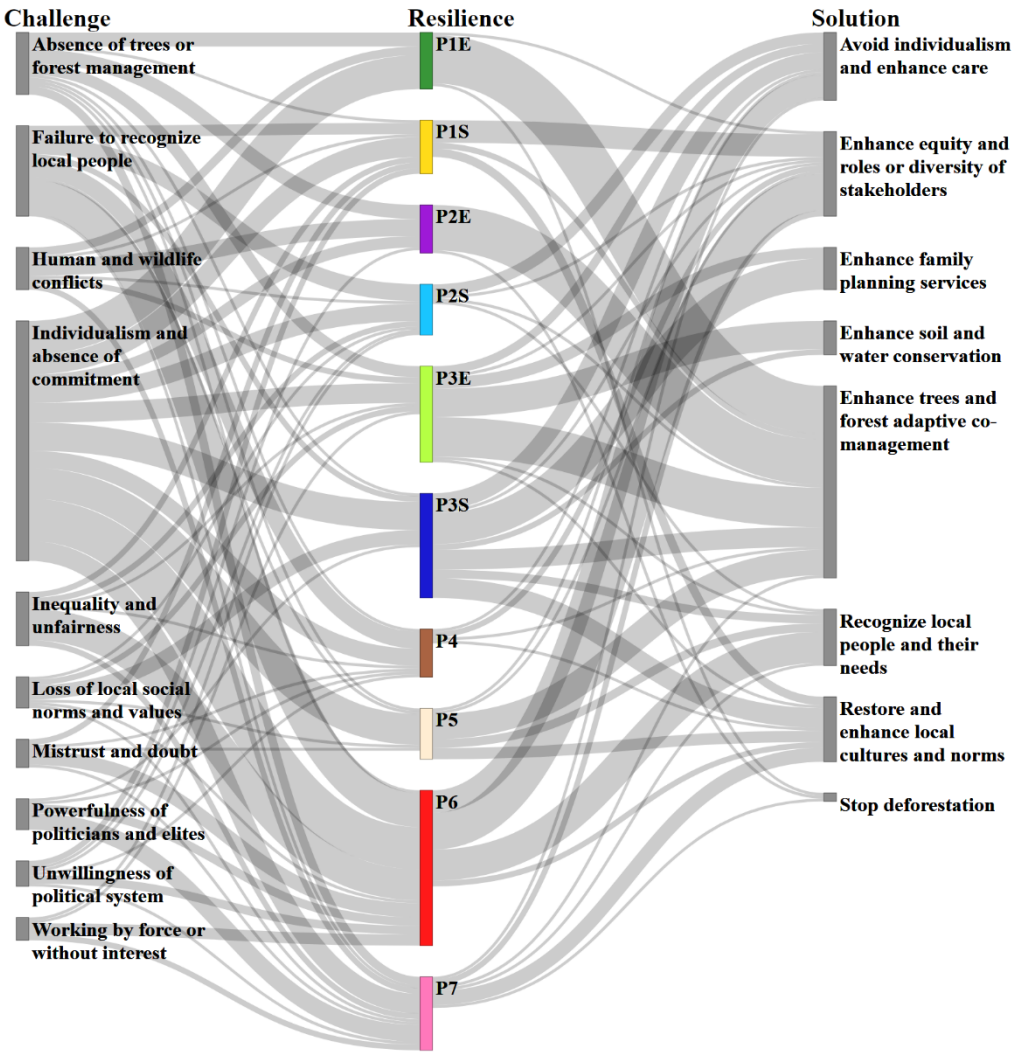

Fig. 6. Sankey diagram of perceived challenges for and solutions to resilience at the systemic level of intent. The width of lines in the diagram denotes the number of stakeholder groups asserting the challenge or solution. For a complete list of perceived challenges for and solutions to resilience for at intent system level, see Tables S2 and S3. For details of resilience principles, see Table 1.

Using all of the above mentioned findings, we prepared a toolkit – a short guideline written in both local language (Oromifaa) and English. This is an input to keep on applying resilience principles to woody vegetation management and enhance resilience of SES and ecosystem service multifunctionality in the region and other similar SES.

We also piloted the implementation of this template via multi-stakeholder workshops and field days. This further motivated the stakeholders, particularly local people, to foster the application of the resilience principles into their context, if there could be bottom-up changes in system goals, rules, paradigms and intent, drawing explicitly on local people and their knowledge. The local participants substantiate the need for these changes and their recognition by citing their situations under ongoing government approaches and some projects like REDD+ in their area.

5. Discussion

The implementation of the project was successful and more or less went according to the plan, regardless of COVID-19. Indeed, the implemented activities lead to the intended results and all objectives of the project were achieved. The project results were presented above and separately as supplementary information (see Fig. S1, S2, S3 and S4).

In general, to the best of our knowledge, our DBU funded project is the first to specifically focus on applying social-ecological resilience principles to woody vegetation diversity management in such neglected farming landscapes. Both theoretically (from literature review) and practically, the project investigated how different stakeholders perceived contemporary resilience principles and apply them in the context of natural resource management, i.e., woody vegetation management in smallholder farming landscapes and thereby, enhance the resilience of SES and landscape multifunctionality. It is also the first project to combine a resilience perspective with a leverage points perspective and provides an insight into the need to recognise local people, and their livelihood and nature stewardship needs, knowledge and experiences and hence, bottom-up changes in system goals, rules, paradigms and intent to enhance both social and ecological diversity for resilience building. This, in turn, will help to better achieve the UN sustainable development goals.

In addition, the project team, partners and the local stakeholders were motivated and put many efforts into the realization of this transdisciplinary project. The project generated useful articles and a template or manual that can stay with stakeholders, wider readers and thus, advance the application of resilience management in smallholder landscapes in the study region and beyond. In piloting the implementation of some of the resilience principles that were prioritized by stakeholders, the project also motivated the stakeholders to further work towards building resilience.

Finally, we recommend to the DBU to continue to support similar projects, or even follow up of the implementation of resilience principles identfied by this particular project. As local participants recommended, there could be a chance to develop or wite a follow-up project proposal to the DBU for the study region based on the results of this small project. This could be an advantage both for the region and for the DBU, in terms of being very much in line with enhancing sustainability in the context of the UN sustainable development goals.

6. Public relations and presentation

Despite travel restrictions, we kept in close contact with our Ethiopian colleagues and continued our contact with local actors in the study area, specifically during our empirical work through the two young researchers we commissioned in Ethiopia. We have good contact with our project partner in Addis Ababa University as well as Stockholm University. Within Leuphana University, we actively took part in weekly team meetings as well as in the Social-Ecological Systems Institute's (SESI) seminar series.

Our papers from this work are under review now, and we trust they will be published for international readers by the *Journal of Environmental Management* and *Ecology & Society* in the near future.

Our results were disseminated and piloted to local stakeholder in the form of briefings, workshops and outreach materials such as books and posters.

The final booklet we produced (both in local language – Afaan Oromo or Oromifaa, and English) is in print now, and we plan for it to be disseminated to end users in mid 2024.

We organized and conducted workshops and field days for all local actors.

7. Conclusions

As to our knowledge, the project was implemented successfully and achieved the following results that can be applied in the study region and beyond, particularly other similar SES in the Global South:

- It identified barriers and opportunities for resilience building and multifunctionality maintenance in the context of wood vegetation management in smallholder farming landscapes;
- It uncovered empirical and theoretical evidence on the significance of all resilience principles, including places of intervention in systems across levels of systemic depth, i.e., from the relatively shallow levels of parameters and feedbacks to the deeper levels of system design and intent, to improve wood vegetation management;
- It produced a useful manual for how to enhance resilience in the context of woody vegetation management in local language (Afaan Oromo) and in English for the study region and beyond; and
- It accomplished multistakeholder workshops and field days, and thereby, started the implementation of resilience principles in the study region.

The project has contributed to a better understanding of the current resilience situation of smallholder farming landscapes, including constraints and opportunities for SES resilience building. In our study, although we collated evidence of the relevance of applying all seven resilience principles to woody vegetation management in the Global South from systematic literature, empirically we found the absence application of almost all resilience principles. In particular, P6 – broadening participation; P1S – managing social diversity and redundancy; P7 – encouraging polycentric governance; and P5 – continuous learning and experimentation; remain challenging in the Global South. For this, the project has helped to identify barriers such as individualism and an absence of commitment or care, lack of awareness and experience sharing, weak government performance or policy implementation, and failure to recognise and prioritise local people and their needs and experiences. This may be due to the ongoing pursuit of top-down and sectoral policies for agriculture and natural resource management, deep-rooted power dynamics and asymmetries, and the marginalisation of local people and their traditional knowledge.

To counteract this, the project has also contributed to identify opportunities or solutions such as enhancing awareness and experience sharing, connectivity among stakeholders across multiple units and levels, adaptive co-management and governance of trees and forest, enacting local social networks and collaboration legally, genuine participation or self–mobilisation of local people, strengthening government structures and policy performance, and enhancing equity and roles of stakeholders, that can facilitate the application at least one of the resilience principles. We also combined a resilience perspective (these findings) with a leverage points perspective and thereby contributed to better understanding of the need to foster transformative changes in system goals,

rules, paradigms and intent, drawing explicitly on local people and their knowledge for resilience management in the study area. In doing so, the project indirectly contributed to the achievement of United Nations Sustainable Development Goals (SDGs).

To ensure the wider application and dissemination of these all findings, the project has produced a template in local language and in English and also conducted multi-stakeholder workshops and field days to pilot the implementation the resilience principles in the region. The project also facilitated the involvement of local stakeholders and partners from the very beginning, which, in turn, increased the understanding of SES resilience building. On top of this, we prepared or wrote two articles based on the findings of the project.

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9. Appendices

- Appendix 1: Report on multi-stakeholders' workshops and filed days.
- Appendix 2. Supplementary results
- Other appendices: PDF files of the two manuscripts currently in review (not for dissemination) and PDF files of the booklet we produced, once in English and once in Aafan Oromo