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APPLYING SOCIAL-ECOLOGICAL RESILIENCE PRINCIPLES TO MANAGE WOODY VEGETATION IN SMALLHOLDER FARMING LANDSCAPES

Girma Shumi and Joern Fischer

PENSOFT

Applying social-ecological resilience principles to manage woody vegetation in smallholder farming landscapes

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The research project “A Social-Ecological Approach to Enhance Tree Diversity in Farmland with Application to a Cultural Landscape in Ethiopia” was funded by the Deutsche Bundesstiftung Umwelt or the German Federal Environmental Foundation. This little book is prepared based on empirical data from southwestern Ethiopia and a literature review that focuses on the Global South.

Front cover: Smallholder Farming Landscape in Gera District, in Kella Harari Kebele. (Photo: Girma Shumi)

Back cover: Smallholder Farming Landscape in in Kella Harari Kebele. (Photos: Girma Shumi)

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Foreword

This little booklet provides an overview of how to apply resilience principles for sustainable tree species diversity management in the context of smallholder farming landscapes. It is based on work carried out within the research project 'A Social-Ecological Approach to Enhance Tree Diversity in Farmland with Application to a Cultural Landscape in Ethiopia'.

The project – building on an ERC-funded, five-year research project ("Identifying Social-Ecological System Properties Benefiting Biodiversity and Food Security – SESyP") – was conducted in Jimma zone, southwestern Ethiopia. Research was centred around the exploration of how different stakeholders perceive and operationalize social-ecological system resilience principles in smallholder faming landscapes in the context of sustainable woody vegetation diversity management in southwestern Ethiopia in particular, and in the Global South in general.

Introduction

Introduction

Biodiversity describes the variability among living organisms, including diversity within species, among species and of ecosystems. Biodiversity provides numerous benefits to humanity, which are often termed provisioning (e.g., food, timber), 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. These benefits are essential for human wellbeing.

Especially the diversity of trees, or woody vegetation – including diversity in species identity, traits, composition and configuration – provides multiple direct and indirect benefits to people. For example, trees can provide wood for house construction, fuelwood, medicine or timber, as well as providing cultural services such as spiritual and educational uses. Trees also help to fertilise and protect soils, and regulate our climate and water. Furthermore, trees serve as a home and a source of food for many other species, and contribute prominently to 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. Such diversity, in turn, underpins ecosystem integrity and is valuable for crop pollination, environmental cleansing, pest and disease regulation. In agricultural settings, trees are an important part of a multifunctional landscape, and help to ensure food security and nutrition, particularly in developing countries, where people fundamentally rely on nature.

Nevertheless, driven by "green revolution" discourses, conventional agricultural intensification, deforestation and land degradation endanger the diversity of trees in many landscapes. The ongoing loss of trees could have major negative ramification effects for humanity and ecosystems in many landscapes around the world.

In this small book, we argue that reversing the loss of trees from agricultural landscapes is best achieved by understanding the intimate connections between people and ecosystems. Such a perspective is termed a "social-ecological systems" perspective. It recognises that agricultural landscapes need to not only generate short-term incomes, but that their long-term sustainability is important for both people and ecosystems. 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 (Fig. 1).

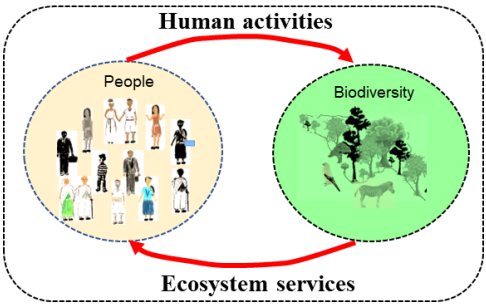


Fig. 1. People and biodiversity influence one another within a social-ecological system (SES).

A social-ecological systems perspective views humans as part of nature, and human-nature interactions form the core of such systems. Social-ecological systems thinking recognises multiple-scale human-nature relations, as well as human dependency and pressure on ecosystems, but also humanity's ability to manage ecosystems sustainably and adaptively. To guide long-term relationships between people and ecosystems, Biggs et al. (2012) identified seven generic principles. Applying these principles to social-ecological systems in general but also to tree diversity management in particular can help to conserve biodiversity and make social-ecological systems adaptable. Using these principles can help to avoid the degradation of these systems into undesirable conditions that may be difficult to reverse.

The following provides an overview of the seven principles identified by Biggs et al. (2012):

PRINCIPLE 1
Maintain diversity and redundancy

- Ecologically, diversity refers to diversity of tree species, their habitats or ecosystems. Redundancy is functional replication of species, which provides options for responding to change or uncertainty, thereby building resilience.

- Socially, diversity refers to the diversity of social actors. Redundancy relates to the functional replication of social actors so that they can provide options for responding to change and adapting to uncertainty, thereby building resilience.

PRINCIPLE 2
Manage connectivity

- Ecologically, connectivity describes conditions under which ecological resources can move through landscapes, including seed dispersal or species movements. Such ecological resource movements are key for resilience.

- Socially, connectivity is the way in which multiple social actors interact with each other and collaborate across social structures, domains, or governance levels. Such social connections are key for resilience.

PRINCIPLE 3
Manage slow variables and feedbacks

- Managing slowly changing ecological variables such as the gradual loss of trees from the landscape, as well as feedbacks between people and ecosystems (e.g., loss of tree benefits) is important to avoid crossing possible thresholds into undesired states.

- Managing slowly changing social variables, such as changes in human population size or human culture, is also important to avoid undesired outcomes.

PRINCIPLE 4
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.

PRINCIPLE 5
Encourage learning and experimentation

- The uncertain and dynamic nature of complex SES requires continuous learning via adaptive management, co-management and collaborative governance.

PRINCIPLE 6
Broaden participation

- Active participation of stakeholders in the management and governance process enhances collective action for resilience.

PRINCIPLE 7
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.

These seven principles are described in much more detail in the following chapters. Each chapter is devoted to one principle, and shows how each principle can help to better manage tree species diversity. Each chapter also suggests tangible activities that can be undertaken to operationalize each principle in the context of smallholder farming landscapes. These activities are drawn from our empirical studies in southwestern Ethiopia as well as from a literature review covering many other landscapes across the Global South.

Summary

- Trees are critical for biodiversity conservation and human wellbeing.
- However, tree diversity is declining in many agricultural landscapes, and this could have negative consequences for both people and ecosystems.
- To manage landscapes, it is useful to think of them as interconnected social-ecological systems.
- Seven social-ecological resilience principles can be used to better manage trees in agricultural landscapes.

Maintaining diversity and redundancy

Maintaining diversity and redundancy for managing woody vegetation diversity in the landscape

Ecologically, diversity is best approximated via the diversity of genes, species, ecosystems and interactions across those levels. Redundancy occurs when multiple species fulfil the same ecosystem function. Socially, diversity is captured by variety in social groups (e.g., different ethnic groups, language groups, genders, age groups or education levels) as well as variety of rules, norms, beliefs and knowledge systems in a specific social-ecological system. Social redundancy exists when multiple actors have similar roles (e.g., managing the landscape for agrobiodiversity). Social-ecological systems will be resilient if they hold diversity and functional redundancies, that is, having elements that overlap in their function. Thus, increasing diversity and functional redundancy of species and social actors in systems with little diversity and redundancy is useful for increasing SES resilience.

These notions directly relate to woody plant diversity management. Resilience can be enhanced through tree species diversity, which can provide particular or multiple benefits directly or indirectly through their interactions in the landscape (in arable land, pastures, wetlands, gardens and forest patches). For example, multiple tree species may serve as bee forage for honey production or provide many other benefits such as the provision of food, timber, medicine and fuelwood. Resilience can also be enhanced if diverse actors, including local people – of different cultures, age groups and knowledge – fulfil functions and actions to maintain trees in the landscape. Particularly, facilitating the maintenance and management of tree species diversity for different purposes via diverse local groups such as men and women, young and old people, with diverse rules, lifeways and experiences, can enhance the resilience of agricultural landscape.

The following is a list of examples of tangible activities that can be undertaken to operationalise this principle and thereby, enhance sustainable tree management in agricultural landscapes.

Tangible activities to enhance diversity and redundancy

1. Enhance supply of a diversity of seeds and seedlings of native species for planting, including material and technical support for community nurseries.

2. Carry out collaborative activities for tree planting, management and co-monitoring that involve a diversity of women, elders, low-income farmers, wealthy farmers and youngsters.

3. Specifically support mobilization efforts by women, elders, low-income farmers, and youngsters in the landscape.

4. Enhance equitable access to and use of trees by women, elders, low-income farmers, wealthy farmers and youngsters.

5. Improve governance structures to facilitate diversified management of trees and forests.

6. Involve NGOs to facilitate community mobilization in tree and forest management.

7. Involve investors in tree and forest management.

Managing connectivity

Managing connectivity for maintaining woody vegetation diversity in the landscape

Ecologically, connectivity refers to connections between habitat patches that can occur via corridors and stepping stones, including scattered remnant trees, small and large patches of forests, or via species interactions that enable species to migrate, disperse, mate, feed and thrive. Connectivity underpins vital ecosystem functions such as pollination, predator-prey interactions and nutrient cycling. Socially, connectivity among actors and across sectors and administrative levels occurs via social networks. Ideally, social connectivity facilitates collaborative resource management. Too much connectivity can make a system rigid, but in practice this problem is usually less prominent than the problem of having too little connectivity.

Connectivity is highly relevant for the sustainable management of woody plant diversity in agricultural landscapes. Ecologically, connectivity can be enhanced if strips or trees, small patches and scattered trees exist in between large patches of forests. Such strips or stepping stones facilitate seed or propagule dispersal, for example by wild animals and dispersal agents like birds, and thereby promote tree species diversity throughout the landscape. Connectivity is especially important for native tree species, whose existence largely depends on natural seed dispersal agents that enable them to persist despite land use and climate change. Socially, tree species diversity management can be enhanced if multiple actors collaborate in tree management across various sectors and governance levels. Connectivity is particularly important for local actors, who can share common perspectives and experiences about tree management and agricultural practices in the landscapes. Here, local social networks can facilitate mutual benefits, in-

formation sharing, and help to build trust, or enforce common rules or bylaws and norms – all of which are important for the collaborative tree management across farming landscapes.

The following is a list of examples of tangible activities that can enhance connectivity for improved tree management in agricultural landscapes.

Tangible activities to manage connectivity

1. Support and strengthen social networks of women, elders, low-income farmers, wealthy farmers and youngsters, as well as interactions and collaboration between these networks.
2. Enhance coordination of diverging ideas, views and interests and thereby, facilitate greater cohesion among different actors, considering especially women, elders, youngsters, and low-income farmers.
3. To prevent forest fragmentation, prevent deforestation and illegal forest encroachment and logging.
4. Establish structures to facilitate and improve social interactions across the landscape and across governance levels.
5. Carefully manage potential conflicts among diverse actors as well as between humans and wildlife.
6. Enhance access to communication technology to improve social connections.

Managing slow variables and feedbacks

Slow variables and feedbacks for managing woody vegetation diversity in agricultural landscapes

Slow variables are variables that change gradually. Ecologically, changes in slow variables are often related to a deterioration in regulating services such as land degradation or climate change. Socially, they are linked to human population growth, poverty, or creeping changes in values and customs. Rapid changes, in contrast, often relate to provisioning services such as food and fuelwood.

Reinforcing (positive) or dampening (negative) feedbacks occur when there is a change in particular variables that loops back to impact the system component emitting other variables. Often, slow variables determine the underlying trajectory of a given social-ecological system, while system dynamics result from interactions and feedbacks among fast variables that respond to the conditions created by the slow variables.

Maintaining woody species diversity and the resilience of social-ecological systems can be improved by carefully managing slow variables or lag effects – that is, the time-delayed response of trees to landscape changes or changes in feedbacks. For example, landscapes that harbour diverse tree species often also provide diverse services. However, agricultural expansion and intensification can cause gradual loss of trees and cause a landscape-level regime shift whereby a landscape may ultimately end up devoid of trees. In this case, stabilizing ecological feedbacks can be strengthened by improving the conditions for natural tree regeneration (a slow, gradual process) or by

controlling the gradual removal of trees by local people (also a gradual process). Socially, it can be important to address gradual human population growth or unsustainable changes in cultural practices (e.g. attrition of traditional values that support the conservation of trees).

In other cases, it is important to disrupt those feedbacks that hold a given farming landscape in a resilient but undesirable regime. For example, an ecosystem might be taken over by invasive species, or a social system might be controlled by development policies that pursue the interests of elites. In such cases, regime shifts towards more favoured states can be triggered by the deliberate removal of invasive trees or assisted regeneration of native species, or by proactive changes to existing policy and institutions.

The following is a list of examples of tangible activities to address important feedbacks and slow variables in the context of managing trees in agricultural landscapes.

Tangible activities to manage slow variables and feedbacks

1. Counteract poverty and generate initiatives that create paid or beneficial employment, including for women, low-income farmers, and youngsters.
2. Slow down gradual depletion of trees for firewood, e.g., by developing alternatives to the use of fuelwood such as cow dung.
3. Ensure equitable access to family planning to slow down population growth.
4. Build on local cultures, norms, values, institutions and customary laws that facilitate the customary ties between people and ecosystems.
5. To avoid long-term degradation of soils, deepen the use of sustainable agricultural methods such as reducing the use of agrochemicals, using crop rotation, and using cow dung and compost as fertilisers.
6. Enhance soil and water conservation practices by using trees to mitigate land and water resource degradation.

Fostering systems thinking

Systems thinking for managing woody vegetation diversity in agricultural landscapes

The resilience of a given SES can be enhanced if scientists, experts, managers and society at large view and understand landscapes as complex adaptive systems (CAS), and use this understanding to manage landscapes in ways that appreciate high levels of interconnectedness, non-linear change, and inherent uncertainty. CAS are shaped from diverse interactions among elements that can discretely or collectively adapt to change, self-organise and evolve, and often produce new behaviour at different spatial and temporal scales. CAS can also shift from one regime to another, often suddenly, producing a system that behaves in different ways than before. Such CAS characteristics make social-ecological systems highly uncertain. CAS thinking provides a suitable cognitive frame that can help actors to manage social-ecological systems in a sustainable way. Fostering CAS thinking by itself may not directly enhance resilience, but it can help to change the cognitive models that reinforce unsustainable management methods and decisions.

Systems understanding can help to maintain and manage woody plant species diversity and the resilience of smallholder farming landscapes, especially if diverse actors collectively use CAS thinking to guide their decision-making. Indeed, shifting away from reductionist (e.g., seeing a tree for its wood only) and sectoral thinking (e.g., striving for agricultural or forest productivity only, and separately) towards holistic and integrated approaches recognises multiple

goals and actors, including low-income smallholder farmers, and their needs and ecological experiences. CAS thinking can help identify and manage slow variables, time lags, and feedbacks (Principle 3). Furthermore, CAS thinking helps to prepare for uncertainty and change, and thereby supports continuous learning and experimentation (Principle 5) in tree management in order to better adapt to unforeseen disturbances in farming landscapes.

The following is a list of examples of tangible activities that can be undertaken to foster systems thinking for the benefit of sustainable tree management in agricultural landscapes.

Tangible activities to enhance systems thinking and its use

1. Encourage stakeholders to see the connections within their landscape, e.g., not seeing land only for crop cultivation, or seeing trees only as a source of wood – but also noting local people's diverse benefits from land and trees, so that they can be managed in an integrated way.
2. Strengthen awareness and sharing of experiences with respect to traditional ecological knowledge.
3. Manage social and ecological systems for their many benefits, including as a safety buffer against natural shocks (e.g., drought, flood), rather than managing them only to produce maximum quantities of few commodities.
4. Establish structures to facilitate social learning and use systems thinking for both environmental and human wellbeing.

Encouraging continuous learning and experimentation

Continuous learning for managing woody vegetation diversity in the landscape

Continuous learning is desirable, because social-ecological systems are complex and thus, knowledge about them is always incomplete, and also needs repeated renewal to adapt to unavoidable uncertainty, changes and shocks. Continuous learning can be facilitated through adaptive management, co-monitoring and governance processes. These processes can facilitate social learning that focuses on the questions: "are we doing things right?", "are we doing the right things?", and "how do we know what the right thing to do is?". Social learning refers to knowledge acquired across wider social units via deliberate or unintended interactions within social networks. By influencing decision-making and governance processes, learning enhances social-ecological resilience.

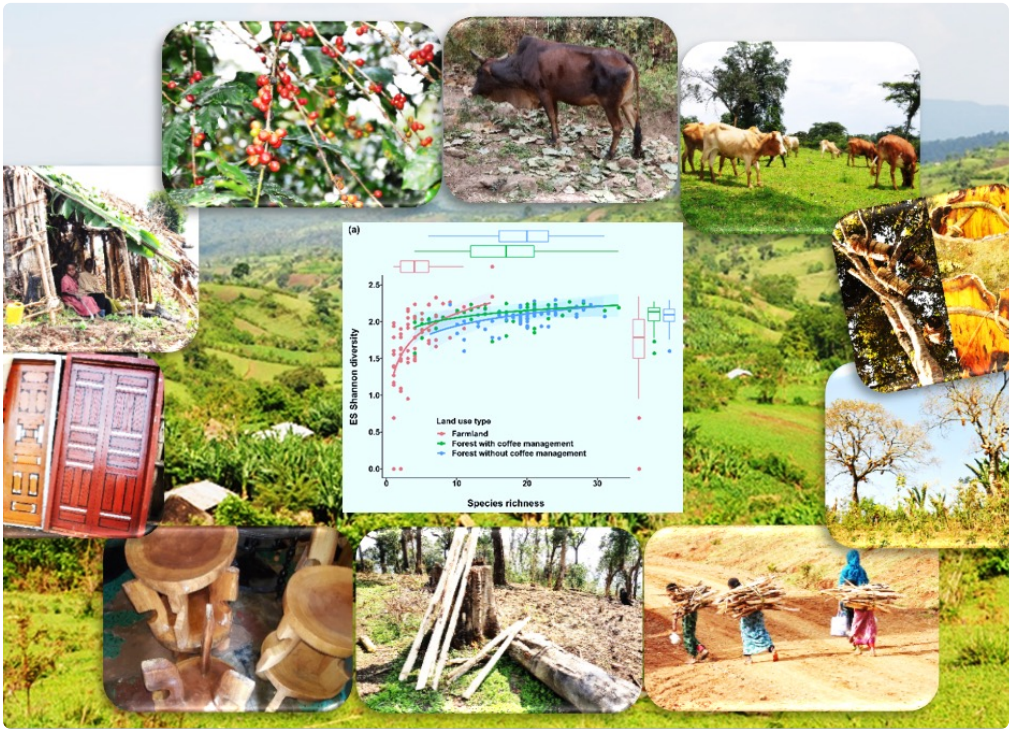
Continuous learning is vital for managing woody plant species diversity in the landscape. Tree attributes such as their lifespan and species-specific uses, and people's long-standing traditional ecological experiences can provide valuable opportunities to augment social learning processes via adaptive tree management. For instance, manipulating trees in different ways and comparing or co-monitoring the impacts of different management practices can enable learning about the responses of species and ecosystem services to different management practices and social-ecological changes. Co-monitoring by diverse actors facilitates knowledge co-production among actors involved in tree management. It also helps to foresee how a given system may perform in the future. Involving a wide range of actors (Principle 6 – broad participation) in co-monitoring processes can also facilitate knowledge sharing across scales, thereby connecting actors across landscapes and governance

levels (Principle 2 –social connectivity). Moreover, social learning helps different actors to understand and empathise with each other's thinking (Principle 4 – enhance systems thinking), thereby building trust, norms and values that may facilitate conflict resolution.

The following is a list of examples of tangible activities that can be undertaken to foster continuous learning for sustainable tree management in agricultural landscapes.

Tangible activities to enhance continuous learning

1. Work with local communities to plant, manage and monitor trees, and learn with them from their experiences.
2. Empower individuals who manage trees to use their knowledge, including women, elders, low-income farmers, wealthy farmers and youngsters.
3. Revitalise local cultures, norms, values, institutions and customary laws that can encourage learning.
4. Encourage the sharing of experiences on how to manage and maintain various tree species and their multiple benefits in the landscape.


(a)
ES Shannon diversity
Species richness
Land use type
Farmland
Forest with coffee management
Forest without coffee management

Broadening participation

Participation for managing woody vegetation diversity in the landscape

Theoretically, participation can range from simply informing people about decisions already made to complete devolution of decision-making powers and management to them. Participation can also occur in all or some stages of social-ecological systems management, from the identification of problems and objectives or policy formulation, to policy implementation, monitoring of results and evaluation of outcomes.

Genuine participation – including the devolution of at least some decision-making powers and management to local people – is important for woody plant species diversity maintenance, and hence, for resilience of social-ecological systems and the ongoing provisioning of ecosystem services in smallholder farming landscapes. Inclusive and genuine participation in tree species maintenance, management and use can have various advantages. First, engaging relevant stakeholders, particularly farmers, in tree and forest management can help to increase trust and build a common understanding that is grounded in existing traditional knowledge and experiences. Second, participation can improve legitimacy, co-monitoring and decision-making. Third, genuine participation can also increase the level of collaboration among actors and transparency of information sharing. This, in turn, facilitates improved understanding of ecological, social, and political perspectives of farming landscape dynamics that may not be discovered by conventional scientific approaches. Fourth, participation can rein-

force the link between research and decision-making, and foster learning and the creation of new rules, norms and institutions for effective landscape governance. By transforming actors' perceptions and attitudes, participation can therefore promote a shift to more sustainable tree management, thereby improving social-ecological resilience of the farming landscape as a whole.

The following is a list of examples of tangible activities that can be undertaken to foster genuine participation for sustainable tree management in agricultural landscapes.

Tangible activities to enhance participation

1. Enhance involvement and encourage self–mobilization of women, elders, low-income farmers, wealthy farmers and youngsters in tree and forest management.
2. Recognize local people's access and use rights to trees.
3. Enhance equity among all stakeholders, including disadvantaged groups.
4. Empower local people to sustaiably manage trees in the landscape.
5. Define clearly the roles of powerful actors, such as government and religious institutions, relative to the roles of local people.

Promoting polycentric governance systems

Polycentric governance for managing trees in the landscape

Governance refers to the structures and processes in which people share power, and shape individual and collective actions. In polycentric governance networks, each unit has some autonomy, and can connect to other units horizontally as well as to higher governmental levels vertically. In doing so, polycentric governance system can enhance social-ecological system resilience by enabling governance to fit to the specific problem being addressed at any given time.

Polycentric governance systems are relevant for the governance of woody plant diversity management and for the resilience of smallholder farming landscapes. Essentially, the arrangement of multiple and nested institutions can mimic smaller scales embedded in smallholder farming landscape and can also benefit from context-specific local knowledge and social networks (e.g., see figure below: blue coloured circle show the smaller scale of units, and red arrows highlight horizontal connections among units). In polycentric governance, networked institutions can tackle tree management and maintenance problems rapidly at the right time via a set of rules that interact across multiple units and levels. For example, they can facilitate the fit between experiences, actions and social-ecological contexts, and enable local actors to manage trees adaptively. Moreover, such nested institutions can also stabilize power imbalance between top-down and bottom-up governance. In doing so, polycentric governance can en-

hance sustainable tree management and maintenance and thereby, social-ecological system resilience through creating institutional modularity (i.e., independently emerging and functioning units), increasing diversity and functional redundancy (Principle 1), improving the connectivity of social and ecological networks (Principle 2) and continued learning and experimentation (Principle 5), and active and genuine participation in tree management (Principle 6).

The following is a list of examples of tangible activities that can be undertaken to enhance polycentric governance systems for sustainable tree management across farming landscape.

Tangible activities to enhance polycentric governance

1. Establish tree management units at multiple levels of governance, from local to regional, including communication and decision structures in which these can interact.
2. Draw on existing local norms and customary laws to facilitate multi-level governance.
3. Ensure transparency and freedom of speech of all actors at all levels of governance.
4. Enforce rules around the management of trees and forests.
5. Enhance collaboration among stakeholders for tree and forest management, for example by establishing committees involving a diversity of actors from multiple levels of governance.

Conclusion

Conclusion

Established social-ecological resilience principles can provide meaningful and tangible guidance for the sustainable management of woody vegetation in smallholder-dominated farming landscapes – with likely positive repercussions for social-ecological resilience and adaptability, and hence, with the possibility to also contribute to the UN Sustainable Development Goals. Applying all seven principles is important in the landscapes of low-income countries in the Global South. As all principles are meant to enhance both social and ecological diversity, the principles partly overlap, and many synergies arise from applying all principles at once. Because of this, tangible activities undertaken to enhance the application of one principle can also improve the application of the other principles.

Some tangible activities – especially for managing diversity and redundancy (P1), connectivity (P2), and slow variables and feedbacks (P3) – might be relatively easy to implement. In contrast, other activities – such as those for enhancing participation (P6), continuous learning (P5) and polycentric governance systems (P7) – might be more challenging. These may require a paradigm shift and political willingness to care for nature and more genuinely recognise local people and their livelihoods and experiences. Tangible activities to more broadly use complex adaptive systems thinking (P4) are often context-specific, but these, too, require us to move away from deep-rooted mental models such as sectoral views of environmental management.

In general, conducting tangible activities to operationalise a particular principle thus needs more holistic and integrative approaches that appreciate diverse goals and local actors. This, in turn, will ensure the best possible use of existing resilience principles for woody vegetation management in smallholder landscapes. Operationalizing the resilience principles outlined in this booklet thus requires the full recognition of local people, most importantly farmers, who have lifelong ecological knowledge and close ties to nature.


Egeree kibba lixa
Itoophiyaa agarsiisuu
Akkuma haalota tahuu dandahan kana hubatten gaaffiiwan armaan gadii of-gaafadhu:
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Appendix

A1. Example of guiding questionnaires used for empirical data collection via focus group discussions of multiple stakeholders in southwestern Ethiopia.

P1 – Maintaining diversity and redundancy

ECOLOGICAL: Maintaining species diversity and redundancy (of their benefits) in the landscape

Date: _____

Data recorded by: _____

Focus group/workshop (sub-group) name/type: _____

Number of participants: _____

Place/locality of meeting: _____

1. What are tree and shrub species that exist (or should exist) that provide benefits in the landscape (i.e., in arable land, pastures, gardens, forest patches and protected areas)? Benefits can be direct (e.g., fuelwood, timber, medicine), or indirect (e.g., soil fertility enhancement, soil erosion control, microclimate regulation, shade for crop or people, and habitat for animals). A checklist of tree and shrub species and benefits is provided.

a. Which are tree and shrub species that exist (should exist) and provide direct benefits in the landscape?

Existing tree and shrub species that provide direct benefits	Tree species that should exist and provide direct benefits

b. Which are tree and shrub species that exist (should exist) and provide indirect benefits in the landscape?

Existing tree and shrub species that provide indirect benefits	Tree species that should exist and provide indirect benefits

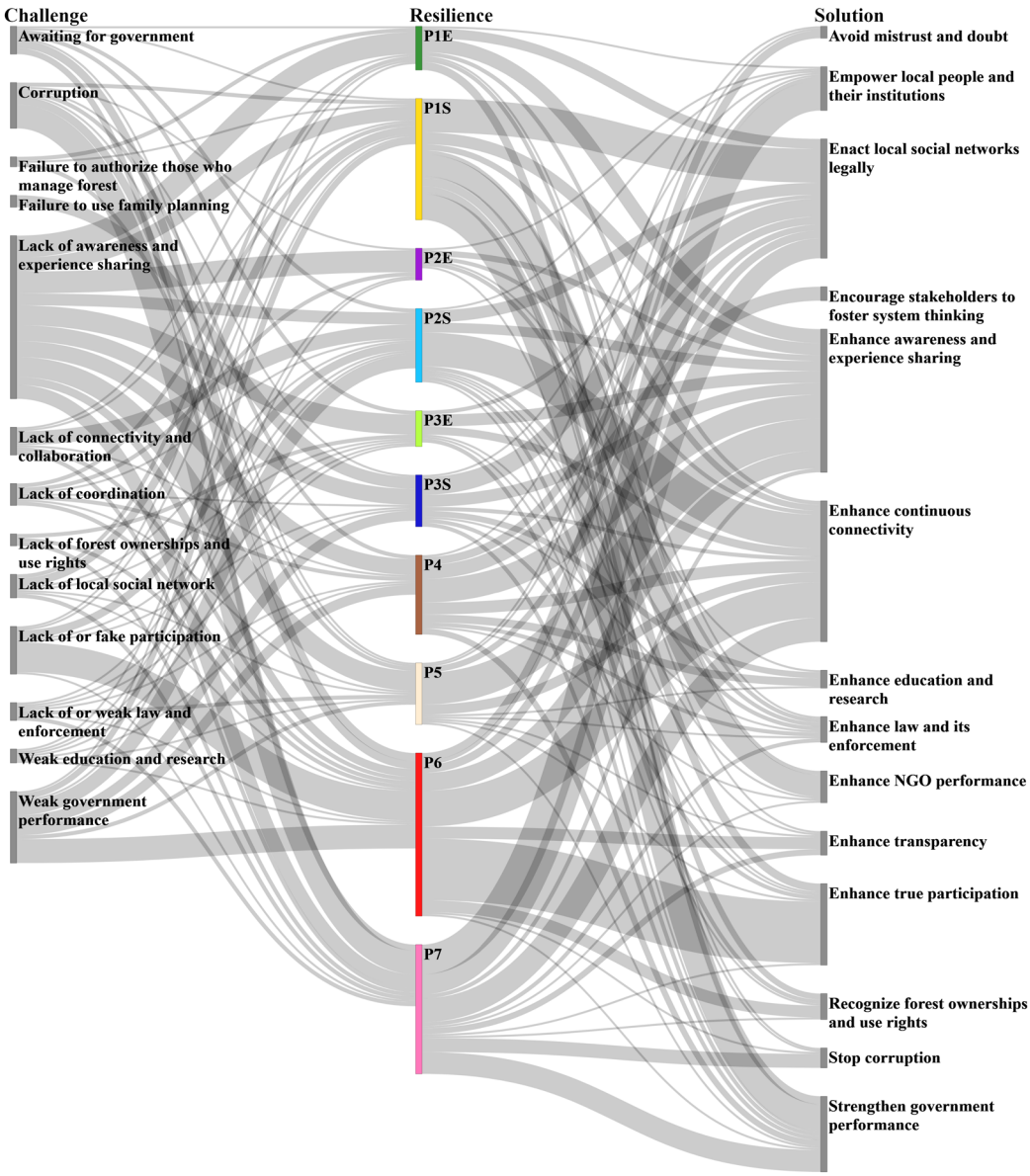
2. How can the diversity of trees and their benefits be maintained in the landscape in the future?

_____
_____
_____

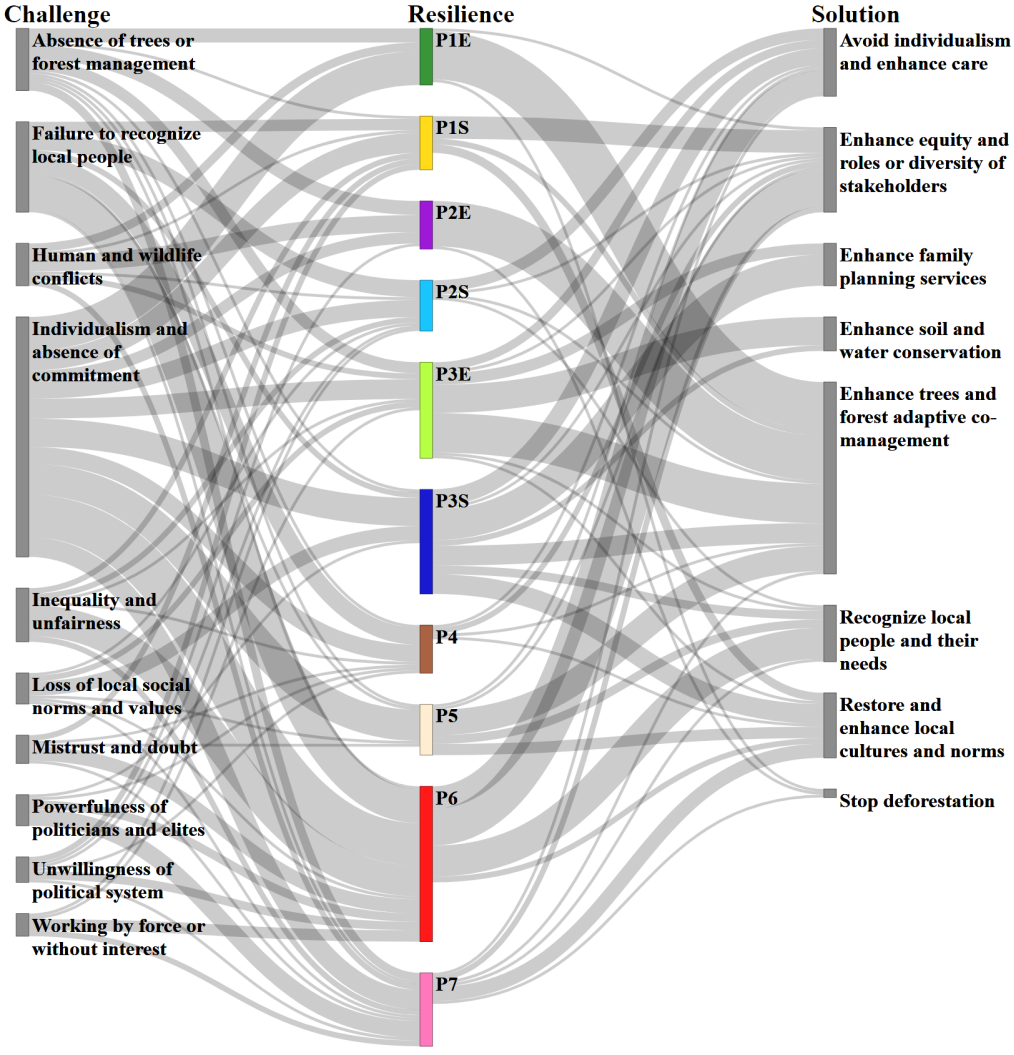
3. Why is the diversity of trees in the landscape not maintained?

_____
_____
_____

A2. A diagram showing the relationship between perceived challenge, resilience principle and solution or tangible activity at system design level in the study area.



A3. A diagram showing the relationship between perceived challenge, resilience principle and solution or tangible activity at system intent level in the study area.



Further reading

Altieri, M. A. (2008). Small farms as a planetary ecological asset: Five key reasons why we should support the revitalisation of small farms in the Global South. Third World Network. https://twn.my/title/end/pdf/end07.pdf.

Biggs, R., M. Schlüter, D. Biggs, E. L. Bohensky, S. Burnsilver, G. Cundill, V. Dakos, T. M. Daw, L. S. Evans, K. Kotschy, A. M. Leitch, C. Meek, A. Quinlan, C. Raudsepp-hearne, M. D. Robards, M. L. Schoon, L. Schultz, and P. C. West. 2012. Toward principles for enhancing the resilience of ecosystem services. Annual Review of Environment and Resources 37:421–48.

Biggs, R., M. Schlüter, and M. L. Schoon, editors. 2015. Principles for building resilience: sustaining ecosystem services in socialecological systems. Cambridge University Press, Cambridge, UK. http://dx.doi.org/10.1017/cbo9781316014240

Fischer, J., T. A. Gardner, E. M. Bennett, P. Balvanera, R. Biggs, S. Carpenter, T. Daw, C. Folke, R. Hill, T. P. Hughes, T. Luthe, M. Maass, M. Meacham, A. V. Norström, G. Peterson, C. Queiroz, R. Seppelt, M. Spierenburg, and J. Tenhunen. 2015. Advancing sustainability through mainstreaming a social-ecological systems perspective. Current Opinion in Environmental Sustainability 14:144–149.

Manlosa, A. O., G. Shumi, K. Hylander, J. Schultner, I. Dorresteijn, et al. 2020. Harmonising biodiversity conservation and food security in southwestern Ethiopia. PENSOFT.

Rivers, M., A. C. Newton, S. Oldfield and Global Tree Assessment Contributors. 2022. Scientists' warning to humanity on insect extinctions. Plants, People, Planet, 1–17.

Shumi, G., J. Loos, and J. Fischer. (under review). Enhancing the sustainability of smallholder farming landscapes in the Global South by applying resilience principles to woody vegetation management.

Shumi, G., H. Wahler, M. Riechers, F. Senbeta, D. J. Abson, J. Schultner, J. Fischer. (under review). Resilience principles and a leverage points perspective for sustainable woody vegetation management in a social-ecological system of southwestern Ethiopia.

Shumi, G., P. Rodrigues, J. Hanspach, W. Härdtle, K. Hylander, F. Senbeta, J. Fischer, and J. Schultner. 2021. Woody plant species diversity as a predictor of ecosystem services in a social-ecological system of southwestern Ethiopia. Landscape Ecology 26:373–391.

Shumi, G., I. Dorresteijn, J. Schultner, K. Hylander, F. Senbeta, et al. 2019. Woody plant use and management in relation to property rights: a social-ecological case study from southwestern Ethiopia. Ecosystems and People 15:303–316.

Shumi, G., P. Rodrigues, J. Schultner, I. Dorresteijn, J. Hanspach, et al. 2019. Conservation value of moist evergreen Afromontane forest sites with different management and history in southwestern Ethiopia. Biological Conservation 232:117–126.

Shumi, G., J. Schultner, I. Dorresteijn, P. Rodrigues, J. Hanspach, et al. 2018. Land use legacy effects on woody vegetation in agricultural landscapes of south-western Ethiopia. Diversity and Distributions 24:1136–1148.

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