


Leveraging change in ecosystem restoration: from planting trees to regenerating people-nature systems

Marina Frietsch ^{a,b,*} , Beth A. Kaplin ^{b,c}, Athanase Mukuralinda ^d, Donath Nkurikiyimana ^e, Appollinaire William ^f, Jean Damascene Bariyanga ^g, Dula Wakassa Duguma ^a, Cecile Kayitanirwa ^h, Myriam Mujawamariya ^{b,i}, Venuste Nsengimana ^{b,i}, Pierre Nshimyumuremyi ^j, Verene Nyiramvuyekure ^a, Jean Nduwamungu ^k, Shema Serge ^l, Ezechiel Turikunkiko ^m, Diogene Tuyizere ^h, Joern Fischer ^a

^a Leuphana University, Social-Ecological Systems Institute, Faculty of Sustainability, Universitätsallee 1, 21335 Lüneburg, Germany

^b Center of Excellence in Biodiversity and Natural Resource Management, University of Rwanda, Kigali, Rwanda

^c School for the Environment, University of Massachusetts, Boston, MA, USA

^d CIFOR-ICRAF, Rwanda Country Office, P.O. Box 227, Huye, Rwanda

^e Dian Fossey Gorilla Fund, Kinigi, Rwanda

^f Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalder Str. 84, 15374 Müncheberg, Germany

^g University of Rwanda, College of Veterinary Medicine and Animal Sciences, School of Animal Sciences and Biotechnology, Nyagatare Campus, P.O. Box 57 Nyagatare, Rwanda

^h Rwanda Wildlife Conservation Association, Kigali, Rwanda

ⁱ University of Rwanda, Department of Biology, College of Science and Technology, Kigali, Rwanda

^j One Acre Fund, Kigali, Rwanda

^k University of Rwanda, Musanze Campus, Rwanda

^l Wildlife Conservation Initiative, Musanze, Rwanda

^m Rwanda Development Board, Gishwati-Mukura National Park, Rutsiro, Rwanda

ARTICLE INFO

Keywords:

Ecosystem restoration
Forest landscape restoration
Leverage points
Social-ecological systems
Regeneration

ABSTRACT

Despite calls for more integrated ecosystem restoration approaches, many restoration projects continue to focus on simple metrics capturing isolated ecological or social system dimensions. To realize the potential of ecosystem restoration to generate a multitude of desirable social-ecological outcomes, we argue that a change in mindsets is needed to move from planting trees to regenerating people-nature systems. Drawing on a leverage points perspective, we propose that changing the paradigms that underpin restoration could shift the modus operandi from an instrumental perspective of 'nature for people' to a relational perspective of 'people with nature'. Following three interacting realms of leverage for transformational change, we use the case study of western Rwanda to exemplarily illustrate how restoration can serve as a critical entry point for *re-connecting* people and nature in degraded landscapes, *re-structuring* the time scales considered in natural resource management, and *re-thinking* the use of diverse types of knowledge in this context. Combining these three realms in place-based restoration efforts can inform new avenues for ecosystem restoration that are rooted in genuine social-ecological relationships. This, in turn, could trigger regenerative dynamics in restoration landscapes – i.e., mutually reinforcing dynamics that support both human and non-human wellbeing. This approach reflects a broader transition from repairing fragmented landscape elements to regenerating integrated social-ecological systems.

* Corresponding author.

E-mail addresses: marina.frietsch@leuphana.de (M. Frietsch), bkaplin@antioch.edu (B.A. Kaplin), A.Mukuralinda@cifor-icraf.org (A. Mukuralinda), dnkurikiyimana@gorillafund.org (D. Nkurikiyimana), williappollo2005@gmail.com (A. William), baridamass@gmail.com (J.D. Bariyanga), dula.duguma@leuphana.de (D.W. Duguma), cecile@rwandawildlife.org (C. Kayitanirwa), mmujawamariya@gmail.com (M. Mujawamariya), venusteok@gmail.com (V. Nsengimana), pierre.nshimyumuremyi@oneacrefund.org (P. Nshimyumuremyi), verene.nyiramvuyekure@leuphana.de (V. Nyiramvuyekure), jeanduwa@gmail.com (J. Nduwamungu), sergeshema20@gmail.com (S. Serge), ezechiel.turikunkiko@rdb.rw (E. Turikunkiko), diogene@rwandawildlife.org (D. Tuyizere), joern.fischer@leuphana.de (J. Fischer).

<https://doi.org/10.1016/j.tfp.2025.101134>

Available online 19 December 2025

2666-7193/© 2026 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

1. Introduction

The recovery of degraded or destroyed ecosystems can contribute to biodiversity conservation, human well-being, and climate change mitigation and adaptation (Gann et al., 2019). In practice, however, many ecosystem restoration efforts remain below their potential (e.g., Maes et al., 2024; Jahel and Lambin, 2025). In response, scientists and practitioners have called for more integrated approaches to restoration that encompass ecological and social system elements as well as their interactions and feedbacks (Fischer et al., 2021; Tedesco et al., 2023).

Still, despite such calls, many restoration projects continue to pursue social and ecological objectives in poorly integrated ways, or even at the expense of one another. In northern India, for example, large-scale tree planting programs resulted in modest shifts in forest composition but offered no substantial benefits for climate change mitigation or local livelihoods (Coleman et al., 2021). In Senegal, tree plantings for the Great Green Wall impeded pastoral livelihoods by converting pastureland, blocking livestock routes, and obstructing access to water points (Turner et al., 2021). In contrast, reports from restoration projects that are genuinely grounded in social-ecological systems thinking show that mutualistic gains for both people and nature are possible. In southern Brazil, for example, forest restoration informed by a social-ecological project design resulted in numerous positive ecological and social outcomes as well as receiving lasting community support (da Silva et al., 2024). These examples illustrate the importance and potential of integrating social and ecological dimension in restoration efforts.

To move social-ecological ecosystem restoration practice forward, we argue that a change in mindsets is needed: too often, restoration projects are still primarily about planting trees rather than about recreating viable relationships between people and nature – despite most projects being implemented in human-dominated landscapes (Erbaugh et al., 2020). Drawing on our experiences from Rwanda, we outline how, ideally, restoration can be a gateway for people to live with nature in ways that enhance both biodiversity and human well-being, signalling a shift from repairing isolated features of a landscape to regenerating the manifold and interacting elements and dynamics that constitute a complex social-ecological system.

2. Leveraging change in ecosystem restoration

There are countless valuable guidelines for ecosystem restoration (e.g., Gann et al., 2019; FAO et al., 2021; Osborne et al., 2021). While these are all useful in different contexts, ultimately, a simple cookbook for social-ecological restoration will not be enough to motivate and inform truly integrative, self-sustaining restoration projects. Rather, we believe that a fundamental shift in mindsets is needed to move from linear thinking towards systems thinking. When the measured goals of a restoration project remain focused on simple metrics such as number of trees or hectares planted, the number of households involved, or the number of jobs generated, this likely neglects vital social-ecological dynamics and may (even inadvertently) continue pathways of top-down governance. In contrast, when we see the goal of restoration in the re-creation of meaningful relationships between people and nature, restoration is not merely something that can be counted, but a fundamental shift in people's being and doing on a daily basis.

Targeting deep leverage points (Meadows, 1999) by changing the paradigms that underpin restoration could shift the modus operandi from an instrumental perspective of 'nature for people' to a relational perspective of 'people with nature' (Reyers and Bennett, 2025). Through this, restoration can help to change the design and intent of a system – i.e., the structure of information flows, rules, power and self-organization, and the underpinning values, goals, and worldviews, respectively (Abson et al., 2017) – and thereby shape the trajectory of restoration landscapes. In the context of ecosystem restoration, fostering such a paradigm shift could be achieved by focusing on three interacting realms of leverage for transformational change laid out by Abson et al. (2017):

people's connections to nature in restored landscapes (*re-connect*), institutional structures and governance mechanisms that enable and shape restoration activities (*re-structure*), and knowledge production and use of diverse knowledge types on ecosystem restoration (*re-think*) (Fig. 1). In Section 3, we provide tangible place-based examples from western Rwanda to illustrate how transformational change could be put into practice along these three realms.

3. Re-connecting, re-structuring, and re-thinking ecosystem restoration in western Rwanda

3.1. Re-connecting humans and nature

First, to *re-connect* humans with more-than-human nature, ecosystem restoration projects need to first recognise where such links remain strongest. In western Rwanda, homegardens are vital spaces of interaction between human and more-than-human nature, but they typically remain underrecognized in a restoration context. Recent research in western Rwanda has shown that the diversity of native trees and shrubs is substantially higher in homegardens than in the surrounding agricultural mosaic where tree planting interventions were implemented as part of restoration projects (Nyiramvuyekure et al., 2025). As such, homegardens are important strongholds of native biodiversity and could be valuable sources of seeds for future restoration activities.

The relatively high diversity of native species in homegardens also indicates that native species are valued by local communities to the extent that they are actively maintained and propagated around the house. Moreover, homegardens are central elements of sustainable nutrition because they harbour diverse food plants that are rich in vitamins and micronutrients (Reyes-Sacdalán et al., 2025).

Thus, homegardens are sources of native biodiversity, sources of nutrition, and important islands of biodiversity within an otherwise impoverished landscape. In addition, their potential to act as repositories of local knowledge, bolster food sovereignty, strengthen local economies, and enhance climate resilience has been documented in other contexts such as Uganda, Mexico, and India (Whitney et al., 2018; Salcedo and Ceccon, 2020; Mallick et al., 2024). This makes homegardens ideal starting points for strengthening the connection between human and more-than-human nature and for carrying this connection into the wider landscape.

3.2. Re-structuring time scales of restoration governance and practice

Second, to *re-structure* ecosystem restoration practice in western Rwanda, governance and finance instruments need to mirror ecological and social realities on the ground. Here, one central aspect is the prevalent mismatch between short-term restoration projects and the long timeframes at which ecological and social restoration processes unfold (Hodge and Adams, 2016; Moreno-Mateos et al., 2020).

Species selection is one example where time plays a central role. In Rwanda – and many other settings – a common argument to justify why introduced species are favoured in restoration plantings is their fast growth that provides much-needed immediate returns to communities (Ruticumugambi et al., 2024; Bapfakurera et al., 2025). While such short-term gains are important, long-term benefits provided by native plant species are also vital for sustained livelihoods, biodiversity conservation, and climate change mitigation and adaptation (Di Sacco et al., 2021).

Similarly, time plays a central role in social processes with needs and preferences related to restoration shifting over time (M. Frietsch et al., 2024). Transdisciplinary approaches can support the participatory development of restoration projects that consider different temporal scales from the perspective of diverse actors. One such approach – the three horizons framework – was recently trialled in Rwanda (manuscript in preparation). By providing a structured approach to think about the current system, desirable futures, and ways to bridge present and future

(Sharpe et al., 2016), the application of the framework showed how concrete ways forward for restoration can be developed when different time frames are made explicit.

By integrating short- and long-term perspectives, restoration projects can deliver sustained benefits in different social-ecological domains grounded in local needs and knowledge – not only in the next years but also in the coming decades and centuries. This is particular critical in western Rwanda, where the majority of people directly rely on the land they live on (National Institute of Statistics of Rwanda, 2023), and where rapid population growth is projected for the coming years (UN DESA, 2019).

3.3. Re-thinking restoration practice through the lens of different types of knowledge

Third, to *re-think* how ecosystem restoration can be put into practice, diverse knowledge systems need to be integrated. Restoration actors hold different types of knowledge that are often only partially being drawn upon in Rwanda – and in many restoration settings elsewhere (Reyes-García et al., 2019). Yet, when scientific and local traditional knowledge are interweaved, more comprehensive understandings of the landscape can be generated, and new solutions be developed (Tengö et al., 2017). Specifically, traditional knowledge can contribute grounded information on historical system states, guide site and species selection, and inform context-sensitive land management and monitoring practices (Uprety et al., 2012; Reyes-García et al., 2019). This, in turn, can enhance social acceptance, economic feasibility, and ecological effectiveness of restoration interventions (Uprety et al., 2012).

Restoration actors in western Rwanda engage in a portfolio of different activities (Taremwa et al., 2022) and approach restoration planning, implementation, and monitoring from different, yet complementary, angles (M. Frietsch et al., 2024). This suggests the availability of a broad spectrum of both traditional and scientific knowledge to inform restoration. However, although valuable traditional knowledge of the benefits associated with native species still exists in Rwanda (Nsengimana et al., 2020; Bulonvu et al., 2025), this knowledge is at risk of being lost as these species disappear from the landscape. This is representative of a larger trend of traditional knowledge being jeopardized because of cultural and ecological changes (Haq et al., 2023). This illustrates that integrating diverse knowledge types is important to (1) preserve valuable existing knowledge and (2) benefit from this knowledge to inform restoration practices tailored to local conditions.

To make the available knowledge actionable, diverse actors need to

work together throughout iterative cycles of restoration activities, systematically and collaboratively assessing, adjusting, and improving restoration policy and practice. Here, living laboratories that bring together committed actors from community, practice, science, and government in a true partnership can be a valuable tool for collaborative restoration planning, implementation, and monitoring (Fischer et al. 2021).

3.4. New avenues for ecosystem restoration western Rwanda

When these three realms of leverage for transformational change – re-connect, re-structure, and re-think – are combined, new, truly integrative avenues for ecosystem restoration can emerge. Such new avenues, in turn, will be more likely to be successful because they are grounded in genuine social-ecological relationships.

One tangible opportunity for a new way to re-connect, re-structure, and re-think in the context of restoration in Rwanda is the development of a coffee corridor connecting three National Parks in Western Rwanda (Reckmann et al., 2025): the Rwandan government has long recognized the potential to connect Nyungwe National Park via Gishwati-Mukura National Park to the Volcanoes National Park (Kisioh, 2015). However, a viable strategy to turn this vision into reality appears elusive to date. A combination of local preferences and practices, future-oriented governance, and local and scientific knowledge could help to guide the development of a new corridor that works for both biodiversity and people.

If successful, such a corridor could trigger regenerative dynamics in several domains. For example, a high diversity of native trees that is itself multifunctional could form a diverse overstorey of a shade coffee system. Such a multifunctional coffee corridor could facilitate synergies between social, economic and ecological objectives (Gather and Wollni, 2022) – native tree dominated, smallholder-owned shade coffee plantations thus could be valuable stepping stones for biodiversity by effectively reducing the isolation of habitat patches (da Rocha et al., 2021) while also contributing to food security and local livelihoods (Manlosa et al., 2020; Hylander et al., 2024; Reckmann et al., 2025).

The process of putting such a corridor into practice is complex, time and resource intensive, and subject to many open questions. Here, the three realms of leverage for transformational change – re-connect, re-structure, and re-think – could be valuable points of reference for how to strike a new path instead of continuing old patterns of isolated environmental management decisions that do not account for the manifold interactions in a social-ecological system. Specifically, a series of

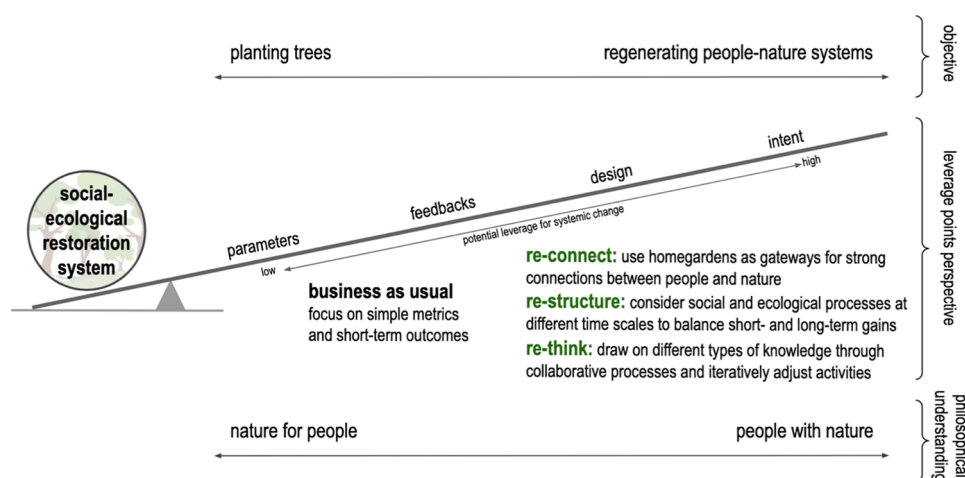


Fig. 1. Three realms of leverage for transformational change – re-connect, re-structure, re-think – can inform integrated social-ecological restoration: by targeting deep leverage points related to the design and intent of a system, restoration can move from *planting trees* to *regenerating people-nature systems* and from an underlying understanding of *nature for people* to a relational worldview of *people with nature* (sensu [Reyers and Bennett, 2025](#)). The concrete recommendations for the three realms of leverage provided here refer to restoration in western Rwanda. Figure based on [Abson et al. \(2017\)](#).

participatory processes (such as the ones outlined in Sections 3.2 and 3.3) could bring together all affected actors to jointly identify steps to reconnect, re-structure, and re-think the social-ecological restoration landscape in the study area. Importantly, the transformation of the restoration system hinges on political support and would not be a one-time effort but a long-term, iterative process.

4. Conclusion

A shade coffee corridor is just one place-based example of how restoration can move beyond simply repairing degraded or destroyed system elements towards creating regenerative, self-sustaining systems that benefit both people and nature. True long-term success will hinge on recognising the ongoing and inherently intertwined social-ecological journey that ecosystem restoration ultimately entails: regenerating social-ecological systems will be far more challenging than just planting trees, but also far more rewarding if it succeeds.

To move forward, we encourage actors who plan, implement, manage, monitor, and research ecosystem restoration in degraded landscapes across the world to recognize the interactions between social-ecological system elements that characterize restoration landscapes – and then tap into the regenerative potential that exists in all social-ecological systems to move from planting trees to regenerating people-nature systems. As illustrated above, a leverage points perspective that (1) makes explicit the importance that underpinning paradigms and mindsets play in system change and (2) offers guidance for putting transformational change into practice can serve as a valuable entry point for exploring pathways towards regeneration in specific restoration landscapes.

Funding sources

This work was supported by the German Research Foundation (grant number FOR5501).

CRedit authorship contribution statement

Marina Frietsch: Writing – original draft, Visualization, Project administration, Conceptualization. **Beth A. Kaplin:** Writing – review & editing, Validation. **Athanase Mukuralinda:** Writing – review & editing, Validation. **Donath Nkurikiyimana:** Writing – review & editing, Visualization. **Appollinaire William:** Writing – review & editing, Validation. **Jean Damascene Bariyanga:** Writing – review & editing, Validation. **Dula Wakassa Duguma:** Writing – review & editing, Validation, Project administration. **Cecile Kayitanirwa:** Writing – review & editing, Validation. **Myriam Mujawamariya:** Writing – review & editing, Validation. **Venuste Nsengimana:** Writing – review & editing, Validation. **Pierre Nshimyumuremyi:** Writing – review & editing, Validation. **Verene Nyiramvuyekure:** Writing – review & editing, Validation. **Jean Nduwamungu:** Writing – review & editing, Validation. **Shema Serge:** Writing – review & editing, Validation. **Ezechiel Turikunkiko:** Writing – review & editing, Validation. **Diogene Tuyizere:** Writing – review & editing, Validation. **Joern Fischer:** Writing – review & editing, Writing – original draft, Supervision, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

References

- Abson, D.J., Fischer, J., Leventon, J., Newig, J., Schomerus, T., Vilsmaier, U., von Wehrden, H., Abernethy, P., Ives, C.D., Jäger, N.W., Lang, D.J., 2017. Leverage points for sustainability transformation. *Ambio* 46 (1), 30–39. <https://doi.org/10.1007/s13280-016-0800-y>.
- Bapfakurera, E.N., Habimana, S., Uwamahoro, P.C., Uwizeyimana, V., Musabayire, C., Zaninka, M.C., Taremwa, N.K., Nibitangaza, S., Uwihirwe, J., 2025. Opportunities and challenges in native species reforestation on smallholder farms in Rwanda: a review. *Rwanda J. Agric. Sci.* 4 (1), 203–220.
- Bulonvu, F., Imani, G., Mujawamariya, M., Kaplin, B.A., Mutabazi, P., Cuni-Sanchez, A., 2025. The importance of native trees and forests: smallholder farmers' Views in south-western Rwanda. *Forests* 16 (8), 1234. <https://doi.org/10.3390/f16081234>.
- Coleman, E.A., Schultz, B., Ramprasad, V., Fischer, H., Rana, P., Filippi, A.M., Güneralp, B., Ma, A., Rodriguez Solorzano, C., Guleria, V., Rana, R., Fleischman, F., 2021. Limited effects of tree planting on forest canopy cover and rural livelihoods in Northern India. *Nat. Sustain.* <https://doi.org/10.1038/s41893-021-00761-z>.
- da Rocha, Brigatti, E., Niebuhr, B.B., Ribeiro, M.C., Vieira, M.V., 2021. Dispersal movement through fragmented landscapes: the role of stepping stones and perceptual range. *Lands. Ecol.* 36 (11), 3249–3267. <https://doi.org/10.1007/s10980-021-01310-x>.
- da Silva, B.A., de Oliveira, R.E., Domingues, T.F., 2024. Multifunctionality, social benefits, and engagement: insights for forest restoration success from a study case in Brazil. *Restor. Ecol.* <https://doi.org/10.1111/rec.14305>.
- Di Sacco, A., Hardwick, K.A., Blakesley, D., Brancalion, P.H.S., Breman, E., Cecilio Rebola, L., Chomba, S., Dixon, K., Elliott, S., Ruyonga, G., Shaw, K., Smith, P., Smith, R.J., Antonelli, A., 2021. Ten golden rules for reforestation to optimize carbon sequestration, biodiversity recovery and livelihood benefits. *Glob. Change Biol.* 27 (7), 1328–1348. <https://doi.org/10.1111/gcb.15498>.
- Erbaugh, J.T., Pradhan, N., Adams, J., Oldekop, J.A., Agrawal, A., Brockington, D., Pritchard, R., Chhatre, A., 2020. Global forest restoration and the importance of prioritizing local communities. *Nat. Ecol. Evol.* 4 (11), 1472–1476. <https://doi.org/10.1038/s41559-020-01282-2>.
- FAO, IUCN, CEM, SER, 2021. Principles For Ecosystem Restoration to Guide the United Nations Decade 2021–2030. FAO. https://cdn.ymaws.com/www.ser.org/resource/resmgr/publications/principles_for_ecosystem_res.pdf.
- Fischer, J., Riechers, M., Loos, J., Martín-López, B., Temperton, V.M., 2021. Making the UN decade on ecosystem restoration a social-ecological endeavour. *Trends Ecol. Evol.* 36 (1), 20–28. <https://doi.org/10.1016/j.tree.2020.08.018>.
- Frietsch, M., Fischer, J., Kaplin, B.A., Martín-López, B., 2024a. The relevance of international restoration principles for ecosystem restoration practice in Rwanda. *Restor. Ecol.* <https://doi.org/10.1111/rec.14085>.
- Frietsch, M., Pacheco-Romero, M., Temperton, V.M., Kaplin, B.A., Fischer, J., 2024b. The social-ecological ladder of restoration ambition. *Ambio* 53 (9), 1251–1261. <https://doi.org/10.1007/s13280-024-02021-8>.
- Gann, G.D., McDonald, T., Walder, B., Aronson, J., Nelson, C.R., Jonson, J., Hallett, J.G., Eisenberg, C., Guariguata, M.R., Liu, J., Hua, F., Echeverría, C., Gonzales, E., Shaw, N., Decler, K., Dixon, K.W., 2019. International principles and standards for the practice of ecological restoration. *Restor. Ecol.* 27 (1), 1–46.
- Gather, J., Wollni, M., 2022. Setting the standard: does Rainforest Alliance Certification increase environmental and socio-economic outcomes for small-scale coffee producers in Rwanda? *Appl. Econ. Perspect. Policy* 44 (4), 1807–1825. <https://doi.org/10.1002/aep.13307>.
- Haq, S.M., Pieroni, A., Bussmann, R.W., Abd-ElGawad, A.M., El-Ansary, H.O., 2023. Integrating traditional ecological knowledge into habitat restoration: implications for meeting forest restoration challenges. *J. Ethnobiol. Ethnomed.* 19 (1), 33. <https://doi.org/10.1186/s13002-023-00606-3>.
- Hodge, I., Adams, W., 2016. Short-term projects versus adaptive governance: conflicting demands in the management of ecological restoration. *Land* 5 (4), 39. <https://doi.org/10.3390/land5040039>.
- Hylander, K., Nemomissa, S., Fischer, J., Zewdie, B., Ayalew, B., Tack, A.J.M., 2024. Lessons from Ethiopian coffee landscapes for global conservation in a post-wild world. *Commun. Biol.* 7 (1), 714. <https://doi.org/10.1038/s42003-024-06381-5>.
- Jahel, C., Lambin, E.F., 2025. Reversing degradation of social-ecological systems: explaining the outcomes of interventions in Africa. *Sustain. Sci.* 20 (2), 439–468. <https://doi.org/10.1007/s11625-024-01568-5>.
- Kisioh, H. (2015). *Gishwati forest reserve—three years interim management plan*.
- Maes, S.L., Perring, M.P., Cohen, R., Akinnifesi, F.K., Bargaues-Tobella, A., Bastin, J.-F., Bauters, M., Bernardino, P.N., Brancalion, P.H.S., Bullock, J.M., Ellison, D., Fayolle, A., Fremout, T., Gann, G.D., Hishe, H., Holmgren, M., Ilstedt, U., Mahy, G., Messier, C., ..., Muys, B., 2024. Explore before you restore: incorporating complex systems thinking in ecosystem restoration. *J. Appl. Ecol.* <https://doi.org/10.1111/1365-2664.14614>.
- Mallick, M., Singh, P.K., Pandey, R., 2024. Harvesting resilience: tribal home-gardens as socio-ecological solutions for climate change adaptation and sustainable development in a protected area. *J. Clean. Prod.* 445, 141174. <https://doi.org/10.1016/j.jclepro.2024.141174>.
- Manlosa, A., Rodrigues, P., Shumi, G., Hylander, K., Schultner, J., Dorresteijn, I., Hanspach, J., Jiren, T.S., Mausbach, M., Abson, D.J., Senbeta, F., Fischer, J., 2020. *Harmonising Biodiversity Conservation and Food Security in Southwestern Ethiopia*. Pensoft.
- Meadows, D., 1999. Leverage Points: Places to Intervene in a System. The Sustainability Institute, Hartland. https://www.donellameadows.org/wp-content/userfiles/Leverage_Points.pdf.

- Moreno-Mateos, D., Alberdi, A., Morriën, E., van der Putten, W.H., Rodríguez-Uña, A., Montoya, D., 2020. The long-term restoration of ecosystem complexity. *Nat. Ecol. Evol.* 4 (5), 676–685. <https://doi.org/10.1038/s41559-020-1154-1>.
- National Institute of Statistics of Rwanda, 2023. The Fifth Rwanda Population and Housing Census—Main Indicators Report. NISR. https://www.statistics.gov.rw/publication/main_indicators_2022.
- Nsengimana, T., Nsengimana, V., Nsanganwimana, F., 2020. Local knowledge and use of wild edible plants in eastern part of Nyungwe National Park in Rwanda: prospects for forest biodiversity conservation. *J. Res. For. Wildl. Environ.* 12 (4), 66–75.
- Nyiramvuyekure, V., Fischer, J., Kaplin, B.A., Mukuralinda, A., Temperton, V.M., 2025. Woody Vegetation Diversity Remains Low After Extensive Restoration Efforts in a Western Rwandan Landscape. Social Science Research Network. <https://doi.org/10.2139/ssrn.5290407> (SSRN Scholarly Paper No. 5290407).
- Osborne, T., Brock, S., Chazdon, R., Chomba, S., Garen, E., Gutierrez, V., Lave, R., Lefevre, M., Sundberg, J., 2021. The political ecology playbook for ecosystem restoration: principles for effective, equitable, and transformative landscapes. *Glob. Environ. Change* 70, 102320. <https://doi.org/10.1016/j.gloenvcha.2021.102320>.
- Reckmann, T., Frietsch, M., Schwenck, C., Mukuralinda, A., Duguma, D.W., Fischer, J., 2025. A coffee corridor for biodiversity and livelihoods: climatic feasibility of shade coffee cultivation in western Rwanda. *Trees For. People* 21, 100941. <https://doi.org/10.1016/j.tfp.2025.100941>.
- Reyers, B., Bennett, E.M., 2025. Whose conservation, revisited: how a focus on people-nature relationships spotlights new directions for conservation science. *Philos. Trans. R. Soc. Lond., B Biol. Sci.* 380 (1917), 20230320. <https://doi.org/10.1098/rstb.2023.0320>.
- Reyes-García, V., Fernández-Llamazares, Á., McElwee, P., Molnár, Z., Öllerer, K., Wilson, S.J., Brondizio, E.S., 2019. The contributions of Indigenous Peoples and local communities to ecological restoration. *Restor. Ecol.* 27 (1), 3–8. <https://doi.org/10.1111/rec.12894>.
- Reyes-Sacdan, N.B., Gonsalves, J., Hunter, D., Monville-Oro, E., & Anunciado, M.S. S. (2025). *Tropical home gardens: biodiverse, climate-resilient and nutrition-sensitive forms of agriculture: a compilation of abstracts*. <https://hdl.handle.net/10568/173390>.
- Ruticumugambi, J.A., Kaplin, B., Blondeel, H., Mukuralinda, A., Ndoli, A., Verdoodt, A., Rutebuka, J., Imanirareba, E., Uwizeyimana, V., Gatesi, J., Nkurikiye, J.B., Verbeeck, H., Verheyen, K., Vancoillie, F., 2024. Diversity and composition of agroforestry species in two agro-ecological zones of Rwanda. *Agrofor. Syst.* 98 (6), 1421–1443. <https://doi.org/10.1007/s10457-024-01011-9>.
- Salcedo, C.A., Ceccon, E., 2020. Socioecological benefits of a community-based restoration of traditional home gardens in Guerrero, Mexico. *ETNOBIOLOGÍA* 18 (3), 94–112.
- Sharpe, B., Hodgson, A., Leicester, G., Lyon, A., Fazey, I., 2016. Three horizons a pathways practice for transformation. *Ecol. Soc.* 21 (2). <https://www.jstor.org/stable/26270405>.
- Taremwa, N.K., Gasingirwa, M.-C., Nsabimana, D., 2022. Unleashing traditional ecological knowledge for biodiversity conservation and resilience to climate change in Rwanda. *Afr. J. Sci. Technol. Innov. Dev.* 14 (1), 204–215. <https://doi.org/10.1080/20421338.2020.1821948>.
- Tedesco, A.M., López-Cubillos, S., Chazdon, R., Rhodes, J.R., Archibald, C.L., Pérez-Hämmerle, K.-V., Brancalion, P.H.S., Wilson, K.A., Oliveira, M., Correa, D.F., Ota, L., Morrison, T.H., Possingham, H.P., Mills, M., Santos, F.C., Dean, A.J., 2023. Beyond ecology: ecosystem restoration as a process for social-ecological transformation. *Trends Ecol. Evol.* <https://doi.org/10.1016/j.tree.2023.02.007>.
- Tengö, M., Hill, R., Malmer, P., Raymond, C.M., Spierenburg, M., Danielsen, F., Elmqvist, T., Folke, C., 2017. Weaving knowledge systems in IPBES, CBD and beyond—Lessons learned for sustainability. *Curr. Opin. Environ. Sustain.* 26–27, 17–25. <https://doi.org/10.1016/j.cosust.2016.12.005>.
- Turner, M.D., Carney, T., Lawler, L., Reynolds, J., Kelly, L., Teague, M.S., Brottem, L., 2021. Environmental rehabilitation and the vulnerability of the poor: the case of the Great Green Wall. *Land Use Policy* 111, 105750. <https://doi.org/10.1016/j.landusepol.2021.105750>.
- UN DESA, 2019. World Population Prospects 2019. United Nations Department of Economic and Social Affairs. <https://population.un.org/wpp/Download/Archive/Standard/>.
- Uprety, Y., Asselin, H., Bergeron, Y., Doyon, F., Boucher, J.-F., 2012. Contribution of traditional knowledge to ecological restoration: practices and applications. *Écoscience* 19 (3), 225–237. <https://doi.org/10.2980/19-3-3530>.
- Whitney, C.W., Luedeling, E., Hensel, O., Tabuti, J.R.S., Krawinkel, M., Gebauer, J., Kehlenbeck, K., 2018. The role of homegardens for food and nutrition security in Uganda. *Hum. Ecol.* 46 (4), 497–514. <https://doi.org/10.1007/s10745-018-0008-9>.