Integrative Conservation

WILEY

INTEGRATIVE CONSERVATION XTBG

PRACTICE AND POLICY OPEN ACCESS

Five Frontiers for Science and Practice of Ecosystem Restoration in East African Forest Landscapes

Dula W. Duguma[1] | Katharina Löhr[2,3] | Vicky M. Temperton[4] | William Apollinaire[3] | Matthias Baumann[5] | Beth A. Kaplin[6,7] | Verene Nyiramvuyekure[1] | Susanne Vögele[8] | Laura Kmoch[9] | Tobias Plieninger[9,10] | Jacqueline Loos[11] | Tsinda Aime[12] | Nzamukosha Beatrice[13] | Sophia Bohn[8] | Uwayezu Ernest[14] | Marina Frietsch[1] | Callixte Gatali[6] | Ndahiriwe Innocent[6,15] | Angelique Kangondo[16] | Bulonvu Franklin[17,18] | Leonidas Maniraho[3,19,20] | Berta Martín-López[1] | Drocelle Mukaneza[17] | Valery Ndagijimana[2,3] | Gaelle Ndayizeye[9] | Martin Nizeyimana[21] | Elias Nyandwi[14] | Venant Nzibaza[6] | Stefan Sieber[3,20,22] | Ping Sun[1] | Jeffrey L. Ullman[16,23] | Gloriose Umuziranenge[24] | Meike Wollni[25] | Joern Fischer[1]

[1]Social-Ecological Systems Institute, Faculty of Sustainability, Universitätsallee 1, Leuphana University, Lüneburg, Germany | [2]Eberswalde University for Sustainable Development (HNEE), Eberswalde, Germany | [3]Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany | [4]Institute of Ecology, Faculty of Sustainability, Universitätsallee 1, Leuphana University, Lüneburg, Germany | [5]Geography Department, Humboldt-Universität zu Berlin, Berlin, Germany | [6]Center of Excellence in Biodiversity and Natural Resource Management, University of Rwanda, Kigali, Rwanda | [7]School for the Environment, University of Massachusetts, Boston, MA, USA | [8]Department of Agricultural Economics and Rural Development, Chair of Environmental and Resource Economics, University of Göttingen, Göttingen, Germany | [9]Department of Agricultural Economics and Rural Development, University of Göttingen, Göttingen, Germany | [10]Faculty of Organic Agricultural Sciences, University of Kassel, Witzenhausen, Germany | [11]Department of Botany and Biodiversity Research, Biodiversity Dynamics and Conservation Group, University of Vienna, Wien, Austria | [12]College of Science and Technology, School of Architecture and Built Environment, Department of Spatial Planning, University of Rwanda, Rwanda | [13]Forestry Department, Rwanda Polytechnic - Kitabi College, Rwanda | [14]College of Science and Technology, Centre for Geographic Information Systems and Remote Sensing (CGIS-UR), University of Rwanda, Kigali, Rwanda | [15]School off Governance, Development and Society, College of Arts and Social Sciences, University of Rwanda, Rwanda | [16]Rwanda Institute for Conservation Agriculture (RICA), Rwanda | [17]College of Science and Technology, Department of Biology, University of Rwanda, Rwanda | [18]Forestry department, Institut Supérieur d'Agroforesterie et de Gestion de l'Environnement de Kahuzi-Biega (ISAGE-KB), DRC, Kalehe | [19]Department of Rural and Community Development, Protestant University of Rwanda, Butare, Rwanda | [20]Thaer-Institute for Agricultural and Horticultural Sciences Agricultural Economics, Humboldt Universität zu Berlin, Berlin, Germany | [21]University of Technology and Arts of Byumba (UTAB), Rwanda | [22]Humboldt Universität zu Berlin, Thaer-Institute for Agricultural and Horticultural Sciences, Urban Plant Ecophysiology, Berlin, Germany | [23]Department of Biological Systems Engineering, University of Nebraska-Lincoln, Lincoln, Nebraska, USA | [24]Protestant Institute of Arts and Social Sciences, Protestant University of Rwanda, Butare, Rwanda | [25]Department of Agricultural Economics and Rural Development and Campus Centre of Biodiversity and Sustainable Land Use, University of Göttingen, Göttingen, Germany

Correspondence: Dula W. Duguma (duguma2011@gmail.com)

Received: 15 October 2024 | **Accepted:** 21 August 2025

Editor-in-Chief: Ahimsa Campos-Arceiz | **Handling Editor:** Gbadamassi G.O. Dossa

Funding: This study was supported by the German Research Foundation (DFG) (Project number 496337053).

Keywords: benefits | ecosystem restoration | equity | food security | multifunctional landscapes | western Rwanda

ABSTRACT

Ecosystem restoration, guided by numerous principles and practical guidelines, has been hailed as a strategy to combat climate change, reduce global biodiversity loss, restore ecosystem services, and enhance human well-being. Yet, translating restoration principles into practice remains challenging for policymakers and practitioners. To address this issue, we identify five frontiers for advancing ecosystem restoration in East Africa's forest landscapes, using western Rwanda as a case study. Instead of drawing on existing high-level ecosystem restoration guidelines, we synthesized locally grounded insights into tangible restoration priorities. We conducted a full-day multi-expert workshop using a "world café" approach to facilitate participatory large-group discussions, involving scientists, practitioners, and decision-makers working on ecosystem restoration in Rwanda. Five critical

frontiers for ecosystem restoration science and practice were identified: (i) defining ecosystem restoration goals and elements of success; (ii) embedding ecosystem restoration in the promotion of multifunctional landscapes; (iii) enhancing food security, nutrition, and livelihoods through ecosystem restoration; (iv) engaging with values and nature's contributions to people in ecosystem restoration; and (v) governing ecosystem restoration for equity. For each of these frontiers, we highlight the state-of-the-art, emerging research priorities, and recommendations for practice and policy to move ecosystem restoration ahead.

1 | Introduction

To combat climate change, reduce the loss of biodiversity and ecosystem services and enhance human wellbeing, the Bonn Challenge was launched in 2011. Initially aimed at restoring 150 million hectares of degraded and deforested landscapes by 2020, its goal was later expanded to 350 million hectares in the New York Declaration on Forests (IUCN 2020). Subsequently, multiple initiatives and programs have been launched from global to local scale to follow through on these pledges. For instance, 34 African countries have pledged to restore 100 million hectares of land by 2030 as part of the African Forest Landscape Restoration Initiative (AFR100) (Messinger and Winterbottom 2016).

To guide ecosystem restoration, numerous principles and practical guidelines have been established by diverse actors from practice and science (Gann et al. 2019; CIFOR-ICRAF 2020; Brancalion and Holl 2020; FAO, IUCN CEM, SER 2021; Elias et al. 2022). Theoretically, these principles and guidelines should support policymakers and practitioners in implementing ecosystem restoration. However, translating existing general principles into tangible ecosystem restoration interventions often remains challenging (Stanturf and Mansourian 2020). Ecosystem restoration covers a broad range of different approaches to restoring degraded ecosystems, ranging from mediation through rehabilitation to restoring native species within a more classical restoration context (Gann et al. 2019). Along this restorative continuum, the level of ecological and social ambition can vary strongly. For this reason, we took a different approach. Instead of working with existing high-level ecosystem restoration guidelines, we synthesized locally grounded insights from researchers and practitioners into tangible ecosystem restoration priorities that emerge from their everyday work. We focus on Rwanda, a country that has taken a pioneering role in ecosystem restoration (Dave et al. 2019; Buckingham et al. 2021).

In 2011, Rwanda committed to restoring 2 million hectares of land as part of AFR100; and currently, dozens of ecosystem restoration projects are taking place in different parts of the country. These projects focus on afforestation and forest landscape restoration, integrated and sustainable forest and land management, agroforestry, and soil conservation (https://afr100.org/country/rwanda). Tree planting is a dominant restoration activity, but especially on steep slopes, is often carried out in combination with other interventions such as terracing. In western Rwanda, many of the currently implemented ecosystem restoration activities are aiming to counteract undesired effects of past large-scale forest loss (Arakwiye et al. 2021) resulting from the conversion of forests to croplands, pastures, and settlements, as well as from fuelwood extraction and widespread artisanal mining (Mutandwa and Kanyarukiga 2016; Arakwiye et al. 2021).

Western Rwanda is an agriculture-dominated landscape, characterized by a tropical temperate climate with abundant rainfall and mountainous topography. The main land covers include cropland, plantation forests, pastures, settlements, tea farms, and a few remnant patches of native forest (Mutandwa and Kanyarukiga 2016; Arakwiye et al. 2021). Residents' dominant economic activity is mixed agriculture, with about 67% and 56% of households engaged in crop farming and livestock husbandry, respectively (National Institute of Statistics of Rwanda NISR 2023). Because arable land is scarce, farming activities are often conducted on steep hillslopes, cleared hilltops, and in valleys. The population density of western Rwanda is high, with over 650 inhabitants per km^2 (National Institute of Statistics of Rwanda NISR 2023). Average landholdings measure less than 1 ha (Mutandwa and Kanyarukiga 2016).

Most recent and ongoing ecosystem restoration activities have focused on planting nonnative trees (e.g., *Pinus spp., Eucalyptus spp., Alnus acuminata, Grevillea robusta*), with unfavorable implications for native fauna and biodiversity conservation (Mutandwa and Kanyarukiga 2016; Arakwiye et al. 2021; Tuyisingize et al. 2022). For instance, Tuyisingize et al. (2022) investigated the distribution of three diurnal primates (*Cercopithecus mitis kandti*, *Allochrocebus lhoesti*, and *Pantroglodytes schweinfurthii*) in the Gishwati-Mukura landscape in western Rwanda and found that the golden monkey (*Allochrocebus lhoesti)* was the only species using the *Pinus*-dominated plantations that had been planted in the mid-1980s. Thus, to more effectively restore biodiversity and increase human wellbeing, many ecosystem restoration activities in the region need to be transformed to address the multiple targets connected to restoration, including combating biodiversity loss and increasing human wellbeing.

In the remainder of this paper, we outline five critical frontiers for ecosystem restoration science and practice, specifically focusing on western Rwanda. Because biophysical and social considerations are intimately connected, a growing number of scientists (including ourselves) call for holistic "social-ecological restoration", which entails a systems perspective that simultaneously deals with ecological and social issues in the landscapes to be restored (Fernández-Manjarrés et al. 2018; Fischer et al. 2021; Tedesco et al. 2023). To advance this ecosystem restoration paradigm in East Africa, this paper synthesizes insights on the current state of ecosystem restoration, emerging challenges, and frontiers for ecosystem restoration research and practice in western Rwanda. We distilled these insights through a full-day multi-expert workshop using a "world café" (Brown and Isaacs 2005) approach to facilitate participatory large-group discussions.

Summary

Ecosystem restoration could help to address climate change, reduce biodiversity loss, and enhance human wellbeing. However, implementing ecosystem restoration remains challenging for policymakers and practitioners. Here, we distilled five frontiers for ecosystem restoration in East Africa's forest landscapes, drawing on western Rwanda as a case study. We organized a workshop with scientists, practitioners, and decision-makers working on ecosystem restoration in Rwanda. Critical frontiers for ecosystem restoration science and practice identified were (i) defining ecosystem restoration goals and elements of success; (ii) embedding ecosystem restoration in the promotion of multifunctional landscapes; (iii) enhancing food security, nutrition, and livelihoods through ecosystem restoration; (iv) engaging with values and nature's contributions to people in ecosystem restoration; and (v) governing ecosystem restoration for equity. For each of these frontiers, we highlight the state-of-the-art, emerging research priorities, and recommendations for practice and policy to move ecosystem restoration ahead.

- **Practitioner Points**
  - Implementing ecosystem restoration remains challenging for policymakers and practitioners.
  - Using Rwanda as a case study, we used a participatory "world-café" approach involving scientists, practitioners, and decision-makers to identify emerging challenges and future research priority areas.
  - We identified five critical frontiers for advancing ecosystem restoration: defining goals and success, landscape multifunctionality, food security and livelihoods, local values and nature's contributions to people, as well as equity and justice.

2 | The World Café Methodology

The world café is a structured conversational method designed to foster collaborative dialogue, share knowledge, cross-pollinate perspectives, and generate innovative ideas (Brown and Isaacs 2005; Silva and Guenther 2018; Löhr et al. 2020). It is grounded in seven integrated design principles: (1) setting the context; (2) creating a hospitable space; (3) exploring questions that matter; (4) encouraging everyone's participation; (5) cross-pollinating and connecting diverse perspectives; (6) listening together for patterns and insights; and (7) harvesting and sharing collective discoveries (Brown and Isaacs 2005). In practice, the method involves arranging small round tables in a café-like setting, with about five participants at each table. Each table hosts an open conversation on a central question or theme for approximately 20 min. At the end of each round, most participants rotate to new tables, while one "table host" remains to summarize the previous discussion and ensure continuity. This structure enables the exchange and evolution of ideas across groups, cross-pollinating ideas and building on previous conversations. Participants record the results of the conversations creatively—through notes, sketches, symbols, or diagrams—on shared paper sheets. The process is highly flexible and can be adapted to various settings for different contexts or themes (Brown and Isaacs 2005).

In our workshop, held on 31 January 2024 in Kigali (Rwanda), we used the world café methodology to explore the state of ecosystem restoration in Rwanda. A total of 34 participants, seated at six café-style tables, engaged in multiple rounds of discussion. The participants represented diverse disciplinary backgrounds—including ecology, sociology, economics, geography, land-use planning, and sustainable landscape management—and included scientists, practitioners, and decision-makers working on ecosystem restoration in Rwanda. Notes were recorded on flipchart paper and later synthesized for analysis. All attendees contributed to the development of this paper and are included in the author group.

Through this process, we identified five frontiers for social-ecological restoration in western Rwanda (Figure 1). These are as follows:

1. Defining ecosystem restoration goals and elements of success;
2. Enhancing the multifunctionality of landscapes through ecosystem restoration;
3. Enhancing food security, nutrition, and livelihoods through ecosystem restoration;
4. Engaging with values and nature's contributions to people in ecosystem restoration; and
5. Governing ecosystem restoration for equity.

This kind of inclusive approach to ecosystem restoration that explicitly focuses on social factors and outcomes (Fischer et al. 2021) is an emerging framing within the restoration community (Osborne et al. 2021; Elias et al. 2022). These frontiers address social goals, whilst not forgetting the importance of ecological factors.

In the following sections, we synthesize key priorities and emerging challenges for each of the five frontiers and derive recommendations for ecosystem restoration science, practice, and policy (Table 1). While our discussion centers on western Rwanda, many of the insights and priorities identified are also applicable to other previously forested parts of East Africa and to tropical forest landscapes globally.

2.1 | Defining Ecosystem Restoration Goals and Elements of Success

Although ecosystem restoration generally aims for the highest level of ecosystem recovery (Gann et al. 2019), what this means in practice is very context-specific. Thus, goal-setting, monitoring, evaluation, and learning are fundamental to achieving ecosystem restoration goals and landscape sustainability. The framing and overarching goal-setting of a specific ecosystem restoration program will affect its implementation strategies, interventions, and monitoring approach. To this end, the ecosystem restoration wheels developed by the Society for Ecological Restoration (SER) (Gann et al. 2019) can provide guidance. The wheels explicitly include both biophysical and social restoration goals: Biophysical considerations entail physical conditions, species composition, structural diversity,

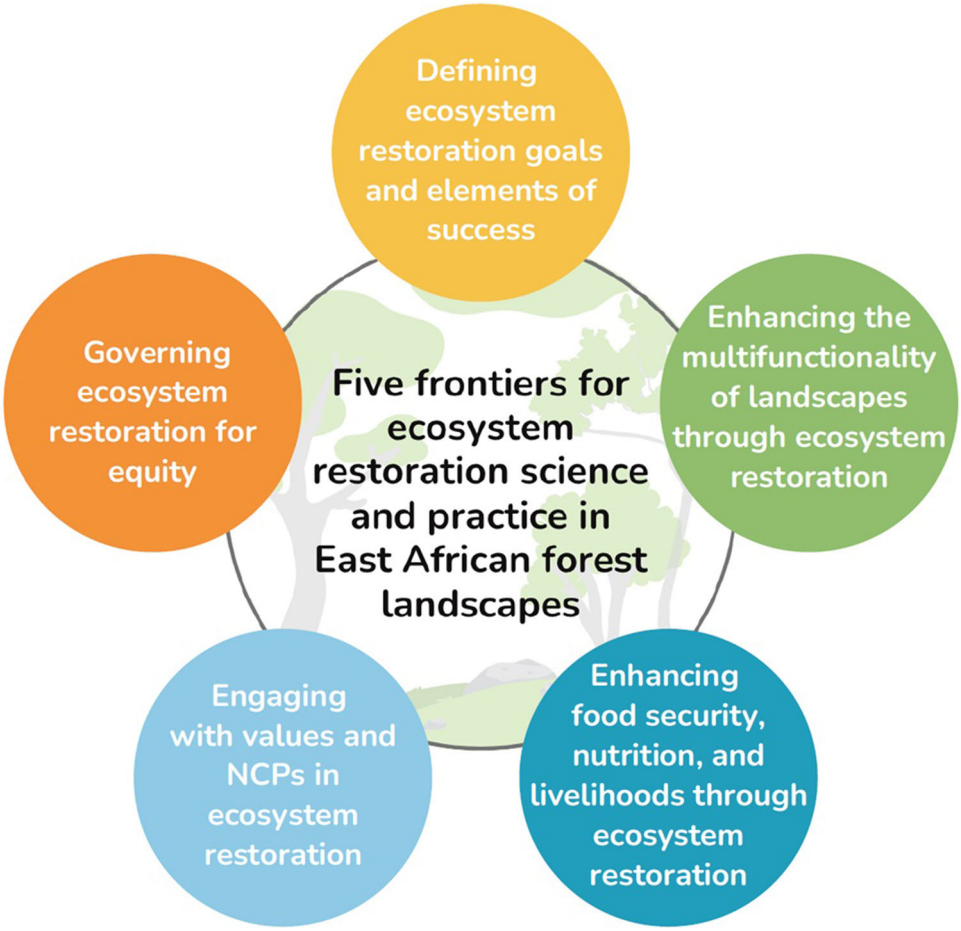

FIGURE 1 | Five frontiers for social-ecological restoration in East African forest landscapes for policy and practice. *Note:* NCP = Nature's Contribution to People.

ecosystem functions, introduced species, and absence of threats; while social considerations include community wellbeing, stakeholder engagement, distribution of Nature's Contribution to People (NCP)s, knowledge enrichment, sustainable economies, and the restoration of natural capital (Figure 2).

Our workshop revealed that multiple actors implement numerous ecosystem restoration activities in western Rwanda. However, these restoration activities only aligned with some (but not all) elements of 'ecosystem restoration success' that the Society for Ecological Restoration proposes. In addition, we identified further important practices which therefore constitute an expansion of the SER wheel (Figure 2). From the workshop, key aspects of ecosystem restoration included the restoration of native tree species, learning from past success stories, consideration of ecosystem functions and services, incorporating adequate reference systems (and baselines), and careful land use planning (given strong competition for land and land availability per capita). In addition, multiple social dimensions of ecosystem restoration activities were considered important for successful restoration. These include the integration and stimulation of traditional knowledge, local stakeholder participation, equitable distribution of benefits for local people, climate change mitigation and adaptation, and the potential to fund restoration through carbon credits.

Beyond these considerations, we identified three broad challenges that require future research. First, there is a lack of a shared vision for ecosystem restoration. There is a need for ecosystem restoration that is based on and implemented by inclusion of local communities in different steps of the restoration process, and with greater consideration of historical and contemporary contexts that acknowledge changing needs both for biodiversity conservation and local communities. Second, there is a limited monitoring capacity of ecosystem restoration. We identified the need for using measurable indicators that meaningfully quantify key desired social-ecological outcomes. Some examples of current restoration indicators include the number of trees planted, hectares of land restored, number of jobs created, presence of community participation, and estimates of carbon sequestration (Mugabowindekwe et al. 2023, 2024). Beyond these indicators, a list of additional, more comprehensive social and ecological indicators that would be valuable to capture and ensure long-term benefits of ecosystem restoration is indicated in Figure 2.

Third, the capacity to reconcile short-term goals favored by landowners and long-term goals required to achieve sustainable social-ecological outcomes is still limited. For example, fast-growing exotic species will continue to dominate in the landscape; they provide short-term benefits to farmers despite their limited ecological contribution to soil, biodiversity conservation,

TABLE 1 | Overview of the five research frontiers discussed in this paper, associated challenges, and recommendations for ecosystem restoration policy and practice.

Frontier	Challenges	Recommendations
Defining ecosystem restoration goals and elements of success	• Lack of shared visions for ecosystem restoration • Limited monitoring capacity • Limited capacity to reconcile short-term and long-term ecosystem restoration goals	• Establish shared visions by integrating local communities' traditional knowledge and perspectives • Define measurable ecosystem restoration goals • Harmonize short-, mid-, and long-term goals
Enhancing the multifunctionality of landscapes through ecosystem restoration	• Mismatch between land-use policies and ecosystem restoration goals • Limited connection of local values and knowledge to native species • Limited knowledge of possible synergies from ecosystem restoration	• Aim for ecosystem restoration that generates positive outcomes for both nature and people • Examine potential trade-offs and synergies resulting from multifunctionality • Assess short-term and long-term benefits and risks of native tree species
Enhancing food security, nutrition, and livelihoods through ecosystem restoration	• Need for collective coordination and land consolidation • Inequitable land-use decision-making • Inadequate market access and value chain management for agricultural products	• Integrate a livelihoods perspective into ecosystem restoration which recognizes links between ecosystems, economic well-being, and food security
Engaging with values and nature's contributions to people in ecosystem restoration	• Prevalence of nonnative species upheld by lack of valuing of native species • Land-use conflicts related to protected areas and agricultural production • Limited inclusion of local ecological knowledge in ecosystem restoration interventions	• Examine plural values and ecosystem restoration benefits to support the transition from exotic species towards Indigenous species-dominated ecosystem restoration • Assess potential synergies and trade-offs resulting from the integration of Indigenous tree species with annual crops • Assess and integrate people's knowledge about indigenous plants and their uses
Governing ecosystem restoration for equity	• Nonconsensual relocation of people for ecosystem restoration projects • Lack of clear governance and management arrangements for equitable sharing of ecosystem restoration benefits	• Codesign context-appropriate relocation and compensation schemes based on scientific evidence • Design effective policy measures to facilitate the equitable distribution of costs and benefits of ecosystem restoration at different scales

and resilience to climate change. Some examples of these short-term benefits include substantial wood volumes that are used for fuelwood, poles, and construction materials that can be used for domestic consumption and income generation (Ndayambaje et al. 2012; Buckingham et al. 2021), to stabilize degraded slopes and reduce erosion, and short-term carbon capture (Mugabowindekwe et al. 2023, 2024). Hence, while nonnative species may present important short-term benefits, they do not match the potential of native species to provide multifunctional benefits from an integrated social-ecological perspective.

2.2 | Enhancing the Multifunctionality of Landscapes Through Ecosystem Restoration

Ecosystem restoration faces many, and partly conflicting, demands at the same time, which makes it inherently challenging. A possible way forward may be to link ecosystem restoration with the concept of landscape multifunctionality. Multifunctionality refers to the capacity of a landscape to simultaneously deliver a broad array of ecological, social, and economic benefits (Schulz and Schröder 2017; Messier et al. 2022), thereby

aligning closely with the concept of social-ecological restoration. While building on the foundational roles of biodiversity as the biophysical basis of ecosystems (Manning et al. 2018; Temperton et al. 2019), providing a broad array of benefits can enhance the resilience, sustainability, and societal relevance of restored ecosystems. Considerable advances in restoring multifunctional landscapes could be made by researching trade-offs and synergies when aiming for multifunctional outcomes, both in terms of ecosystem functions and service outcomes.

Ecosystem restoration in western Rwanda has focused on fast-growing, nonnative tree species to stop soil erosion on steep slopes and meet subsistence farming needs (Mutandwa and Kanyarukiga 2016; Tuyisingize et al. 2022). These efforts have resulted in successful agroforestry and woodlot reclamation and catchment restoration. However, the low share of native tree species used in these restoration interventions has led to low biodiversity (Ndayambaje et al. 2012; Kim et al. 2022). For example, Tuyisingize et al. (2022) showed in their study on the diversity and distribution of three diurnal primates in restoration sites of different gradients that ranges from natural regeneration of native species to pine monoculture plantations that only one primate was found in pine-dominated plantation - which was mainly attributed to the lack of native food plants in exotic plantations. Studies from other countries, for example, China (Brancalion and Chazdon 2017) and Ethiopia (Tesfaw et al. 2022; Lemessa et al. 2022), have also indicated that monoculture plantations, such as eucalyptus, had led to losses of bird and bee diversity. In addition, while local communities are often directly involved in agroforestry, and encouraged to plant trees on their farmlands, they might get sidelined in large-scale ecosystem restoration projects. Furthermore, there seems to be a general disconnect between local people and local biodiversity, although recent studies of local people's knowledge of and preference for native tree species show a greater depth of understanding than hitherto recognized, which thus far remains untapped (Mujawamariya unpublished data; Kaplin unpublished data). During our workshop, we identified three future research priorities to enhance the restoration of multifunctional landscapes.

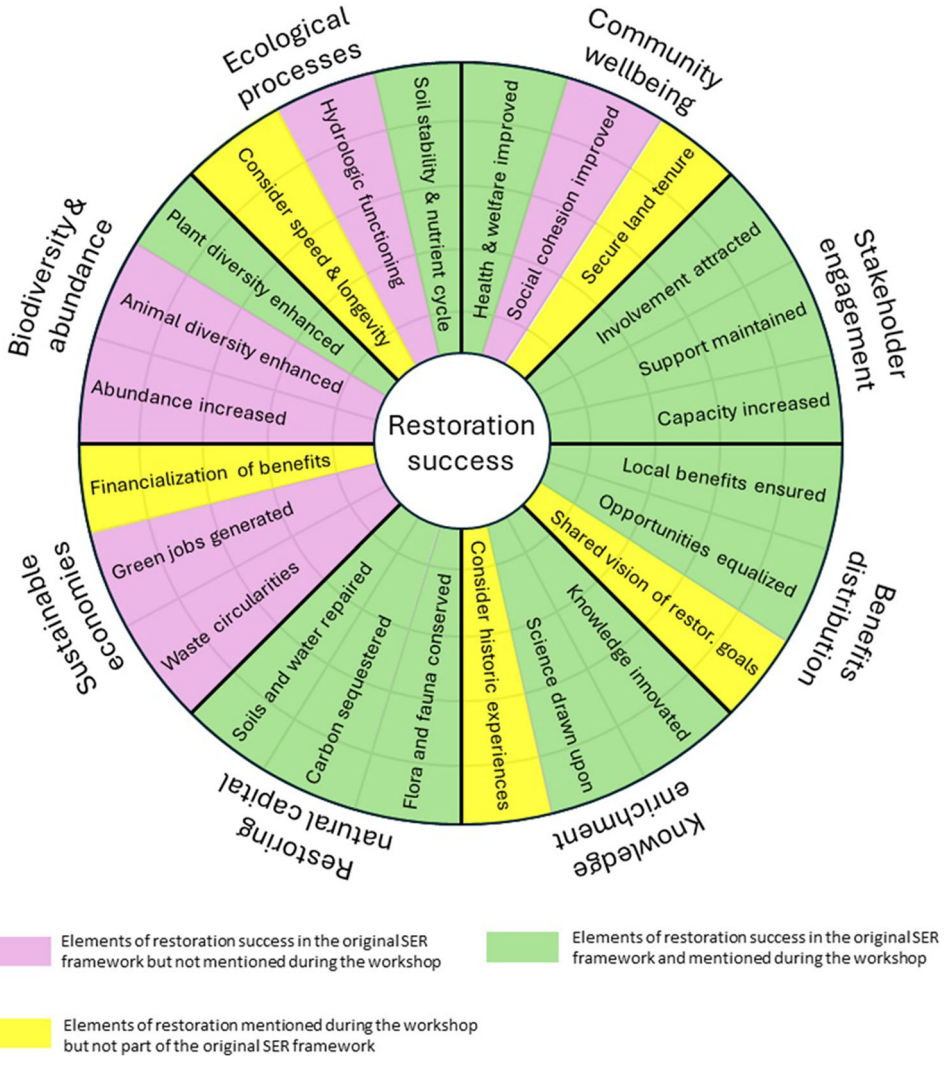

FIGURE 2 | Illustration of social-ecological restoration goals in western Rwanda (figure adapted from the Society for Ecological Restoration (SER); Gann et al. 2019): purple, green, and yellow highlighting show restoration elements originally considered by the SER but not explicitly raised during our workshop, elements considered by the SER and explicitly raised during our workshop, and elements not raised by the SER but emerging during our discussion, respectively.

First, better understanding multifunctionality is critical for both ecosystem restoration research and practice. Ecosystem restoration activities in western Rwanda have primarily focused on ecosystem management, repairing function, and reducing negative societal impacts, rather than restoring native communities for biodiversity outcomes (Gann et al. 2019). Agricultural policy in Rwanda, particularly the crop intensification program (Cioffo et al. 2016), and forestry policies that limit adaptive management approaches (e.g., inflexible forest management plans), may not yet match or support the type of ecosystem restoration or planting needed for particular landscapes. Limited knowledge of native tree seedling growth and mortality rates, coupled with difficulties in sourcing native seeds and a disconnect between the traditional ecological knowledge and environmental management – particularly among rural farmers (Hartel et al. 2023) – has contributed to farmers' preference of non-native tree species. Additionally, there is a widespread perception that all native trees grow very slowly (authors' communication at the field); which is in fact not always the case. This approach has been at the expense of recognizing multiple potential benefits including biodiversity and cultural values (Slade et al. 2017) that can be associated with using native species for restoration (Cuni-Sanchez et al. 2019).

Second, to establish multifunctional landscapes that provide both social benefits (such as delivery of ecosystem services like material, nonmaterial, and regulating services) and ecological benefits (such as a range of different ecosystem functions including productivity, nutrient and water cycling, decomposition, herbivory or pollination), there is a need to connect values, knowledge, and perspectives of local people to native tree and shrub species. This includes species' potential for medicinal, food, and other cultural and economic uses, as well as a better understanding of which intercropping combinations can deliver the best outcomes in terms of fruit provisioning, food security, and ecological restoration. Restoring multifunctional landscapes could, in theory, contribute to the recovery of native ecosystems (Gann et al. 2019) and needs to involve local people more directly than it has so far (Arakwiye et al. 2021). These potentially diverse benefits for local ecosystems and people's livelihoods need highlighting to both project donors and implementers.

Third, whilst aiming for multifunctional outcomes, integrating a greater diversity of native trees and their various uses would enhance both ecosystem functioning and services, leading to currently unrecognized synergies. There is a strong need to explore the science and practice of where such synergies may be and where there may be clear trade-offs.

2.3 | Enhancing Food Security, Nutrition, and Livelihoods Through Ecosystem Restoration

Ecosystem restoration has major, yet unfulfilled, potential to enhance livelihoods and food security for many countries facing food security challenges, including Rwanda. The latest Comprehensive Food Security and Vulnerability Analysis (CFSVA) of 2021 states that around one-fifth of the Rwandan population is either moderately or severely food insecure (National Institute of Statistics of Rwanda NISR 2021). According to this report, the prevalence of food insecurity is highest in the Western Province at around 35%. Across Rwanda, low and irregular meal frequency and limited nutrient diversity in the food consumed lead to malnutrition and a high, although declining, stunting rate of almost one-third of all children (National Institute of Statistics of Rwanda NISR 2021). Malnutrition phenomena are pronounced in rural areas dominated by small-scale agricultural livelihoods, where food availability is dictated by seasonal food production, and food affordability is a major challenge (Hickey et al. 2016; Bolarinwa et al. 2020). In the face of agricultural constraints resulting from landscape degradation, well-managed ecosystem restoration can increase food diversity and production and promote diverse ecological and socioeconomic opportunities (Rwanda Ministry of Environment 2022). Therefore, careful consideration of strategies to improve both ecological condition and socioeconomic well-being is essential.

During our workshop, we identified three ways in which tree planting as an ecosystem restoration strategy can improve people's food security, nutrition, and livelihoods. The first is the direct provision of fruits and vegetables from trees and crops within agroforestry intercropping. In particular, the direct provision of these agricultural products increases the (micro-) nutritional value of the food consumed through vitamins, minerals, and phytonutrients (Hall et al. 2022).

The second is an indirect benefit of agroecology on people's food security and livelihoods through the provision of NCPs that increase resilience to disturbances such as landslides, droughts, and heavy rainfall (Baudron et al. 2019). The NCPs provided by trees range from moisture and nutrient retention to soil conservation and habitat for pollinators and other species. These services can in turn enhance crop productivity in agroforestry systems, provided that tree-crop interactions are non-competitive (Cyamweshi et al. 2023).

The third benefit of tree plantings for people's food security and livelihoods is through income generation. Income generation can be stimulated through increased yields or new cash crops, the production of fodder for livestock, or the sale of tree-related products (e.g., wood products, medicine, honey), which are particularly important for poorer households (Ndoli et al. 2021). Wood from trees is also a major source of energy for cooking and an important construction material (Rasmussen et al. 2017). Thus, ecosystem restoration has the potential to increase household productive assets and expand income-generating livelihoods. In this regard, Bucagu et al. (2014) highlight the critical importance of a sustainable allocation of household resources to improve soil fertility and increase the value of household assets. All these direct and indirect impacts of ecosystem restoration, which potentially improve the affordability, accessibility, stability, and nutritional content of food, need to be considered holistically and, in particular, balanced in their interactions, taking the contextualized local conditions into account. To date, ecosystem restoration in Rwanda has not reached its full potential in terms of enhancing food security and livelihoods.

During our discussion, we identified two key challenges and limitations to ecosystem restoration that translate to priorities for further research. First, the average landholding per farmer is

small, so that collective coordination or land consolidation is often needed to implement ecosystem restoration effectively (Kim et al. 2022; Mukoobwa et al. 2023). The flow of resources to the implementing farmers can therefore be limited by non-inclusive governance of ecosystem restoration projects (Buckingham et al. 2021). Issues raised during our workshop relate to the power and process of decision-making about how a given land area is used and which tree and crop species are planted. Inequitable access to household resources at the intra-household level can lead to different household members sharing unequally in the economic benefits of ecosystem restoration. This is particularly true for women, whose preferences are rarely taken into account in ecosystem restoration projects, despite their significant contribution to plant care, processing, and food preparation (Kiptot and Franzel 2012).

Second, inadequate market access and value chain management for agricultural products limit opportunities for agricultural marketing and upgrading. This limits livelihood diversification in terms of on-farm and off-farm work, which is positively associated with economic wellbeing (Quandt et al. 2019; Kangondo et al. 2023). Even when the necessary infrastructure of tree nurseries and market linkages are provided, there is often a lack of awareness and knowledge about the socioeconomic benefits of ecosystem restoration activities, suggesting a need for enhanced extension services (Kiyani et al. 2017; Mukoobwa et al. 2023). As people rely on functioning ecosystems within agricultural landscapes to secure their food and livelihoods, ensuring integrated and sustainable ecosystem restoration is critical for improving food security and nutrition in Rwanda.

2.4 | Engaging With Values and Nature's Contributions to People in Ecosystem Restoration

Plural values and nature's contributions to people gain traction as ecosystem restoration research concepts, through their sweeping promulgation in international biodiversity assessments (IPBES 2018, 2022) and related scholarly publications (Díaz et al. 2018; Zafra-Calvo et al. 2020). Plural values thinking entails the notion that actors' sets of values of nature differ (Carmenta et al. 2023; Pascual et al. 2023). This can spur conflicts and injustices in ecosystem restoration decision-making (Loos et al. 2024), when actors' values clash or remain unrecognized, and may complicate ecosystem restoration success, as agreement on what to appraise and how may be hard to reach (Carmenta et al. 2023; Pascual et al. 2023).

Nature's contributions to people framings advance the ecosystem services literature (Díaz et al. 2018; Kadykalo et al. 2019) by offering a conceptual framework that allows for both context-specific and generalized perspectives on the benefits and burdens that nature brings to rural people's lives (Pascual et al. 2017). Ecosystem restoration actors need such analytical tools to grasp how concomitant landscape changes reconfigure the intrinsic, instrumental, and relational values, and bundled contributions of nature that different stakeholders ascribe to alternative land uses (Ellis et al. 2019; Meyfroidt et al. 2022).

Previous research on ecosystem services – including an appraisal of ecosystem services preferences with communities near Gishwati forest (Dawson and Martin 2015) and Rwanda-wide models of carbon, soil- and water-related ecosystem services (Rukundo et al. 2018; Bagstad et al. 2020) – has created a strong foundation for ecosystem restoration-focused plural valuation studies in western Rwanda. In our discussion, three research priorities emerged:

First, managing the transition from exotic to indigenous species (Mulyoutami et al. 2023) necessitates a shift away from the value paradigm of 'doing restoration quickly' that dates back to Rwanda's earliest restoration efforts. Though timber and fuel provision from fast-growing species remain relevant, the importance of native species is ascending on the national policy agenda. Values research can back this dynamic, by analyzing trade-offs and synergies that arise from the integration of indigenous tree species with annual crops; by identifying value-laden policy barriers that limit farmers' restoration choices on private land (e.g., regulations that hinder the integration of forest liana that farmers desire); and by alleviating young people's disinterest in native trees, by making their values visible.

Second, tensions related to protected areas in western Rwanda need to be understood and mediated with sensitivity to power imbalances to reconcile biodiversity conservation, tourism, and agricultural production. Values research can help to appraise how perceptions of the contributions of protected areas differ among stakeholders, foremost policymakers, and forest-adjacent residents. Results from such research could then inform the design of adequate compensation schemes to account for livelihood resources that communities living near newly gazetted conservation areas may lose. This includes lost access to bushmeat and traditional medicines, for instance, as well as food and farm income losses due to crop raids. Options to limit knock-on effects from the latter (e.g., school dropouts to guard crops) were identified as another contentious aspect that needs addressing through policy measures.

The third priority is to embrace ecosystem restoration as a two-way learning opportunity (Martini et al. 2023). The advancing policy aims to proactively expand native tree species across western Rwanda's restoration landscapes provides an entry point for reactivating and adequately valuing rural people's traditional nature-related knowledge (e.g., about indigenous plants and their uses). Values research can elicit such knowledge and document how different actors (e.g., female beekeepers) benefit from ecosystem restoration interventions. Such a shift in restoration research and practice requires the support of powerful actors such as international donors and government officials to embrace a more inclusive restoration paradigm that is based on diverse actors' plural values. By empowering local communities in ecosystem restoration processes, and leveraging their insights, future programs would thus be well-set to meet increasingly ambitious ecosystem restoration objectives.

2.5 | Governing Ecosystem Restoration for Equity

Environmental equity is an important pillar of environmental justice, emphasizing the fair distribution of resources, (dis) benefits, and responsibility among stake- and right-holders (Rawls 1958; Sen 2009). This is especially important in

restoration contexts where a wide range of actors with different needs and priorities interact (Wells et al. 2021). While institutional structures might support egalitarian frameworks for obtaining justice, the abilities and needs of different local stakeholders need consideration in deciding whom to involve, to what extent, and in which processes of ecosystem restoration. In a similar vein, environmental equity also means holding those who cause harm accountable and requiring them to avoid and mitigate negative consequences.

One way to assess environmental equity is through three widely accepted dimensions of environmental justice (Sikor et al. 2014): distribution, procedure, and recognition. Distribution considers the costs and benefits related to an intervention, whereas the procedure to allocate this distribution puts emphasis on the decision-making and implementation processes that lead to these distributions. Moreover, it is also crucial for environmental equity to recognize the right- and stakeholders affected by these decisions (Martin et al. 2016), including their diverse and plural knowledge and value systems (Pascual et al. 2021). Incorporating environmental equity into ecosystem restoration planning and implementation thus involves not only considering outcomes but also the processes to get there (Loos et al. 2023). Furthermore, it is crucial to consider contextual variables (McDermott et al. 2013), such as people's affectedness, capabilities, agency (Nussbaum 2011), and community levels of trust and cohesion to facilitate inclusive design and enhance overall restorative capacity (Frietsch et al. 2023).

The urgency to restore large parts of Rwanda's landscape is evident from the threat of soil erosion and landslides (Mugisha et al. 2020), which cause environmental degradation but also loss of livelihoods, conflict, and fatalities (BBC 2023). Recognizing those most vulnerable to such threats, the Rwandan government carries out relocations to protect its citizens (Kabalisa and Kagambira 2021). Related to this, our workshop identified two emerging challenges that require future research priorities:

First, there are concerns about the nonconsensual relocation of people as a result of ecosystem restoration interventions, highlighting the need for adequate accompanying communication to inform people of the need for the intervention, and for co-designing appropriate compensation for the hardship of relocation. While the Rwandan government provides compensation, whether or not these compensations can be considered appropriate is context-specific (Uwayezu and T. de Vries 2020). For resettlement to be considered equitable, for example, it must not only provide alternative livelihoods, especially for those who depend on clay pottery, wood collection, and hunting for survival (distributive justice), but also allow for participation in decision-making processes, i.e., who, when, where, and how to resettle (procedural justice) (Loos et al. 2024).

Second, there is a need for clear governance and management arrangements to avoid moral hazard and single beneficiaries and to ensure that the various benefits of ecosystem restoration interventions, such as reduced soil erosion and improved food security, are shared equitably. However, achieving consensus on which principle of justice to prioritize – merit-based, needs-based, or equity-based – remains a challenge, particularly given the urgency of ecosystem restoration efforts and the time required to build trust and capacity for equitable practices.

3 | Conclusion: Emerging Priorities for Policy and Practice

Based on the five frontiers for ecosystem restoration outlined above, we propose the following research priorities and recommendations for future ecosystem restoration practice and policy. While these recommendations are informed by discussions on ecosystem restoration in western Rwanda, they are most likely also relevant for ecosystem restoration in similar settings in East Africa and tropical forest landscapes around the world.

- To define measurable ecosystem restoration goals against which success can be assessed; to establish a shared vision of ecosystem restoration goals between practitioners and decision-makers; to integrate local communities' traditional knowledge and perspectives into ecosystem restoration processes; to adequately consider reference ecosystems when assessing restoration success; and to harmonize short- and midterm goals with long-term objectives.
- To work towards multifunctionality, i.e., ecosystem restoration that generates positive outcomes for both nature and people; and to examine the potential trade-offs and synergies associated with multifunctionality, whether in the short-term or long-term, including an assessment of the short-term and longer-term risks and benefits of native tree species.
- To consider the importance of ecosystem restoration from a livelihood perspective, recognizing the important links between ecosystems, economic wellbeing, and food security for all household members at all times.
- To carry out research on plural values and ecosystem restoration benefits to support the transition from the current approach of ecosystem restoration with exotic species towards indigenous species-dominated restoration. Research is urgently needed on potential synergies and trade-offs that may arise from the integration of indigenous tree species with annual crops, and on rural people's nature-related knowledge about indigenous plants and their diverse uses.
- To examine the impact of ecosystem restoration in relation to the equitable distribution of costs and benefits at different scales (household, community, and landscape) as well as to research the social-ecological context of relocated or to-be-relocated people, and to design relocation interventions considering the suitability of the new location (socially and ecologically), access to social services, compensation for relocation hardships, and the relocation process.
- The recommendations outlined above all benefit from transdisciplinary approaches that bring together all stakeholders involved in and affected by ecosystem restoration. Here, approaches such as real-world experiments (living labs) that engage local communities in the codesign and evaluation of organizational innovations, including planting more native species, business cooperative models, and

extension schemes, with the aim of promoting and supporting ecosystem restoration that help to explore the role of social cohesion, trust, ownership, inclusiveness, and information sharing in the success of ecosystem restoration can be promising.

Author Contributions

Dula W. Duguma: conceptualization, methodology, data curation, writing – original draft, writing – review and editing. **Katharina Löhr:** methodology, data curation, writing – original draft, writing – review and editing. **Vicky M. Temperton:** conceptualization, methodology, data curation, funding acquisition, writing – review and editing. **William Apollinaire:** methodology, data curation, writing – review and editing, visualization. **Matthias Baumann:** conceptualization, methodology, data curation, funding acquisition, writing – review and editing. **Beth A. Kaplin:** conceptualization, methodology, data curation, writing – review and editing. **Verene Nyiramvuyekure:** methodology, data curation, writing – review and editing, conceptualization. **Susanne Vögele:** conceptualization, methodology, data curation, writing – review and editing. **Laura Kmoch:** conceptualization, methodology, data curation, funding acquisition, writing – review and editing. **Tobias Plieninger:** methodology, data curation, funding acquisition, writing – review and editing, conceptualization. **Jacqueline Loos:** conceptualization, methodology, data curation, funding acquisition, writing – review and editing. **Tsinda Aime:** methodology, data curation, writing – review and editing. **Nzamukosha Beatrice:** methodology, data curation, writing – review and editing. **Sophia Bohn:** methodology, data curation, writing – review and editing. **Uwayezu Ernest:** methodology, data curation, writing – review and editing. **Marina Frietsch:** conceptualization, methodology, data curation, funding acquisition, writing – review and editing, visualization. **Callixte Gatali:** methodology, data curation, writing – review and editing. **Ndahiriwe Innocent:** methodology, data curation, writing – review and editing. **Angelique Kangondo:** methodology, data curation, writing – review and editing. **Bulonvu Franklin:** methodology, data curation, writing – review and editing. **Leonidas Maniraho:** methodology, data curation, writing – review and editing. **Berta Martín-López:** methodology, data curation, funding acquisition, writing – review and editing. **Drocelle Mukaneza:** methodology, data curation, writing – review and editing. **Valery Ndagijimana:** methodology, data curation, writing – review and editing. **Gaelle Ndayizeye:** methodology, data curation, writing – review and editing. **Martin Nizeyimana:** methodology, data curation, writing – review and editing. **Elias Nyandwi:** methodology, data curation, writing – review and editing. **Venant Nzibaza:** methodology, data curation, writing – review and editing. **Stefan Sieber:** methodology, data curation, funding acquisition, writing – review and editing. **Ping Sun:** methodology, data curation, writing – review and editing. **Jeffrey L. Ullman:** methodology, data curation, writing – review and editing. **Gloriose Umuziranenge:** methodology, data curation, writing – review and editing. **Meike Wollni:** methodology, data curation, funding acquisition, writing – review and editing. **Joern Fischer:** conceptualization, methodology, data curation, funding acquisition, writing – review and editing, writing – original draft.

Acknowledgments

We are grateful for funding by the German Research Foundation (DFG) as part of the research project "FOR 5501: A social-ecological systems approach to inform ecosystem restoration in rural Africa" (Project number 496337053).

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

References

Arakwiye, B., J. Rogan, and J. R. Eastman. 2021. "Thirty Years of Forest-Cover Change in Western Rwanda During Periods of Wars and Environmental Policy Shifts." *Regional Environmental Change* 21: 27. https://doi.org/10.1007/s10113-020-01744-0.

Bagstad, K. J., J. C. Ingram, G.-M. Lange, et al. 2020. "Towards Ecosystem Accounts for Rwanda: Tracking 25 Years of Change in Flows and Potential Supply of Ecosystem Services." *People and Nature* 2: 163–188. https://doi.org/10.1002/pan3.10062.

Baudron, F., S. A. Tomscha, B. Powell, et al. 2019. "Testing the Various Pathways Linking Forest Cover to Dietary Diversity in Tropical Landscapes." *Frontiers in Sustainable Food Systems* 3: 97.

BBC. 2023. "Rwanda Floods and Landslides Kill More Than 130 People." *BBC News*. https://www.bbc.com/news/world-africa-65469374.

Bolarinwa, O. D., K. Ogundari, and A. B. Aromolaran. 2020. "Intertemporal Evaluation of Household Food Security and Its Determinants: Evidence From Rwanda." *Food Security* 12: 179–189. https://doi.org/10.1007/s12571-019-00986-z.

Brancalion, P. H. S., and R. L. Chazdon. 2017. "Beyond Hectares: Four Principles to Guide Reforestation in the Context of Tropical Forest and Landscape Restoration." *Restoration Ecology* 25: 491–496. https://doi.org/10.1111/rec.12519.

Brancalion, P. H. S., and K. D. Holl. 2020. "Guidance for Successful Tree Planting Initiatives." *Journal of Applied Ecology* 57: 2349–2361. https://doi.org/10.1111/1365-2664.13725.

Brown, J., and D. Isaacs. 2005. *World Cafe: Shaping Our Futures Through Conversations That Matter*. Berrett-Koehler Publishers.

Bucagu, C., B. Vanlauwe, M. T. Van Wijk, and K. E. Giller. 2014. "Resource Use and Food Self-Sufficiency at Farm Scale Within Two Agro-Ecological Zones of Rwanda." *Food Security* 6: 609–628. https://doi.org/10.1007/s12571-014-0382-0.

Buckingham, K., B. Arakwiye, S. Ray, O. Maneerattana, and W. Anderson. 2021. "Cultivating Networks and Mapping Social Landscapes: How to Understand Restoration Governance in Rwanda." *Land Use Policy* 104: 104546. https://doi.org/10.1016/j.landusepol.2020.104546.

Carmenta, R., J. G. Zaehringer, P. Balvanera, et al. 2023. "Exploring the Relationship Between Plural Values of Nature, Human Well-Being, and Conservation and Development Intervention: Why It Matters and How to Do It?" *People and Nature* 5: 1720–1738. https://doi.org/10.1002/pan3.10562.

CIFOR-ICRAF. 2020. Principles for Successful Tree Planting. CIFOR-ICRAF. https://www.worldagroforestry.org/output/cifor-ciraf-principles-successful-tree-planting.

Cioffo, G. D., A. Ansoms, and J. Murison. 2016. "Modernising Agriculture Through a 'New' Green Revolution: The Limits of the Crop Intensification Programme in Rwanda." *Review of African Political Economy* 43: 277–293. https://doi.org/10.1080/03056244.2016.1181053.

Cuni-Sanchez, A., G. Imani, F. Bulonvu, et al. 2019. "Social Perceptions of Forest Ecosystem Services in the Democratic Republic of Congo." *Human Ecology* 47: 839–853. https://doi.org/10.1007/s10745-019-00115-6.

Cyamweshi, R. A., S. Kuyah, A. Mukuralinda, et al. 2023. "Farming With Trees for Soil Fertility, Moisture Retention and Crop Productivity Improvement: Perceptions From Farmers in Rwanda." *Small-scale Forestry* 22: 649–667. https://doi.org/10.1007/s11842-023-09547-x.

Dave, R., C. Saint-Laurent, L. Murray, et al. 2019. *Second Bonn Challenge Progress Report: Application of the Barometer in 2018*. IUCN, International Union for Conservation of Nature.

Dawson, N., and A. Martin. 2015. "Assessing the Contribution of Ecosystem Services to Human Wellbeing: A Disaggregated Study in Western Rwanda." *Ecological Economics* 117: 62–72. https://doi.org/10.1016/j.ecolecon.2015.06.018.

Díaz, S., U. Pascual, M. Stenseke, et al. 2018. "Assessing Nature's Contributions to People." *Science* 359: 270–272. https://doi.org/10.1126/science.aap8826.

Elias, M., M. Kandel, S. Mansourian, et al. 2022. "Ten People-Centered Rules for Socially Sustainable Ecosystem Restoration." *Restoration Ecology* 30: e13574. https://doi.org/10.1111/rec.13574.

Ellis, E. C., U. Pascual, and O. Mertz. 2019. "Ecosystem Services and Nature's Contribution to People: Negotiating Diverse Values and Trade-Offs in Land Systems." *Current Opinion in Environmental Sustainability* 38: 86–94. https://doi.org/10.1016/j.cosust.2019.05.001.

FAO, IUCN CEM, SER. 2021. *Principles for Ecosystem Restoration to Guide the United Nations Decade 2021–2030*. FAO.

Fernández-Manjarrés, J. F., S. Roturier, and A.-G. Bilhaut. 2018. "The Emergence of the Social-Ecological Restoration Concept." *Restoration Ecology* 26: 404–410. https://doi.org/10.1111/rec.12685.

Fischer, J., M. Riechers, J. Loos, B. Martin-Lopez, and V. M. Temperton. 2021. "Making the UN Decade on Ecosystem Restoration a Social-Ecological Endeavour." *Trends in Ecology & Evolution* 36: 20–28. https://doi.org/10.1016/j.tree.2020.08.018.

Frietsch, M., J. Loos, K. Löhr, S. Sieber, and J. Fischer. 2023. "Future-Proofing Ecosystem Restoration Through Enhancing Adaptive Capacity." *Communications Biology* 6: 377. https://doi.org/10.1038/s42003-023-04736-y.

Gann, G. D., T. McDonald, B. Walder, et al. 2019. "International Principles and Standards for the Practice of Ecological Restoration. Second Edition." *Restoration Ecology* 27: S1–S46. https://doi.org/10.1111/rec.13035.

Hall, C. M., L. V. Rasmussen, B. Powell, C. Dyngeland, S. Jung, and R. S. Olesen. 2022. "Deforestation Reduces Fruit and Vegetable Consumption in Rural Tanzania." *Proceedings of the National Academy of Sciences* 119: e2112063119. https://doi.org/10.1073/pnas.2112063119.

Hartel, T., J. Fischer, G. Shumi, and W. Apollinaire. 2023. "The Traditional Ecological Knowledge Conundrum." *Trends in Ecology & Evolution* 38: 211–214. https://doi.org/10.1016/j.tree.2022.12.004.

Hickey, G. M., M. Pouliot, C. Smith-Hall, S. Wunder, and M. R. Nielsen. 2016. "Quantifying the Economic Contribution of Wild Food Harvests to Rural Livelihoods: A Global-Comparative Analysis." *Food Policy* 62: 122–132. https://doi.org/10.1016/j.foodpol.2016.06.001.

IPBES. 2018. The IPBES Assessment Report on Land Degradation and Restoration. Zenodo.

IPBES. 2022. Methodological Assessment of the Diverse Values and Valuation of Nature of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Zenodo.

IUCN. 2020. "Restore Our Future: Bonn Challenge." Impact and Potential of Forest Landscape Restoration. https://www.bonnchallenge.org/sites/default/files/resources/files/%5Bnode%3Anid%5D/Bonn%20Challenge%20Report.pdf.

Kabalisa, V., and M. Kagambira. 2021. "Disaster Risk Management of Higher Risk Areas on Floods and Landslides in Rwanda." *International Journal of Advance Research, Ideas and Innovations in Technology* 7: 1543–1549.

Kadykalo, A. N., M. D. López-Rodriguez, J. Ainscough, et al. 2019. "Disentangling 'Ecosystem Services' and 'Nature's Contributions to People." *Ecosystems and People* 15: 269–287. https://doi.org/10.1080/26395916.2019.1669713.

Kangondo, A., D. W. Ndyetabula, N. Mdoe, and G. I. Mlay. 2023. "Rural Youths' Choice of Livelihood Strategies and Their Effect on Income Poverty and Food Security in Rwanda." *African Journal of Economic and Management Studies* 14: 643–662.

Kim, S. K., F. Marshall, and N. M. Dawson. 2022. "Revisiting Rwanda's Agricultural Intensification Policy: Benefits of Embracing Farmer Heterogeneity and Crop-Livestock Integration Strategies." *Food Security* 14: 637–656. https://doi.org/10.1007/s12571-021-01241-0.

Kiptot, E., and S. Franzel. 2012. "Gender and Agroforestry in Africa: Who Benefits? The African Perspective." In *Agroforestry - The Future of Global Land Use*, edited by P. K. R. Nair and D. Garrity, 463–496. Dordrecht: Springer Netherlands.

Kiyani, P., J. Andoh, Y. Lee, and D. K. Lee. 2017. "Benefits and Challenges of Agroforestry Adoption: A Case of Musebeya Sector, Nyamagabe District in Southern Province of Rwanda." *Forest Science and Technology* 13: 174–180. https://doi.org/10.1080/21580103.2017.1392367.

Lemessa, D., B. Mewded, A. Legesse, et al. 2022. "Do *Eucalyptus* Plantation Forests Support Biodiversity Conservation?" *Forest Ecology and Management* 523: 120492. https://doi.org/10.1016/j.foreco.2022.120492.

Löhr, K., M. Weinhardt, and S. Sieber. 2020. "The "World Café" as a Participatory Method for Collecting Qualitative Data." *International Journal of Qualitative Methods* 19: 1609406920916976. https://doi.org/10.1177/1609406920916976.

Loos, J., F. Benra, M. Berbés-Blázquez, et al. 2023. "An Environmental Justice Perspective on Ecosystem Services." *Ambio* 52: 477–488. https://doi.org/10.1007/s13280-022-01812-1.

Loos, J., G. Cortés-Capano, M. Riechers, C. Walsh, and J. Leventon. 2024. "Enhancing the Transformative Potential of Interventions for the Sustainable Use of Natural Resources." *Biological Conservation* 296: 110691. https://doi.org/10.1016/j.biocon.2024.110691.

Manning, P., F. van der Plas, S. Soliveres, et al. 2018. "Redefining Ecosystem Multifunctionality." *Nature Ecology & Evolution* 2: 427–436. https://doi.org/10.1038/s41559-017-0461-7.

Martin, A., B. Coolsaet, E. Corbera, et al. 2016. "Justice and Conservation: The Need to Incorporate Recognition." *Biological Conservation* 197: 254–261. https://doi.org/10.1016/j.biocon.2016.03.021.

Martini, E., T. Pagella, E. Mollee, and M. van Noordwijk. 2023. "Relational Values in Locally Adaptive Farmer-to-Farmer Extension: How Important?" *Current Opinion in Environmental Sustainability* 65: 101363. https://doi.org/10.1016/j.cosust.2023.101363.

McDermott, M., S. Mahanty, and K. Schreckenberg. 2013. "Examining Equity: A Multidimensional Framework for Assessing Equity in Payments for Ecosystem Services." *Environmental Science & Policy* 33: 416–427. https://doi.org/10.1016/j.envsci.2012.10.006.

Messier, C., J. Bauhus, R. Sousa-Silva, et al. 2022. "For the Sake of Resilience and Multifunctionality, Let's Diversify Planted Forests!." *Conservation Letters* 15: e12829. https://doi.org/10.1111/conl.12829.

Messinger, J., and B. Winterbottom. 2016. "African Forest Landscape Restoration Initiative (AFR100): Restoring 100 Million Hectares of Degraded and Deforested Land in Africa." *Nature & Faune* 30: 14–17. http://www.fao.org/3/a-i5992e.pdf.

Meyfroidt, P., A. de Bremond, C. M. Ryan, et al. 2022. "Ten Facts About Land Systems for Sustainability." *Proceedings of the National Academy of Sciences* 119: e2109217118. https://doi.org/10.1073/pnas.2109217118.

Mugabowindekwe, M., M. Brandt, J. Chave, et al. 2023. "Nation-Wide Mapping of Tree-Level Aboveground Carbon Stocks in Rwanda." *Nature Climate Change* 13: 91–97. https://doi.org/10.1038/s41558-022-01544-w.

Mugabowindekwe, M., M. Brandt, A. Mukuralinda, et al. 2024. "Trees on Smallholder Farms and Forest Restoration Are Critical for Rwanda

to Achieve Net Zero Emissions." *Communications Earth & Environment* 5: 113. https://doi.org/10.1038/s43247-024-01278-x.

Mugisha, P., A. Ngoga, J. D. Rutagengwa, et al. 2020. "Analysis of Landslide Vulnerability and Community Risk Awareness in Rwanda." *Journal of Environment Protection and Sustainable Development* 6: 16–24.

Mukoobwa, D., B. Zaninka, and C. Patrick Mugunga. 2023. "The Assessment of Agroforestry Practices in Mukura Sector, Huye District, Southern Rwanda." *International Journal of Forestry Research* 2023: 2288114. https://doi.org/10.1155/2023/2288114.

Mulyoutami, E., H. L. Tata, Y. A. Silvianingsih, and M. van Noordwijk. 2023. "Agroforests as the Intersection of Instrumental and Relational Values of Nature: Gendered, Culture-Dependent Perspectives?" *Current Opinion in Environmental Sustainability* 62: 101293. https://doi.org/10.1016/j.cosust.2023.101293.

Mutandwa, E., and R. Kanyarukiga. 2016. "Understanding the Role of Forests in Rural Household Economies: Experiences From the Northern and Western Provinces of Rwanda." *Southern Forests: a Journal of Forest Science* 78: 115–122.

National Institute of Statistics of Rwanda (NISR). 2021. *Comprehensive Food Security and Vulnerability Analysis – 2022 Report*. National Institute of Statistics of Rwanda (NISR).

National Institute of Statistics of Rwanda (NISR). 2023. *The Fifth Rwanda Population and Housing Census*. National Institute of Statistics of Rwanda (NISR).

Ndayambaje, J. D., W. J. M. Heijman, and G. M. J. Mohren. 2012. "Household Determinants of Tree Planting on Farms in Rural Rwanda." *Small-Scale Forestry* 11: 477–508. https://doi.org/10.1007/s11842-012-9196-0.

Ndoli, A., A. Mukuralinda, A. G. T. Schut, et al. 2021. "On-Farm Trees Are a Safety Net for the Poorest Households Rather Than a Major Contributor to Food Security in Rwanda." *Food Security* 13: 685–699. https://doi.org/10.1007/s12571-020-01138-4.

Nussbaum, M. C. 2011. *Creating Capabilities: The Human Development Approach*. Harvard University Press.

Osborne, T., S. Brock, R. Chazdon, et al. 2021. "The Political Ecology Playbook for Ecosystem Restoration: Principles for Effective, Equitable, and Transformative Landscapes." *Global Environmental Change* 70: 102320. https://doi.org/10.1016/j.gloenvcha.2021.102320.

Pascual, U., W. M. Adams, S. Díaz, S. Lele, G. M. Mace, and E. Turnhout. 2021. "Biodiversity and the Challenge of Pluralism." *Nature Sustainability* 4: 567–572. https://doi.org/10.1038/s41893-021-00694-7.

Pascual, U., P. Balvanera, C. B. Anderson, et al. 2023. "Diverse Values of Nature for Sustainability." *Nature* 620: 813–823. https://doi.org/10.1038/s41586-023-06406-9.

Pascual, U., P. Balvanera, S. Díaz, et al. 2017. "Valuing Nature's Contributions to People: The IPBES Approach." *Current Opinion in Environmental Sustainability* 26–27: 7–16. https://doi.org/10.1016/j.cosust.2016.12.006.

Quandt, A., H. Neufeldt, and J. T. McCabe. 2019. "Building Livelihood Resilience: What Role Does Agroforestry Play?" *Climate and Development* 11: 485–500. https://doi.org/10.1080/17565529.2018.1447903.

Rasmussen, L. V., C. Watkins, and A. Agrawal. 2017. "Forest Contributions to Livelihoods in Changing Agriculture-Forest Landscapes." *Forest Policy and Economics* 84: 1–8. https://doi.org/10.1016/j.forpol.2017.04.010.

Rawls, J. 1958. "Justice as Fairness." *Philosophical Review* 67: 164–194. https://doi.org/10.2307/2182612.

Rukundo, E., S. Liu, Y. Dong, et al. 2018. "Spatio-Temporal Dynamics of Critical Ecosystem Services in Response to Agricultural Expansion in Rwanda, East Africa." *Ecological Indicators* 89: 696–705. https://doi.org/10.1016/j.ecolind.2018.02.032.

Rwanda Ministry of Environment. 2022. *Development of Agroforestry and Sustainable Agriculture Project: Environmental and Social Management Framework (ESME)*. African Development Bank Group.

Schulz, J. J., and B. Schröder. 2017. "Identifying Suitable Multifunctional Restoration Areas for Forest Landscape Restoration in Central Chile." *Ecosphere* 8: e01644. https://doi.org/10.1002/ecs2.1644.

Sen, A. 2009. *The Idea of Justice*. Harvard University Press.

Sikor, T., A. Martin, J. Fisher, and J. He. 2014. "Toward an Empirical Analysis of Justice in Ecosystem Governance." *Conservation Letters* 7: 524–532. https://doi.org/10.1111/conl.12142.

Silva, S., and E. Guenther. 2018. "Setting the Research Agenda for Measuring Sustainability Performance – Systematic Application of the World Café Method." *Sustainability Accounting, Management and Policy Journal* 9: 455–469. https://doi.org/10.1108/SAMPJ-06-2017-0060.

Slade, E. M., L. Kirwan, T. Bell, C. D. Philipson, O. T. Lewis, and T. Roslin. 2017. "The Importance of Species Identity and Interactions for Multifunctionality Depends on How Ecosystem Functions Are Valued." *Ecology* 98: 2626–2639. https://doi.org/10.1002/ecy.1954.

Stanturf, J. A., and S. Mansourian. 2020. "Forest Landscape Restoration: State of Play." *Royal Society Open Science* 7: 201218. https://doi.org/10.1098/rsos.201218.

Tedesco, A. M., S. López-Cubillos, R. Chazdon, et al. 2023. "Beyond Ecology: Ecosystem Restoration as a Process for Social-Ecological Transformation." *Trends in Ecology & Evolution* 38: 643–653. https://doi.org/10.1016/j.tree.2023.02.007.

Temperton, V. M., N. Buchmann, E. Buisson, et al. 2019. "Step Back From the Forest and Step Up to the Bonn Challenge: How a Broad Ecological Perspective Can Promote Successful Landscape Restoration." *Restoration Ecology* 27: 705–719. https://doi.org/10.1111/rec.12989.

Tesfaw, A., D. Alemu, F. Senbeta, and E. Teferi. 2022. "Eucalyptus Succession on Croplands in the Highlands of Northwestern Ethiopia: Economic Impact Analysis Using Farm Household Model." *Resources* 11: 71. https://doi.org/10.3390/resources11080071.

Tuyisingize, D., W. Eckardt, D. Caillaud, M. Ngabikwiye, and B. A. Kaplin. 2022. "Forest Landscape Restoration Contributes to the Conservation of Primates in the Gishwati-Mukura Landscape, Rwanda." *International Journal of Primatology* 43: 867–884. https://doi.org/10.1007/s10764-022-00303-0.

Uwayezu, E., and W. T. de Vries. 2020. "Can In-Kind Compensation for Expropriated Real Property Promote Spatial Justice? A Case Study Analysis of Resettlement in Kigali City, Rwanda." *Sustainability* 12: 3753. https://doi.org/10.3390/su12093753.

Wells, H. B. M., E. H. Kirobi, C. L. Chen, et al. 2021. "Equity in Ecosystem Restoration." *Restoration Ecology* 29: e13385. https://doi.org/10.1111/rec.13385.

Zafra-Calvo, N., P. Balvanera, U. Pascual, et al. 2020. "Plural Valuation of Nature for Equity and Sustainability: Insights From the Global South." *Global Environmental Change* 63: 102115. https://doi.org/10.1016/j.gloenvcha.2020.102115.