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Managing tree cover to restore farm productivity and build landscape and livelihood resilience in West Africa

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Abstract Land restoration and sustainable natural resource use are critical societal concerns that impact both the health of ecosystems and human well-being. There is increasing recognition of the importance of restoring degraded land and landscapes, culminating in the UN Decade of Ecosystem Restoration (2021–2030). This special issue sheds light on how trees can help restore landscapes and is organized around 3 domains: ecological and genetic variation, restoration of species and lands, and species management in production systems. Successful tree cover interventions consider species, practices, and their management within the production systems to optimize impacts. A solid understanding of the variation in tree materials and their different functional traits can help restoration project planners and managers select the best interventions, such as direct seeding and Farmers' Managed Natural Regeneration (FMNR). Simultaneously, the use of these approaches must be context-specific and consider the severity of land degradation. The Land Degradation Surveillance Framework (LDSF), a tool that helps determine the severity of land degradation, can be used to help tailor interventions to the local extent of land degradation.

Keywords Functional traits · Planting material · Farmer-managed natural regeneration · Direct seeding · Sustainable production · Tree-based restoration · Tree management

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Introduction

Trees and woody species play critical roles in both preventing land degradation and restoring degraded, deforested landscapes (AbdelRahman 2023; Cowie et al. 2018; van der Esch et al. 2022). Land degradation is exacerbated by climate change, which can result in biodiversity loss and jeopardize the livelihood of local communities (Hermans and McLeman 2021; Herrmann et al. 2020; Sultan and Gaetani 2016). The combined impact of climate change and land degradation is a major threat to food security worldwide, including in West Africa (WCA). WCA is a vast region with highly diverse landscapes, peoples, cultures, and institutions. The population is predominantly rural: 60% depend primarily on agriculture, which satisfies 80% of their needs (Aboudou et al. 2015; Mechiche-Alami and Abdi 2020; Sissoko et al. 2011). The region consists of three main agroecological zones (Sahel, sub-humid, and humid) with very strong climatic gradients, diverse vegetation cover and varied biomass and soil carbon content (Kay et al. 2019; Nicholson 2018; Saiz et al. 2012). Despite these differences, agriculture and livelihoods in both zones are interconnected and in a state of change. They share common challenges including poverty, food, and nutrition insecurity, degrading social and environmental resources, poor access to regional and global markets, conflicts, and insufficient and inadequate support for agricultural research and development from national governments (Kemmerling et al. 2022). Produce, people, and money move extensively within the region, so issues that arise in one area have implications elsewhere. The countries of the region are among the poorest in the world according to the Multidimensional Poverty Index (MPI) (Alkire and Robles 2017), which estimates that 60–90% of people in WCA are below the $ 1.90 per day poverty line. Hunger and abject poverty are endemic and are most acute among rural populations (Bjornlund et al. 2022).

Both humid and dryland areas of West Africa are seriously affected by climate change. All countries in the region depend predominantly on rainfed agriculture, which is central to their ability to achieve the UN Sustainable Development Goals (SDGs) (Aboudou et al. 2015; Mechiche-Alami and Abdi 2020; Sultan and Gaetani 2016). In the humid zones of West Africa, the most critical issues are deforestation and forest degradation resulting from extensive farming practices, urbanization, and artisanal mining. In the Sahel, declines in agricultural productivity, shortages of non-timber forest products (NTFPs) and fuel wood, and land degradation are major concerns (Hermann et al. 2020; Maisharou et al. 2015).

As a result of these drivers, the pattern of tree cover is changing. Climate change, planned interventions, and other societal processes also influence changing tree cover. In the humid zone, there is a loss of closed forests, but tree cover on agricultural land is increasing to buffer climate change effects on full sun farming systems of coffee and cocoa (Asitoakor et al. 2022; Schroth et al. 2016; Zomer et al. 2016). Similarly, in the Sahel, the situation is mixed: there is a clear decline in tree density and diversity in some places, (Gonzalez et al. 2012; Ouedraogo et al. 2014) while vegetation is recovering in other areas where active restorative actions have taken place (Zomer et al. 2016). Research on the drivers (Ouedraogo et al. 2014; Reij and Garrity 2016) and impacts of tree cover change (Bayala et al. 2020; Binam et al. 2015, 2017) show that the regeneration of trees on farms in the drylands of West Africa can increase cash income, caloric intake, dietary diversity, crop yield, and livestock productivity, thereby providing a safety net for rural communities (Adams et al. 2016; Binam et al. 2017; Sinare and Gordon 2015).

ICRAF has worked on participatory tree domestication in West Africa and on-farm tree biodiversity conservation with a range of national partners, NGOs, and farmer organizations since the late 1980s. This work has improved smallholder farmers' livelihoods by enabling farmers to increase their incomes and access other benefits derived from indigenous trees and shrubs (Leakey et al. 2022; Seghieri 2019). ICRAF's work includes the development and scaling-up of innovations in the domestication of indigenous tree species, tree-based farming systems, landscape restoration, non-timber forest product value chains, and innovative agricultural advisory services (Degrande et al. 2015). Reviews on the impacts of this work are sparse and partial (Boffa 2015; Leakey et al. 2022) and some key insights related to climate change response, as well as recent transdisciplinary research around scaling of the innovations mentioned above, remain unpublished. There is burgeoning interest in efforts focused on parklands and Farmers' Managed Natural Regeneration (FMNR) led by NGOs (Reij and Garrity 2016).

This special issue pulls together a synthesis of research for development results about tree-based land restoration across sub-humid and dry West Africa. A selection of new research articles based on novel field data is presented.

Papers contained in the special issue

This special issue contains 9 papers, organized around three domains: (1) ecological and genetic variation, (2) restoration of species and lands, and (3) species management in production systems.

Ecological and genetic variation

To successfully use a species in ecosystem restoration, one must have good knowledge of how it varies, its specific niche, and how it associates with other species to form functional groups. The first paper in the Ecological and Genetic Variation domain (Kalinganire et al. 2023) reports on the survival and growth of 10-year-old *Adanonsia digitata* trees and clone trials in Sadore (Niger) and Samanko (Mali). The results indicate that trees from West Africa (Benin, Burkina Faso, Mali, Niger, Senegal, and Togo) have a tendency towards faster growth than those from East Africa (Kenya, Malawi, Mozambique, Sudan, and Tanzania), and the trees from drier locations tend to be better adapted. The differences found between the planting sites also exist in the natural distributions of the species.

Drabo et al. (2023) report low genetic variation and adaptation to poor soils of *Senegalia macrostachya* from different ecological niches. This study also provides information on the optimal seed maturity period, which is important for producing viable seeds for reforestation programs.

Until recently, the use of tree species for land restoration was limited to a small number of exotics. However, there is now a strong move towards the use of local species, as exotics are not well adapted to local climates and have limited uses in local communities. New restoration programs should be based on local users' perceptions of tree functions and functional traits. Clinquart et al. (2023) surveyed farmers in Central Mali and based on their responses, grouped tree species as follows: woody/timber trees, fruit/cash crop trees, and fodder trees. It is important to note that farmers' perceptions of tree functions and traits were context-specific and cannot be used generically.

Restoration of species and lands

When selecting species for use in restoration, it is important not only to choose species with local uses, but to also consider and understand how the selected species regenerate.

The first paper in the Restoration of Species and Lands domain tested direct seeding on 6 local species in combination with fungicide application and the size of the planting hole (Ky-Dembele et al. 2023). Species tested included both orthodox (*Adansonia digitata, Faidherbia albida, Ziziphus mauritiana*) and recalcitrant species (*Cordyla pinnata, Saba senegalensis, Vitellaria paradoxa*). Direct seeding in 60 cm deep holes was found to be best for emergence and relative growth rates for *A. digitata, F. albida, Z. mauritiana*, and *V. paradoxa*. This has important implications for Farmer Managed Natural Regeneration (FMNR), which becomes much simpler and less expensive if direct seeding is an option (Reij and Garrity 2016). FMNR is being promoted in WCA, and the observed regreening of part of the Sahel is largely due to this practice.

Camara et al. (2023) investigated the benefits and constraints of FMNR in the peanut basin of Senegal. They identified increased soil fertility, soil moisture conservation, and availability of wood and non-timber forest products as the main benefits of FMNR, and illegal logging, animal roaming, and the difficulties of using animal traction on a farm having many trees/shrubs as the main constraints. Significant factors predicting FMNR adoption include ethnicity, access to external support, receptivity to technological innovations, mode of land acquisition, and the type of production. In addition to the multiple benefits provided by FMNR, it is also a useful tool for helping restore ecosystems and their functions. The paper also addresses what is needed to support and promote FMNR at the policy level. Specifically, policymakers must have access to good spatial information on restoration potentials to guide the design and implementation of restoration interventions in the context of limited resources.

Takoutsing et al. (2023) used a set of indicators (soil organic carbon, erosion prevalence, enhanced vegetation index, normalized differences water index, and Net Primary productivity) to classify lands in need of restoration into 3 categories: no action required in the short term, moderate action required, and very heavy restoration needed. Potential techniques to restore landscapes included tree planting, soil, and water conservation practices, FMNR, and integrated soil fertility management. Their results using LDSF can help identify hotspot areas for restoration and thus help target investment.

Species management in production systems

A recent study revealed that more than one-quarter of tree cover in Africa is found outside forests (Reiner et al. 2023). This suggests more attention is needed on how to sustainably manage non-forest tree cover to support the livelihoods of local communities. To successfully restore landscapes, tree management must be considered alongside the aspects addressed in the first two domains above. Bayala et al. (2023) evaluated the sustainable management of *Gliricidia sepium* (Jacq.) Walp. and *Pterocarpus erinaceus* Poir. for fodder production from 1997 to 2015. They found that for optimal marketable fodder production, it is best to prune *G. sepium* every 3 months, while 4 months is the optimal pruning interval for *P. erinaceus*. Fodder production from both species was very profitable for peri-urban animal rearing.

Similarly, Sanogo et al. (2023) found planting grafted accessions of *Tamarindus indica* is both financially viable and economically profitable compared to non-grafted *T. Indica* in Senegal.

Trees can also be incorporated into annual cropping systems, although the crop yield results are mixed. Maize yields were found to decline substantially when trees such as *Allanblackia floribunda* were added to the cropping system in Nigeria (Koyejo et al. 2023). A similar trend was observed with *A. floribunda* incorporated into mung bean production. Grain yields were reduced with the inclusion of *A. floribunda* when mung beans were spaced at 30×20 cm, whereas with 20×20 cm mung bean spacing, the beans had a higher yield as a sole crop. With the introduction of *A. floribunda*, bean yields improved due to improved soil properties. Indeed, besides soil pH, P, K, Ca and Mg increased steadily during the first 3 years after *A. floribunda* trees were planted, which is beneficial for crop production (Koyejo et al. 2023). Clearly, there are trade-offs between crop yield and associated tree growth. Optimizing production and sustainability of mixed tree-annual crop systems in the face of climate change remains key in West Africa.

Conclusion

Improved skills in the use of tools like LDSF, better knowledge of planting materials and tree regeneration (FMNR, direct seeding, planting, and grafting), and improved tree management enable more tailored, context-specific restoration operations that are more likely to accomplish their restoration goals. Although the pieces of work presented in this special issue were conducted separately, a better knowledge management system can help bring them together and provide useful information for future restoration efforts.

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