Learning from agrarian dynamics to tailor community-led forest restoration in the Tshopo province, Democratic Republic of the Congo

A. PEROCHES[a,b,c], E. DUBIEZ[c,d], B. BISIMWA[e], M. OSWALD[b], J.M. PAILLAT[b], C. LUCAS[a] and G. LESCUYER[c,e]

[a]*Agrarian Systems Consulting, 430 chemin de l'hirondelle, 34170 Castelnau-le-Lez, France*
[b]*ISTOM, ADI-Suds, 4 rue Joseph Lakanal, 49 000 Angers, France*
[c]*CIRAD Forêts et Sociétés, University of Montpellier, Campus International de Baillarguet, 34398 Montpellier, France*
[d]*IFR, Brazzaville, Congo*
[e]*CIFOR, Center for International Forestry Research, Kisangani, DR Congo*

Email: adrien@agrarian-systems.org, emilien.dubiez@cirad.fr, bishaben2013@gmail.com, m.oswald@istom.fr, jm.paillat@istom.fr, corentin@agrarian-systems.org, Guillaume.lescuyer@cirad.fr

HIGHLIGHTS

- The proportion of farming systems supported did not correspond to the likely distribution of the population in Tshopo Province. Older and middle-aged customary rights holders were more supported than young customary rights holders and non-natives.
- Older and middle-aged customary rights holders gave significantly more importance to indigenous trees for timber and caterpillar production, while young customary rights holders focused mainly on fruit trees.
- Middle-aged and young customary rights holders prefered to plant in home gardens compared to older customary rights holders who already have mature home gardens.
- The survival rates of planted trees differed significantly by farming system. Older customary rights holders had the best survival rates (63.0%), while middle-aged and young customary rights holders' rates were slightly lower (52.1% and 51.9% respectively).
- Considering the agrarian dynamic, it is proven that in order to be effective, a forest restoration project with local people must target tree species with the potential to improve the productivity of farming systems.

SUMMARY

The strategies and efficacy of forest restoration initiatives in Central Africa are poorly documented. To this end, we examined the usefulness of a holistic methodology (combining agricultural diagnosis with forestry measurement) to explain the results of a forest restoration project in Tshopo Province in the DRC. To do this, an initial analysis based on the agrarian diagnostic structure was carried out and linked to project monitoring data – interviews with all beneficiaries who had planted trees (n=89) and measurements in their fields (planting sites, species planted and mortality rates 12 months after planting). The study shows that the uptake and results of the forest restoration initiative can be largely explained by the diversity of farming systems. Finally, our diagnostic method offers interesting rationales for forest restoration interventions in Central Africa, in order to adapt project objectives to the local context and diversity of farming systems, and ultimately to improve project performance.

Keywords: tree plantations, agrarian diagnosis, smallholders, tropical forest restoration, Central Africa

Apprendre des dynamiques agraires pour adapter la restauration forestière avec les communautés locales dans la province de la Tshopo, République démocratique du Congo

A. PEROCHES, E. DUBIEZ, B. BISIMWA, M. OSWALD, J.M. PAILLAT, C. LUCAS et G. LESCUYER

Les stratégies et l'efficacité des initiatives de restauration forestière en Afrique centrale sont peu documentées. C'est pourquoi nous avons testé l'utilité d'une méthodologie holistique (combinant diagnostic agraire et mesures forestières) pour expliquer les résultats d'un projet de restauration forestière dans la province de la Tshopo, en RDC. Pour ce faire, une première analyse basée sur la structure du diagnostic agraire a été réalisée et mise en relation avec les données de suivi du projet – entretiens avec tous les bénéficiaires ayant planté des arbres (n=89) et mesures dans leurs champs (sites de plantation, espèces plantées et taux de mortalité 12 mois après la plantation). L'étude montre que l'adoption et les résultats de l'initiative de restauration forestière peuvent être largement expliqués par la diversité des systèmes de production. Finalement, notre méthode de diagnostic offre des pistes intéressantes pour les interventions de restauration forestière en Afrique centrale, afin d'adapter les objectifs des projets au contexte local et à la diversité des systèmes de production, et in fine d'améliorer les performances des projets.

Aprender de la dinámica agraria para adaptar la restauración forestal comunitaria en la provincia de Tshopo de la República Democrática del Congo

A. PEROCHES, E. DUBIEZ, B. BISIMWA, M. OSWALD, J.M. PAILLAT, C. LUCAS y G. LESCUYER

Las estrategias y la eficacia de las iniciativas de restauración forestal en África Central están poco documentadas. En este contexto, se analizó la utilidad de una metodología holística (que combina el diagnóstico agrícola con la medición forestal) para explicar los resultados de un proyecto de restauración forestal en la provincia de Tshopo de la RDC. Para ello, se realizó un análisis inicial basado en la estructura de diagnóstico agrario que se vinculó a los datos de monitoreo del proyecto: entrevistas con todos los beneficiarios que habían plantado árboles (n=89) y mediciones en sus fincas (lugares de plantación, especies plantadas y tasas de mortalidad 12 meses después de la plantación). El estudio muestra que la aceptación y los resultados de la iniciativa de restauración forestal pueden explicarse en gran medida por la diversidad de los sistemas agrícolas. Por último, este método de diagnóstico ofrece argumentos interesantes para las intervenciones de restauración forestal en África Central, con el fin de adaptar los objetivos de los proyectos al contexto local y a la diversidad de los sistemas agrícolas y, en última instancia, mejorar el rendimiento de los proyectos.

INTRODUCTION

Forest restoration is recommended as a means to limit, compensate or reverse the trend of forest degradation and deforestation (Bastin *et al.* 2019, Chazdon 2008, Lewis *et al.* 2019). It relies on various approaches (e.g. regeneration, plantations and agroforestry) with the aim, in a delimited territory, of limiting the degradation of an already slightly degraded forest ecosystem or, conversely, restoring the ecological functionalities of a degraded ecosystem, while also improving the livelihoods of local populations (Besseau *et al.* 2018, Chazdon 2008, Chazdon and Brancalion 2019, Gann *et al.* 2019, Guizol *et al.* 2022).

Since 2010, several international initiatives such as the Bonn Challenge, the UN Decade of Ecosystem Restoration or the AFR100 emerged, in addition to various other campaigns to promote tree planting (Holl and Brancalion 2020, Martin *et al.* 2021). Relating to the Bonn Challenge and the AFR100 initiative, the Central African Forests Commission (COMIFAC), responsible for coordinating efforts related to forest and environmental matters in the region, has issued a political commitment to restore 25% of degraded lands by 2025 (including 8 million hectares in the Democratic Republic of the Congo – DRC) (Guizol *et al.* 2022).

The involvement of local communities is considered to be a critical factor in the success of forest restoration (Herbohn *et al.* 2022, Holl and Brancalion 2022). As most of the degraded areas are located in the 'rural complex' zone (Shapiro *et al.* 2023) and within small farms (Shyamsundar *et al.* 2022), farmers, as the primary land users, play a pivotal role. In addition, in line with the international objectives for forest restoration, the improvement of the livelihoods of smallholders should be a priority (Holl and Brancalion 2022).

Past and current forest restoration initiatives are poorly monitored (Martin *et al.* 2021) and often fail (Holl and Brancalion 2020). In general, top-down interventions generally fail to address local challenges, such as those related to socio-economic factors, natural resource management, land tenure and land-use rights (Stanturf and Mansourian 2020). The most common monitoring parameter is limited to the number of trees planted, both in Central Africa (Peroches *et al.* In prep.) and throughout the tropics (Martin *et al.* 2021). However, Martin *et al*. (2021) recommend monitoring systems to determine whether planted trees survive to maturity and meet the needs of local stakeholders. In general, as in the case of the evaluation of the EcoMakala tree planting project in the DRC (Bouyer *et al*. 2013), the results are presented in broad terms and raise few questions about the different types of actors who maintain and conserve (or even regenerate) plantations on the ground. However, differences between actors appear to exist, as in the example of the Makala Project in Kongo Central (Péroches *et al*. 2019).

In this context of major failures in past and present forest restoration initiatives (Martin *et al.* 2021, Holl and Brancalion 2020), researchers need to challenge the international objectives of restoration by utilising on-the-ground realities to inform stakeholders engaged in restoration activities. A rigorous assessment of the number of surviving trees and their condition after replanting, as well as an analysis of the practices of local tree managers and their evolution in relation to past and current planting initiatives, could provide vital knowledge to restoration stakeholders (Gnacadja and Vidal 2022, Marshall *et al.* 2022, Stanturf and Mansourian 2020). Firstly, the definition of 'success' in restoration needs to be contextualised. Then, researchers should identify and participate in ongoing processes to better understand social and landscape evolution (Mansourian *et al.* 2022). For example, the analysis of local disturbance regimes is essential to understand forest restoration outcomes (Marshall *et al.* 2022). Furthermore, without addressing the long-term needs of local people, restoration is likely to be short-lived, particularly if the main benefits are temporary and disappear when donor support is withdrawn (Stanturf and Mansourian 2020).

Therefore, the study of farming systems, their evolution and their environment (landscape and socio-economic components) could incorporate most of the factors defined in the literature (Gnacadja and Vidal 2022, Marshall *et al.* 2022, Stanturf and Mansourian 2020). For example, Péroches *et al.* (2019) showed differences in tree planting strategies depending on farming systems in the Kongo Central Province, in the DRC. Furthermore, they stated the importance of understanding the current evolution of the forest landscape and subsequently the agrarian dynamics.

This research questions the relevance of using a holistic method based on comparative agriculture concepts (Cochet 2015) to analyse and interpret local farmers' practices and their evolution, in order to provide a dynamic framework to explain the status and evolution of the forest restoration initiative. The main hypothesis is that there is a link between the evolution of farming systems and the dynamics of forest restoration in the 'PROmote and Formalise Artisanal Exploitation of Timber in Central Africa' (PROFEAAC) project intervention area, located in the Tshopo Province of the DRC. To achieve this, the paper presents a description of (i) the landscape, (ii) the farming systems and (iii) the farmers' practices, using a diachronic approach inspired by comparative agriculture concepts. For the specific issue of the restoration project, we tested (i) whether plantation characteristics (purpose, number and location) differ significantly between farming systems, and (ii) whether the success rate of planted trees, with regard to mortality, differs significantly between farming systems.

MATERIALS AND METHODS

Study area

The study was carried out in Tshopo Province, Isangi District and Yalikandja-Yanonge Sector, in the Democratic Republic of the Congo. Eight villages, located in the Totuku and Yangandi groups, were included in the study (Lucas *et al.* 2020). Four of them were located between 5 and 15 km from Yanonge centre along the Yanonge-Yatolema road (Yakamba, Yangandi, Yaosenge and Celco), and the other four (Yakondi, Yelimbo, Bolongo 2 and Yaolonga) were located between 5 and 10 km from Yatolema along a road that follows the Lomami River. Yanonge is located about 80 km down the Congo River from Kisangani, the capital of the Tshopo province and a city of 1.37 million inhabitants. Yatolema is located 95 km from Kisangani by road.

According to a census carried out by a development project (CTB 2013), the total population of the two groups was 7,391 in 2013. Since then, the population of these two groups increased by at least 22% in 7 years and is estimated to be around 9,000 in 2020, representing an annual growth rate of around 2.5% (Lucas *et al.* 2020).

The area is mostly covered by transitional evergreen and semi-deciduous forest (Réjou-Méchain *et al.* 2021). However, on the Yanonge-Yatolema road, the rural complex extends approximately 6 km from the road to the forest boundary. On the Yatolema-Lomani road, this complex extends approximately 3 km from the road to the forest boundary (Lucas *et al.* 2020) (Figure 1).

Forest restoration support strategy

The overall objective of the PROFEAAC project was to reduce the degradation of rural complex forests in Central Africa through the formalisation and rationalisation of small-scale logging. One of the objectives of the project was to develop local pilot activities for the regeneration and reforestation of timber species within the project area (Figure 1).

After informing the villagers about the objectives of the project, a diagnosis was carried out in the eight villages in November 2020 to collect information on social organisation, main economic activities, land and natural resource management, land occupation, food systems and farming systems (Lucas *et al.* 2020). Secondly, volunteers were identified through expressions of interest. Volunteers had to be permanent residents of the village, recognised by the customary authorities as landowners and available to attend the training sessions. They were required to submit a duly completed and signed individual expression of interest form. The form contained information on the farmer's profile (age, sex, marital status, number of children, name of village and clan), the land they owned (number, area and distance from the village via landscape unit) and a description of their forest restoration project (area, distance of the landscape unit chosen for reforestation from the village, land tenure, desired tree species and objectives of the forest restoration project).

Once the beneficiaries had been selected, participatory meetings were held in each village (in May and June 2021) to define the stages of forest restoration, the timeframe for implementing these stages, and the collective and individual roles of each person. As a result of this work, nurseries were built in the locations chosen by the beneficiaries (in September to November 2021 for seven villages and in March 2022 for one village) and collective training was provided at village level on the production of forest and fruit plants in the nurseries (in November 2021 for seven villages and March 2022 for one village). A total of 2 290 plants were produced for the first planting campaign (68% local tree species and 32% fruit trees) and 1 960 plants for the second planting campaign (20% local tree species and 80% fruit trees). Finally, between April and May 2022 the beneficiaries, grouped by village, received training on planting techniques in a field chosen by the volunteers themselves.

Two planting seasons were carried out by the volunteers, from April to June 2022 and from October to December 2022. The seedlings produced collectively were distributed equally among the beneficiaries who had participated in the maintenance and preparation of the seedlings in the nursery.

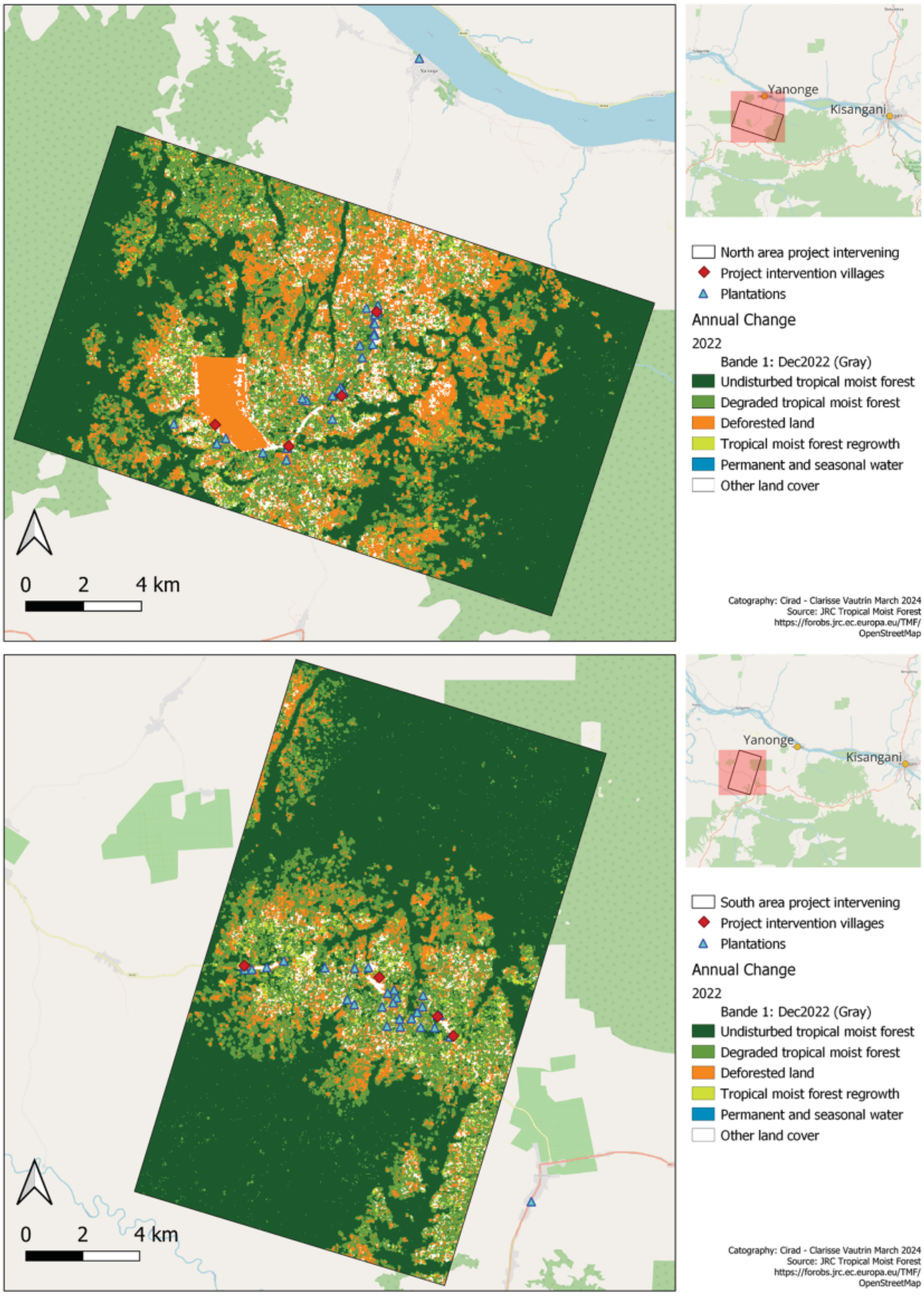
Initial diagnosis of farming systems

The initial diagnosis was based on the agrarian diagnostic structure (Barral *et al.* 2012, Lacoste *et al.* 2016) combined with complementary social science methods (social transect, focus group and participatory mapping). The diagnosis was carried out in two distinct steps.

Step 1: Landscape analysis

Landscape analysis is the study of spatial factors that could explain farmers' strategies, such as the amount and distribution of available natural resources. Its aim is to delineate and describe the different landscape units of a given territory, characterize their resources and derive hypotheses about their

FIGURE 1 *State of forest cover in 2022 in the North (top) and South (bottom) study areas (Data: Joint Research Centre)*



specific uses from there (Lacoste *et al.* 2016, Moreau *et al.* 2012). Other outcomes of this first step are the familiarization with the study area and the identification of local contacts. These help to identify relevant questions to ask farmers in the second step (Lacoste *et al.* 2016).

The landscape analysis was initially carried out by reading satellite images. The extraction of cartographic data was carried out using R software (version 4.2.2) to characterise forest cover dynamics from 1990 to 2022, based on the Joint Research Centre's (JRC) 'Tropical Moist Forest' data (from Landsat imagery at 0.09 ha resolution – pixel size of 30 m by 30 m) (Vancutsem *et al.* 2021). In the two study areas, the analyses were carried out in a 10 km buffer zone from the road to the forest surrounding the sampled villages (223 km^2 per area). This 10 km distance is approximately the maximum distance from the plots where people work on a daily basis, or from the routes they take to collect forest products. Five JRC classes were used:

- *Undisturbed tropical moist forest*: closed evergreen or semi-evergreen with no disturbance (degradation or deforestation) observed over the full observation period defined by the Landsat data availability.
- *Degraded tropical moist forest*: closed evergreen or semi-evergreen forest that has been temporarily disturbed for up to 2.5 years maximum (900 days) with the last disruption observed dating from 2021 at the latest).
- *Deforested land*: either (i) a permanent conversion of forest to non-forest land that started before 2020 (i.e. no vegetation regrowth was detected over 2020–2022) or (ii) ongoing deforestation (disturbances started after 2020).'
- *Regeneration*: a two-phase transition from moist forest to (i) deforested land and then (ii) vegetative regrowth. A minimum 3-year duration (2020–2022) of permanent moist forest cover presence is required to classify a pixel as forest regrowth (to avoid confusion with agriculture).
- *Other land uses*: refers to non-tropical moist forest cover and includes savannah, deciduous forest, agriculture, evergreen shrubland, non-vegetated cover and afforestation.

The second phase of the landscape analysis was carried out through direct field observations, complemented by participatory mapping using interactive models (Larzillière *et al.* 2013). Direct observations were made by walking through the study area along transects of interest (n=16, two per village). Participatory mapping (n=8, one per village) made it possible to accurately describe the local landscape units with their local names and to understand the customary rules and management of natural resources (Larzillière *et al.* 2013, Lucas *et al*. 2020).

Step 2: Characterization of current farming systems using a historical approach

This step seeks to discover how land use and farming practices have changed in recent history, leading to the current farming systems (Barral *et al.* 2012, Lacoste *et al.* 2016). More specifically, it consists of understanding the evolution of agro-ecosystem management, and capturing the differentiation processes and diversity of current farming systems resulting from local technical breakthroughs, agrarian economics and policy changes (Moreau *et al.* 2012). Indeed, at the farm level, individual choices are limited to a set of possibilities as a result of historical differentiation processes (Cochet and Devienne 2006).

The historical investigation was initially conducted through in-depth and semi-structured interviews with older farmers, following a questionnaire but leaving answers open-ended to encourage discussion (n=16, two per village). The inquiry commenced with an exploration of the farm's general characteristics and moved on to an examination of the farm's chronological history. Questions were asked about: the origin of the farm and capital; the commencement of farming, the family structure and the role of siblings; changes in the farm area, workforce, equipment, production orientation and practices; and the current state of the farm, occupation of children, notable events and changes in production levels (Lacoste *et al.* 2016). In the specific case of the DRC, where customary institutions play a significant role in the management of land and natural resources and relations between farmers, particular emphasis was placed on developing a comprehensive understanding of the social organization, as already recommended in the literature (Dubiez *et al.* 2013, Vermeulen *et al.* 2011). To this end, in addition to agrarian diagnosis techniques, focus groups (n=16, two per village) (Evans *et al.* 2006, Pierre and Cassagne 2005) and social transects (n=8, one per village) (Evans *et al.* 2006) were conducted to ascertain: number of households customary organization, spatial distribution of lineage and village history. The social transect consists in crossing a village from one side to another recording the community infrastructures (chief's house, school, dispensary, sheds, shops, pumps, etc.) as well as each house, including several details about each household (lineage, particular social role, approximate number of household members).

This field approach inspired by agrarian diagnosis (Barral *et al.* 2012, Lacoste *et al.* 2016) makes it possible to identify types of farming systems, including a review of their history and an understanding of their current functioning. The approach was intended to be holistic, incorporating elements related to farm capital, family structure, farm area and its evolution, form of labour, equipment, past and current production, target markets and technical routes (work steps, total time per step, equipment and labour used, period, etc.), non-agricultural activities, and hopes for the future of the farm. These interviews (n=24, two to three per village) were also semi-structured and in-depth but were designed to represent the diversity of farming systems based on a reasonable sample of farming systems.

Project monitoring and results analysis

Project monitoring was carried out between May and June 2023. This was based on interviews with all beneficiaries who had planted trees (n=89). The field surveys made it possible to characterize the planting sites, the species planted and the mortality rates six to 12 months after planting, depending on the plot. The primary objective of the interviews was to collect detailed data on the beneficiaries' farming systems with the aim of establishing a correlation between the field results and the initial diagnosis results.

To identify possible differences in the training process, plantation characteristics (purpose, location and species chosen) and evolution (mortality rate) as a result of the planter's farming system, five chi-square tests were carried out using the R 4.2.2 software. Given the small sample available (n=89 planters), the confidence interval used was 90%. In addition, given the very small sample available for the 'non-natives' farming system (n=2 planters), we did not include their plantations in our statistical analysis.

RESULTS

Description of farming systems

Discriminant factors

The study area is a pioneer front where villages are located at the interface between the so-called ‘rural complex’, which combines shifting cultivation plots, fallows, degraded woodlots, villages, and roads (Shapiro *et al.* 2023), and areas of dense forest with little or no degradation (Figure 1 and Figure 2). This area is experiencing an increase in degradation within both the rural complex and the dense forest area. This degradation can be directly linked to the considerable demographic growth in the area (the population has increased by 2.5% each year since 2013) which creates a need for more cultivated land. In the North, the area of undisturbed forest decreased by half between 1990 and 2022, and the forest cover decreased from 91% to 46% of the territory. In the South, over the same period, the area of undisturbed forest decreased by a third and the forest cover decreased from 96% to 64% of the territory (Figure 2).

The landscape is then divided into villages (along the road), undisturbed forest (never felled by communities) and degraded, deforested and regenerated forest (Figure 1), creating a mosaic of cultivated fields, palm plantations and forest fallow. This classification based on satellite data is not sufficiently precise to understand the agricultural practices occurring. However, in relation to types of forest and fallows, eight landscape units were defined during the participatory mapping and landscape analysis (Table 1). Within these areas, various activities are carried out to collect timber and non-timber products. The ownership of these areas and the associated rights of use and access may vary from one village to another, depending on the level of forest degradation and deforestation. For example, in Yaosenge and Yakamba (North part) where the forest is most severely degraded, primary forest (*Ngonda*) is typically owned by households (with a direct link to lineage head), contrary to other villages where *Ngonda* is still a common resource (such as in the southern part).

All the farmers interviewed considered farming and cassava production as their main activity. The basic food cropping systems identified consistently combined cassava with short-duration crops (rice, maize, beans and peanuts) which are grown for one to two years after clearing the forest, followed by a fallow period of between two and 20 years. These cropping systems can be divided into at least four categories according to the type of fallow or forest cleared before cultivation: cassava can be cultivated after a short fallow period (cultivation after *Fufuke*), after a longer fallow period (cultivation after *Sukulakoko*), after secondary forest (*Lokombe*) or after primary forest (*Ngonda*).

Two other cropping systems are practised: small oil palm plantations (<1 ha to 3 or 4 ha) with local artisanal processing, and the home garden with fruit trees, bananas and sometimes annual crops. Home gardens are developed by young households after marriage and are used for self-sufficiency. Oil

FIGURE 2 *Evolution of land use from 1990 to 2022 in the North (top) and South (bottom) study areas (Data: Joint Research Centre)*

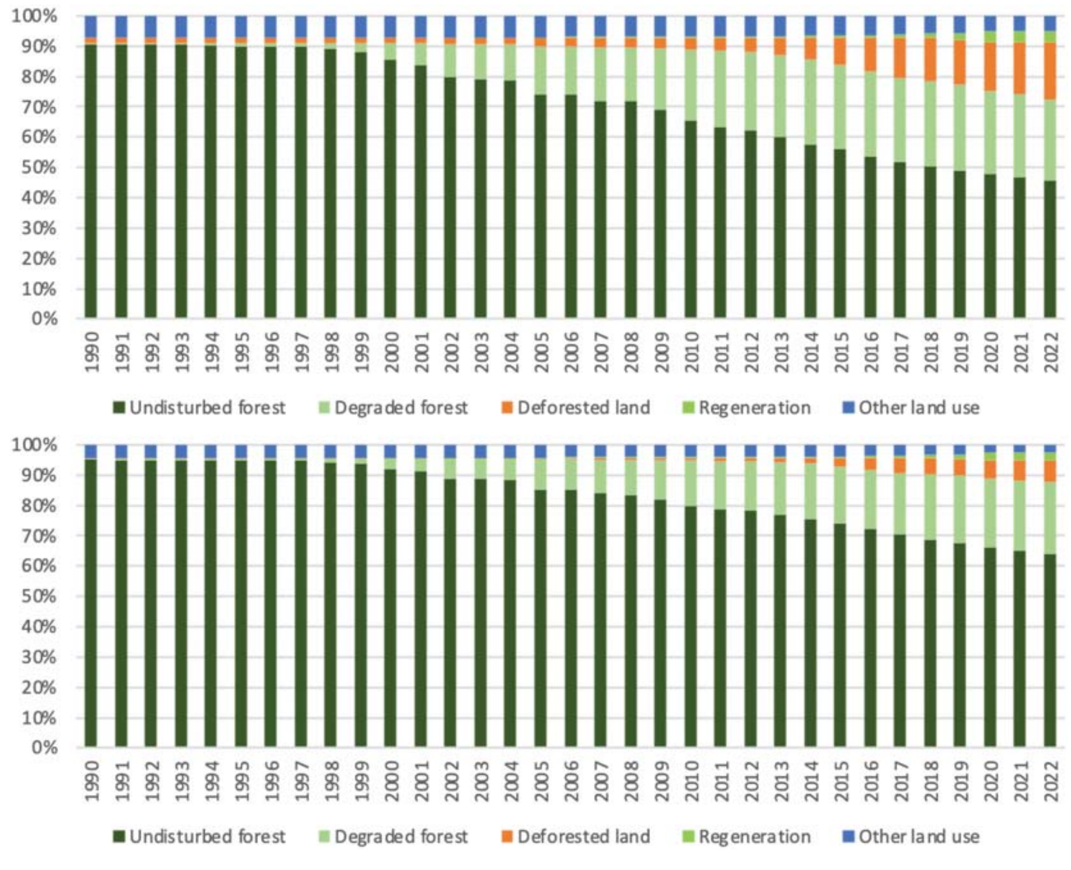


TABLE 1 *Description of landscape units in the study area*

Landscape Units	Name in Kimbole	General description	Main products	Rights of use
Village	*Bokenge*	Where people live. Includes houses and gardens.	Fruit, small livestock	Sell: Household head Cultivation: Household Planting trees: Household Collect agricultural and forest products: Household Hunt: Lineage members
Field	*Ikane*	Areas dedicated to the development of food crops (maize, rice, cassava, cowpeas, peanuts etc) with young palm trees and firewood collection. These areas are individualised and obtained either by opening up fallow land or forest.	Cassava, rice, maize, beans, peanuts, firewood	Sell: Lineage head Cultivation: Household Planting trees: Household Collect agricultural and forest products: Household Hunt: Lineage members
Young Fallow	*Fufuke*	Forest fallow for 1 to 10 years.	Mushrooms, caterpillars, traditional medicines, honey, small mammals, timber	
Old Fallow	*Sukulakoko*	Forest fallow for 11 to 20 years where the basal area of the trees and their density is greater than that of young fallow land. These areas are intended to be recultivated.		
Secondary Forest	*Lokombe*	Forest fallow for more than 20 years, where the species present and their respective densities begin to resemble primary forest (with an observable difference in diameter).		
Palm plantation	*Matoko / Ngazi*	There are both old and young palm plantations. The old plantations were established several decades ago and are close to the villages, while the young palm plantations are further away and are the result of farmers selecting and maintaining palm trees in their fields.	Palm nuts	
Old village	*Lilua Likonyo*	These are places of worship or places where the community used to live and which, having been converted into ancestral burial grounds, have also become places of worship.	No production	No production
Undisturbed Forest	*Ngonda*	This is a forest that, according to the community, has not been cleared. This forest is characterised by large-diameter trees with a canopy of 30 to 40 metres. It is also the place where communities open up fields to acquire new land for the development of food crops, but also to increase their land capital.	Caterpillars, mushrooms, leaves (maranthaceae, *Gnetum africanum*), bushmeat, fruit, traditional pharmacopoeia, honey, timber,	Sell: Lineage Head Collect forest products: Lineage members (or household with a direct link with the lineage head in Yaosenge and Yakamba) Hunt: Lineage members Land clearing: Household with the consent of the head of the lineage (household in Yaosenge and Yakamba)

palm, which is consumed locally and sold to external markets, is the main source of cash income. Smallholder palm plantations, developed through assisted natural regeneration and enrichment by direct seedling in fields close to the village, are important for the farmers. However, depending on how they were established, they vary greatly in age, density and productivity.

If agricultural techniques remain stable over time, this is not the case for the rural population, which is increasing in the area. Thereby, the risk for farmers is a decrease in the fallow period or the cultivated area per household, and thus a decrease in food production per household. To compensate, farmers have the option of clearing more primary forest and extending the cultivation and fallow mosaic, as illustrated in Figure 2. Our historical analysis demonstrates that one of the most important concerns for heads of household is to secure as much land as possible before the other households in the lineage and to pass it on to their children. In fact, the customary right to cultivate and further to manage land is acquired through the 'right of the axe' exerted to convert a forest area into agricultural plots. Therefore, clearing an area to open a new farming plot gives as well rights on the surrounding areas.

Typology of farming systems

The type of forest land cleared for cultivation (*Fufuke, Sukulakoko, Lokombe* or *Ngonda*) differs according to farming system (Table 2). Furthermore, the landscape and historical analyses highlight two main factors that differentiate farming systems: (i) households' access to forested land (fallows and forests), in terms of their quantity and quality, and to palm fields and (ii) labour. Agricultural tools and financial capital are less determinant.

There are three ways to access land for cultivation at the household level: (i) the clearing and sowing of a suitable plot of primary forest land (*Ngonda*) by a customary holder which allows the individualisation of this land as well as the surrounding forest areas, (ii) land already individualised by customary holder household is passed on from father to son (during the father's lifetime or at time of his death), and (iii) non-natives can rent land from customary holders for the duration of a cassava cycle (temporary transfer of *usus* and *fructus*). In accordance with customary practice, only direct members of the lineage are entitled to clear new *Ngonda* areas. All lineage members have fallows passed from their fathers. Non-natives are required to pay rent to customary owners.

As the *Ngonda* forest is usually far from the village centre and clearing the land requires a lot of labour, not all farmers are able to do this, and a categorization can be made based on the age of the farmer.

The first type of farming system (FS1) is the 'large customary rights holder' (Table 2). These are heads of households over the age of 45. They have already inherited all the land they can from their fathers (particularly the palm fields), they have cleared as much of the primary forest as possible and have begun to pass on some fields to their eldest sons. They keep old fallows and palm plantations and pass on young fallows (*Fufuke*) to their sons. These fallows can be definitively passed on or can be returned to the head of the household, depending on the needs of the family. The youngest children are still in the household and thus the available workforce is large (four to five people) which enables the cultivation of old fallows (*Sukulakoko*). In addition, they can mobilise their oldest children to help them (FS3) and pay some workforce and/or rent out some land to allochthones (FS4) or young autochthones (FS3). Their aim now is to improve the quality of their land capital rather than the quantity (particularly by trying to extend the palm plantations) at the same time as feeding a large number of family members.

The second type of farming system (FS2) is the 'middle customary rights holder' (Table 2). These are heads of households aged between 30 and 45. They have already inherited some or all of their father's land. They are currently clearing the primary forest (*Ngonda*) that has not yet been distributed to improve the household's land capital. They must support a large family but few children are old enough to work in the fields every day and support their parents. In addition to primary forest (*Ngonda*), they cultivate young fallows (*Fufuke* and *Sukulakoko*) and have already inherited or developed palm plantations. These palm plantations are often managed by extended families (fathers and brothers). The head of the family is generally an FS1 farmer. The FS2 head of household's aim is to clear as much primary forest and pass on as much land as possible to their children.

The third type (FS3) is the 'young customary rights holder' (Table 2). They are heads of households under the age of 30. They have only been independent of their parents' household for a few years but are still linked to them in order to have access to land to cultivate and to help their parents in the fields. They have only inherited little land (almost only young fallows – *Fufuke*) from their kins because most of fathers are still living. Once a piece of land has been inherited from the father, it generally remains under the control of the young farmer. However, until the father's death, though access to arable land is guaranteed by customary law, the rights to fallow land depend on the father's will, who may sometimes redistribute the land according to the family's needs. As the land they have at their disposal is small, some of them rent land to leave their own fallow. They have to work with their parents in addition to on their own farms. More than half of

TABLE 2 *Application of the typology's human indicators to the 89 volunteers who took part in the PROFEAAC forest restoration initiative (M=Mean and SD=Standard Deviation)*

Farming System	Number of farming systems interviewed	Age of household head (in years)		Household size (Number of people)		Family workers (Number of people)		Multiple earners (in %)
		M	SD	M	SD	M	SD	
FS1 – Large customary rights holder	36	51.8	9.9	6.8	3.4	4.6	2.2	36.1
FS2 – Middle customary rights holder	38	35.9	4.9	6.2	2.3	3.5	1.7	47.4
FS3 – Young customary rights holder	13	27.4	5.6	5.0	1.8	2.8	1.0	53.8
FS4 – Non-natives	2	32.0	9.9	6.0	5.7	2.5	0.7	100.0

them have a supplementary non-farming activity (hunting, fishing, construction, carpentry, etc.). Their children are too young to work in a field on their own, which is why they have not started to clear the *Ngonda* forest. Finally, depending on their fathers, some of them have already inherited rights to family palm plantations. However, these palm plantations are still managed by their fathers and older brothers.

The last type (FS4) are the 'allochthones' (Tables 2 and 3). These farmers do not have the required lineage and so, unlike the other three types, are not customary landowners. They must rent land from customary owners for a short period to cultivate it. They all have other jobs (such as teacher, health centre manager, etc.) and farming is a way to feed their family.

Relations between farming systems and restoration activities

Types of farming systems supported

Following the presentation of the project in the eight target villages, 273 volunteers submitted an application form (March 2021). Based on the information provided in the form, and in particular the ratio of the area the farmer wished to restore to the total area available (all available fallow land) which should be less than 75%, 125 farmers were selected (April 2021) to be trained in forest tree production in nursery and planting. Finally, out of the 125 volunteers 101 participated to the training. In the end, 89 farmers planted trees. Their farming system types are shown in Table 3 and their involvement in the whole restoration process is shown in Table 4.

While a decrease in numbers between the list of volunteers who submitted a participation form (n=273) and the final beneficiaries (n=89) was observed for all farming systems, there was a significant difference between the farming systems according to the Chi-square test (*p-value* = 2.2e-16). There was a 75% decrease in FS4, a 70% decrease in FS2 and FS3 and a 63.6% decrease in FS1. We can also see that from the beginning to the end of the process, FS3 and especially FS4 were less affected by the project than FS1 and FS2 (Table 4).

The most represented farming systems in the project were the FS1 (40.4%) and FS2 (42.7%) (Table 4), which does not correspond to the likely distribution of the population in the province of Tshopo. In fact, according to the INS (2021), 36.4% of the adult population is between 20 and 29 years old (corresponding to young customary rights holders, FS3), 41.4% is between 30 and 49 years old (corresponding to middle customary rights holders, FS2) and 22.2% is over 50 years old (corresponding to large customary rights holders, FS1). More specifically, young farmers are largely under-represented (14.6%) among the beneficiaries and older farmers are over-represented (40.4%). Non-natives are little affected by the project (2.2% of beneficiaries) but they are less represented in our study area.

Plantation results ranked by farming system

When the average number of trees planted by farmers from all farming systems was between 40 and 50, there was a significant difference (*p-value* = 3.796e-09) in the type of trees planted per farming system (Table 4). FS1 and FS2 gave more importance to native trees for timber and caterpillar production (47.3% and 45.9% of trees planted respectively), whereas young customary rights holders focused mainly on fruit trees (67.6% of trees planted).

Considering all planting locations, there were significant differences between farming systems in terms of the number of tree plantation sites (*p-value* = 0.002477) and the type of location (*p-value* = 0.09427) (Table 5). For all farming systems, more than 80% of the farmers chose at least two different plantation sites, usually in their home garden and the mosaic of cultivated fields and forest fallow (at least 63.9%). FS2 farmers had the largest number of plantations (47.4% had three plantations). In terms of planting site location, the FS2 and FS3 farmers preferred home gardens (44.1% and 48.1% of their plantations were in home gardens, respectively) compared to FS1 farmers who already had mature home gardens (Table 5).

Survival rates of planted trees differed significantly (*p-value* = 2.2e-16) according to farming system. FS1 farmers had the best survival rates (63.0%), whereas the FS2 and FS3 groups were slightly lower (52.1% and 51.9%, respectively) (Tables 4 and 5).

TABLE 3 *Application of the typology's land indicators to the 89 volunteers who took part in the PROFEAAC forest restoration initiative (M=Mean and SD=Standard Deviation)*

Farming System	Useful Agricultural Area (in ha)		Annual area under food crops (in ha)		Area of private primary forest (*Ngonda* – in ha)		Area of secondary forest (*Lokombe* – in ha)		Area of old fallows (*Sukulakoko* – in ha)		Area of young fallows (*Fufuke* – in ha)		Area of palm plantations (*Matoko* – in ha)	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
FS1 – Large customary rights holder	26.5	16.0	1.9	1.0	6.4	6.4	2.2	5.4	3.8	4.5	8.9	6.5	3.7	2.3
FS2 – Middle customary rights holder	19.6	11.7	2.5	1.9	5.0	5.5	1.2	2.9	2.3	2.1	6.2	4.0	2.5	1.9
FS3 – Young customary rights holder	6.0	4.5	1.1	0.8	0.0	0.0	0.1	0.3	1.1	2.0	2.3	2.4	1.3	1.5
FS4 – Non-natives	5.8	8.1	0.8	1.1	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.8	3.0	4.2

TABLE 4 *Main restoration results concerning planters and planted trees by farming system (M=Mean and SD=Standard Deviation)*

Farming System	Number of interested farmers	Number of final beneficiaries	Proportion of beneficiaries to total number of interested farmers (in %)	Proportion of beneficiaries to total number of planters (in %)	Number of trees planted: Local timber trees		Local trees hosting caterpillars		Fruit trees		Total	
					M	SD	M	SD	M	SD	M	SD
FS1 – Large customary rights holder	99	36	36.4	40.4	19.2	12.5	2.4	2.6	26.1	17.5	47.7	26.2
FS2 – Middle customary rights holder	123	38	30.9	42.7	14.9	8.4	2.6	3.0	23.8	18.1	41.2	24.8
FS3 – Young customary rights holder	43	13	30.2	14.6	13.1	6.5	1.7	2.5	33.5	14.2	48.2	17.0
FS4 – Non-natives	8	2	25.0	2.3	17.5	4.9	5.5	0.7	17.0	11.3	40.0	17.0
All Farming Systems	273	89	100.0	100.0	16.4	10.2	2.4	2.8	26.0	17.3	44.8	24.2

DISCUSSION

Limitations of the study

The research was based on a single year of monitoring. As such, it is not possible to draw conclusions on the medium-term survival of the trees, as the data do not allow for the evolution of growth, of the farmers' management methods, or even of the creation, or not, of plantations in an endogenous dynamic without direct support from the project. Long-term monitoring is recommended, although the structure of the project (with only 4 years of support) does not permit it.

The time spent in the field did not allow us to carry out a detailed technical and economic analysis of the farming systems, nor a census of the fruit trees, palm trees or timber trees scattered across the landscape, which might have allowed us to estimate the actual benefits to households.

Our diagnostic method, which was based on the principles of comparative agriculture, required the mobilisation of five experts for two full weeks, with significant associated logistical costs. Nevertheless, it had three advantages that offered interesting opportunities for forest restoration interventions.

First advantage: to adapt project objectives to the local context

The use of an agrarian diagnostic before the design and implementation of activities, facilitates a more tailored and effective adaptation of the forest restoration intervention to the local population and endogenous dynamics, both at the intervention area level and at the farming system level. In relation to the initial objectives, these diagnostic tools can guide either the type of farming system to be supported or the choice of technical options to be proposed to support the range of farming systems in an intervention area.

In the PROFEAAC project's intervention area, the farming systems' strategies have been identified through the agrarian diagnosis:

- First, farmers are currently focusing on opening new plots by cutting down the primary forest to compensate for dwindling forest fallow periods and to acquire new household-level usufruct rights to land currently held at the lineage level. Consequently, in the project area, workers in the household are promptly mobilised to acquire new areas by means of land clearance. In this context, trees of local species are mostly seen as an obstacle to land appropriation.
- Secondly, perennial plantations, primarily palm plantations and secondarily fruit trees in home gardens and sometimes scattered in fields, for self-consumption or sale on the local market, are an important form of household capital. Palm plantations are developed slowly through assisted natural regeneration in fields and fallow land, securing land tenure but also encouraging farmers to open up new land for food production. Fruit trees are planted in home gardens and, more rarely, in fields by direct seeding without selection.

TABLE 5 *Main restoration field results by farming system (M=Mean and SD=Standard Deviation)*

Farming System	Proportion (in %) of beneficiaries with			Proportion (in %) of plantations located in			Survival rate of planted trees	
	3 plantations	2 plantations	1 plantation	Fields (*Taungya*)	Fallows Enrichment	Home Garden Enrichment	M	SD
FS1 – Large customary rights holder	30.6	52.8	16.7	42.4	18.6	39.0	63.0	24.3
FS2 – Middle customary rights holder	47.4	39.5	13.2	44.1	11.8	44.1	52.1	26.7
FS3 – Young customary rights holder	38.5	61.5	0.0	39.3	8.0	48.0	51.9	29.7
FS4 – Non-natives	0.0	50.0	50.0	66.7	0.0	33.3	46.6	60.4
All Farming Systems	38.2	48.3	13.5	43.9	13.5	42.6	56.0	27.0

This identification of farming systems strategies showed that investing labour in planting and maintaining timber trees was not a priority for farmers. In short, there was no endogenous restoration dynamic. Farmers prioritised improving their capital by acquiring new land (by clearing undisturbed forest) and developing palm plantations (and perhaps fruit trees, but further research is needed to confirm this) in a context of increasing pressure on land availability.

A prior understanding of the current dynamics enabled the project to focus its planting activities on species that are useful to potential beneficiaries i.e. timber species, species that produce non-timber forest products (caterpillars in this case) or fruit trees. These choices are the result of a compromise between the initial ambitions of the project (planting timber trees) and the expectations of the local population (developing plantations with a short return on investment, such as fruit trees).

Second advantage: to adapt project objectives to farming systems

Our diagnostic methods describe the heterogeneity of rural societies and production systems. Building a typology of farming systems to compare agricultural development interventions has already proven useful in Central Africa (Chimi *et al.* 2023, Tittonell *et al.* 2010). However, in this study, by combining landscape and historical analyses, we are not only highlighting significant differences between types of farming systems but also providing qualitative evidence to explain the ongoing processes responsible for those differences.

As in the case of Kongo Central (Peroches *et al.* 2019), this study demonstrates that the diverse farming systems led to the implementation of disparate tree-planting strategies and also yielded different technical results. Firstly, it can be observed that the project's technical offers did not interest the different farming systems uniformly. Secondly, the project beneficiaries were mostly FS1 and FS2 farmers rather than FS3 or FS4. Young farmers (FS3) were mainly interested in fruit trees for their home gardens, while the large (FS1) or medium (FS2) customary rights holders were more interested in local species for timber or caterpillar production. For young farmers, fruit trees enable them to (i) develop perennial capital and (ii) mark their property when boundaries with their brothers' properties are unclear (fruit species are perceived as more personal than indigenous species that could grow naturally). Better technical results for FS1 and FS2 can be explained by better access to land and labour.

Third advantage: to increase the project's performance

The preliminary diagnosis of production systems made it possible to identify the profiles of rural households that might be interested in planting trees for specific reasons. In Central Africa, as in our study area, these households are still few and far between, given the acceleration in the rate of net deforestation and forest degradation over the last fifteen years. This makes it all the more important to identify households that are likely to contribute to reversing these trends.

Supporting households that have solid reasons for replanting and maintaining trees has a direct impact on the success rate of these plantations. At the tree scale, the proposed approach has led to relatively high survival rates after 6 months or 1 year (from 46.6% to 63.0% depending on the management system, 56.0% on average) (Table 5) compared with other initiatives in Central Africa. For comparison, in Kongo Central Province, the native species plantations established by the beneficiaries of the Makala project had an average survival rate of 36% (after four years), and in naturally assisted regeneration fields, the rate of survival was 29% for stumps and 40% for the seedlings and root suckers selected for conservation (after three and half years) (Peltier *et al.* 2014, Péroches *et al.* 2019). In eastern Cameroon, native species plantations supported by a forestry company showed a survival rate of only 16% (after one year) (Semereab 2006).

CONCLUSION

Forest restoration remains a challenge in Central Africa. International targets will be difficult to achieve without local strategies, a detailed understanding of farmers' methods and the development of specific interventions for households that are likely to engage in tree planting for a variety of reasons.

Due to their social status, young customary landowners and allochthones were not in a favourable position to establish forest plantations. However, young customary landowners were interested in certain species (fruit trees) which were not foreseen in the original project activities. Finally, survival rates varied significantly according to the type of production system, favouring households with the most favourable social position.

The PROFEAAC project area, like much of Central Africa, is under strong demographic pressure, leading to an increase in deforestation that will be difficult to halt in the short or medium term. Taking into account the agrarian dynamics, the objectives of forest restoration are called into question. Indeed, the forest conservation aspect will certainly be overtaken by the vigour of pioneer fronts. However, through an understanding of farming systems, support can be provided for selective conservation, assisted regeneration or the introduction of trees into agricultural systems (including perennial plantations) to improve household livelihoods and reduce or mitigate the impact of forest degradation.

ACKNOWLEDGEMENTS

Principal funding was provided by the French Fund for World Environment (FFEM – grant number CZZ 2123.01) as part of the implementation of the project 'PROmote and Formalize Artisanal Exploitation of Timber in Central Africa' (PROFEAAC). Adrien Péroches' PhD is funded by the National Agency for Technological Research (ANRT) under grant number CIFRE 2021/1614. Finally, Adrien Péroches thanks Sophie Connolly for the English editing.

REFERENCES

BARRAL, S., TOUZARD, I., FERRATON, N., RASSE-MERCAT, E., and PILLOT, D. 2012. *Assessing Smallholder Farming: Diagnostic analysis of family-based agricultural systems in a small region* (SEARCA).

BASTIN, J.-F., FINEGOLD, Y., GARCIA, C., MOLLICONE, D., REZENDE, M., ROUTH, D., ZOHNER, C.M., and CROWTHER, T.W. 2019. The global tree restoration potential. *Science* **365**(6448): 76–79. https://doi.org/10.1126/science.aax0848

BESSEAU, P., GRAHAM, S., and CHRISTOPHERSEN, T. 2018. *Restauration des paysages forestiers: La clé d'un avenir durable* (p. 45). Partenariat mondial pour la restauration des paysages forestiers.

BOUYER, O., MAURICE, J., LE CROM, M., and RUTINIGIRA, L. 2013. *Evaluation finale du projet EcoMakala – Viabilisation durable de l'approvisionnement en boisénergie des populations rurales riveraines de la ville de Goma (République Démocratique du Congo)* (p. 140). SalvaTerra.

CHAZDON, R. 2008. Beyond Deforestation: Restoring Forests and Ecosystem Services on Degraded Lands. *Science* **320**(5882): 1458–1460. https://doi.org/10.1126/science.1155365

CHAZDON, R., and BRANCALION, P. 2019. Restoring forests as a means to many ends. *Science* **365**(6448): 24–25. https://doi.org/10.1126/science.aax9539

CHIMI, P.M., MALA, W.A., ESSOUMA, F.M., FUNWI, F.P., KAMDEM, M.E.K., NGAMSOU ABDEL, K., NGANMEGNI, L.F.F., POKAM, E.Y.N., FOBANE, J.L., MATICK, J.H., BELL, J.M., and MBOLO, M.M. 2023. Farm typology and structure of farmer decision making: The case of the production basin of the forest-savannah transition zone, Centre Cameroon Region. *Land Use Policy* **134**: 106908. https://doi.org/10.1016/j.landusepol.2023.106908

COCHET, H. 2015. *Comparative Agriculture*. Springer/Quae.

COCHET, H., and DEVIENNE, S. 2006. Fonctionnement et performances économiques des systèmes de production agricole: Une démarche à l'échelle régionale. *Cahiers Agricultures* **15**(6): 506–513. https://doi.org/10.1684/agr.2006.0028

CTB. 2013. *Plan de développement local du secteur de Yalikandja-Yanonge territoire d'Isangi/district de la Tshopo/Province Orientale Période 2013-17* (p. 94). CTB RD Congo.

DUBIEZ, E., VERMEULEN, C., TONNEAU, J.-P., YAMBA YAMBA, T., MVOLO, B., and LARZILLIERE, A. 2013. Le paysage comme outil d'aménagement des terroirs villageois. *BOIS and FORETS DES TROPIQUES* **315**(315): 11. https://doi.org/10.19182/bft2013.315.a20534

EVANS, K., DE JONG, W., CRONKLETON, P., LYNAM, T., KUSUMANTO, T., and PIERCE COLFER, C. 2006. *Guide to participatory tools for forest communities*. Center for International Forestry Research.

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., DECLEER, K., and DIXON, K.W. 2019. International principles and standards for the practice of ecological restoration. Second edition. *Restoration Ecology* **27**(S1). https://doi.org/10.1111/rec.13035

GNACADJA, L., and VIDAL, A. 2022. How can science help to implement the UN Decade on Ecosystem Restoration 2021–2030? *Philosophical Transactions of the Royal Society B: Biological Sciences* **378**(1867): 20210066. https://doi.org/10.1098/rstb.2021.0066

GUIZOL, P., DIAKHITE, M., SEKA, J., BRING, C., MBONAYEM, L., AWONO, A., OYONO, P.-R., MOKPIDIE, D., NDIKUMAGENGE, C., and SONWA, D.J. 2022. La restauration des paysages forestiers (RPF) en Afrique centrale. In *Les forêts d'Afrique centrale – Etat des forêts 2021*. CIFOR.

HERBOHN, J., OTA, L., GREGORIO, N., CHAZDON, R., FISHER, R., BAYNES, J., APPLEGATE, G., PAGE, T., CARIAS, D., ROMERO, C., PUTZ, F.E., and FIRN, J. 2022. The community capacity curve applied to reforestation: A framework to support success. *Philosophical Transactions of the Royal Society B: Biological Sciences* **378**(1867): 20210079. https://doi.org/10.1098/rstb.2021.0079

HOLL, K.D., and BRANCALION, P.H.S. 2020. Tree planting is not a simple solution. *Science* **368**(6491): 580–581. https://doi.org/10.1126/science.aba8232

HOLL, K.D., and BRANCALION, P.H.S. 2022. Which of the plethora of tree-growing projects to support? *One Earth* **5**(5): 452–455. https://doi.org/10.1016/j.oneear.2022.04.001

LACOSTE, M., LAWES, R., DUCOURTIEUX, O., and FLOWER, K. 2016. Comparative agriculture methods capture distinct production practices across a broadacre Australian landscape. *Agriculture, Ecosystems and Environment* **233**: 381–395. https://doi.org/10.1016/j.agee.2016.09.020

LARZILLIÈRE, A., VERMEULEN, C., DUBIEZ, E., YAMBA YAMBA, T., DIOWO, S., and MUMBERE, G. 2013. La maquette interactive, un outil novateur de participation. *Bois et forets des tropiques* **315**(315): 21. https://doi.org/10.19182/bft2013.315.a20535

LEWIS, S.L., WHEELER, C.E., MITCHARD, E.T.A., and KOCH, A. 2019. Regenerate natural forests to store carbon. *Nature Comment* **568**: 25–28. https://doi.org/10.1038/d41586-019-01026-8

LUCAS, C., PEROCHES, A., DUBIEZ, E., BISIMWA, B., and LESCUYER, G. 2020. *Caractérisation des contextes socio-économiques et environnementaux de sept villages des Groupements Totuku et Yangandi dans le Secteur de Yalikandja-Yanonge, Province de la Tshopo, en République Démocratique du Congo (RDC)* (p. 57). Projet PROFEAAC – Asc – CIRAD – CIFOR.

MANSOURIAN, S., KLEYMANN, H., PASSARDI, V., WINTER, S., DERKYI, M.A.A., DIEDERICHSEN, A., GABAY, M., PACHECO, P., VALLAURI, D., and KULL, C.A. 2022. Governments commit to forest restoration, but what does it take to restore forests? *Environmental Conservation* **49**(4): 206–214. https://doi.org/10.1017/S0376892922000340

MARSHALL, A.R., WAITE, C.E., PFEIFER, M., BANIN, L.F., RAKOTONARIVO, S., CHOMBA, S., HERBOHN, J., GILMOUR, D.A., BROWN, M., and CHAZDON, R.L. 2022. Fifteen essential science advances needed for effective restoration of the world's forest landscapes. *Philosophical Transactions of the Royal Society B: Biological Sciences* **378**(1867): 20210065. https://doi.org/10.1098/rstb.2021.0065

MARTIN, M.P., WOODBURY, D.J., DOROSKI, D.A., NAGELE, E., STORACE, M., COOK-PATTON, S.C., PASTERNACK, R., and ASHTON, M.S. 2021. People plant trees for utility more often than for biodiversity or carbon. *Biological Conservation* **261**: 109224. https://doi.org/10.1016/j.biocon.2021.109224

MOREAU, P., RUIZ, L., MABON, F., RAIMBAULT, T., DURAND, P., DELABY, L., DEVIENNE, S., and VERTÈS, F. 2012. Reconciling technical, economic and environmental efficiency of farming systems in vulnerable areas. *Agriculture, Ecosystems and Environment* **147**: 89–99. https://doi.org/10.1016/j.agee.2011.06.005

PELTIER, R., DUBIEZ, É., DIOWO, S., GIGAUD, M., MARIEN, J.-N., MARQUANT, B., PEROCHES, A., PROCES, P., and VERMEULEN, C. 2014. Assisted Natural Regeneration in slash-and-burn agriculture: Results in the Democratic Republic of the Congo. *bois et forets des tropiques* **321**(321): 67. https://doi.org/10.19182/bft2014.321.a31220

PEROCHES, A., DUBIEZ, E., FAYOLLE, A., KOUTIKA, L.-S., MAPENZI, N., VERMEULEN, C., OSWALD, M., and LESCUYER, G. In Prep.. From tree fellers to planters: A systematic review of forest restoration initiatives involving local populations in Central Africa. *Small-Scale Forestry*.

PEROCHES, A., DUBIEZ, E., PELTIER, R., PROCES, P., DIOWO, S., YAMBA-YAMBA, T., and VERMEULEN, C. 2019. Les Plans Simples de Gestion destinés à la production de bois-énergie en périphérie de Kinshasa: La participation et la restauration à l'épreuve du foncier. *bois et forets des tropiques* **340**. https://doi.org/10.19182/bft2019.340.a31698

PIERRE, J.-M., and CASSAGNE, B. 2005. *Etude sur le plan pratique d'aménagement des forêts naturelles de production tropicales africaines – Application au cas de l'Afrique centrale – Volet 2 Aspects Sociaux* (p. 98). ATIBT.

REJOU-MECHAIN, M., MORTIER, F., BASTIN, J.-F., CORNU, G., BARBIER, N., BAYOL, N., BENEDET, F., BRY, X., DAUBY, G., DEBLAUWE, V., DOUCET, J.-L., DOUMENGE, C., FAYOLLE, A., GARCIA, C., KIBAMBE LUBAMBA, J.-P., LOUMETO, J.-J., NGOMANDA, A., PLOTON, P., SONKE, B., TROTTIER, C., VIMAL, R., YONGO, O., PELISSIER, R., and GOURLET-FLEURY, S., 2021. Unveiling African rainforest composition and vulnerability to global change. *Nature* **593**(7857): 90–94. https://doi.org/10.1038/s41586-021-03483-6

SEMEREAB, E. 2006. *Etude de la dynamique des essences commerciales au sein des jachères issues de l'agriculture itinérante Badjoué (Cameroun)* (p. 96) [Mémoire de Fin d'Etudes]. Faculté Universitaire des Sciences Agronomiques de Gembloux.

SHAPIRO, A., D'ANNUNZIO, R., DESCLEE, B., JUNGERS, Q., KONDJO, H.K., IYANGA, J.M., GANGYO, F.I., NANA, T., OBAME, C.V., MILANDOU, C., RAMBAUD, P., SONWA, D.J., MERTENS, B., TCHANA, E., KHASA, D., BOURGOIN, C., OUISSIKA, C.B., and KIPUTE, D.D. 2023. Small scale agriculture continues to drive deforestation and degradation in fragmented forests in the Congo Basin (2015–2020). *Land Use Policy* **134**: 106922. https://doi.org/10.1016/j.landusepol.2023.106922

SHYAMSUNDAR, P., COHEN, F., BOUCHER, T.M., KROEGER, T., ERBAUGH, J.T., WATERFIELD, G., CLARKE, C., COOK-PATTON, S.C., GARCIA, E., JUMA, K., KAUR, S., LEISHER, C., MILLER, D.C., OESTER, K., SAIGAL, S., SIIKAMAKI, J., SILLS, E.O., THAUNG, T., TRIHADMOJO, B., VEIGA, F., VINCENT, J.R., YI, Y., and ZHANG, X.X. 2022. Scaling smallholder tree cover restoration across the tropics. *Global Environmental Change* **76**: 102591. https://doi.org/10.1016/j.gloenvcha.2022.102591

STANTURF, J.A., and MANSOURIAN, S. 2020. Forest landscape restoration: State of play. *Royal Society Open Science* **7**(12): 201218. https://doi.org/10.1098/rsos.201218

TITTONELL, P., MURIUKI, A., SHEPHERD, K.D., MUGENDI, D., KAIZZI, K.C., OKEYO, J., VERCHOT, L., COE, R., and VANLAUWE, B. 2010. The diversity of rural livelihoods and their influence on soil fertility in agricultural systems of East Africa – A typology of smallholder farms. *Agricultural Systems* **103**(2): 83–97. https://doi.org/10.1016/j.agsy.2009.10.001

VANCUTSEM, C., ACHARD, F., PEKEL, J.-F., VIEILLEDENT, G., CARBONI, S., SIMONETTI, D., GALLEGO, J., ARAGÃO, L.E.O.C., and NASI, R. 2021. Long-term (1990–2019) monitoring of forest cover changes in the humid tropics. *Science Advances* **7**(10): eabe1603. https://doi.org/10.1126/sciadv.abe1603

VERMEULEN, C., DUBIEZ, É., PROCES, P., MUKUMARY, S.D., YAMBA, T.Y., MUTAMBWE, S., PELTIER, R., MARIEN, J.-N., and DOUCET, J.-L. 2011. Enjeux fonciers, exploitation des ressources naturelles et Forêts des Communautés Locales en périphérie de Kinshasa, RDC. *Biotechnol. Agron. Soc. Environ.*