A trilateral network for agroforestry and integrated regenerative landscape management to support climate resilient development and food security

Abba Waziri Ngurno, Tim Pagella, Eefke Mollee, Lindsay C. Stringer*

*Project lead and corresponding author:
lindsay.stringer@york.ac.uk

March 2025

Executive summary

Agroforestry is a sustainable land use approach which deliberately integrates trees and woody shrubs with crops and/or animals, for environmental, economic and social benefits. The scale of application ranges from the integration of trees on farm plots to landscape scale interventions driven through processes including farmer managed natural regeneration (FMNR). Agroforestry and FMNR are a highly promising climate-smart technology in addressing the intertwined challenges of food security, climate change, land degradation and poverty.

This scoping project sought to build networks across the UK, Brazil, Ghana and Nigeria, and identify opportunities for collaboration and knowledge sharing, using literature review, stakeholder analysis, online workshops held between December 2024 and January 2025, and interviews with those unable to participate in the workshops or who wanted to provide additional information. During these activities we sought to find out:

- What has worked in terms of agroforestry technology design, scaling and adoption (in Brazil, Ghana and Nigeria)
- The major challenges and barriers affecting the adoption and scaling of agroforestry technologies and practices (in Ghana and Nigeria)
- The major barriers to transformational change relevant to Ghana and Nigeria, considering lessons from Brazil

Many successful agroforestry technologies and practices considered issues of ecosystem stewardship, equity and justice, inclusivity and diversity of knowledge, in line with the enablers of climate resilient development identified by the IPCC.

Challenges and barriers encompassed socio-cultural and institutional, environmental, policy and governance, resourcing and infrastructural and knowledge, capacity and skills challenges. Gender inequality was also a key issue in Ghana and Nigeria. While some barriers can be addressed by single stakeholders (e.g. governments can address insecure land tenure that cause farmers not to want to invest in agroforestry), other challenges (e.g. lack of knowledge and capacity, technological and infrastructure issues) are best tackled through multi-stakeholder approaches.

Our findings revealed a broad understanding of the value of agroforestry alongside challenges in all countries associated with its scaling. Agroforestry design is highly context-sensitive which creates challenges for wider adoption. There are collaborative opportunities in using technology to enable farmers to better adapt agroforestry to their context (using mobile apps, for example), for knowledge brokers to convene stakeholders, and for greater domestication to enable valued tree species to be used more widely. There were also different institutional models (and challenges) in all three countries. Sharing experiences could help shape policy and institutions that better support agroforestry expansion, while also helping the benefits from agroforestry restoration to be shared more equitably.

Table of Contents

TABLES

FIGURES

LIST OF ACRONYMS

ANR	Assisted Natural Regeneration
APP	Agricultural Promotion Policy (2016-2020)
AR6	Sixth Assessment Report
CDA	Centre for Dryland Agriculture
CRD	Climate Resilient Development
CSA	Climate Smart Agriculture
CSIR	Council of Scientific & Industrial Research
FAO	Food and Agricultural Organisation
FARA	Forum for Agricultural Research in Africa
FMNR	Farmer Managed Natural Regeneration
IPCC	Intergovernmental Panel on Climate Change
LPG	Liquified Petroleum Gas
MDAs	Ministries Departments and Agencies
MoFA	Ministry of Food and Agriculture, Ghana
NAPA	National Adaptation strategy and Plan of Action
NGOs	Non-Governmental Organisations
IDPs	Internally Displaced Persons
IITA	International Institute for Tropical Agriculture
SSA	Sub-Saharan Africa
UK PACT	United Kingdom Partnering for Accelerated Climate Transitions

1. Introduction

1. 1 Background and context

In northern regions of Ghana and Nigeria, as in much of sub-Saharan Africa, landscapes are rapidly changing. Climate change combined with growing populations have increased demand for fuelwood, timber, and agricultural land which, in turn, have become powerful drivers of land degradation. In both regions trees have long played a significant role in supporting people's livelihood systems and food security, buffering them from environmental stress. As agriculture struggles to cope with climate change with hazards such as drought causing yields to decrease, people are again looking to trees to support their livelihoods. Trees are used both positively to provide ecosystem services that support agricultural production, and negatively, when removed completely, such as for fuelwood (1-3). This increased pressure on tree resources is having a large detrimental effect on tree species diversity across the region (4). Wood selling and charcoal production are a major source of income for rural households and have large markets (5,6). It was estimated that on average, 77 trees were cut down for every 3,600 m^2 of farmland in northern Nigeria (2). In northern Ghana, important economic trees like Shea (*Vitellaria paradoxa*) are cut down for fuelwood and charcoal production (1).

Fuelwood remains the main source of cooking energy in rural areas and in most urban areas, with few alternatives in northern Nigeria. The recent petroleum subsidy removal has further increased prices of Liquified Natural Gas (LPG) for urban households, causing a return to firewood for cooking even where LPG infrastructure is in place (7). These drivers have had a significant yet poorly documented impact on tree cover with the FAO (8) estimating that Nigeria would lose about 400,000 ha (about 5%) of its natural forest to agricultural land expansion and urbanization between 2010 and 2015, with the impact most evident in the Sudano-Sahel zone. These challenges, alongside significant increased risk from climate change, have raised interest in agroforestry: a sustainable land-use system that integrates trees, crops, and/or livestock on the same land to enhance productivity, soil fertility, and environmental resilience, as well as farmer managed natural regeneration (FMNR): the systematic regrowth and management of trees and shrubs from felled tree stumps, sprouting root systems or seeds to create a more diverse agroecosystem. However, many barriers to agroforestry and FMNR exist and the prioritisation of short-term survival to meet urgent food security needs often means agroforestry is not considered an option by rural households.

This report sets out the findings from our Innovate UK funded scoping project which considers agroforestry and FMNR as climate smart agriculture technologies that can help to address the combined need to sustainably increase agricultural productivity and incomes, adapt and build resilience to climate change and reduce or remove greenhouse gas emissions. In line with the funder specifications, we focus specifically on Ghana and Nigeria, while also drawing on lessons from Brazil.

Our analysis was informed by the concept of Climate Resilient Development (CRD). CRD involves actions that simultaneously address greenhouse gas emissions, climate change adaptation and sustainable development, with emphasis on four enablers (Figure 1): i) ecosystem stewardship, ii) equity and justice, iii) inclusivity and iv) diversity of knowledge (9). The four enablers of CRD are critical when designing any

agroforestry and FMNR technologies, ensuring social issues such as gender inequalities are addressed, and diverse knowledge and perspectives are considered when designing, scaling and commercialising these technologies.

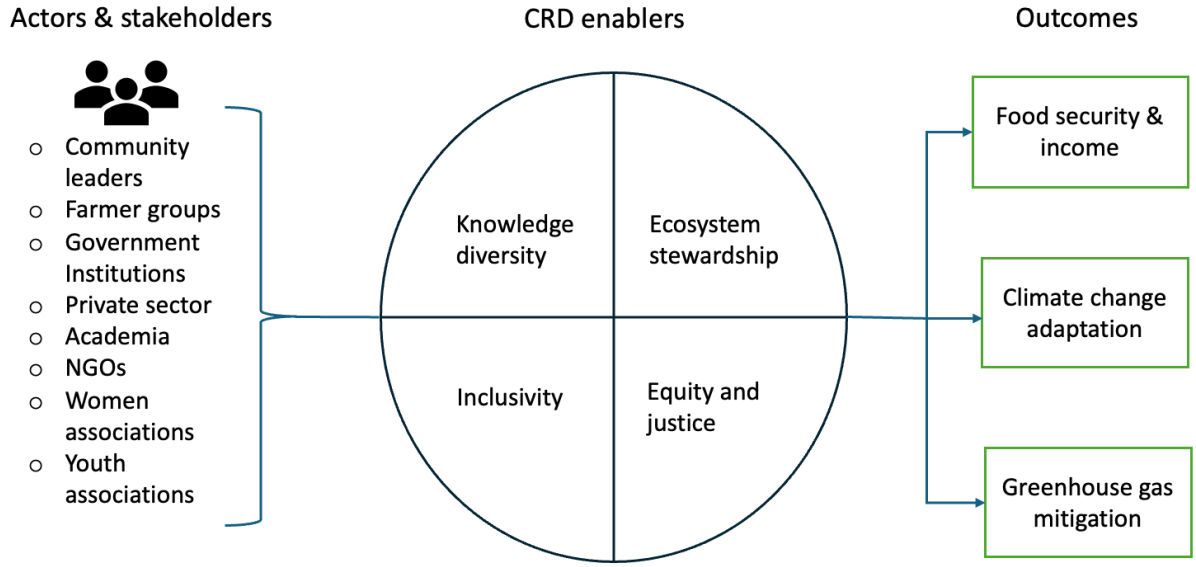

Figure 1: The four CRD enablers (centre), showing how different actors and stakeholders (left) can work together to achieve the goals of agroforestry (right)

Source: Authors

1.2 Background to agroforestry

Agroforestry is widely recognised as a sustainable land management approach and is integral to land restoration efforts across the Sahel (10). It is utilised to various degrees in sub-Saharan Africa (SSA), including in northern Nigeria and Ghana (11), where it is seen as a promising Climate-Smart Agriculture (CSA) intervention that can enhance the resilience and livelihoods of rural households and support productive and sustainable landscape management (12).

In principle, agroforestry supports the resilience and livelihood of rural communities through the wide range of products and ecosystem services it can deliver. In the Shea parklands of the southern Sahel, trees in agroforestry systems provide households with sources of income through the sale of wood, nuts and fruits (13), fuelwood and fodder (3). The trees also contribute directly to food security, providing both traditional medicines and being a key source of micronutrients (14). At scale, agroforestry systems provide a broader set of regulating ecosystem services particularly in terms of regulation of the microclimate, soil erosion control, improved water and nutrient cycling, windbreaks, carbon sequestration, while also enhancing the biodiversity of plant and animal species (10,15, 11).

In the northern regions of Nigeria and Ghana, common agroforestry practices include scattered trees on parklands (or agroforestry parklands) (Figure 2) (16, 15), farmer-managed natural regeneration (FMNR) (Figure 3) (17), alley cropping (rows of trees or shrubs between which agricultural or horticultural crops are grown; 18, 3), apiculture (3, 14), bush farming where patches of land for agriculture are cleared but some trees are deliberately retained (19), and homestead gardens (13). Many of the trees used in

these practices are multipurpose species, providing a range of benefits and services to rural households in the two regions, helping farmers to diversify their food production and income streams, and reducing their overall vulnerabilities to risk of crop failure, particularly resulting from climate uncertainties (20). Agroforestry practices are carried out on different land use types, including in forests, farmlands, open field/communal land, and homestead farms among others (5, 21, 6). Similar tree species used in agroforestry in both northern Nigeria and Ghana include *Adansonia digitata, Parkia biglobosa, V. paradoxa, Mangifera indica, Vitex doniana, Tamarindus indica, Azadirachta indica,* and *Balanites aegyptiaca* (16, 15, 6).

Figure 2: Parkland agroforestry system in Kano state, Nigeria with scattered trees and livestock grazing on plant remains.

This photo was taken in Kano state, Nigeria, when the farmers were beginning to prepare their land for the rainy season and for planting. Photo credit: Abba Ngurno

Figure 3: Management of a young tree in an FMNR system in northern Ghana

Photo credit: Jonathan Naaba, TreeAid Ghana

FMNR is one form of agroforestry that has been widely promoted by Non-Governmental Organisations (NGOs) in our African study regions (5, 22). This traditional farming practice is regarded as one of the most appropriate and low-cost methods of landscape restoration in African drylands (23). It involves selective management and protection of tree saplings and stumps, roots and seedlings (24, 25), through thinning and pruning, to enable them to regrow in landscapes dominated by free grazing animals who would normally browse on any natural regeneration of trees. The practice was popularised by Tony Rinaudo from World Vision working in Niger, where it was adapted to be taken to scale. Significantly, FMNR utilises the local knowledge of farmers in landscape restoration, by supporting the natural regrowth of native species, and does not involve the active planting of trees (5), afforestation or reforestation, which other forms of agroforestry demand.

In both regions trees are primarily managed by women. Women's rights in terms of access to natural resources are nevertheless given low recognition due to societal gender norms, with women's participation in agriculture in northern Nigeria being very low and women lacking access to land ownership in northern Ghana (19, 22). In the case of FMNR, while climate change affects the management practice such as the possibility to resprout coppiced shoots and the growth of saplings (15), the main challenges are in the form of socio-cultural and legal barriers which make it difficult to upscale the approach. These difficulties also raise questions about who determines

who should benefit from certain tree products, and which local institution(s) could and should play a role in managing resource demands for livestock grazing, household energy and crop farming (17). All these questions present wider risks and benefits in relation to socially equitable outcomes in practicing FMNR, particularly given ongoing conflict between herders and farmers, and high levels of poverty among women and smallholder farmers (17).

As well as examining dryland Ghana and Nigeria, this scoping study also incorporated the experiences of and lessons from stakeholders working in similar bio-physical contexts in the semi-arid region of Brazil. In these systems, agroforestry practices include integrated crop-livestock-forestry (26), silvopastoral practices (with trees, forage, and livestock integrated on pastureland) (27), Assisted Natural Regeneration (ANR) (which can incorporate the restoration of degraded forest landscape through protection and management of naturally regenerating trees) (28), FMNR and successional agroforestry (29).

Agroforestry systems that combine crop and pasture production are regarded as effective strategies for improving soil health and enhancing carbon sequestration in Brazil (30), where cattle production is predominantly carried out on pasture (31). However, nearly 70% of Brazil's pastureland is degraded or undergoing degradation (32), highlighting the urgent need for sustainable land management practices. Consequently, the Brazilian government is incentivizing the uptake of sustainable production technologies like the silvopastoral system through its Low Carbon Agriculture (LCA) initiative, with about 2 million ha of land currently under silvopastoral management (33). The LCA is part of Brazil's commitment to reduce greenhouse gas emissions in the agricultural sector as made at the 15th UN Conference on Climate Change in 2009 (27). This initiative has been supporting farmers adopting sustainable land management practices that reduce greenhouse gas emissions in agriculture.

Recent research has evaluated the different components of integrated systems, including silvopasture, in the semi-arid region of Brazil to better inform farmers about the appropriate combination and composition of system components (i.e. trees-crops-pasture). The effect of tree species density and spacing arrangement on agricultural crop yield was evaluated (26), alongside livestock performance under the silvopastoral system (27). From a process perspective, knowledge co-creation for development of agroforestry with farmers and local actors in a participatory approach in coffee systems, as well as local certification of tree products to improve their access to markets, have also emerged as important (29; Figure 4).

Figure 4: Stakeholder engagement and co-creation in coffee agroforestry systems in Brazil. *Photo credit: Heitor Teixeira and CTA-ZM*

1.3 Methods used in the scoping study

Using the four CRD enablers as a framework in this project, diverse stakeholders and actors were identified and engaged in both northern regions of Ghana and Nigeria, and Brazil, through online workshops, interviews and meetings. We also undertook a wide-ranging literature review. This mixture of methods allowed us to:

1. Synthesise the current status of agroforestry in both African regions and in Brazil (as presented in the previous section)

2. Identify the challenges and barriers to scaling and adoption in Ghana and Nigeria; and

3. Unravel the barriers to transformational change in agroforestry in Ghana and Nigeria, considering lessons from Brazil.

The next section synthesises our findings and discusses the challenges and barriers to agroforestry in northern Ghana and Nigeria.

2. Scoping project findings

2.1 Challenges and barriers to agroforestry in northern Ghana and Nigeria

Most of the challenges and barriers affecting adoption and scaling of agroforestry technologies and practices in both northern regions of Ghana and Nigeria are similar, and can be categorised as environmental, resourcing, socio-cultural and institutional, policy and governance, knowledge, capacity and skills, and infrastructure challenges (Figure 5). Often these categories work in combination affecting the scaling and adoption of agroforestry. All our data sources suggested that these issues can be linked back to a lack of consideration of the four enablers of CRD (ecosystem stewardship, equity and justice, inclusivity and knowledge diversity), to various extents.

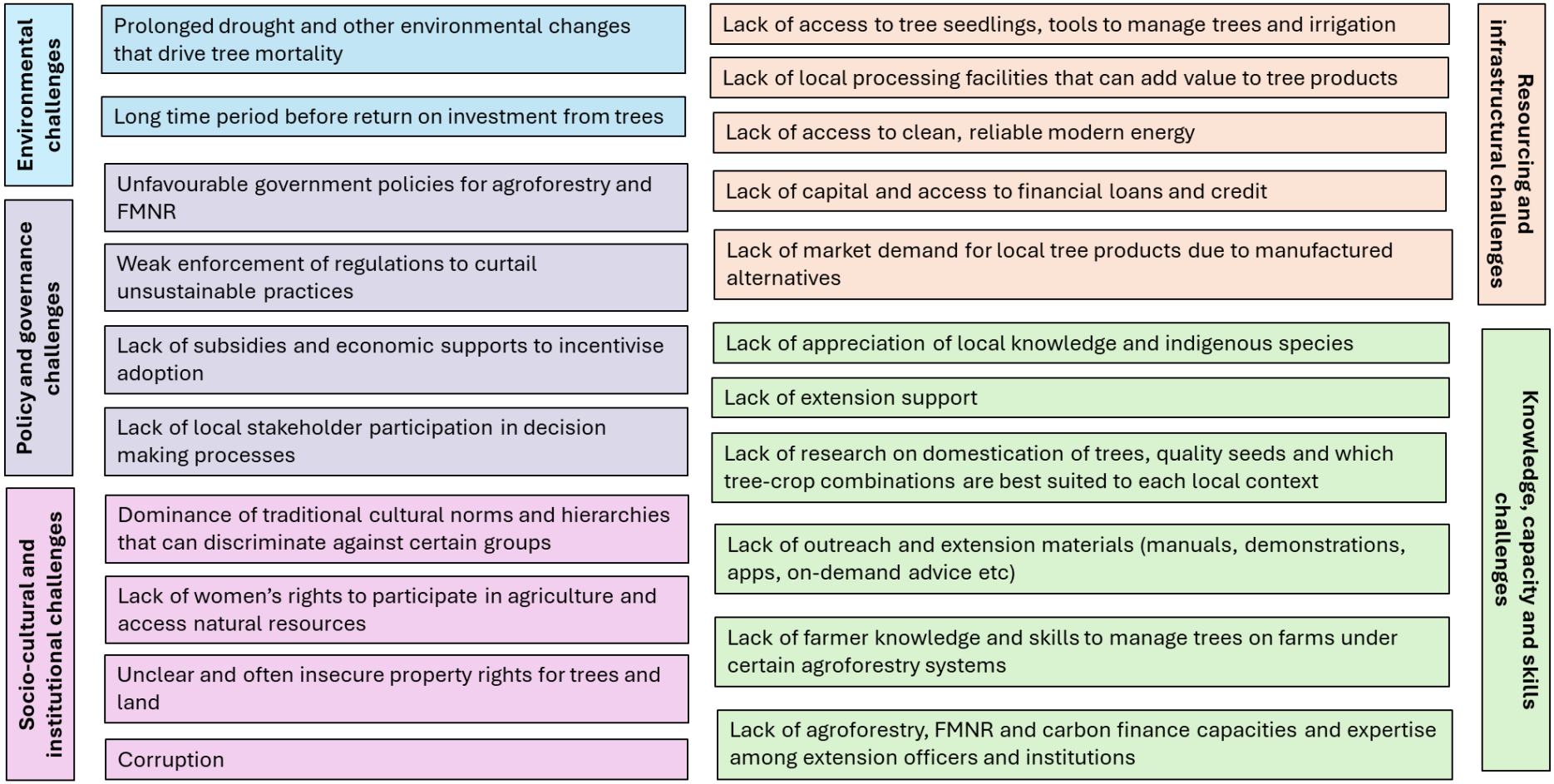

Figure 5: Challenges and barriers to scaling and adoption of agroforestry and FMNR in northern Nigeria and Ghana synthesised across data sources

2.1.1 Environmental challenges and barriers

Climate change variability is negatively affecting agriculture (and agroforestry) in both regions. Recurring drought and shorter rainfall duration are causing farmers to engage in forest degradation, in order to expand their agricultural land (34, 2). Workshop discussions identified the need to support farmers in areas of low crop yield, particularly to help them reduce post-harvest losses, prevent pests and to adopt improved seed varieties, thus reducing the likelihood of them turning to forest degradation alternatives.

Brushlands, which are important seed banks for trees, are often cleared for farming in northern Nigeria (4), affecting the abundance of seedlings of naturally regenerating tree species, with farmers failing to retain trees on the cleared land. In northern Ghana, there is increased pressure on tree resources during the dry season for food and animal feed (1). Management practices involved in FMNR also face threats from climate change, as sprouting of coppiced trees and survival of saplings are affected by drought and floods (35, 15), particularly species like Baobab (*A. digitata*) and Shea (*V. paradoxa*). Overgrazing further affects the regeneration of young tree wildings and saplings, as most branches and leaves of native tree species are palatable to livestock. This is particularly problematic when overgrazing occurs together with burning of fields to clear land (14).

Tree-crop interactions are an important issue in the literature and during our workshops emerged as a barrier to scaling agroforestry. Certain trees compete with crops for nutrients and water, and the shade trees provide can negatively affect the crop yield understory. For example, economically important trees like Shea and African locust bean have seen negative interactions with agricultural crops like maize, groundnut and yam in northern Ghana (21). Planting unsuitable tree species, or growing trees and crops in configurations that do not deliver positive outcomes for both trees and crops can lead to low crop yields and affect farmers' perceptions of agroforestry, causing them to reject it as a feasible practice (36, 7). While research has tended to focus on *Faidherbia albida* – a leguminous tree that improves soil fertility, there is generally a lack of adequate information on which tree-crop combinations work best under certain conditions. This highlights the need for research in understanding the system components, to evaluate the effect of aspects such as tree species, density, spacing and arrangement with crops on farmland, as well as understanding at which times of year animals should graze in the fields.

High demand for fuelwood and timber has not only caused deforestation, but a decline in indigenous tree species that are economically and ecologically important to farming communities in both regions, limiting FMNR (16, 4). While discouragement from engaging in charcoal production and wood selling, alongside awareness-raising of the potential benefits from agroforestry, are important and necessary actions, the impacts on the value chains for these products need comprehensive consideration, particularly when many of the people engaged in charcoal and wood fuel sales are women and other vulnerable groups such as Internally Displaced People (IDPs). Similarly, overharvesting of tree products for traditional medicine has also contributed to reduced seed viability and diversity of native tree species (1, 6).

Popular trees such as *Moringa oleifera, P. biglobosa, Faidherbia albida,* and *Vitellaria paradoxa* that are known for their products and values are now less widespread in the

Sudano-Sahelian zone of northern Nigeria (4). The implication of the decline of these native tree species is reduced seed viability and genetic diversity, which are important in natural regeneration. In the upper West region of northern Ghana, women attributed the decline of *V. paradoxa* (Shea), which is economically important to them, to illegal logging, mechanized farming, and bush fires (37). Workshop participants reported that Shea trees are not fruiting like they used to, so there is a need to understand the causes of this, particularly as farmers are removing trees that are not bearing any fruits or providing them with benefits.

Bush fires are a major challenge for agroforestry and forestry in northern Ghana. Activities of farmers and hunters such as cooking on farms, honey harvesting, and setting traps for animals with fires, often lead to uncontrolled fire that engulfs large areas of forest and trees (1). This is particularly problematic in prolonged dry spells (which are increasing under climate change) and when fuel loads in the fields are high. This again affects the viability of seeds, seedlings and destroys seed banks, leading to a lack of *in situ* resources to support FMNR and agroforestry.

2.1.2 Resourcing and infrastructural challenges and barriers

Poverty is widespread among rural households in both regions (14, 22), with high dependence on rainfed farming, forest and tree resources for livelihoods (38). Without alternative livelihood opportunities that can free up local resources for investment in agroforestry, it can pose a challenge, particularly when wood and charcoal sales remain lucrative and put forests and agroforestry / parkland trees at risk.

Despite growing access to markets for fuelwood and timber as demand increases, market access challenges for tree products remain an important barrier in scaling and adoption of agroforestry in both regions. In some cases, there is simply a lack of markets, e.g. for tree species like Moringa which can be used medicinally and as food. A more widespread issue is that manufactured alternatives have sometimes flooded the market, causing demand for traditional tree products that are locally processed and utilized to decrease (4). For example, Baobab (*A. digitata: Kuka*) which is highly nutritious and contains higher amounts of vitamin C than exotic fruits like oranges (11) has largely been replaced with industry-made Vitamin C. Shea (*V. paradoxa, Hausa: Kadanya*) which is locally used for skin care by rural households has been replaced with Vaseline, while stock cubes have been replacing African locust bean (*P. biglobosa, Hausa: Dorawa*) as a flavouring for food (4). This has led to a shift in species composition. In large parts of the region, the most visible trees are *Azadirachta indica* (Neem) and *Piliostigma thoningii* (Camel's foot tree) which are fast growing and in high demand for fuelwood and furniture (4). Lack of market certainty for non-timber tree products has therefore contributed to a decline in tree species diversity in the region and undermines the uptake of agroforestry and FMNR.

Farmers are understandably sceptical about planting trees without a guaranteed demand for their tree products (3). While there is a market and high demand for Shea nuts from export buyers in northern Ghana, it creates inequalities as it comes at the expense of women who locally process butter. Those women who pick Shea nuts gain, and those who process them into butter lose, as it is no longer profitable to process it for local markets when the international market gives higher returns (39). It also reduces accessibility to local communities. The Ghana workshop discussions noted the need to support Shea processing value chains, as emphasis is largely on Shea

nut collection and selling. With increased competition among women for Shea nut picking due to the high demand, there is also erosion of local knowledge on the processing side. This is also the case in northern Nigeria, where loss of markets for locally processed traditional tree products has led to loss of valuable cultural practices and local knowledge, reducing the importance of trees to farming communities, particularly when they also now depend on industry-made similar products (4, 40).

As well as market challenges for agroforestry products, there is also a lack of access to carbon markets. Several challenges hinder rural farmers' participation in these markets in both regions. Rural farmers are unfamiliar with carbon markets and lack the technical knowledge on how they work, as training and education on CSA practices like agroforestry that are required to participate in the carbon market are still limited. Small land holding sizes and land tenure insecurity are also barriers for farmers to participate in carbon trading, as investment in the carbon market is long-term and buyers may require proof of land ownership (which many farmers do not have due to the type of land tenure systems/arrangements in both countries). There are also no policies or regulations in place to support farmers' participation in the carbon market in the study regions.

Lack of access to finance, subsidies and loans are a major barrier to agroforestry scaling in both regions. Smallholder farmers find it difficult to access loans from financial institutions in Nigeria due to their small plot sizes, while women lack access to land and find access to finance even more difficult than male smallholders. Government subsidies also sometimes fail to reach the rural farmers due to institutional barriers (particularly corruption). Limited access to credit and high interest rates stops farmers from accessing loans and using that money to enter into agroforestry. Financial institutions and private investors are not interested in investing in agroforestry due to the long gestation period of trees (3), a lack of understanding of the wider benefits and the high risks involved in tree planting, particularly linked to tree survival under a changing climate. Financial institutions tend to be more concerned about when the farmer will pay back their loan, and with trees, it takes a minimum of 3 to 5 years before financial benefits are realized. The long gestation period of trees is thus a major barrier to scaling agroforestry to farmers. Timber in northern Ghana cannot be harvested for around 20 years (until the trees reach maturity). Partly this long lead-in time is due to the climate variability in the region. Farmers tend to reject the adoption of the trees due to their lack of immediate benefits, even though they can get around 40% return on investment at the point of harvest. There is a need for more awareness creation and education for both farmers and financial institutions on the long-term benefits of tree planting (36).

Uptake of modern technologies further needs to be supported by appropriate wider infrastructure as a core component of the enabling environment. Low education levels among rural farming households may be a challenge to the promotion of some of the innovative digital technologies that are emerging, linked to mobile phone apps and satellite remote sensing, while lack of reliable electricity and internet connectivity can exacerbate the situation. The over-dependence of rural households on fuelwood and charcoal for cooking is due to the lack of access to affordable Liquified Natural Gas (LPG) fuel and appropriate cook stoves. In Nigeria, even if there is access to a cook stove and LPG, the high price of gas due to the recent removal of the subsidy on petroleum products may still pose a challenge for rural households.

It is well established that innovations must be locally-led and informed, considering the local context and culture, as well as being easy for farmers to understand and use (36). Workshop participants emphasised that the approach to implementing such technologies must be participatory. Agricultural technologies like drip irrigation which utilizes little water have been promoted to farmers in northern Nigeria, but due to the semi-arid climate, water scarcity remains a problem and domestic water needs supersede those of farming. There is also lack of access to tree seedlings and infrastructure that guarantees the supply of seedlings of desired tree species to farmers (3). Further equipment and infrastructural barriers include a lack of access to the tools to manage trees on farms in an FMNR system (e.g. cutlasses, secateurs etc).

2.1.3 Policy and governance challenges and barriers

Unfavourable government policies in both regions present major barriers. In Nigeria, inconsistent policies have led to low investment in agriculture and agroforestry. New governments often abandon the policies they inherited from the previous government, and this has stagnated the development of the agricultural sector since the return to democracy in 1999. Government ministries, departments and agencies (MDAs) in Nigeria tend to work in isolation rather than cooperating with one another and ensuring sectoral coordination across their different policies. This makes policy implementation a challenge and highlights the need to harness synergy and co-benefits through collaboration between MDAs.

Research undertaken in an irrigation-free indigenous tree restoration project in Kano and Jigawa states identified lack of policy consistency in relation to the role of tree restoration in climate change mitigation and socio-economic development across policy documents in the climate change, forestry, energy and agriculture sectors (41). Policy documents such as the National Adaptation strategy and Plan of Action (NAPA) (2011), National Action Plan on Gender and Climate Change, and Agricultural Promotion Policy (APP) (2016-2020) mention the role of trees in improving livelihoods and addressing climate risk but lack detail on the specific actions or approach to be taken. Some policy documents (e.g. the Economic Sustainability Plan 2020) do not mention any role for trees and agroforestry in economic development. The only policy document that clearly indicates the specific roles of trees (including detailed actions to be taken) and restoration of indigenous tree species for rural socio-economic development and resilience to climate change is the National Forest Policy 2020 (41).

There are also no government-provided incentives or subsidies for farmers who enter into agroforestry. Lack of stakeholder engagement and participation in the government's project decision making processes has led to a low success and adoption rate, both among larger afforestation and reforestation initiatives as well as other restoration efforts including agroforestry and FMNR. In Ghana, the government has planted over 52 million trees over a 4-year period (2020-2024), but most failed to survive, as the species planted were not always suitable for the local conditions. Prioritising indigenous species could yield better outcomes.

Consulting the local communities and engaging them in the programme could also have delivered different results. Government tree planting efforts in the northern region of Nigeria is largely focused on trees to combat desertification and desert encroachment (42) without paying attention to desirability of the particular species to

the communities or considering their economic significance. Nigeria workshop participants underscored the need for agroforestry projects to be community driven, noting that such approaches support a project's sustainability. Communities do not proactively protect and care for interventions if they have not been involved with them and do not feel a sense of ownership and stewardship. This is also one of the reasons why tree nursery beds established by both the government and World Bank have failed in Nigeria.

Poor implementation and enforcement of regulations to curtail the illegal activities of mining, wood logging, overharvesting of tree products for medicine, clearance of forest for farming and overgrazing by livestock (1-3) often drive land degradation and conflict in both regions. There are reported cases of migrants and pastoralists coming into the northern region of Nigeria to fell trees and destroy farmlands (6). Such clashes mean that farmers are reluctant to invest in tree-based livelihood options on their farms. In northern Ghana, the Fulani ethnic group are largely blamed by communities for overgrazing, destruction of farmlands and bushfires (17), leading to anti-Fulani sentiment and ethnic profiling of the Fulani group (43), even though the Fulani are not the only herders in the region (17). Politically, Fulani are not recognized as citizens in Ghana, despite having been settlers in the country since the mid-19th century (44). Regarded as migrants, the Fulani have rights to land through rent or lease (17). When it comes to decision-making and participation in agroforestry and FMNR interventions, the Fulani are marginalized and excluded. The World Vision FMNR project in northern Ghana found that farming community members were against the participation of the Fulani in the intervention, including being against their access to natural resources on communal land where the FMNR interventions were implemented (17, 45). There are also reported cases of such incidences of marginalization in the north-central region of Nigeria, fuelled by the political class and rulers. Herders, including the Fulani, sometimes allow their cattle to stray into farmlands which leads to destruction of food crops and trees (1), fuelling conflict. Such exclusion from decision making processes relating to land management (as in the case of the FMNR project in Ghana) is a key barrier to agroforestry and FMNR, especially as this group are key users of pasture and grazing land.

2.1.4 Socio-cultural and institutional challenges and barriers

Cultural norms and traditions in both northern Ghana and Nigeria have often marginalised vulnerable groups such as women and the youth. Age hierarchy plays an important role when it comes to decision-making processes in northern Nigeria. Elders in the community are the ones who are approached when it comes to decision making - with the women and youth often considered important to engage with as the elders make the decisions on behalf of the communities. Similarly, scaling an innovation requires reaching farmers through a respected (usually male) figure in the community (e.g. a cleric or community leader). Women thus lose out as a result of cultural norms and traditions in both regions.

Another social barrier is the insecurity and conflicts in northern Nigeria that are driving food insecurity and poverty. Farmers in some parts of the region cannot access their farmlands, with the situation even more dire in the drylands. Armed bandits are operating in the Sudan savanna region (Northwest) (42) and Boko Haram are in the Sahel (Northeast). This has made the Sudano-Sahel region highly prone to conflict, socio-economic vulnerability, renders livelihoods unstable and leaves households'

food insecure (46). The insecurity has also led to loss of land rights/security for many rural households, finding that when they return after displacement, their land has been taken over by others. The insecurity has also affected monitoring and expansion of already established agroforestry projects (e.g. shelterbelt establishment in northeast) in the region, which presents a key barrier to their success.

Farmers sometimes consider that trees do not work well with their agricultural crops, which is a challenge to the scaling of agroforestry. Workshop participants revealed that there are superstitious beliefs attached to certain trees like tamarind (*T. indica*). Local people have a spiritual attachment to the tree and many think that nobody should go near it; a belief that has been passed down to and accepted by the younger generations. However, newer approaches are not always so easily accepted and passed on. In northern Nigeria, persuading farmers to adopt new innovations is a major challenge, partly due to scepticism about whether the new approach will succeed or not and partly due to the time lag in experiencing the benefits. There is also the fear that any new intervention may cause them to lose control over their land. These fears are grounded in the nature of the land tenure system. In recent years, Nigeria's state governments have developed an interest in large farm estates, with estate investors being given huge areas of land to develop their businesses. Most of the lands allocated for farm estates have encroached on people's land in the communities. In turn, the situation has created a lack of trust between technology providers and farmers.

The land tenure system in both regions is a major barrier to scaling and adoption of agroforestry and FMNR. Ghana runs a two-way complex legal system of resource governance: the traditional customary laws and the official government legal system of resource governance (47). This has negative implications for sustainable land management, as separate laws are applied for ownership of resources on land. The customary arrangement is often determined by the power hierarchy at the community level, with kinship, social status, class, position in society, gender and resident status being the factors that together determine who has the rights and access over resources on land (including tree products) (5).The president in Ghana formally serves as the keeper and protector of all trees and forest for the communities, however, there are no laws on how non-timber forest products are managed (48). In some areas of northern Ghana, the chiefs own the land and decide which tree species are to be planted and/or retained (36).

In northern Nigeria, sub-national governments hold the authority of managing and protecting forest (2) and reserve the right to any land for development purposes under the Land Use Act of 1978. This archaic law has not only made rural farmers vulnerable to having their land taken away from them, but also prevents them from carrying out sustainable practices like agroforestry. The literature reports various cases of abuse of the law by the government (3).

Issues of resource governance and social inequality also exist in FMNR when it comes to the products of naturally regenerating trees. In Ghana, all naturally regenerating trees belong to the government. Hence, farmers may be sceptical about managing trees on their farms as the government can effectively "give away" trees on farmers' fields once the tree reaches maturity, without even consulting the farmer. Farmers will not adopt any practice that they think they will not benefit from. In northern Ghana,

who benefits from which trees, when and how, is socially differentiated and affects how benefits and risks are distributed due to their different land and tree tenure arrangements (17). In some communities, sub-Chiefs called “tree chiefs” reserve the harvesting rights of valuable pods of African locust beans (*P. biglobosa*) even on private farmlands, meaning this tree has a different status to other species (21). This traditional arrangement demonstrates the challenges of a dual legal system that treats trees, different tree species and land differently. Even though a male farmer has full tenure rights over their land, it is not the case when it comes to the trees on the same land (so the right to one does not necessarily mean the right to the other) (21). The inequitable access to and control over natural resources not only has implications for scaling and adoption of FMNR (17), but also for tree species diversity. The tree tenure arrangements for African locust bean have led to the decline of this tree species in farmers’ fields, as they pay more attention to the protection and management of Shea tree (*V. paradoxa*), over which they have full control and rights (21). Shea tree holds a significant gender and economic value to rural households in northern Ghana, with its nut picking and processing primarily carried out by women (19). Due to this economic importance, Shea also comes under a different arrangement when it comes to farmers leasing their lands to tenants. The tenant has no right over the Shea tree. The landowner still holds the full access right to Shea on the leased land (17). Tenant farmers are nevertheless allowed to access other fruit trees, just not Shea nuts for any purpose.

2.1.5 Knowledge, skills and capacity challenges and barriers

Agroforestry requires skills and training as to how to manage trees on farms with agricultural crops and livestock. Access to extension services is poor/low in both regions, yet extension is key in disseminating information, sharing knowledge and innovations, building farmers’ capacity and providing training. Where NGOs try to fill the extension void, it often leads to farmers receiving mixed messages that are sometimes contradictory, particularly because NGO emphases tend to be on the specific aspects supported by their (often short-term) funding and they often do not coordinate with one another. Technologies like FMNR utilize local knowledge of farmers, and knowledge sharing between farmers. However, farmers in Nigeria often lack adequate knowledge and skills in training their fellow farmers on agricultural technologies - a barrier that becomes more acute as younger generations shift away from agriculture and move to urban areas in search of jobs.

The parkland agroforestry system, common in both regions, has been part of the traditional farming system for centuries, but there is surprisingly limited information on other forms of agroforestry systems used in the areas (16, 3). Other agroforestry technologies such as alley cropping systems (which requires understanding of pruning regimes) (10) will require training not just for the farmers, but the extension agents too. Extension workers need the most up-to-date technical knowhow on how agroforestry and FMNR work.

Institutional capacity building is also important in scaling agroforestry and FMNR. Government institutions’ top-down and often non-participatory approach has led to failure of many tree planting initiatives as farmers simply have not been engaged, do not understand how to care for the trees, and lack a sense of environmental stewardship over them. These factors undermine both the adoption and scaling of agroforestry and FMNR. There is a pressing need for capacity building of government

institutions. Similarly, in both Ghana and Nigerian workshops, participants further highlighted the importance of training government institutions on the financial opportunities linked to carbon and climate finance, with relevant outreach and capacity building of farmers needed on this aspect as well.

3. Linking the identified challenges and barriers to the CRD enablers

The barriers and challenges outlined above are all closely interrelated. The CRD enablers – ecosystem stewardship, equity and justice, inclusivity and knowledge diversity, manifest in the engagement and interactions between various stakeholders and actors in decision-making processes and actions that enhance climate resilience and sustainable development (9). This is significant in designing a scalable and adaptable system like agroforestry, to ensure all voices, knowledge and experience are considered in the development of an overall enabling environment.

The goals of agroforestry and FMNR are consistent with that of CRD (i.e. mitigation, adaptation and development), and have the potential to chart more resilient pathways for farming communities (49) in both northern regions of Ghana and Nigeria. The challenges and barriers identified from the workshops, interviews and literature review are currently diverting the communities away from CRD pathways, leaving them more vulnerable to the negative effects of climate change. The current state of agroforestry and FMNR technologies in both African regions is not consistent with the four enablers of CRD. This is explored further in the sections below.

3.1 Ecosystem stewardship

Ecosystem stewardship refers to people taking the responsibility to sustainably use, manage and protect their natural environment and the services it provides. From the perspective of CRD, advocacy around ecosystem stewardship is about ensuring that the people's relationship with their natural environment is not just about the multiple benefits they derive from it, but rather, understanding that the sustainability of their livelihood depends on the survival and protection they give to the environment. Findings from the review and stakeholder engagement activities suggest that in both northern Ghana and Nigeria, farming communities see their natural environment as a resource or provider that supports their livelihoods, rather than a system that needs care and protection.

This was revealed to be very different from Brazil (where perhaps both Nigeria and Ghana can learn from). In Brazil there is more sense of stewardship towards the natural environment. As discussed during the Brazil workshop, farmers have been learning from nature by planting trees with their crops in a way that improves biodiversity and mimics natural ecosystems. This brings about a sense of connection to the land and the environment, and allows for restoration of degraded farmlands, hills and pastoral areas, supporting farming of food crops and trees that in turn underpin livelihoods. The social movements and farmer unions, including the landless movements in Brazil, give the farmers a sense of responsibility to protect their land, and stand against social injustice and inequalities.

3.2 Equity and Justice

Equity and justice demand the fair participation of all groups, including vulnerable and marginalized groups at all levels of decision-making processes. This is particularly

significant as most of the interrelated socio-cultural, policy and governance barriers we identified are driving inequity in access to resources and hindering fair representation of local stakeholders in decision-making processes. In turn, this affects uptake of agroforestry and FMNR. Other equity and justice issues are related to the cultural norms and power relations at the community level. In northern Nigeria, women and youths are marginalised when it comes to decision making, meaning the outcomes of decision processes may not be desirable to them (49) or worse still, can further marginalised them. The socio-cultural situation makes it difficult for their voices to be heard, exacerbating inequitable outcomes. In northern Ghana, women do not own land even though they are the major tree resource users. This affects their participation in agroforestry and FMNR. Similarly, certain ethnic groups like the Fulani are marginalised and forbidden to use natural resources in some communities, leading to conflict.

Not only is there a lack of consideration of equity and justice in both northern Nigeria and Ghana, but the identified barriers are leading communities away from a CRD pathway. Designing, scaling and adoption of agroforestry and FMNR technologies and innovations in both regions will require fair and just participation of all groups – irrespective of social class, status, gender and position in society in decision making processes that is desirable to all. In Brazil, participatory bottom-up approaches are given more adequate attention when it comes to technologies and practices like agroforestry and FMNR, creating a more accessible technology for all. Experiences shared during the Brazil workshop on working with communities in Zona da Mata in co-designing interventions and knowledge sharing between researchers and local actors, highlights the importance of local participation in project decision making processes. The UK-Pact project on irrigation-free FMNR technology in northern Nigeria also utilised co-creation of knowledge with local farmers, and emphasised women's participation. Women are primary users of tree products, so their equitable participation allows for better decision and choices on which tree species they prefer to be regenerated.

3.3 Inclusivity

The findings on lack of equity and justice in both regions are also relevant to the lack of inclusivity. Ensuring that everyone is given equal opportunity to participate and contribute in decision-making processes to voice out their concerns and needs is important in charting a way for agroforestry and FMNR technologies to support communities' pursuit of CRD in both regions. For participation to take place however, all groups need to be recognised as equally deserving of a say. The socio-cultural and policy and governance barriers identified are more relevant in this regard, as rights to participation and inputs of women and youths in decision making processes are not recognized, communities are brewing unfavourable sentiments towards certain ethnic groups, while governments' top-down approach with a lack of local stakeholder participation in their project decision making processes are all barriers to inclusivity. Inclusivity is vital to deliver adoptable and scalable agroforestry and FMNR technologies in both regions.

3.4 Knowledge diversity

Considering different types of knowledge including the local knowledge of farming communities in designing, scaling, commercialisation and adoption of agroforestry and FMNR technologies is vital. The local knowledge and experiences of the farming

communities must reflect in all the processes (from design to implementation), in a way that is relevant, acceptable and useful to all (49), and can shed important light on the local context. In both Ghana and Nigeria, economic barriers have led to erosion of local knowledge due to a lack of markets for locally processed tree products. Communities processed and utilized tree products of Shea, African locust beans, Baobab, etc., but flooding of the local market with similar industry-made products and a lack of market for the locally processed tree products, has led to reduced importance of native tree species and their products in northern Nigeria (4). Female Shea butter processors in northern Ghana are losing out due to high demand for Shea kernels by the international market. This is leading to loss of valuable local knowledge on Shea processing in both northern regions of Ghana and Nigeria, with jobs and opportunities to improve local livelihoods and resilience being lost.

Agroforestry and FMNR present an important opportunity to support rural livelihoods in both northern regions of Ghana and Nigeria. They offer the potential to deliver improved food and nutritional security and income, resilience to the negative impacts of climate change, as well as greenhouse gas mitigation. Doing so will advance progress toward sustainable development and CRD. However, the identified barriers demonstrate that a lack of understanding and consideration is given to the four CRD enablers, leading the communities away from CRD pathways. Consideration of the four CRD enablers in designing, scaling and adoption of agroforestry and FMNR requires multi-stakeholder, multi-level participatory engagement to address these systemic barriers.

The next section discusses the opportunities for collaboration and knowledge sharing in which some lessons from Brazil were discussed that are relevant in addressing the identified barriers and CRD considerations.

4. Opportunities for collaboration and knowledge sharing

The online workshops provided opportunities for participants working in Brazil, Nigeria and Ghana to share experiences and knowledge on what has worked and what has not in terms of agroforestry and FMNR adoption and scaling. Discussions considered the challenges and barriers, as well as the barriers to transformational change, revealing lessons from Brazil that are relevant to both Ghana and Nigeria.

Collaboration opportunities to jointly apply for funding opportunities, journal publications, learning exchange programmes, among others were discussed during the workshops, meetings and interviews. Knowledge gaps and research opportunities that will support the scaling, adoption and commercialisation of agroforestry products were also identified and discussed in the workshop plenary sessions and are presented in section 5.

Knowledge sharing of key lessons from Brazil, which Nigeria and Ghana can learn from, could usefully focus on four main areas: social movements and farmer cooperatives, participatory approaches and technology co-design involving farmers, local certification schemes and policies supporting market development. Each of these is discussed below.

4.1 Social movements and farmer cooperatives

Brazil has strong social movements and all family farmers (i.e. smallholder farmers) are part of cooperatives, associations and local unions. These institutions have supported family farmers to ensure their voices are heard. This is an important lesson for both Nigeria and Ghana where smallholder farmers are often marginalized when it comes to policy decisions, subsidies and interventions.

In Nigeria, the large-scale farmers, who constitute not more than 5% of the farmers, are the largest beneficiaries of government support and interventions. Subsidies and economic incentives meant for smallholder farmers in rural areas often fail to reach them due to challenges such as corruption. While farmer associations and cooperatives exist in Nigeria, governments mostly do not involve them in their decision-making processes. Access to microcredit, finance and loans in both Ghana and Nigeria is challenging for smallholder farmers, particularly while interest and repayment rates remain high. Through unions and associations, like in Brazil, smallholder farmers could undertake collective actions to demand system transformation.

4.2. Participatory approaches and co-design of technologies with farmers

Bottom-up participatory approaches and co-design of technologies like agroforestry are showing promising results in Brazil and can be usefully taken up in both Ghana and Nigeria. This way of designing and promoting technology improves understanding of the challenges, enables experience and knowledge sharing between researchers and farmers, as well as supporting farmer-to-farmer learning. It helps scientists to evaluate their own knowledge in the application context of the technology while the co-development process leads to the generation of new knowledge while also building from the existing knowledge of the farmers. In Brazil, demonstration plots were often developed on farmers' own land so they could see and compare the changes with their conventional practices, evaluating the results in their own contexts, jointly with researchers. This lesson is particularly important for policy makers and innovation providers in both Ghana and Nigeria as they often adopt top-down approaches that exclude the perspectives of the communities in which the intervention is implemented. This is one of key reasons why tree planting initiatives fail in both African countries.

4.3. Local certification and participatory guarantee system

The agroecological self-certification of tree products by local farmers in Brazil helps farmers to obtain certification locally, which helps provide a guaranteed market for their products. This bottom-up participatory process for local certification also facilitates peer-to-peer learning and knowledge exchange between farmers and helps in marketing products.

Local certification is carried out by academic institutions, where researchers support extension officers and farmers to deliver the accreditation. The local certification process also trains local farmers on the packaging of their products to help ensure they are appealing for the market. This could be an important way forward in enhancing market access for local farmers in both Nigeria and Ghana, as there is little or no experience in the local agroecological certification of agroforestry and FMNR products. Developing a contextually appropriate local certification system could help reduce unsustainable practices. Agroecological approaches shun the excessive

application of chemicals that sometimes prevent the sale of products internationally and can support climate change mitigation efforts.

4.4. Policy to support smallholder farmers to have a market for their farm produce

Family farmers in Brazil are increasingly linked to the government's school feeding programme, helping them to develop a market for their products. Nigeria also has such a targeted policy in the form of the "national home-grown school feeding programme", where farm produce is purchased from local farmers to feed students in schools. However, institutional barriers such as corruption mean smallholder farmers often fail to benefit from the programme as large-scale farmers dominate the supply chains. If designed and implemented properly, Brazilian experiences have shown that the programme can lead to new local jobs (e.g. local cooks in schools) as well as creating a market for smallholder farmers to sell their farm products.

5. Research opportunities and knowledge gaps

Research opportunities and knowledge gaps were identified through the literature review, online workshops, meetings and interviews, pointing towards opportunities for future collaborations with stakeholders and partners across the three countries. Priority needs include research on system components, improved data and information, an improved understanding of the policies and incentives to support agroforestry and FMNR uptake, rapid capacity building, and improved infrastructure to support adoption and scaling.

5.1 Research on system components (both agroforestry and FMNR)

Better understanding of tree-crop interactions is needed, as this is a key barrier to scaling and adoption of agroforestry. Agroforestry requires the use of the right trees in the right place at the right time and to deliver its potential, requires the pairing of appropriate tree and crop species. If inappropriate species are used, crop yields can be affected, e.g. by over-shading of crops. In both Ghana and Nigeria, there is very little or no information on research on the system components of agroforestry (i.e. the best tree-crop combinations) with some farmers thinking that trees undermine their crop production. This gap is significant in order to understand which species should be promoted to the farmers, and how they should be set out on-farm. Workshops highlighted the following specific questions:

i. What tree species work well with agricultural crops in each context?
ii. What density of trees and what mix of species should be on a given area of land in order to maximise benefits?
iii. What should be the arrangement of the trees and the spacing between the crops and trees?

5.2 Paucity of data

In both northern Ghana and Nigeria, agroforestry and FMNR are being practiced locally by some land users. However, there is limited baseline data on uptake and adoption. Workshop participants considered the need for answers to questions such as:

i. How many indigenous tree species are there being used in agroforestry systems in both countries?
ii. Who is benefiting from the agroforestry and FMNR and how is the distribution of those benefits being managed? Who is losing out?
iii. What were the historical forms of tree cover in both regions and what possible roles do they have in future agroforestry systems?
iv. What local practices and technologies are being used already that offer potential for scaling?

5.3 Role of government policy in supporting adoption of agroforestry and FMNR
Government policies in both African regions do not encourage adoption of agroforestry by smallholder farmers and are often unfavourable to scaling and adoption of agroforestry. This requires targeted interventions that address questions such as:

i. What incentives can governments in both Ghana and Nigeria provide to smallholder farmers to promote adoption while also reducing corruption and elite capture of these?
ii. How can governments prioritise participation of local stakeholders in their afforestation and reforestation initiatives to ensure desirable tree species by farmers are planted and community ownership is promoted?
iii. How can local institutions be strengthened to enforce regulations on illegal logging, overgrazing and overharvesting of tree products for medicines by local communities and migrants?
iv. How can spaces for dialogue be created to reduce conflicts between farmers and herders and how can policy better recognise and target marginalised groups?
v. Which land tenure models offer sufficient security to farmers to orient them towards longer-term land management approaches such as agroforestry?

5.4. Lack of knowledge, skills and capacity
Agroforestry requires skills and training on managing trees on farms with agricultural crops and livestock. In both African regions, there is need to understand:

i. To what extent is knowledge on the various forms of agroforestry technologies (aside from parkland systems) generated and transferred to farmers?
ii. How is limited access to extension services affecting the skills and capacities of farmers to adopt new technologies like agroforestry?
iii. What interventions can reduce the loss of local knowledge in agroforestry practices and processing?
iv. What specific skills and training are needed to enable farmers to better care for the trees in their agroforestry systems?

5.5. Lack of infrastructure
Due to low levels of education among local farmers and lack of infrastructure in the form of e.g. reliable internet services, rural electricity supplies and access to seedlings and equipment, the following questions must be answered to support utilisation of digital technologies and other innovations:

i. How can agroforestry and FMNR be promoted to farmers using mobile phone apps?
ii. What opportunities are there to support irrigation-free species and the development of local nurseries?

iii. How can domestication and breeding of economically valuable tree species support uptake and how can domestication rates be improved?
iv. Are there technologies that can help improve soil fertility that could benefit both crops and trees within agroforestry systems?
v. How can social innovations such as associations and cooperatives improve access to equipment?

Some of these knowledge gaps require engagement of particular individual stakeholders. The next section outlines the key stakeholders and their roles in this scoping study, alongside their potential contributions to future collaborative projects targeting these questions.

6. Key stakeholders and their roles in potential collaborations

The UK partners in this project were the University of York and Bangor University. In developing the stakeholder network across countries, it was vital to identify key partner institutions in each country. We worked closely with the Federal University of Vicosa (UFV), Brazil, the Centre for Dryland Agriculture (CDA) at Bayero University Kano (BUK), Nigeria and with the Forum for Agricultural Research in Africa (FARA) and the Council for Scientific and Industrial Research (CSIR) and their networks, Ghana. A project lead was assigned from each key institution in each country to help with coordinating activities for the project and to assist in identifying stakeholders to be engaged in the online workshops (Table 1). The key institutional partners in the study regions thus provide important entry points for potential future collaborations and are paramount in contributing contextually grounded knowledge and experiences, as well as having considerable reach into local and national networks.

Table 1: List of organisations engaged in the workshops from Nigeria, Ghana and Brazil and their stakeholder groups. Key partner institutions are indicated by an asterisk (*)

Nigeria	Ghana	Brazil
Dryland Initiative for Ecosystem Restoration and Capacity Building (NGO)	World Vision Ghana (NGO)	Universidade Federal de Santa Catarina (Academic)
Local Government Service Commission, Jigawa (Government)	MoFA, Upper East (Government)	Instituto Federal Catarinense (Academic)
National Association of Women in Agriculture (NGO)	Presbyterian Agricultural Service (Private business)	Centro Sabio (NGO)
Eyes on the Environment Initiative (NGO)	TreeAid Ghana (NGO)	State University of Ponta Grossa (Academic)
Arewa Women Initiative for Climate Change (NGO)	Forestry Commission Ghana (Government)	Universidade de São Paulo (Academic)
GIS & Remote Sensing Unit, NASRDA (Government research)	CSIR-Savanna Forestry Research Institute (Research)	Federal University of Parana (Academic)
National Agency for Great Green Wall (Government)	Peasant Farmers Association (Association)	Cooperative Organisation of Agroecology (NGO)
Department of Forestry, Katsina (Government)	Ghana Agroecology Movement (NGO)	Embrapa (Government research)
Ministry of Agriculture and Natural Resources, Yobe (Government)	University for Development Studies (Academic)	Federal University of Viçosa (UFV) (Academic)*
Seed Project Company Ltd (Private business)	Water Resource Commission (Government)	
Bayero University Kano (Academic)*	MoFA, Upper West (Government)	
Green Spider (Private business)	KNUST (Academic)	
Nigerian Agribusiness Group (Private business)	Centre for Indigenous Knowledge & Organisational Development (Private business)	
University of Abuja (Academic)	MoFA Northern region (Government)	
Forestry Research Institute of Nigeria (Government research)	Forestry Research Institute of Ghana (Government research)	
DeepNeks Ltd (Private business)	CSIR-Savanna Agricultural Research Institute	
	Forum for Agricultural Research in Africa (FARA)*	

Partnerships emerged as key in addressing agroforestry and FMNR knowledge gaps. Potential collaborations could involve, for example:

- Government organisations working with academics and NGOs to improve participation of local stakeholders in their policy decision making processes
- Academics, private sector businesses and agricultural extension officers collaborating to provide skills training and capacity building. Here, the role of knowledge exchange enterprises could be important
- Researchers, NGOs and businesses need to work with farmers and local communities to co-design agroforestry and FMNR technologies that are suitable to the local context of the farming communities in a bottom-up approach.

It was clear from workshop discussions that participants were building new networks and meeting new people. Some of them were already working with and collaborating with each other. The kinds of stakeholder collaborations and partnerships we have identified are therefore both necessary and feasible. In addition to the diverse workshop participants in each country, two businesses were engaged from the UK (Farmsmarter App and Aquagrain), both of which are working in the agri-food sector and indicated their interest in possible future collaborations. Other businesses that we would like to collaborate with would be those that focus on marketing and commercialisation of local products, knowledge exchange, the development of entrepreneurship, local certification and infrastructure development. We did not include these specific types of business stakeholders in the scoping study as the need for their engagement emerged as an outcome from the workshop discussions.

The Council for Scientific and Industrial Research - Savanna Agricultural Research Institute (CSIR-SARI), Ghana indicated they would like to collaborate to address the research agenda that emerged from the workshops. Two other organisations from Brazil have also indicated interest in collaborating but did not attend the workshops: Embrapa Environment – a government agricultural research organisation and SuperaPark, an Agri-Tech innovation park. The practicalities of the collaborations will largely depend on the funding opportunities that become available in the coming months and years.

7. Reducing gender and social inequalities in northern Nigeria and Ghana through agroforestry and FMNR

This scoping project has demonstrated that agroforestry and FMNR have the potential to support women and other vulnerable groups in northern Nigeria and Ghana by reducing poverty, generating income and enhancing their resilience to climate change. Women are the primary users of tree products in both regions. In northern Nigeria, women are actively involved in the value chain of tree products such as Baobab, Moringa, Tamarind, and hibiscus (7). They utilize the fruits and leaves of these trees to produce local refreshments, food for household consumption, and sell tree products to raise income (22). The collection and processing of Shea nuts falls directly under women in northern Ghana, with women holding valuable knowledge of the tree, and generating income from the sale of Shea nuts and processed Shea butter (19).

Despite women being the primary users of tree products, socio-cultural and legal challenges are still a barrier for women's full participation in agroforestry and FMNR in both regions. Women in northern Ghana are not allowed to own land (19), with access to land for farming only through their husbands. In northern Nigeria, women's participation in farming is very low, as the northern culture sees farming as a male job due to the labour-intensive activities involved in farming (13). In both African regions, women's participation in decision-making processes is largely restricted, as the family head (usually male) is the sole decision maker in the household. Women's rights are afforded low recognition in both regions, with their livelihood choices largely remaining under the control of men (22, 50). Risks from conflict mean women farmers can often feel vulnerable, highlighting the need for efforts to tackle insecurity and to protect women farmers.

To address these challenges, targeted interventions are needed to support women's recognition and participation in agroforestry and FMNR, particularly in areas such as entrepreneurship and value chain development. The International Institute for Tropical Agriculture's (IITA) SEEDEQUAL initiative successfully empowered female farmers in Jigawa and Benue states of northern Nigeria by involving them in the seed production value chain for soya and cowpea. The initiative trained approximately 130 women in seed production and gender-responsive climate-smart legume farming. It also provided training on good agronomic practices, such as optimal planting times, row spacing, and pest management, while improving access to extension services through female extension officers and facilitating market access. Learning from these projects will be vital in driving forward adoption and scaling.

Similar targeted interventions could be applied to agroforestry and FMNR, where women could be trained in new technologies for processing tree products and supported to access broader markets, as was the case in the UKPACT supported project on indigenous non-irrigated trees. Linked to this support is a further need for equipment that is gender friendly. Women are predominantly engaged in the post-harvest handling and processing of crops. In northern Ghana, women traditionally process Shea nuts into butter, but the growing demand for Shea kernels is undermining their businesses, as the market for kernels is more lucrative than that for processed butter (39). By improving women's access to markets for locally processed Shea butter, their participation in agroforestry and FMNR could be significantly improved. Women's skills also need building in terms of financial management, combined with awareness raising of micro-credit opportunities and carbon markets.

Agroforestry and FMNR offer promising pathways to reduce gender and social inequalities in both northern Nigeria and Ghana. However, achieving this potential requires addressing socio-cultural and legal barriers through targeted interventions that empower women, improve their access to resources, and strengthen their roles in value chains. Often however, this is a long-term process as behavioural and cultural changes can take time to embed and need to be supported by education and awareness raising efforts. Nevertheless, by doing so, agroforestry and FMNR offers considerable potential to contribute to more equitable and sustainable development in both regions, which will ultimately support CRD. At the same time, it is important to recognise that gender is only one characteristic that can contribute to marginalisation. Overall, an approach that takes into account intersectionality (the combination of

characteristics that can shape marginalisation, discrimination and privilege) will be necessary to target social inequalities through agroforestry and FMNR.

8. Barriers to transformational change in agroforestry and FMNR in northern Ghana and Nigeria

Transformational changes are those that can catalyse further changes or speed up change. The barriers to transformational change in agroforestry and FMNR identified by stakeholders in the workshops and interviews are consistent across both regions and hinder the rapid scaling and adoption of agroforestry and FMNR technologies. Advancing transformative change that leads to radical shifts in the rural farming system of both regions requires addressing the socio-cultural, legal, policy and governance, infrastructural, and knowledge, skills and capacity barriers among others, many of which are embedded within the wider system. The sections below consider innovation, evidence of effectiveness and capacity and capability.

8.1 Innovation

In terms of innovative technologies, stakeholders have identified the potential of technologies such as the introduction of grafted seedlings and quality seed varieties of Baobab, and domestication of native tree species, alongside local certification schemes to verify farmers' processed tree products. Grafted seedlings can reduce the time to fruiting of trees – providing quicker benefits to farmers. According to one of the workshop participants, the Ghana Forestry Research institute has developed a Shea tree variety that produces fruit in four years that is already available in the market. Shea is an important economic tree for women in northern Ghana, and there are reported declines in Shea trees in the region. While these ways forward may sound supportive to women, the challenges of access to land, affordability and accessibility of the grafted Shea seedlings will remain a challenge. Quality Baobab seeds have not yet been developed so sit at a low level of technology readiness and unlikely to speed up change. For now, Baobab can produce a lot of leaves that can serve as fodder for animals, while the fruits serve as food and medicine. However, overharvesting of the leaves can reduce fruit production. Farmers therefore require training on the appropriate pruning regime, whereby they harvest the leaves periodically.

Tree domestication is the process of selecting desirable tree species for breeding and cultivation. This process helps in preservation of the selected tree species. Most native tree species in both northern Ghana and Nigeria, such as *V. paradoxa, P. biglobosa, A. digitata, and Moringa oleifera,* have not been domesticated, and their fast decline could pose a threat to the loss of the diversity of these tree species. Domesticating these trees will ensure their preservation and diversity in both regions.

8.2 Evidence of effectiveness

Our scoping report findings suggest that there is not enough evidence yet to assess whether transformational change is likely in our topic area (agroforestry and FMNR), despite the identification of lessons that could be translated between Brazil and African contexts. For example, local peer-to-peer certification of farm products is a socially innovative approach that has been used in Brazil. This is a bottom-up participatory approach that supports local farmers to obtain local certification for their farm products – reducing costs and helping to achieve a market guarantee and price premium for certified products. This will support commercialisation of tree products for farmers, by

providing access to markets, which is a challenge to commercialisation in northern Nigeria.

The suggested innovations can support the transformation of agroforestry and FMNR in both northern Nigeria and Ghana, however, some of the systemic barriers outlined above will have to be addressed in order to support inclusive and fair access and adoption of such innovations, in line with the CRD enablers.

We have revealed several key technical knowledge gaps in terms of e.g. which crop and tree combinations work best together in the specific contexts of the case studies, which planting configurations and densities are appropriate and so on. Without proven knowledge as to what works in each context however, adoption and scaling to a transformational extent appears unlikely.

We used a climate resilient development lens in our analysis which recognizes the importance of four enablers: ecosystem stewardship, equity and justice, diverse knowledge and inclusivity. These enablers come from the IPCC's (9) AR6 Working Group 2 report which was written over a five-year period, involving 270 authors from 67 countries. The IPCC report contains over 34,000 cited references and incorporates 62,418 expert and government review comments. This provides a strong evidence base which points towards the ingredients for success in delivering climate resilient development which can usefully be applied to CSA. Evidence from our workshops in Brazil in particular showed strong agreement that these enablers are important in the success of their coffee agroforestry systems. Workshop participants reported that stakeholder engagement and dialogue from the outset of technology roll-out is needed, combined with knowledge co-creation and learning that combines science with local farmer experiences. At the same time, successes require public policies that incentivise shifts towards regenerative agroforestry practices. Together these factors spur people to care for the land and foster a sense of environmental stewardship.

8.3 Capacity and capability

Our analysis has demonstrated that many of the barriers are deeply rooted within the political, economic, social and cultural context of the countries in the scoping study. These human or societal aspects of the challenge are difficult to change over rapid timescales as behavioural changes take time to embed into society. Overall, our findings suggest that adoption and scaling of agroforestry is not a technical challenge, but rather, a socio-technical one. Addressing this requires interdisciplinary collaborations (which could include stakeholder groups and individuals from the networks we have developed within the scoping project) as well as multi-stakeholder partnerships, building from the strengths that each of the different types of stakeholders can bring, enhancing capacity and building a stronger evidence base.

Capabilities and potential will not be achieved in the absence of inclusive and equitable capacity building. The knowledge sharing during this study has provided a useful springboard to start to address capacity gaps, identify a research agenda targeting critical questions, and to draw attention to the importance of local knowledge in shaping uptake and scaling, considering the potential roles of key stakeholder groups. Nevertheless, further efforts are needed in this regard to overcome the identified barriers to transformation.

9. Conclusion

This project has built a trilateral network between the UK, Brazil, Ghana and Nigeria with a view to identifying opportunities for collaboration and knowledge sharing to promote climate-smart agriculture in the form of agroforestry and FMNR for sustainable food production systems in Ghana and Nigeria. Using a CRD lens, it has set out the major challenges, barriers and gaps to agroforestry and FMNR uptake and scaling in Ghana and Nigeria, considering relevant research, innovations, technologies and practices that could be shared across the countries involved to support transformation. Particular emphasis was placed on gender and exploring actions that could help to reduce gender and social inequalities. The project findings emphasise the importance of partnerships and collaborations in moving forward. We hope this report can inform innovators, researchers and funders as to the major knowledge and innovation needs in order to deliver the sustainable food production systems of the future.

10. References

1. Andoh, J., Acquah, S. B., Oduro, K. A., Obiri, B. D., Obeng, E. A., Guuroh, R. T., Opuni-Frimpong, E., Akpalu, S. E., Agyekum, C. K., Kusi, K. K., & Ofori, D. A. (2024). Drivers of deforestation and forest degradation and local capital assets in community resource management areas: Implications for REDD+. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-024-05415-6

2. Mohammed, U. K. (2022). Fuelwood Gap Theory: Exploring Fuelwood Source Regions in Northern Nigeria's Drylands. *AFRIGIST Journal of Land Administration and Environmental Management*, *2*(1), 1–16. https://doi.org/10.54222/afrigist/jgst/v2i2.1

3. Danjuma, M. N., Mohammed, S., & Karkarna, M. Z. (2018). Farmers' Participation in the Agroforestry System in Northwestern Nigeria. *Nigerian Journal of Environmental Sciences and Technology*, 2(2), 257–265. https://doi.org/10.36263/nijest.2018.02.0093

4. Usman, M., & Nichol, J. (2019). Trends in farmland tree stocks in the agroforestry landscape of northern Nigeria: Reconciling scientific and stakeholder perceptions. *Journal of Rural Studies*, 66, 87–94. https://doi.org/10.1016/j.jrurstud.2019.01.006

5. Kandel, M., Benamba, C., Alare, R. S., Agaba, G., & Schreckenberg, K. (2020). Achieving scalable and equitable resource governance in farmer- managed natural regeneration in northern Ghana. ETFRN News, 169-176. https://www.tropenbos.org/resources/publications/etfrn+news+60:+restoring+african+drylands

6. Tukur, R., & Rabi'u, M. (2013). Indigenous trees inventory and their multipurpose uses in Dutsin-ma Area Katsina. *European Scientific Journal.* 9(11) e-ISSN: 1857-7431.

7. Nigeria Workshop (2024). Agroforestry technologies and practices in Nigeria. *CSA Scoping Project for Innovate UK.*

8. Food and Agriculture Organization of the United Nations (FAO) (2011). State of the World's Forests. Rome, FAO. *Available at:* https://www.fao.org/4/i2000e/i2000e00.htm

9. IPCC (2022): *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp

10. Muschler, R. (2016). Agroforestry: Essential for Sustainable and Climate-Smart Land Use? *Tropical Forestry Handbook, Second Edition*, 2013–2116. https://doi.org/10.1007/978-3-642-54601-3_300

11. Rosenstock, T. S., Dawson, I. K., Aynekulu, E., Chomba, S., Degrande, A., Fornace, K., Jamnadass, R., Kimaro, A., Kindt, R., Lamanna, C., Malesu, M., Mausch, K., McMullin, S., Murage, P., Namoi, N., Njenga, M., Nyoka, I., Paez Valencia, A. M., Sola, P., Steward, P. (2019). A Planetary Health Perspective on Agroforestry in sub-Saharan Africa. *One Earth* 1(3), 330–344. https://doi.org/10.1016/j.oneear.2019.10.017

12. Food & Agriculture Organization of the United Nations (FAO) (2013). Climate Smart Agriculture Sourcebook. *Available at:* https://www.fao.org/climate-smart-agriculture-sourcebook/en/

13. Gupa, M. A., Bello, A. G., Nasir, A. M., & Barau, A. A. (2023). Agroforestry as a Strategy for Livelihood Resilience to Socially Destabilized Area of Borno State, Nigeria. *International Journal of Agriculture, Food and Biodiversity*, 2(2), 1–7. *Available online at:* https://journals.unizik.edu.ng/ijafab/article/view/4175

14. Opoku Mensah, S., Ibrahim, S.-K., Jacobs, B., Cunningham, R., Owusu-Ansah, D., & Adjei, E. (2024). Benefits of farmer managed natural regeneration to food security in semi-arid Ghana. *Agriculture and Human Values*, 41(3), 1177–1193. https://doi.org/10.1007/s10460-024-10546-7

15. Ndaginna, I., & Bryce, M. (2022). Farmer-managed natural regeneration (FMNR) on Nigeria's drylands: The influence of changing climate on agroforestry trees management. *XV World Forestry Congress 2-6 May 2022,* Coex, Seoul, Republic of Korea.

16. Akpalu, S. E., Anglaaere, L., Damnyag, L., Dawoe, E. K., Abunyewa, A. A., & Akpalu, M. M. (2022). Floristic composition of agroforestry parklands in the semi-arid zone of Ghana: A special focus on *Faidherbia albida* (Delile) A. Chev. *Trees, Forests and People*, 9, 100310. https://doi.org/10.1016/j.tfp.2022.100310

17. Kandel, M., Agaba, G., Alare, R. S., Addoah, T., & Schreckenberg, K. (2021). Assessing Social Equity in Farmer-Managed Natural Regeneration (FMNR) Interventions: Findings from Ghana. *Ecological Restoration*, 39(1–2), 64–76. https://doi.org/10.3368/er.39.1-2.64

18. Abukari, A. (2019). Contribution of agroforestry to improving food security in the sagnarigu district of northern Ghana. *Agriculture and Forestry Journal 3:1 pp. 1-5, e-ISSN 2602-5795. Available online at:* http://ojs.univ-tlemcen.dz/index.php/AFJ/

19. Kent, R. (2018). “Helping” or “Appropriating”? Gender Relations in Shea Nut Production in Northern Ghana. *Society & Natural Resources*, 31(3), 367–381. https://doi.org/10.1080/08941920.2017.1382626

20. Renard, D., and Tilman, D. (2019). National food production is stabilized by crop diversity. *Nature* 571, 257–260. https://doi.org/10.1038/s41586-019-1316-y

21. Poudyal, M. (2011). Chiefs and Trees: Tenures and Incentives in the Management and Use of Two Multipurpose Tree Species in Agroforestry Parklands in Northern Ghana. *Society & Natural Resources*, 24(10), 1063–1077. https://doi.org/10.1080/08941920.2010.523059

22. Favretto N, Dallimer M, Stringer LC, Ado S, Baba Yakubu I, Jibrin JM, Barau A. (2021). Harnessing benefits for climate change mitigation through irrigation free indigenous tree restoration: sharing knowledge and building capacity. Best practice guidelines manual: *Version for institutional stakeholders*. *UK and Nigeria: University of Leeds and Bayero University Kano. Available at:* https://environment.leeds.ac.uk/research-project/123/sustainability-research-institute/1693/harnessing-benefits-for-climate-change-mitigation-through-irrigation-free-indigenous-tree-establishment-sharing-knowledge-and-building-capacity

23. Akodéwou, A., Madi, O. P., Ambomo Tsanga, F., Rousgou, R., & Peltier, R. (2024). Three decades of *Faidherbia albida* agroforestry in Far North Region, Cameroon. *Tropical Forest Issues*, *62*. https://doi.org/10.55515/BTBP7343

24. Abasse, T., Massaoudou, M., Ribiou, H., Idrissa, S., & Guimbo Iro, D. (2023). Farmer managed natural regeneration in Niger: The state of knowledge. *Tropenbos International.* https://doi.org/10.55515/BYIZ5081

25. Reij, C., & Garrity, D. (2016). Scaling up farmer-managed natural regeneration in Africa to restore degraded landscapes. *Biotropica*, 48(6), 834–843. https://doi.org/10.1111/btp.12390

26. Teodoro, A. G., Rodrigues, L. M., Rocha, J. H. T., Santos, A. J. M., Backes, C., Lopes, L. C. A., Ribon, A. A., Giongo, P. R., & Fernandes, P. B. (2023). Effects of tree species and planting density on the total yield of an agroforestry system

in the Brazilian Cerrado. *New Zealand Journal of Agricultural Research*, 1–14. https://doi.org/10.1080/00288233.2023.2274409

27. Santos, D. de C., Guimarães Júnior, R., Vilela, L., Maciel, G. A., & França, A. F. de S. (2018). Implementation of silvopastoral systems in Brazil with Eucalyptus urograndis and *Brachiaria brizantha*: Productivity of forage and an exploratory test of the animal response. *Agriculture, Ecosystems & Environment*, 266, 174–180. https://doi.org/10.1016/j.agee.2018.07.017

28. Souza de Paula, A., S fair, J. C., Trindade, D. P. F., Rito, K. F., Tabarelli, M., & Barros, M. F. (2023). The role of seed rain and soil seed bank in the regeneration of a Caatinga dry forest following slash-and-burn agriculture. *Journal of Arid Environments*, 211, 104948. https://doi.org/10.1016/j.jaridenv.2023.104948

29. Brazil Workshop (2025). Agroforestry technologies and practices in Brazil. *CSA scoping project, Innovate UK*

30. Carvalho, J.L.N., Raucci, G.S., Frazão, L.A., Cerri, C.E.P., Bernoux, M., Cerri, C.C., (2014). Crop-pasture rotation: a strategy to reduce soil greenhouse gas emissions in the Brazilian Cerrado. *Agriculture Ecosystem Environment* 183, 167–175. https://doi.org/10.1016/j.agee.2013.11.014

31. Ferraz, J.B.S., Felício, P.E.D., (2010). Production systems - an example from Brazil. *Meat Science Journal* 84 (2), 238–243. https://doi.org/10.1016/j.meatsci.2009.06.006

32. Dias-Filho, M.B., (2014). Diagnosis of pastures in Brazil. Embrapa Amazônia Oriental (Document 402), Belém, *PA, p. 38. Electronic version (2014) Available online at:* www.cpatu.embrapa.br/publicacoes_online

33. Embrapa (2016). LPF em números. *Retrieved on July 1, 2017, from Embrapa website. Available online at:* https://www.embrapa.br/busca-de-publicacoes/-/publicacao/1064859/ilpf-em-numeros

34. Fagariba, C. J., Song, S., & Soule Baoro, S. K. G. (2018). Climate Change Adaptation Strategies and Constraints in Northern Ghana: Evidence of Farmers in Sissala West District. *Sustainability*, 10(5), 1484. https://doi.org/10.3390/su10051484

35. Bayala, J., Sanou, J., Bazié, H. R., Coe, R., Kalinganire, A., & Sinclair, F. L. (2019). Regenerated trees in farmers' fields increase soil carbon across the Sahel. *Agroforestry Systems*. https://doi.org/10.1007/s10457-019-00403-6

36. Ghana Workshop (2025). Agroforestry technologies and practices in Ghana. *CSA scoping project, Innovate UK*

37. Pienaah, C. K. A., Baruah, B., & Luginaah, I. (2024). Women's perspectives on addressing the decline of Shea trees in Northern Ghana. *GeoJournal*, 89(1), 9. https://doi.org/10.1007/s10708-024-11023-8

38. Zira, B. D., & Gupa, M. A. (2020). Determinants of Agroforestry Practitioners Income in Semi-Arid Region of Nigeria. *Asian Journal of Agricultural Extension, Economics & Sociology*, 67–72. https://doi.org/10.9734/ajaees/2020/v38i230311

39. Yaro, J. A. (2006). Is deagrarianisation real? A study of livelihood activities in rural northern Ghana. *The Journal of Modern African Studies* 44 (1):125–156. https://doi.org/10.1017/S0022278X05001448

40. Etemike, L., Efanodor, H., (2015). Contemporary globalisation and the rural economy in Nigeria. *American International Journal of Social Science* 4(3), 14-27. ISSN 2325-4165 (Online). Center for Promoting Ideas, USA. *Available online at:* www.aijssnet.com

41. Favretto N, Dallimer M, Stringer LC, Ado S, Baba Yakubu I, Jibrin JM, Barau A. (2022). Tree restoration, climate change mitigation and cross-sectoral policy coherence in Nigeria. UK and Nigeria: *University of Leeds and Bayero University Kano. Available online at:* https://spiral.imperial.ac.uk/server/api/core/bitstreams/057ae6c0-20ed-4c8f-b454-270f7d1b2524/content

42. Omokhafe., O. K. (2019). Climate Smart Gum Arabic Crop Investment in Arid Zones: An Agroforestry Model in Nigeria. *Specialty Journal of Geographical and Environmental Science*, 3 (3–2019). *Available online at:* www.sciarena.com

43. Soeters, S., R. Weesie and A. Zoomers. (2017). Agricultural investments and farmer-Fulani pastoralist conflict in West African drylands: A northern Ghanaian case study. *Sustainability* 9: 2063. https://doi.org/10.3390/su9112063

44. Tonah, S., (2002). Fulani pastoralists, indigenous farmers and the contest for land in Northern Ghana. *Africa Spectrum* 37:43–59. Stable URL: http://www.jstor.com/stable/40174917

45. Weston, P., R. Hong and V. Morrison. (2013). End-of-phase evaluation report. World Vision Australia/Ghana. *Available online at:* https://www.worldvision.com.au/docs/default-source/meta-evidence-briefs/evidence-of-impact-farmer-managed-natural-regeneration.pdf?srsltid=AfmBOor2SaKfmsKTUymXHE4kAPm4NlMTwn1oQ4BaKOsdroMtosqjYEWw

46. Nigeria Inform Risk Index (NIRI, 2020). Annual Report: from Office of the Coordination of Humanitarian Affairs (OCHA). *Available online at:* https://www.unocha.org/publications/map/nigeria/nigeria-inform-risk-index-2020-october-2020

47. Akaateba, M.A., (2019). The politics of customary land rights transformation in peri-urban Ghana: Powers of exclusion in the era of land commodification. *Land Use Policy* 88:1–10. https://doi.org/10.1016/j.landusepol.2019.104197

48. Ministry of Lands and Natural Resources. (2016). Tree Tenure and Benefit Sharing Framework in Ghana. Accra, Ghana. *Terms of reference for the ministry of land and natural resources draft document. Available online at:* https://documents1.worldbank.org/curated/en/188161468250870735/text/E4204v10Ghana000220201300Box374390B.txt

49. Taillandier, C., Cörvers, R., & Stringer, L. C. (2023). Growing resilient futures: Agroforestry as a pathway towards climate resilient development for smallholder farmers. *Frontiers in Sustainable Food Systems*, *7*, 1260291. https://doi.org/10.3389/fsufs.2023.1260291

50. Apusigah, A. A. (2009). The gendered politics of farm household production and the shaping of women's livelihoods in Northern Ghana. *Feminist Africa* 12 (12):51–67*. Available online at:* https://www.jstor.org/stable/48725911

Acknowledgements

Thank you to Dr Eleanor Jew and Tchiyiwe Moyo who assisted with workshop facilitation, and our key institutional partners in Nigeria at Bayero University Kano Centre for Dryland Agriculture (Prof Aliyu Barau and Prof Jibrin M. Jibrin), in Ghana Forum for Agricultural Research in Africa (Abdulrazak Ibrahim) and CSIR-Savanna Agricultural Research Institute (Isaac Kodzo Amegbor), and Brazil Federal University of Viçosa (Prof Heitor Mancini Teixeira).