THE ECONOMICS OF LAND DEGRADATION

The Case for Farmer Managed Natural Regeneration (FMNR) in the Upper West Region of Ghana

An Economics of Land Degradation study carried out in the framework of the “Reversing Land Degradation in Africa by Scaling-up Evergreen Agriculture” project

www.eld-initiative.org

Main authors:
Vanja Westerberg, Angela Doku, Lawrence Damnyag

Contributing Authors:
Gordana Kranjac-Berisavljevic, Stephen Owusu, Godfred Jasaw, Edward Yaboah, Salvatore Di Falco

Reviewers:
Romano De Vivo
Richard Thomas

Editor:
Jenifer Provost

Visual Concept: MediaCompany, Bonn Office
Layout: warenform, Berlin

Photography:
Vanja Westerberg & Daniel Banuoko

Acknowledgements:
Numerous organisations and individuals have provided invaluable input for this study. In particular, we are thankful for the scientific and/or logistic support provided by Fred Nimoh from Kwame Nkrumah University of Science and Technology; Professor Edward Yeboah from the Soil Research Institute; Fidel Apraku from the Ministry of Forestry and Agriculture; Beatrice Dossah from the Environmental Protection Agency; Bugre Rexford Yamdorg from World Vision; Frederick Dayour and Josephine Yuora Terkpeng of the University for Development Studies; Niklas Seipel and Luis Costa, Altus Impact associates; James Ellison and Stephanie Solf from GIZ in Wa; and the ELD secretariat, in particular Lara Beisiegel, Maya Suzuki and Carina Maria Bock. We are also highly grateful to CIKOD - namely, the Deputy Director, Daniel Faabelangne Banuoku and Samuel Faamuo Tampulu for providing access to project sites and expert advice on farming techniques and policy issues. We are also grateful to the many farmers who participated in the household survey and focus group discussion as well as the interviewers, Adam Mujeeb-Rahman, Abass Asani, Donatus Dunne, Abraham Dayour, Sebastian Batasuma Dari Vincent Buobodaare, Vitus Gala, Ernestina Buunaaisie, Issahaque Ibrahim and Mubarak A. Yasannah from the University for Development Studies (UDS). Finally, we owe our sincere gratitude to the European Commission and the German Federal Ministry for Economic Cooperation and Development (BMZ), who provided the funding for this study.

Suggested citation:
Vanja Westerberg, Angela Doku, Lawrence Damnyag, Gordana Kranjac-Berisavljevic, Stephen Owusu, Godfred Jasaw, Edward Yaboah, Salvatore Di Falco (2019). Reversing Land Degradation in Drylands: The Case for Farmer Managed Natural Regeneration (FMNR) in the Upper West Region of Ghana. Report for the Economics of Land Degradation Initiative in the framework of the “Reversing Land Degradation in Africa by Scaling-up Evergreen Agriculture” project.

Available from: www.eld-initiave.org

The Case for Farmer Managed Natural Regeneration (FMNR) in the Upper West Region of Ghana

An Economics of Land Degradation study carried out in the framework of the “Reversing Land Degradation in Africa by Scaling-up Evergreen Agriculture” project

January 2019

www.eld-initiative.org

List of Abbreviations

ADB	Asian Development Bank
AfDB	African Development Bank
BMZ	German Federal Ministry for Development and Economic Cooperation
CBA	Cost Benefit Analysis
CIKOD	Center for Indigenous Knowledge and Organisational Development
CIFOR	Center for International Forestry Research
CSIR	Council for Scientific and Industrial Research
EC	European Commission
ELD	Economics of Land Degradation
EPA	Ghana Environmental Protection Agency
FMNR	Farmer Managed Natural Regeneration
FAO	Food and Agriculture Organization of the United Nations
GHS	Ghanaian cedi
GIZ	German International Development Cooperation
GSIF	Ghana Strategic Investment Framework
Ha	Hectare
ICRAF	World Agroforestry
IRR	Internal Rate of Return
kg	kilogram
LDN	Land Degradation Neutrality
MLFM	Ghana Ministry of Lands, Forestry and Mines
MOFA	Ghana Ministry of Food and Agriculture
MSE	Mean squared error
NGO	Non-government organisation
NPK	Nitrogen, Phosphorous, Potassium
NPV	Net Present Value
NTFPs	Non-Timber Forest Products
PV	Present Value
r	Real discount rate
SDG	Sustainable Development Goal
SLM	Sustainable Land Management
UDS	University for Development Studies
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar

Table of Contents

List of Tables

List of Figures

About the ELD Initiative and the "Reversing Land Degradation in Africa through Scaling-up Evergreen Agriculture" project

Land degradation, desertification, and droughts are widespread global issues that increasingly threaten the future of our environment. They lead to a loss of services from land and land-based ecosystems that are necessary for human livelihoods and economic development. Food production, water availability, energy security, and other services provided by intact ecosystems are jeopardised by the ongoing loss of land and soil productivity.

Desertification already affects around 45 per cent of the African continent (ELD Initiative 2017), indicating an urgent need for action. Failure to act on this threat will have severe negative impacts on economies and sustainable development opportunities.

The Economics of Land Degradation (ELD) Initiative is a global initiative established in 2011 by the European Union (EU), the German Federal Ministry for Economic Cooperation and Development (BMZ), and the United Nations Convention to Combat Desertification (UNCCD). The Initiative provides specific scientific support to decision-makers on national and international levels. A broad network of partner experts and institutions supports the Initiative, which aims at transforming the global understanding of the economic value of productive land and improving stakeholder awareness of socio-economic arguments to promote sustainable land management.

The ELD Initiative provides ground-truthed tools and assessments that allow stakeholders to undertake cost benefit analyses of land and land-uses through total economic valuation and include this information in decision-making. The ELD Secretariat coordinates the Initiative, which is hosted by the Sector Project BoDeN within the German International Cooperation (GIZ) in Bonn, Germany.

Land degradation is explicitly included in objective 15 of the United Nations' sustainable development goals (SDGs) which were adopted in 2015. SDG 15 aims at *"protecting, restoring and promoting sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss"*.

Objectives 15.3 and 15.9 aim at achieving land degradation neutrality as well as integrating ecosystems and biodiversity values into national and local planning. On an international level, the United Nations Convention to Combat Desertification (UNCCD) has been appointed as a custodian agency for SDG 15.3 and – by developing economic arguments – the ELD Initiative complements the work of the scientific and technical committee of the convention.

Land degradation is a complex and detrimental problem that affects many aspects of human life. Therefore, it cannot only be eliminated by implementing some technical or technological measures. The fight against degradation instead requires holistic measures that will simultaneously enable to reduce poverty (SDG 1), improve food security (SDG 2), manage water and wastewater sustainably (SDG 6), enhance economic development (SDG 8), encourage sustainable consumption and production (SDG 12), improve adaptation to climate change (SDG 13), and contribute to freedom and justice (SDG 16).

The project *Reversing Land Degradation in Africa by Scaling-up EverGreen Agriculture* started in 2017 and aims to improve livelihoods, food security, and climate change resilience by restoring ecosystem services. The project's target countries are Ethiopia, Ghana, Kenya, Mali, Niger, Rwanda, Senegal, and Somalia. The EU and BMZ co-financed the action. It is carried out jointly by the ELD Initiative and the World Agroforestry Centre (ICRAF).

The role of the ELD Initiative within this project is to raise awareness of the threats and opportunities of different land-use options by supporting and communicating cost benefit analyses in each target country. Simultaneously, the Initiative extends the capacity of national institutions and experts in assessing economic benefits of investments in sustainable land management in consideration of land degradation costs.

The present report has been developed in the framework of such a process on a national level. It provides decision-makers with scientific information on the economic consequences of land degradation and possible pathways to improved rural livelihoods and land regeneration.

Key scientific findings

Farmer Managed Natural Regeneration (FMNR) is a low-cost land restoration technique used to combat land degradation amongst subsistence farmers. In FMNR systems, farmers use pruning to encourage the growth of trees and shrubs that occur naturally in their fields. It involves selecting and protecting the most vigorous stems and managing threats to remaining branches from livestock, fire and competing vegetation. Trees and crops grown together provide multiple benefits to farmers, crops, climate and wildlife.

With the assistance of the local NGO, Center for Indigenous Knowledge and Organisational Development (CIKOD), FMNR has been used by farmers since 2014 to regenerate degraded agricultural lands in the Lawra and Nandom districts of the Upper West Region of Ghana. With the careful management and prevention of bush fires, FMNR counters traditional slash-and-burn practices.

To analyse the impact of FMNR on farmer livelihoods and in order to quantify the results, applied researchers from Altus Impact, the University of Geneva, the University for Development Studies, the Council for Scientific and Industrial Research, and the Kwame Nkrumah University of Science and Technology in Ghana conducted an ELD study as part of the "Reversing Land Degradation in Africa by Scaling-up Evergreen Agriculture" project in the course of 2019. The key findings are summarised in the following:

- **FMNR constitutes a long-term investment in soil quality.** Through the use of FMNR and crop rotation, farmers can increase productivity of their cropland by an estimated 83 per cent within five years. As tree density increases so does the crop yield. A typical FMNR farmer in the Lawra district has 13 trees per acre[1] (33 trees per hectare), with a minimum of 4 different tree species and a typical non-FMNR farmer has 5 trees per acre (13 trees per hectare).

- **Farmers undertaking FMNR are significantly better off than conventional farmers.** In fact, by replacing slash and burn practices with FMNR in association with crop rotations,[2] farmers can earn an additional four Ghana cedis (GHS) from enhanced forest and crop produce for every Ghana cedi invested.

  The net present value of forest and crop produce where FMNR is adopted along with crop rotations is in the order of GHS 3,182 per acre over a 20-year horizon at 5 per cent discount rate, equivalent to an annuity of GHS 255 per acre per year (EUR 102/ha)[3]. For an average sized farm with 2.3 acres of land, this corresponds to GHS 587 (EUR 94) per year. This is a substantial amount, considering that the lower food poverty line, i.e. what is needed to meet the nutritional requirements of household members, is GHS 792 (EUR 126) per adult equivalent per year (Ghana Statistical Service 2018).

  When accounting for the societal costs, notably the training of fire fighters and lead FMNR farmers, the net present value benefit of adopting FMNR with crop rotations is GHS 2,395 per acre over a 20-year horizon. For every Ghana cedi invested, society enjoys three Ghana cedis of return when accounting for direct provisioning services alone (i.e. enhanced forest and crop produce). As numerous other ELD studies have shown, there are also wider societal benefits associated with sustainable land management, such as enhanced carbon sequestration and aquifer replenishment (e.g. Sibidé et al. 2015; Westerberg & Myint 2015). It was beyond the scope of this study to assess these additional benefits, but the total societal benefits of FMNR are therefore likely to be considerably larger than those estimated here.

---

1 *1 hectare = 2.5 acres. Throughout this paper, we are using acres as that is the measure of land size used conventionally by farmers in the study area.*

2 *Referred to as the FMNR & SLM scenario in the report.*

3 *Using the following conversions: 1 GHS/acre = 0.4 EUR/hectare on the basis that 1 acre=0.4 ha and GHS 1 = EUR 0.16.*

Returns to FMNR and SLM	Financial perspective Farmer	Economic perspective Society*
Net present value (NPV) of which:	3,182	2,395
NPV from enhanced crop production (GHS/acre)	786	NA
NPV from enhanced forest products (GHS/acre)	2,396	NA
Net benefit per year per acre (GHS/acre/year)	255	192
Net benefit per year per farm (GHS/farm/year)	587	442
Benefit cost ratio	3.8	2.7
Internal rate of return	33%	26%
Conclusion from indicators	**YES**	**YES**

*Accounting for the societal costs of implementing FMNR (training and materials by CIKOD) and provisioning ecosystem service benefits from forest and crop products. In reality however, FMNR provides additional societal benefits, such as enhanced carbon sequestration and erosion control, that have not been accounted for here.

- **FMNR communities are considerably more food secure and climate resilient.** In qualitative terms, focus groups discussions showed that FMNR farmers are more food secure relative to non-FMNR farmers since they can harvest a wide range of on-farm forest products (fruits, nuts and pods) during the dry season when they otherwise would face food shortages. The average present value of enhanced forest produce (e.g. ebony fruits, shea nuts, dawadawa seeds, mango fruits and fuelwood) as a result of adopting FMNR is in the order of GHS 190 per acre per year.

Climate change poses an increasingly severe challenge to agricultural livelihoods due to an increased frequency and intensity of extreme weather events. Thus, income diversification plays a crucial role in reducing food insecurity and vulnerability under these challenges.

The Upper West Region has the highest poverty incidence rate in Ghana and agriculture employs more than 80 per cent of the active workforce. For this reason, farmers should be given priority for pro-poor policy targeting (Ghana Statistical Service 2018). Awareness raising and investments into FMNR are promising strategies.

Recommendations to specific stakeholder groups

On the basis of the study results, a number of recommendations to land users, NGOs, development organisations, lending institutions and policy makers have been developed. These have been derived from the study itself and as a result of recommendations from an FMNR policy workshop held in Accra on the 27th of November 2019, where study results were presented and discussed with relevant stakeholders.

Key recommendations to land users

Recommendation 1: Invest in Farmer Managed Natural Regeneration (FMNR) for long term returns

The reduction and careful management of fires will help farmers regenerate indigenous high-value tree species that contribute to enhanced crop productivity of maize, sorghum, groundnut, beans and millet, as trees can help regenerate and retain soil fertility.

- In this way, farmers can also improve nutrition and calorie intake (e.g. from dawadawa seeds, ebony and mango fruits) and ensure more stable income during the year.
- In present value terms, farmers stand to make GHS 255 more per year per acre of farmland (EUR 102/ha). This means that for every Ghana cedi spent on regenerating tree cover, farmers can make four Ghana cedis of additional benefits.
- The payoff period is 3.3 years, implying that shortly into the third year after starting the practice of FMNR, farmers will have recovered their additional expense and will enjoy higher yearly incomes than the farmers who do not regenerate trees.

Recommendation 2: Intercrop with legumes for higher agricultural productivity

Maize is a popular crop in the study area, but it demands a constant supply of minerals as it grows. To keep soils healthy and nutrient-rich, it is recommendable for farmers to:

- Intercrop maize with legumes, like beans or groundnuts, which increase soil nitrogen. Additionally, an average farmer can make a considerable improvement in his crop revenues by GHS 140 per acre (EUR 56/ha) when intercropping with legumes. Approximately one third of farmers in the case-study area plant maize as mono crop. This proportion is likely to be higher for the Upper West as a whole and where CIKOD is not operating.

Recommendation 3: Other SLM activities can be adopted to build the long-term health of soils:

- Farmers using tied ridges, mounds and mulching, earn at least GHS 100 more per acre (EUR 40/ha) of farmland managed than those who don't use these land management practices.
- Composting needs to be of sufficient quality to make a difference in terms of agricultural productivity.
- Healthy soils are more resilient to weather shocks. Sustainable land management can improve farmers' ability to adapt to a diverse range of shocks and overcome unforeseen events. The sale of on-farm forest products can also provide a safety net in the face of adverse events.

Key recommendations to NGOs, international development aid organisations, and rural lending institutions

Recommendation 1: Focus on Farmer Managed Natural Regeneration (FMNR)

Re-greening through FMNR is an efficient way to regenerate the productivity of farmlands, improve farmer incomes, and address the chronic food shortages during the dry season, as many indigenous trees provide valuable produce during that period. With more than 80 per cent of the working population engaged in subsistence agriculture in the Upper West Region, improving farming practices through FMNR should be considered as a priority intervention sector.

Recommendation 2: Empower community leaders and focus on fire management

Effective fire management hinges on exemplary leadership among village chiefs, awareness about the consequences of uncontrolled fire, and community cohesion. For this purpose, any initiative that serves to train village chiefs in fire management and leadership abilities will help foster the necessary foundation for effective FMNR adoption, as seen for example in the Gozori community in the Upper West Region.

Additionally, community cohesion can be promoted through participatory processes and the creation of 'communal conservation areas'. This was successfully done by CIKOD in the Kalsagri and Paavu communities in the Lawra district, where the FMNR practices were first piloted on highly degraded communal land. FMNR also helped to resolve disputes between the two communities.

Recommendation 3: Focus on monitoring and tracking changes to help improve access to investment capital
Given the scale of the challenges posed by land degradation and climate change, it is essential that private investment is used to mitigate and adapt to these circumstances. Organisations involved in promoting FMNR should make the business case for regreening investments and show that these pay off.

This requires detailed tracking and monitoring of the costs associated with implementing FMNR, as well as the benefits of FMNR for governmental and non-governmental organisations and farmers. By assisting selected FMNR and non-FMNR farmers in keeping track of their costs, revenues and profits, an evidence base may be built, which will help convince donor, government and lending institutions that FMNR is a low-cost investment with significant economic returns.

Recommendation 4: Improve coverage of rural credit
Rural credit is limited in the Upper West Region, reflecting the high cost of service delivery, but also the perceived 'high risk' associated with agricultural lending. In the Lawra district, the terms of most loans range between three months and one year, with interest rates in the order of 20 per cent and higher. Short-term loans for agricultural inputs do not allow for repayment from the sale of forest produce that may be harvested several years after a farmer adopts FMNR.

Lending institutions (credit unions, rural banks, money lenders, etc.) should therefore be encouraged to supply adequate short, medium and long-term financing for FMNR. At the same time, access to 'patient capital' at lower interest rates can be promoted by empowering farmers to document their returns from FMNR and through the development of mobile banking. Finally, further research is needed amongst rural lending institutions in the Upper West Region to understand how these institutions assess whether a project is viable.

Key recommendations to public decision-makers

Recommendation 1: Focus on Farmer Managed Natural Regeneration (FMNR) to meet international commitments. FMNR contributes significantly to:

- Nationally determined contribution objectives under the United Nations Framework Convention on Climate Change (UNFCCC), such as land-based mitigation plans including wildfire management in the transition and Savanna drylands of Ghana.
- National land degradation neutrality targets under the United Nations Convention to Combat Desertification (UNCCD), such as the rehabilitation and sustainable management of degraded shrubs, sparsely vegetated areas for improved production, and reduction in bush and wildfires by 2030.
- United Nations Sustainable Development Goal (SDG) 1 No Poverty; SDG 2 Zero Hunger; SDG 13 Climate Action; and SDG 15 Life on Land.

Recommendation 2: Integrate agriculture and evergreen farming into school curriculums
Considering that farming is the backbone of the Ghanaian economy, it is of relevance to integrate agricultural subjects into school curriculum. Since 2017, the emphasis has been on environmental science but with very limited content on farming.

Recommendation 3: Manage bush fires and encourage cooperation between the Ministry of Food and Agriculture and the Forestry Commission in extension service provision
Preventing large-scale bush fires depends on good fire management frameworks that build on participatory processes and are suited to local conditions. Aggressive anti-fire policies have not been effective in Ghana or in West Africa as a whole. They have often resulted in distrust and hostility between government agents and community members (Laris and Wardell 2006). However, the effective management of fires is crucial to improve long-term soil fertility and to regenerate biomass as well as maintain

indigenous tree species that are becoming increasingly rare in the Upper West Region.

To ensure upscaling of FMNR and its wider economic and environmental benefits, knowledge of participatory fire management and fire reduction techniques should be mainstreamed into the agricultural extension services under the Ministry of Food and Agriculture (MOFA) and the activities of the Forest Services Division of the Forestry Commission of Ghana. Those efforts should also target tree growers outside forest reserves in Ghana. For that purpose, enhanced cooperation between the Ministry of Food and Agriculture, the Forestry Commission, and the Forestry Research Institute of Ghana is necessary. It is also important that FMNR and basic forestry concepts are integrated into the curriculum of agricultural colleges.

Recommendation 4: Use economic instruments to promote FMNR and develop more inclusive agricultural programmes

Today, FMNR efforts are mostly led by NGOs, while government-led agricultural programmes focus on the promotion of conventional (i.e. input intensive) and mechanised farming in the Upper West Region. There is a case for re-thinking existing programmes that support Agriculture in the Upper West, notably those that focus on the use of heavy tractors, which require a leveled farmland to operate effectively. Instead, it is relevant to subsidize machinery and equipment that is adapted to FMNR as well, such as smaller tractors and cultivators, one-row or hand-held planters, roller-crimpers for conservation agriculture and bullock plows using animal traction, and also extensive use of equipment such as cutlasses, wellington boots and protective gear.

Such wider government programmes would empower farmers to choose what agricultural practices to employ, according to their assets and preferences. For example, some parts of the Upper West Region are not considered suitable for mechanised farming with heavy machinery (Lawra, Wa West and Nadawli) because fields are small and farmers are poor. In these areas, FMNR is often the most promising option for improving agricultural productivity and income.

Along the same lines, public institutions and NGOs should speak with the same voice on the field in the dissemination of technologies like FMNR to avoid confusing farmers.

Recommendation 5: Reconsider NPK fertiliser dose recommendations and fertiliser subsidies

The Abuja Declaration on Fertilisers for an African Green Revolution and the National Fertiliser Subsidy Programme aim to increase fertiliser use from 12 kilograms (kg) per hectare (ha) to 20 kilograms per hectare (Government of Ghana 2019). We find no evidence that it is economically optimal for farmers in the Upper West Region. The agronomic use efficiency of fertiliser application depends on the dose and how it combines with other farming inputs and practices. When farmers in the Upper West Region spend beyond GHS 10/acre (approximately 10 kg of NPK/ha) revenues from additional yields are less than the additional costs spent on the fertilisers.

Currently, 50 per cent of farmers in the Lawra district use no fertilisers at all. The other 50 per cent who purchase fertilisers spend an average of GHS 110/acre, equivalent to 70 kg NPK/ha. This is not only costly for farmers but also for the nation. Imported and subsidised NPK fertiliser weighs heavily on the public treasury and the country's balance of payments. Moreover, farmers who are dependent on conventional fertiliser inputs will face steep increases in their production costs if subsidies come to an end, thus lessening their resilience.

Anecdotal evidence from the field also suggest that cheap inputs are prompting farmers to adopt quick and easy farming practices rather than experimenting with sustainable land management practices that improve long term soil health. The case for subsiding fertiliser and other inputs should therefore be reconsidered and it is recommended that fertiliser dosage recommendations are adapted to local conditions.

Recommendation 6: Government can play a role in covering funding gaps and lowering the risk of farming

In terms of access to rural finance, most farmers in the Lawra district have access to working capital at high interest rates. Working capital meets seasonal needs for inputs, labor and production services, but does not allow for repayment from the sale of forest produce.

There is a lack of longer-term credit and other financial services that are necessary for farmers to invest in asset acquisition for FMNR and Sustainable Land Management practices. Without access to the flexibility of investment capital, farmers cannot easily expand or upgrade their business or overcome unforeseen events.

The government can help leverage financing from banks to farmers through various mechanisms, such as credit guarantees, partnering with insurers to provide agricultural insurance and through the improvement of farmers' collateral. By facilitating investments in key assets for FMNR uptake, farm enterprises can grow and move to the next level.

Recommendation 7: Improve land and tree tenure and farmers collateral

The holders of allodial and freehold land titles under customary land ownership do not exercise ownership rights over naturally occurring trees in Ghana. It is the official right of the government to manage these trees both in and outside of forest reserves on behalf of the traditional authorities (Akapme 2016). As such, there is a need for policy and legal frameworks to be reformed so that ownership of naturally occurring timber trees of reserves is vested in the communities concerned. This would help motivate farmers and forest-adjacent communities to embrace forest management and conservation efforts for effective implementation of tree growth mechanisms and for the reduction of illegal logging (Akapme 2016). Availability of collateral (e.g. land titles or tree titles) would also have positive effects on farmers' access to credit, since hard collateral is typically required as protection against default.

In summary, our study shows that FMNR addresses multiple problems simultaneously, including: land degradation, soil infertility, food insecurity and fuel wood, timber and fodder shortages. By combining FMNR with other Sustainable Land Management practices, agricultural yields can be further improved. Moreover, well-conceived FMNR projects facilitate good governance, greater collaboration and community cohesion.

Significant obstacles to up-scaling of FMNR remain, however, ranging from lack of fire management, limited availability of rural credit, contradictory policy incentives and the absence of strong land and tree tenure rights for smallholder farmers. NGOs, the private sector and government agencies can address different aspects of the situation and help create an enabling environment for farmers to practice FMNR.

PHOTO:

Fuelwood harvesting from tree-prunings

Introduction

Across the Sudano-Sahelian belt and vast areas of the African Savannas, the preservation of culturally and traditionally relevant indigenous trees species along with the cultivation of land is an ancient practice (Cook and Grut 1989). Such agroforestry areas are often referred to as 'farmed parklands' (Cook and Grut 1989). However, during the past few decades, the degradation of parklands has been widely reported. Evidence of degradation has been shown in terms of reduced tree densities and population structure, ageing trees and lack of regeneration (Okullo et al. 2003). According to Chevalier (1946), the Sudanian Savanna zone had the highest density of shea trees in the 1940s with a population of 230 trees per hectare. Now it has been reduced to as few as 11 trees per hectare (Nikiema et al. 2003).

Ghana's deforestation rate is about 2 per cent per year, which is 135,000 hectares per year (Government of Ghana 2016; Forest Commission 2017a). According to the Global Forest Watch (2019) over the period 2001 to 2018, the Upper West region had the highest rate of forest cover loss in Ghana, followed by the Upper East and the Northern region.

The natural habitats of trees are being lost due to a combination of natural, socio-economic and political factors including widespread deforestation, the cutting of trees for firewood or charcoal, unviable farming practices such as shifting cultivation, and population growth. These activities result in shortened fallow periods, on which regeneration of indigenous species rely (Cemanski 2015).

Conflicting land-use activities, such as uncontrolled bush burning, extensive cattle grazing, and small-scale mining also contribute to the degradation of agricultural, range, and forest land (MOFA 2019). Agricultural programmes also tend to focus on mechanisation and the use of disc ploughing which mght be inappropriate for Savannah environments. Widespread land degradation and water erosion are observed from international development workers[1] (Ellison 2019, personal communication).

In addition, the northern regions of Ghana – especially the Upper East and Upper West – have experienced unusually high climate variability and ensuing floods, droughts, bushfires and storms within the last 30 years. Specific examples include the floods of 2007, 2008 and 2019 (Karbo et al. 2014; the Watchers 2019).

As a consequence of these developments, soil fertility and yields have declined in the Upper West Region (MOFA 2019), thus undermining food security. Moreover, this region is the third most impoverished region of Ghana, and with a limited resource and income base, farmers are particularly vulnerable to weather extremes. While agricultural output has grown at 5.5 per cent per year since 2001, it has been mainly driven by land expansion as opposed to agricultural intensification (FAO, IFAD and WFP 2015).

In light of these facts and the imminent importance of reversing the observed trend in land degradation, the Center for Indigenous Knowledge and Organization Development (CIKOD) – a community-focused NGO that began in 2014 – supports farmers in the Lawra and Nandom districts which are located in the northwestern part of the Upper West Region of Ghana. Both districts are profoundly affected by annual bush fires. With steeper slopes and higher population pressure than the southern parts of the region, soil erosion is a substantial problem in those districts (MOFA 2019).

CIKOD has been at the forefront of advocating for the use of indigenous knowledge systems and institutions of governance in the fight against poverty, hunger and disease in the country (Karbo et al. 2014). Their interventions in the Upper West Region started in 2014 with the purpose of regreening secondary forests, fallow lands and farmlands while simultaneously raising crop yields and incomes of subsistence farmers through the introduction of sustainable land management practices and FMNR strategies (Karbo et al. 2014).

1 Ploughing at a shallow depth (10-15 cm), when repeated for many years, means that a strong force is exerted downward. Eventually hardpans will develop even on light soils (Ellison 2019, personal communication).

1.1 Farmer Managed Natural Regeneration

FMNR seeks to reconcile sustainable food production, conservation of soils and protection of biodiversity. It involves selecting and protecting the most vigorous stems regrowing from living stumps of fallen trees or naturally growing tree-bushes, pruning off all other stems and pollarding the chosen stems to grow into straight trunks (Weston et al. 2015). Conventionally, regrowth undergoes slashandburn agriculture in the fields before each crop season. Since FMNR is the regrowth of living stumps, it is slightly different from the broad common understanding of 'agroforestry', which mainly refers to the planting of tree seedlings.

The existing literature on the impacts of FMNR is relatively sparse, especially considering the prevalence of the practice. According to Weston et al. (2015), FMNR as a practice is found everywhere in the Sahel and only differs in magnitude and tree density (Weston et al. 2015). Some of the most well-known examples are in Niger where smallholder millet-growing farmers in the southern part of the country have been protecting and managing trees and shrubs that regenerate spontaneously on their farmland (Larwanou et al. 2006). Nowadays, they have 20 to 60 trees per hectare whereas they only had 2 or 3 trees per hectare in the mid-1980s (Reij and Garrity 2016).

1.2 Types of ecosystems and the importance of FMNR to rural economies

FMNR is seen as a major contributor to the regreening efforts performed on areas affected by land degradation. When incorporated into farmlands, trees can help increase water infiltration into the soil and reduce soil temperatures, which in turn improves the annual yields of crops grown together on the land (Sidibé et al. 2015; Bayala et al. 2012). Tree cover also improves above and below ground carbon sequestration and reduces wind speed, hence protecting the crops (Westerberg et al. 2016). During the focus group discussions in our case study area, the local populations reported that perceived enhanced crop productivity and availability of on-farm forest products are the most valued benefits among farmers. Therefore, we focus on the value of these provisioning ecosystem services[2] when assessing the economics of FMNR, although the full range of ecosystem services is much broader. In the following, we review the existing evidence base for the role of forest products and synergies between trees and crop yields.

Forest products

Forest products are the backbone of rural household economies in sub-Saharan Africa, albeit often ignored in national income accounting and development planning. Timber and Non-Timber Forest Products (NTFPs) serve as energy sources, foodstuffs, medicinal products, construction materials, as well as equipment for agricultural activities (Cavendish 2000; Sheil and Wunder 2002; Vedeld et al. 2004). For instance, fruit trees can provide vital nutrients that may otherwise be scarce. Regular pruning of trees can increase fruit yields and reduce competition with crops (Musvoto et al. 1995). Other species, such as neem tree, ebony, or mahogany, are all excellent sources of lumber for construction (Jamnadass 2011). In the Guinean-type savanna of northern Ghana, the most important trees in the farmed parklands are the shea tree (*Butyrospermum parkii*) and the West African locust bean, also called dawadawa (*Parkia clappertoniana*). Such indigenous trees are naturally adapted to local soils and climates and can survive environmental stresses better than introduced species (McKay et al. 2005).

Finally, trees can also serve as essential buffers for households facing financial challenges. In the Talensi FMNR project in Ghana, farmers particularly valued the assurance of knowing that the value of timber stored in trees on household farms and communal reforestation plots could be cut and sold in a moment of need (Weston et al. 2013).

---

2 Nonetheless, we recognise that impact on crop yield is the result of changes in regulating ecosystem services – e.g. improved nutrient cycling and soil water retention - which in turn may boost crop yields.

Tree and crop yield synergies: existing evidence
In Niger, an estimated five million hectares have been regreened via FMNR. Balaya (2012) found that when tree cover is low, production of cereals is low (about 200 kg/ha). As tree density increases, yields reach 300 kg/ha. The highest yield was 500 kg/ha and usually occurred where FMNR had been used for quite some time. Thus, the doubling of yield is due to trees (Balaya et al. 2012) and can be attributed in large part to enhanced soil carbon (Balaya et al. 2019). In the Maradi Region of Niger, Haglund et al. (2011) found that crop production values of FMNR adopters were almost 60 per cent higher than of non-adopter. In Place and Binam (2013), crop yields in four West African dryland countries were between 15 and 30 per cent higher among FMNR adopters than non-adopters.

However, in the absence of pruning, it has been shown that yields of sorghum and millet under dawadawa and shea trees are lower compared to the yields in the open fields (Kessler 1992). The yield reduction is attributable to reduced light under trees but can be alleviated with pruning (Bayala et al. 2003). For example, in Burkina Faso, the highest millet and sorghum yields were found under totally crown pruned dawadawa and shea trees. Application of pruned shea leaves as mulch also had a positive effect on millet performance (Bayala et al. 2003; Teklehaimanot 2004).

When farmers are familiar with FMNR and begin to adopt it, the average costs per hectare of promoting on-farm natural regeneration are lower and they can produce fruit for decades without much further investment (Cemanski 2015; Reij and Garrity 2016).

1.3 International and national policy context

The promotion of FMNR and agroforestry are aligned with current national policy and development priorities in Ghana. As a signatory to the United Nations Convention to Combat Desertification (UNCCD) and herewith SDG target 15.3 on Land Degradation Neutrality, and as a member of the African Union's Great Green Wall initiative – a continental vision to halt desertification and land degradation – Ghana has demonstrated its commitment to enhance the sustainability of agricultural systems and combat land degradation.

Secondly, at the national level, policies and regulations to promote sustainable savanna woodland management are numerous (see Quansah 2017a, 2017b and 2017c for a comprehensive review). The first project dates back to 1993, when Ghana began implementing its National Environmental Plan under the Ghana Environmental Resource Management Project. Other more recent examples include the Ghana Strategic Investment Framework (GSIF) for Sustainable Land Management (SLM) (2009-2015). Its main goal is to 'improve natural resource-based livelihoods by reducing land degradation' through field-based programmes and projects; increasing capacity building of public and private sector SLM-related service providers; and improving the enabling policy, legal, institutional and financial environment for SLM. The GSIF is currently being revised for upscaling in order to include the Sustainable Development Goals (SDGs) as well as Ghana's Land Degradation Neutrality (LDN) targets.

In 2006, Ghana also developed a national wildfire management policy with the objective of 'developing and promoting integrated wildfire prevention and control practices based on appropriate technologies and systems' (MLFM 2006). According to Lignule (2017), the policy has mostly been implemented through public awareness raising programmes and through the training and equipment of fire volunteer groups. However, staff in fire management agencies and the members of local communities often lack adequate skills to conduct the participatory processes which are required to understand local fire issues and to conduct training in wildfire management (FAO 2011). Also, incentives such as clear land use rights for local people to derive direct benefits from responsible fire use are often lacking (Lignule 2017). Fire remains an obstacle to regreening and a main driver of land degradation; 60 to 90 per cent of nitrogen in plant biomass is lost during fires and the nutrients in ashes are blown away by the strong winds (Anslay et al. 2006).

Moreover, natural regeneration arguably runs contrary to the way that North Ghanaian agriculture has been evolving over the last 30 years as a result of policies and programs that have focused on conventional farming techniques and traditional mechanisation. For example, programmes and incentive packages targeting the farming sector are mainly restricted to subsidising fertilizer inputs, seeds and conventional tractors that do not include no/low-till options. The Planting for Food and Jobs (PFJ) programme provides highly subsidised inputs – e.g. seeds and fertilisers cost at 50 per cent of the market price (Agra 2019). In the view of local NGOs and international development workers this can undermine investments into sustainable land use practices (Banouko 2019, personal communication) and could possibly even encourage extensification on marginal lands that otherwise would not support farming (Ellison 2019, personal communication).

Public extension service provision is reported by the NGO CIKOD to be focused on the application of conventional farming inputs along with a limited set of sustainable land management practices such as composting (Banuoku, CIKOD, 2019, personal communication). See the discussion in Chapter 8 for more information. To further complicate matters, the Directorate of Agricultural Extension Services under the Ministry of Food and Agriculture (MOFA) is responsible for extension services to farmers. However, the activities related to FMNR (i.e. pruning, thinning, grafting, fire management, etc.) fall under the Forestry Services Division and Wildlife Division of the Forestry Commission (FSD & WD of FC) and are not covered by MOFA. Therefore, there is an urgent need to ensure more synergy between the activities and mandates of MOFA and FSD & WD of FC to ensure that woodland management techniques are extended to the farming sector.

In conclusion, the current implementation of the national policies and strategic plans outlined above could considerably contribute to regreening and fighting land degradation in Ghana. However, as highlighted by Kranjac-Berisavljevic et al. (2019), their active enforcement is lacking and their objectives are sometimes in contradiction to ongoing programmes.

1.4 Project objectives and contribution to existing literature

As part of the Regreening Africa study in Ghana, the Lawra district of the Upper West region, was selected as the case study area due to the low productivity of the farming sector, the recurrent climatic impacts and high deforestation rate. The presence of CIKOD however, has demonstrated that there is a road to prosperity and land regeneration.

PHOTO

A farm practising FMNR and using tied-ridges in the village of Kalsasgri in the Lawra district

This assessment therefore aims to analyse and strengthen the evidence base for FMNR as a cost effective means to fight land degradation and improve farmer livelihoods. Based on the impact of interventions led by CIKOD in the Lawra district, we have five years of solid evidence base upon which to conduct our impact assessment and cost-benefit analysis.

It should also be said that in addition to FMNR, CIKOD is promoting various sustainable land management practices, different from common practices such as composting and fertiliser use, that are taught by public extension service providers.

All of these activities have an impact on farmers' yields and revenues. Yet, to the best of our knowledge, no studies have untangled the effect of FMNR itself from other farming practices. In this study, we use production function modelling to assess the individual contribution of each farming input and land management practice to on-farm household income. This is a novel and important contribution to the existing literature.

We also look closer at the reasons motivating farmers to initiate FMNR and the main constraints on scaling up FMNR. This is done to understand how future policies should be designed in order to incentivise regreening farming practices. Moreover, we use experimental economics to elicit farmers' preference for present consumption versus future consumption. Such personal discount rates help us understand the payoffs that are necessary to incentivise farmers to adopt FMNR.

Our study complements an earlier work by Weston et al. (2015) that investigated a FMNR project led by World Vision in the district of Talensi in the semi-arid Upper East Region of Ghana. They employed a 'social return on investment' approach in order to identify which project outcomes created the most value in the lives of the project's key stakeholders. They found that FMNR was instrumental in securing the livelihoods of subsistence farming households, especially when considering both market and non-market outcomes. Furthermore, they showed that FMNR could increase household incomes by USD 887 per year, including the total value of social, health, environmental and economic benefits. In the Talensi district, FMNR farmers have an average tree density of 57 per hectare (from a baseline of five per hectare).

1.5 Partner institutions

A number of partner institutions in Ghana have been a part of the ELD study, as shown in Table 1. The University for Development Studies (UDS) in Wa, Ghana, organised and led the data collection for this study under the supervision of Dr. Godfred Seidu Jasaw and Dr. Gordana Kranjac-Berisavljevic. Moreover, focus groups were conducted by Lawrence Damnyag from the Council for Scientific and Industrial Research (CSIR) - Forest Research Institute, and Stephen Owusu from the CSIR – Soil Research Institute. Also, Beatrice Dossah from the Environmental Protection Agency (EPA) in Accra is the ELD Ghana Ambassador.

In order to undertake the field research and identify farmers engaged in FMNR, the fieldwork and focus group teams worked with Daniel Faabelangne Banuoku from CIKOD. As aforementioned, CIKOD is a NGO based in Wa and has conducted interventions in FMNR along with other SLM measures. World Vision and the Kwame Nkrumah University of Science and Technology (KNUST) have also provided valuable inputs. Lastly, throughout the study process, a core research group was formed and provided feedback and inputs on specific questions occurring during the analytical phase. We thank all members of the partner institutions who contributed to our study.

The remainder of the report is organised as follows: Chapter 2 present the case-study area; Chapter 3 presents the methods used for the valuation study; Chapter 4 describes the typical farming practices in the case-study area, as well as the drivers and obstacles to FMNR uptake; Chapter 5 uses empirical data from the ELD household survey to illustrate the economics of farming in the Lawra district and the various sustainable land management and farming inputs that are used by farmers.

In Chapter 6, we analyse the actual contribution of FMNR to agricultural productivity and in Chapter 7 the value of the enhanced forest produce is estimated. In Chapter 8, data from Chapters 6 and 7 is used to undertake the Cost Benefit Analysis. Finally, Chapter 9 discusses the results and draws conclusions on how to effectively up-scale FMNR practices.

TABLE 1:

ELD Ghana partner institutions

Partner institution	ELD member
Research Institutions	
University of Development Studies (UDS)	Godfred Seidu Jasaw (Fieldwork leader) Gordana Kranjac-Berisavljevic (Fieldwork leader) Benjamin Musah abu Dzigbodi Adzo Doke
Council for Scientific and Industrial Research (CSIR)	Professor Edward Yaboah, (Deputy Director of CSIR) Lawrence Damnyag (Forest Research Institute, focus group leader) Stephen Owusu (Soil Research Institute, focus group leader) Alhassan Nuhu Jinbaani (Savanna Agricultural Research Institute)
Kwame Nkrumah University of Science and Technology (KNUST)	Fred Nimoh Thomas Adjei-Gyapong
NGOs	
Center for Indigenous Knowledge and Organisational Development (CIKOD)	Daniel Faabelangne Banuoku
World Vision	Bugre Rexford Yamdorg
Government	
Environmental Protection Agency (EPA)	Beatrice Dossah (ELD Ambassador)
Ministry of Forestry and Agriculture (MOFA)	Fidel Apraku
GIZ Ghana	Stephanie Solf
Directorate of Crop Services, Ministry of Forestry and Agriculture (MOFA)	Anthonio Christian

CHAPTER

02 Case study area

2.1 The case study area and the CIKOD conservation centre

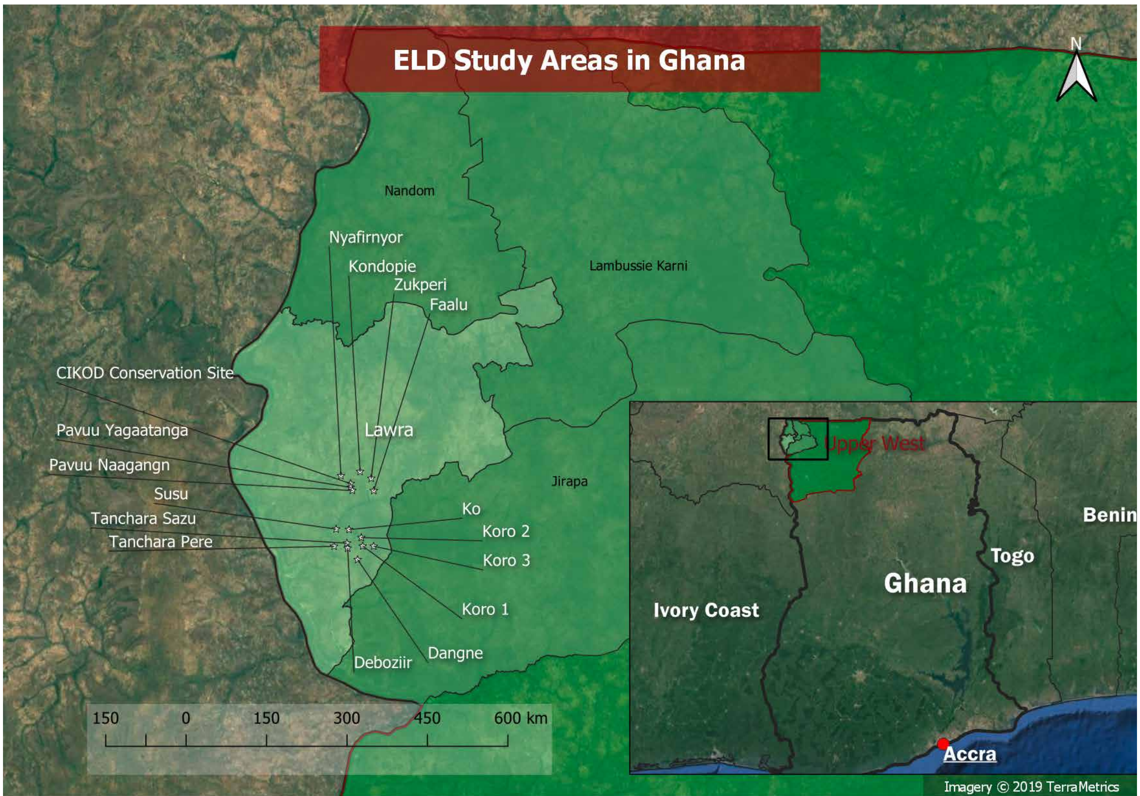
The data and information used for this study come from expert interviews, focus groups, and household surveys with farmers. A total of 550 households were surveyed in 18 villages, namely: Kondopie, Kalsagri, Tanchara Saanza, Ko (1, 2, and 3), Susu, Koro, Doboziir, Pavuu Yagateng, Pavuu Naagangn, Faalu, Zukperi, Nyafinyor, Tangpuor, Orbli, Konwobre and Tabier (Figure 1).

Communities were selected on the basis of their distance to the main CIKOD conservation centre, distinct traditional chief authorities, and the number of years that the community has been practicing FMNR. The first interventions started in 2014 in Kondopie. In addition, the household questionnaire were also administered in three control villages (Orbli, Konwobre and Tabier) which are not part of the CIKOD intervention perimeter.

The CIKOD conservation centre is located in the Lawra district within the Kalsagri and Pavuu communities. The centre is used as a learning site for the farmers within its catchment area and farmers typically walk to the centre for training. They can then apply the acquired knowledge all year but most particularly in the farming season (i.e. from March to December).

FIGURE 1:

ELD case-study area



With an average of 100 households in each of the 15 CIKOD intervention villages in the Lawra district, CIKOD has reached an estimated 80 per cent (Table 3a) of the households, i.e. 1200 households, either through direct training or through transmission of learning from one neighbour to another. In theory, the entire rural population in the Lawra districts could uptake FMNR across 60,000 acres (24,000 ha) of farmland (MOFA 2011). When including the Nandom district, a total of 35 villages have been reached by CIKOD and some 2500 voluntary fire fighters have been trained to date (CIKOD 2019).

2.2 Geographical characteristics

The Upper West Region is in the northwestern corner of Ghana. It is bordered to the south by the Northern Region, to the east by the Upper East and Northern Regions, and to the north and west by the Republic of Burkina Faso. The region covers a geographical area of 18,476 square kilometres, constituting 12.7 per cent of the total land area of Ghana (MOFA 2019). It is estimated that about 70 per cent is arable.

The Upper West Region has 11 districts. The Lawra district is located in the most upper northwestern part of the region (Figure 1). The Lawra district has 66,000 inhabitants (citypopulation 2019). However, many of the highly educated people are migrating out of the district to seek job opportunities elsewhere. The adult literacy rate is estimated at 19 per cent in the Lawra district (UNDP 2011).

The climate of the Upper West Region is characterised by a short, single-peak rainfall season and a long dry season from October to the end of April. The Lawra and Nandom districts belong to zone Bs of Koeppen's classification (dry climate with annual evaporation exceeding annual precipitation) with an average rainfall of <900 millimetres per year. During the rainy season, the maritime air from the southwest monsoon combined with strong atmospheric convection cause high rainfall and humidity levels, ultimately reaching 69 per cent in August. In some years, the first rains in April and May are followed by dry spells of three to five weeks, resulting in serious crop damage. The long term mean annual temperature of the Upper West Region is about 27.2°C.

The agro-ecological zone of the Lawra district may be described as Sudan Savanna zone, characterised by scattered trees – such as Baobab (Adansoniadigitata), dawadawa (Parkiaclappertoniana), shea (Butyrospermumparadoxum subsp.parkii), and Acacia albida – and a sparse ground cover of grasses (MOFA 2019).

2.3 Land and tree tenure

In northern Ghana, land is traditionally held for future generations by the fetish priests. However, the right to cultivate land is traditionally prerogative of clan heads who can subsequently allocate it to family heads. Usually, local people cultivate land through generations and pay a token part of the harvest to the traditional ruler and/or fetish priest.

In the Northern Region of Ghana, indigenous trees that are naturally occurring in the Dagomba traditional area – such as shea trees or dawadawa – belong to the chief of that tree species (Amoako et al. 2015). In the Gonja and Mamprusi traditional areas, the trees are owned by traditional landowners who are chiefs, sub-chiefs and family elders. However, there is a rule that prohibits a person from harvesting fruits from another person's farm without permission (Amoako et al. 2015).

The same rule on fruit harvesting and traditional/family elder ownership of trees pertain in the Upper East and West Regions. Throughout the entire country, naturally occurring trees – particularly timber tree species – belong to the state. The holders of allodial and freehold land titles under customary land ownership do not exercise ownership right over these trees. It is the official right of the government to manage the trees both in and outside of forest reserves on behalf of the Traditional Authorities (Akapme 2016).

Therefore, there is a need for legal frameworks to be reformed so that ownership of naturally occurring timber trees off-reserve is vested in the communities concerned. This would help incentivise farmers and forest-adjacent communities to invest in forest management and conservation in order to effectively implement tree growth processes and reduce illegal logging (Akapme 2016).

03 Methods

To understand the economics of Farm Managed Natural Regeneration (FMNR) and the implications for farmer livelihoods, we relied on expert interviews, focus groups with farmers and quantitative analysis of a household survey. The data and information from these sources have been used to build the Cost Benefit Analysis (CBA) of FMNR. The theoretical foundation of the CBA is explained in the following.

3.1 Data collection and questionnaire design

In order to value the adoption of FMNR as a farming practice, a detailed valuation survey was implemented with nearly 600 farmers between March and April 2019. The survey had several objectives:

- To develop an understanding of the farm characteristics within the Lawra district in the Upper West Region;
- To assess the economic value of adopting FMNR and other sustainable land management practices as well as the welfare economic impacts of upscaling FMNR practices within the two districts;
- To understand drivers and constraints to FMNR adoption.

Households were randomly sampled, with interviewers randomly approaching every 3rd or 4th farm household. Face-to-face interviews were conducted on the farms with one representative household member, using tablets and Computer Assisted Personal Interviewing (also known as CAPI) software. Each interview lasted on average 45 minutes and was carried out by six undergraduate and doctoral students from the University of Development Studies. The population from which the sample was selected included farmers cultivating more than 0.5 acres of land and living within the Lawra district, representing approximately 17,000 households.

After deleting pre-tests and incomplete questionnaires, the total sample was 534 households. Roughly 50 households that grow crops other than millet, sorghum, groundnut and maize on their main plots were subsequently dropped from the analysis since the questionnaire was not designed to elicit production values from these crops.

The final sample of households used for the analysis of this study is 483 households, of which 251 households live in CIKOD intervention areas and 232 are in the other control villages that have not benefited from CIKOD interventions.

In collecting a sample that reaches a desired level of statistical precision, Neuman (1991) suggests a ratio of 30 per cent for small populations (those under 1,000) and 10 per cent for moderately large populations (those of 10,000). However smaller samples can be justified when the underlying population is homogeneous (e.g. mainly agrarian), such as our case study area. For example, if the target population of agricultural households is 90 per cent of rural households, then the appropriate sample size to reach a 95 per cent confidence level for sample statistics would be approximately 300 (UNSD 2008). The UNDP (2011) estimates that 83 per cent of the Lawra district working population is engaged in subsistence agriculture. As such, our sample size is largely sufficient in representing the overall farming population and reaches the desired confidence levels of our results.

3.2 Scenarios

The analysis focuses on the farm-level by comparing the per acre returns from farming under FMNR and non-FMNR farming. We employ three different scenarios:

1. *Non-FMNR scenario:* Farmers intercrop cereals and legumes and have low tree densities of five trees per acre.
2. *FMNR scenario*: Farmers employ intercropping with legumes, have a high tree density (13 trees per acre) and deliberately engage in FMNR practices associated with pruning, thinning and reduction of fires.
3. *FMNR & SLM scenario:* Farmers employ intercropping with legumes and undertake crop rotations. They also have a high tree density (average of 13 trees per acre) and deliberately engage in FMNR practices associated with pruning, thinning and reduction of fires. The FMNR & SLM scenario is associated with higher land preparation costs, and training and equipment costs are also accounted for.

These scenarios were elaborated on the basis of the models and arguments exposed in Chapters 5 and 6. It should also be mentioned that the majority of farmers in the case study area (64 per cent) are intercropping cereals with leguminous species such as groundnuts, soy and beans. Therefore, in all three scenarios used for the final CBA (Chapter 8), it is assumed that farmers undertake intercropping with legumes.

3.3 Cost Benefit Analysis

The adoption of FMNR practices involves investment costs on the part of the farmer, particularly in relation to pruning and participation in training activities in the first years. Benefits also change over time, as soils start to regenerate and trees reach maturity thus allowing for the harvesting of timber and NTFPs.

To appreciate the livelihood improvements from FMNR practices, it is important to account for the flow of costs and benefits over the time horizon (T) that is being evaluated. For this purpose, we derive the net present value (NPV) of the non-FMNR and the FMNR systems, as shown in Equations 1 and 2. The overall net benefits of adopting the FMNR farming system is given as the difference between the two (Equation 3).

Equation 1

$$NPV_{non\text{-}FMNR} = \Sigma \text{ net crop income}_t / (1+r)^t + \Sigma \text{ onfarm forest income}_t / (1+r)^t$$

Equation 2

$$NPV_{FMNR} = \Sigma \text{ net crop income} / (1+r)^t + \Sigma \text{ on-farm forest income} / (1+r)^t - \Sigma \text{ FMNR implementation \& management costs } (1+r)^t$$

Equation 3

$$NPV_{non\text{-}FMNR \rightarrow FMNR} = NPV_{FMNR} - NPV_{non\text{-}FMNR}$$

The annual value of the year-to-year benefits (i.e. the annuity value) from FMNR is calculated according to Equation 4. It is the annual present value of the future flow of income at the specified interest rate.

Equation 4

$$Annuity_{Conventional \rightarrow FMNR} = \frac{r \times NPV}{1-(1+r)\text{-}t}$$

where
r = discount rate
t = time horizon (20 year)
NPV = Net Present Value

3.4 NPV model inputs

To measure on-farm forest income for Equations 1 and 2, we relied on a combination of interviews with CIKOD extension service providers, literature review, and households' self-reported physical quantities of harvested products – whether for their own household use or for sale. FMNR adopters typically have more trees on their farm, but in the early years after adopting FMNR many of them will not yet have reached fruiting stage. Therefore, we also accounted for the change in the productive capacity of trees from one year to the other.
Focus groups served to elicit the price at which the given goods usually sell at farm/forest gate or on local markets (i.e. within village). In any given year *t*, the on-farm forest income is given by Equation 5.

Equation 5

$$\text{Forest income}_t = \text{production}_t \times \text{price per unit}$$

When a product is not sold in markets, the value was inferred from barter values or the value of close substitutes, following the Poverty Environment Network guidelines developed by CIFOR (Angelsen et al. 2011).

Agricultural income is defined as the value added during a specific time period from assets that a household has access to, such as labour and land (Angelsen et al. 2011). Net crop income (for FMNR and non-FMNR farmers) for any year *t* is calculated for the farmer's main plots on the basis of the household survey for the 12 months preceding the interview, according to Equations 6 through 9.

Equation 6

$$\text{Net crop income}_t = \text{revenue}_t - \text{input cost}_t - \text{other costs}_t \text{ (for FMNR activities)}$$

Equation 7

$$\text{Revenue}_t = \Sigma \text{ Quantity}_t \times \text{Price}$$

Equation 8

Input cost = Σ Q × P (seeds, fertilizers, chemicals, hired labour, tractor costs for land preparation ...)

Equation 9

Hired labor cost = Number of days (weeding, land preparation and harvesting) × daily wage

Revenue is the product of the quantity harvested of all products from the farmer's main plots and the price for those products. Input cost is the sum total of spending on inputs (e.g. hired labour, seeds, fertilisers, pesticides) and deducted from crop revenues. Hired labour includes labour for land preparation, weeding, and harvesting. It does not include labour for FMNR activities, which is included in other costs. We apply three other assumptions:

- Own labour value is not deducted from net crop income. This method follows the approaches used in other livelihood environment studies (e.g. Cavendish 2002).
- However, when estimating the additional costs of adopting FMNR, we use the shadow wage rate to infer the labour costs since the activities are additional to the existing workload and mostly take place during the peak farming season. This often obliges farmers to hire extra labour for these activities.
- Gross values of forest products are used in the on-farm forest income calculation. In traditional communities, harvesting of most forest products do not require high skill levels; many of these products can be extracted with minimal capital investment and the opportunity cost of unskilled rural labour is low. For this reason, the costs of capital and labour costs are not deducted from the value of forest products in estimating on-farm forest income.

Agricultural production function modelling
Crop production and crop revenue are affected by the presence of trees. To understand and assess the contribution of FMNR to crop production, other factors affecting crop production (e.g. fertiliser use, hired labour inputs and tractor use) need to be controlled for (Chapter 5). Therefore, we use a semi-log production function to assess the contribution of all farming inputs and practices to agricultural productivity.

3.5 The accounting period

A 20-year time horizon has been chosen for the valuation study. Farmers and decision-makers are likely to be most concerned with the more immediate future. However, the impacts of FMNR interventions stretch far beyond the first years. Regenerated tree species such as dawadawa, shea and ebony will not start bearing fruits until year 15 but can thereafter produce for another 100 years. In that sense, FMNR is a long-lasting intervention. However, impacts become more uncertain beyond 20 years as we have less knowledge about how climate change impacts trees, agricultural yields or prices. Therefore, we constrain our analysis to 20 years, albeit knowing that the true net benefits of FMNR are longerlasting.

3.6 Discount rate

The discount rate is a critical parameter in cost benefit analysis whenever costs and benefits differ in their distribution over time, especially when they occur over a long time period. We used a descriptive approach and farmers' own rate of time preference to select an appropriate discount rate.

3.6.1 The descriptive approach for project appraisal

The descriptive approach is based on the opportunity cost of drawing funds from the private or public sector using the real interest rate[3]. Accordingly, the cost of investing Ghanaian cedis in FMNR is the value that each cedi would have produced in its alternative use. Therefore, for FMNR to be worthwhile at the societal level, the invested capital should grow more than if the 'cedi' had been invested elsewhere, for example on other forest landscape restoration projects in Ghana.

3 The real interest rate is equal to the nominal lending interest rate adjusted for inflation. It is not appropriate to use the nominal rate, since most variation in these rates is due to changes in inflationary expectations whereas the rate of return on capital (e.g. factories or equipment) is fairly stable over time.

To reflect this opportunity cost, central bank interest rates have often been used. Based on a review of project appraisals conducted by the African Development Bank (AfDB), a discount rate ranging from 1012 per cent is used in AfDB projects (ADB 2013). The Asian Development Bank (ADB) uses a discount rate of 9 per cent for projects related to agriculture, energy, transport and urban development, and a lower rate of 6 per cent for projects targeting poverty (ADB 2017).

In terms of farmers' true opportunity costs, we know that part of the funding for FMNR (see Chapter 6) is provided as grants by CIKOD itself. Given that there is no opportunity cost of such funds to farmers because they cannot invest the grant elsewhere, the effective interest rate may be considered zero. However, other investments are required by the farmers themselves for basic tools and labour time for FMNR activities. Such resources could be invested elsewhere. **Therefore, we consider that 5 per cent is a reasonable discount rate to reflect the actual opportunity costs of investing in FMNR from the farmer's perspective.** We also use 10 per cent to reflect the opportunity cost of the grants and financial capital deployed by CIKOD, and a 23 per cent discount rate to reflect a conservative estimate of farmers' own rate of time preferences and the interest rates among local finance providers (rural banks, micro-credit facilities, money lenders, etc.) as argued below and in Chapter 7.

3.6.2 Experimental economics - Elicitation of farmers' time preferences

Empirical literature has shown that individuals in lower income brackets tend to have a significantly higher preference for current consumption relative to future consumption, and thus have higher discount rates (Pender 1996; Yesuf and Bluffstone 2008; Tanaka 2010). This is due to uncertainty about future circumstances and the need to survive now, making imminent needs override any capacity or willingness to invest in the future.

Given this information, we have also elicited discount rates from our sample of farmers. In doing so, respondents were asked about their choice of receiving a payoff now versus a payoff in 12 months (Table 2). This represents a time horizon to which they are well acquainted, since the main harvest in the Upper West Region happens once a year during October/November (FAO n.d.). The payoffs in the survey were hypothetical with no actual payoffs given to respondents.

TABLE 2:

Time preference elicitation – 12-month payoffs

Payoff alternative	Payment Option A (cedis paid now)	Payment Option B (cedis paid later)
1	50	60.8
2	50	66.8
3	50	73.2
4	50	80.1
5	50	87.5
6	50	95.3

An individual's discount rate is based on their switching point within the payoff alternatives.

However, it is noteworthy to highlight that in our sample, 54 per cent of respondents never chose to opt for the future option, implying that they have a very high discount rate. When these individuals were asked how many Ghanaian cedis they would accept in order to take the future payoff, many farmers cited responses that were larger than 200 per cent. In essence, they all favoured present consumption over future consumption. This finding suggests that even low-cost investment projects such as FMNR will not be adopted by a sizeable fraction of farmers in the absence of grants for the adoption costs.

Given the very high upper-bound of discount rates for those who did not choose any of the future payoffs, we instead based our observation on the average discount rates of those who agreed to future payoffs. Among them, the average discount rate was 23 per cent for the 12-month payoff. This coincides with the interest rate applied by various financial institutions (money lenders, family, rural banks, micro-credit facilities etc.) in the case study area. **Therefore, we make a sensitivity analysis of the results from the Cost Benefit Analysis, using a 23 per cent discount rate as well.** See Chapter 7 for further insights.

CHAPTER

04 CIKOD evergreen landscape interventions, farmer motivations, and constraints to FMNR adoption

The Centre for Indigenous Knowledge and Organisation Development (CIKOD) has worked in the Lawra and Nandom districts to supports farmers to regreen degraded lands using the FMNR techniques. CIKOD has created a conservation area in the Kalsagri and Pavuu communities and uses the centre as a learning station for the farmers within its catchment. The farmers learn about Sustainable Land Management (SLM), including FMNR, and can apply these techniques when managing their farmlands and landscape.

In the following chapter, we use insights from seven focus groups in CIKOD intervention villages. We use this information to explain how FMNR and other SLM practices are undertaken, as well as the perceived benefits and costs associated with adopting these land management practices. This serves as a foundation for undertaking the CBA in the subsequent chapters.

4.1 Focus group findings

4.1.1 Motivations for engaging in FMNR

Farmers have a large range of motivations for desiring to nurture trees on farmland and to adopt FMNR practices. In particular, they have observed that

PHOTO:

Part of the ELD study team finds shade under a mango tree in Kondopie

with the old way of farming "*by clearing the land and burning all residues and making mounds for planting, benefits were fast dwindling and we needed to try new ways of farming to see whether we would have better yields(…). We think it is paying off well*". As a result, most farmers have dedicated their land to FMNR in the Zukperi community. Farmers also highlighted that in the past there were a lot more cattle and organic manure. Now, they have to find other ways of fertilising their fields and FMNR responds to that need. Additionally, they have observed that with the increase in tree density, windstorms destroying crops and property have reduced because the trees serve as wind breaks.

The timber and Non-Timber Forest Products (NTFPs) are also compelling motivators. In Zukperi for example, farmers mentioned improved access to lumber for construction and fruit for food. The availability of fruit allows them "*not to worry about to what to be fed for the day*" and make their working days more effective, as they do not have to go back home to eat. Other livelihood improving goods include fuelwood from pruning, timber poles, and canes for making baskets and so-called 'kasog' (chicken cages). Their livestock holdings also benefit since they do not stray too far away to look for food. The reader is invited to read Damnyag et al. (2019) to grasp the full range of benefits.

PHOTO:

Stephen Owusu from the ELD study team takes soil samples from a communal FMNR site near Pavuu

PHOTO:

Pre-testing of the ELD household survey with a farmer in Kondopie

4.1.2 FMNR in the study area

The understanding of FMNR by farmers in the study area is a collection of activities consisting of tree pruning, thinning and no-burning. In preparing (fallow) land for cultivation, there is neither clear cutting nor burning of the trees, shrubs and residues. Instead, farmers undertake selective removal of trees followed by the sowing or seeding. The preservation of naturally occurring trees and shrubs is done by pruning and thinning out, as well as identifying economic tree seedlings on farmlands and marking them with pegs to nurture them to grow. The nurturing of these tree seedlings is done in the course of land preparation and weeding of the farm, and through the making of firebreaks. Pruning is typically done in a specific location of the farmland where there is a cluster of young regenerating planting plants and shrubs. As stated by one farmer:

"*Before learning about FMNR, we just left the tree to grow on its own; even though it did not take a good shape and also took a longer time to grow. But now as we prune, the trees grow well and one can easily get a straight tree stem for lumber when the need arises. Most of the trees like the shea, dawadawa, and others are naturally regenerated rather than consciously planted. Burning the bush destroys all young trees; therefore the practice of no-burning helps preserve these young trees from being destroyed*".

In addition, farmers engage in spot cleaning around matured tree species and make fire belts around farmlands to prevent burning of trees and farmland from adjacent wildfires. As a whole, the retention of economic trees on farmland belongs to mainstream practice among farmers, but the pruning, thinning and no-burning is new to farmers.

4.2 Complementary sustainable land management practices

Other SLM practices adopted by farmers who benefited from CIKOD trainings include the following. Each is described in further detail by farmers themselves in Damnyag et al. (2019).

- **Crop rotations:** farmers rotate crops on the plots of cultivated land. For example, a groundnut field in the last planting season is exchanged for a sorghum field intercropped with groundnuts. This is done to fight the 'striga' weed which is common on cereal fields.
- **Mulching of farmlands:** the leaves from trees on farmlands are left undisturbed on the fields and they serve as mulch for the soil. This practice helps retain moisture in the soil even days after a dry spell.
- **Composting:** it is done by digging holes and filling them with crop residues and animal droppings together with ashes and sprinkled water. The compost is allowed to decompose and then used to fertilise crops.
- **Tied ridges:** while the traditional method of farming involves the making of mounds, most farmers in CIKOD intervention villages have switched from mounds to farming on ridges in order to enable the conservation of soil moisture, even when there is a dry spell within the rainy season. Ridges can be opened if a place becomes waterlogged.
- **Application of animal droppings and manure from waste-dump sites:** when a farmer is not able to prepare compost he can gather and apply animal droppings to his field to boost soil fertility.
- **Planting in rows:** farmers sow seeds of food crops in rows instead of irregular planting.
- **Retention of crop residue between ridges:** instead of burning, farmers retain crop residues on the farm by burying them with sand on the spaces created in-between ridges. The crop residues are left to decay to add nutrients to the soil. The crop residues are normally packed in gullies along the ridges and covered with sand. This is done immediately after harvest to allow for it to decompose.
- **Zero or minimum tillage of farmlands:** many farmers have adopted the zero tillage method where seeds are sowed in the farmland without tilling the land. Farmers in Kalsagri noticed that crops do better than where the areas were ploughed.
- **Use of new and improved seeds varieties:** farmers plant seeds like the 'obaatampa' or 'bilihifa' for maize, which are high yielding and have a shorter maturity period as compared to older varieties. They must combine this with putting the appropriate number of seeds in the hole while sowing.
- **Preservation of specific tree species:** certain species, such as *Faidherbia albida* (Gozan) and *Ficus gnaphalacarpa* (Kankang), improve soil fertility when preserved on farmlands.
- **Management of specific tree species:** farmers manage tree species that are known for decreasing crop yields (e.g. *Azatdirachta indica* known as neem and *Anogeisus leiocarpus* also called sigtir) on farmlands while also planting trees for fuelwood (neem, teak, cassia) in marginal areas that will not adversely impact crop yields.

4.3 Obstacles to adoption of FMNR and FMNR costs

Engaging in FMNR practices is not without some challenges. For example, some tree species impact soil fertility adversely, such as the neem tree (*Azatdirachta indica),* although they are a ready source of lumber for construction and fuelwood.

4.3.1 Labour costs and mechanisation costs

The main obstacles to FMNR adoption, as expressed by farmers, is the increased cost of land preparation of areas with a higher tree density. Farmers have to spend more funds to hire people to prune shrubs and clear the areas under larger trees which the tractor cannot reach. On uneven farmland, it is also more complicated and expensive to use tractors for land preparation. Other labour costs are associated with the creation of fire belts around the boundaries of plots to protect farmlands from bush fires. Some farmers are creating fire belts by clearing the bushes from the edges of plots that are dedicated to FMNR activities so that they do not get affected when there are bush fires. Additionally, farmers have to do regular pruning and thinning to create room for sunshine to reach the crops. Due to these additional efforts, the labour costs for farmers practicing FMNR are higher.

4.3.2 Collective action problems and externality costs

In the southwestern part of the study area, the community of Tanchara has benefited from CIKOD interventions for the last two to three years. However, the community is still fighting against bush fires. According to focus group discussions, not every member of the community has accepted FMNR practices so they still burn the bushland which is stalling the efforts of farmers that are practicing FMNR activities. Illegal felling of trees is also a problem, as trees are sometimes being cut down by charcoal makers without prior notice. These actions are discouraging farmers from practicing FMNR and investing their time in its activities (Damnyag et al. 2019).

4.3.3 Fixed investment costs

There are some upfront fixed costs associated with adopting FMNR. Most of these costs are related to acquiring tools and equipment to effectively practice FMNR, especially those used for both pruning and compost making (e.g. cutlasses, wheelbarrows and pickaxes). According to farmers, safety workwear – like the wellington boots and gloves – that allows the farmer to prune his shrubs with less stress is not available. As bushes increase, venturing into the fields comes with its own risks of stepping on a snake or a thorn that can hurt the farmer, hence the need for proper clothing. Not all farmers can afford the required clothing and often the equipment is not readily available at markets (Damnyag et al. 2019).

4.3.4 Training and transportation costs

For CIKOD and any societal actor who bear these expenses, there are also training costs. These are detailed in Chapter 6. Some communities are located far away from the CIKOD learning centre in Kalsagri. A farmer said in one focus group:

"*It is a tiring exercise to walk a distance there to learn, especially on an empty stomach for the whole day without any refreshment. A lot of farmers get tired after some time and hence their focus on the work is shifted. It would really be helpful if at least we are refreshed, to keep farmers energized to learn. The few who are able to go to the centre have to come back and teach other farmers, which sometimes does not happen effectively*".

4.4 Summarising constraints and costs of FMNR

In summary, farmers have a wide range of motivations for uptaking SLM practices, including FMNR. Overall, they experience a sense of improved well-being, from enhanced nutrition, soil fertility and income. The constraints to FMNR are associated with:

1. The mechanisation of land. In particular, ploughing the land with tractors become more expensive and complicated. As a result there is a need to hire more labour for land preparation.
2. There are also some minor investment costs related to training of farmers and the acquisition of new tools.
3. As long as some farmers continue conventional farming practices of slash-and-burn, costs of fire prevention will remain high. Thus, with higher adoption rates of FMNR, it can be expected that fire prevention costs will go down. Until then, FMNR involves additional labour costs.

In the following chapter, we will show that while all these costs are real, they are not detrimental to the overall profitability and economic interest of FMNR farming over conventional non-FMNR farming.

05 Characteristics of farmers and their cropping systems

In this chapter we analyse the cropping systems of the farmers in the study area. In doing so, we focus on what they do on their main plots in terms of farming inputs and their evergreen and Sustainable Land Management (SLM) practices. Subsequently, this information is used to assess the productivity of farmland and what determines farmers' levels of agricultural income. Before doing so, we first consider the characteristics of the farmers in our sample.

5.1 Socio-demographic characteristics of survey respondents

Tables 3a and 3b show the characteristics of the farmers in the ELD survey. In terms of the household heads, 75 per cent are male, the average age is 54 years old, and they have lived in the village in which they were interviewed for an average of 40 years. Only 8 per cent of the household heads come from another region in Ghana. Some 43 per cent have completed high school, but only 22 per cent of the household heads are literate. The latter is in accordance with census data: According to the UNDP (2011), the literacy rate is 19 per cent in the Lawra district. The average household size is seven family members, of which nearly half (three out of seven) are less than 16 years old. Within the household population, about one third has benefited from trainings by CIKOD and almost half has learned about SLM practices from other farmers. Finally, in terms of gender representation, half of the primary respondents that were interviewed are women.

TABLE 3A:

Socio-demographic characteristics of farm households (n=483)

Socio-economic characteristics	Share		Share
Gender of the main respondent (=male)	49%	Gender of the household head (=male)	76%
Relation of the main respondent to the HH		Household head is literate	22.3%
Head	62%	Household head is a migrant	8.2%
Wife	21%	Household has received training from CIKOD on FMNR	33%
Other	17%	Household has learned about SLM from the practices of other farmers	48%
Highest education level achieved by any one in the HH?		Per cent of households classified as FMNR farmers, qualitatively assessed by interviewer	
Primary school completed	27%	Business as Usual/Non-FMNR farmers	47%
High school completed	42%	FMNR farmers	44%
Tertiary education completed	13%	FMNR & SLM	10%
Non-formal education	0.3%		
None	17%		

TABLE 3B:

Socio-demographic characteristics of farm households (n=483)

Other socio-economic characteristics	Average	Min	Max
What is the age of the household head?	54	18	100
Number of years the respondent has lived in the community	40	0	100
Household members less than 16	3	0	12
Household members between 16 and 50	3	0	20
Household members over 50	1	0	9
Total number of household members	7	1	29

5.2 Characteristics of cropping systems

On farmers' main farming plots, they grow three main crops: maize, sorghum or groundnuts. However, maize is the favourite crop among farmers but for the most part it is intercropped with beans, groundnuts, millet, or sorghum, as seen in Figure 2. Farmers have an average of two acres dedicated to the main crop, with a minimum of 0.1 acres and a maximum of 42 acres (Table 4).

FIGURE 2:

Crops and crop combinations on farmers' main plot, by frequency

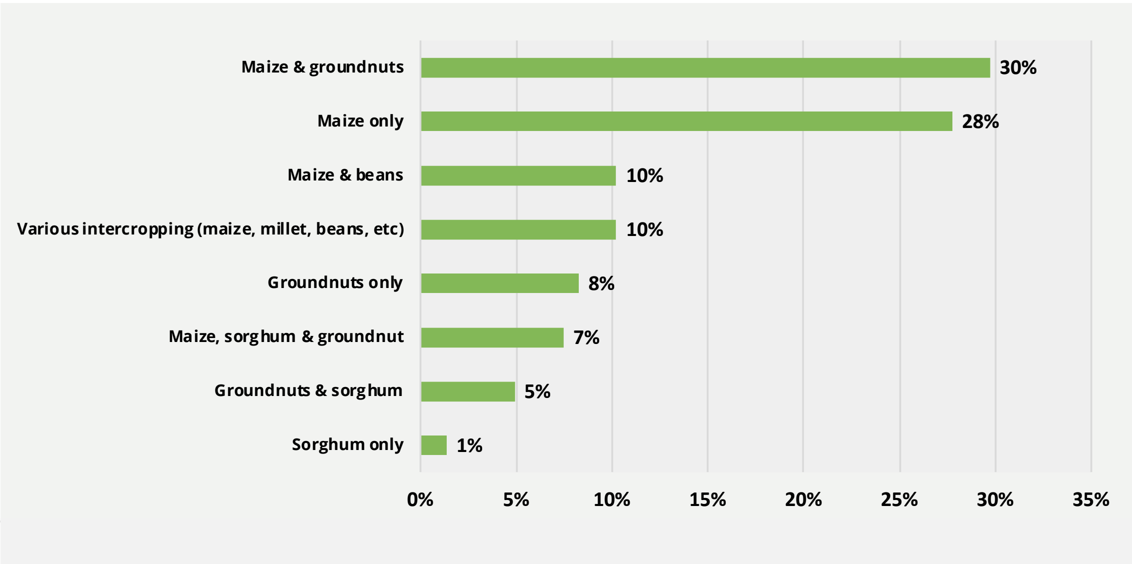


TABLE 4:

Acreages of farmland among interviewed households, n=483

Acres of farmland	Mean	Median	sd	min	max
Acres for the main plot per household	2.3	2*	2.1	0.5	42
Total acres of land per household	4	3.5	3.2	0.5	54
Acres dedicated to	Maize	Sorghum	Millet	Beans	Groundnuts
Median	2	1	1	1	1

*Equivalent to 0.8 hectares

5.3 Explaining the productivity of cropland

For those farmers who only crop maize without combining other crops, the mean yield is 125 kg per acre (= 312 kg per hectare) with a considerable dispersion of yields (Table 5).

However, the majority of farmers (65 per cent) undertake intercropping with various proportion of different crops (e.g. 30 per cent groundnuts and 70 per cent maize). **Since we cannot expect farmers to estimate the share of each crop on a given plot with precision, crop specific yields (in kilograms per acre) are not a viable or rigorous measure of the actual productivity of the land for those farmers. Therefore, we estimate the value of the harvest from the main plots in terms of the total revenues derived from the plots** using standardised prices, notably the median farm gate prices from the last harvest season (2018/2019) as reported in Table 5.

TABLE 5:

Yields of maize crops that are not intercropped with legumes Farm gate market prices of the main crops

Variable	Mean	Median	St dev	Range	N
Yield (kg/acre)	125*	98	78	(20.5-547)	132
Farmgate market prices					
Maize (GHS/kg)	1.8	1.8	0.76	(1.5 - 2.1)	470
Sorghum (GHS/kg)	2.3	2.3	0.65	(2 - 2.5)	122
Beans (GHS/kg)	2.9	2.5	1.29	(2 - 3)	63
Groundnuts (GHS/kg)	3.3	2.5	1.75	(1.5 - 2.5)	287
Soya (GHS/kg)	2.3	2.3	0.19	(2.1 - 2.5)	3
Crop revenue/acre**	**392**	**300**	**290**	**35-2040**	**483**

*Equivalent to 312 kg/hectare. ** For the average farmer that combine maize or sorghum with other crops.

5.4 Main cash costs and net crop income

5.4.1 Tractors for land preparation and hired labour

Land preparation is done using manual labour and tractors for ploughing. Only 20 per cent of households have not used tractor services. Tractors are usually procured from third parties (paid per acreage or man-day terms) making this an expensive input into production. Farmers spend an average of GHS 71 per acre cultivated.

Tractors are either paid per man-day or per acre land that was worked, with a maximum spending of GHS 300 per acre. The majority of farm households (76 per cent) hire labour to help with weeding, land preparation and harvesting. The average household spends GHS 68 per acre on hired labour.

5.4.2 Seeds, fertilisers and pesticides, and net crop income

Farmers either purchase or use their own seeds. About 38 per cent of farmers have purchased seeds at a median price of GHS 4 per kg. Seeds are also purchased in bags and bowls. This results in an average expenditure of GHS 22 per acre. Fertilisers are bought in 25 kg bags. The average cost of a bag is GHS 90 and the average spending on fertiliser (mostly solid) across the whole sample is in the order of GHS 62 per acre. Excluding those who do not spend anything on fertilisers, approximately 50 per cent of the farmers' average spending is in the order of GHS 110 per acre, which is substantial. Farmers make very limited use of herbicides and insecticides. Only 5 per cent of farmers reported spending on either input, resulting in a mean spending of GHS 2 per acre per household across the sample population. With revenue of GHS 392 per acre and spending of GHS 191 per acre, the average smallholder farmer has a net crop income of GHS 200 per acre (EUR 80/ha). Table 6 summarises those costs.

TABLE 6:

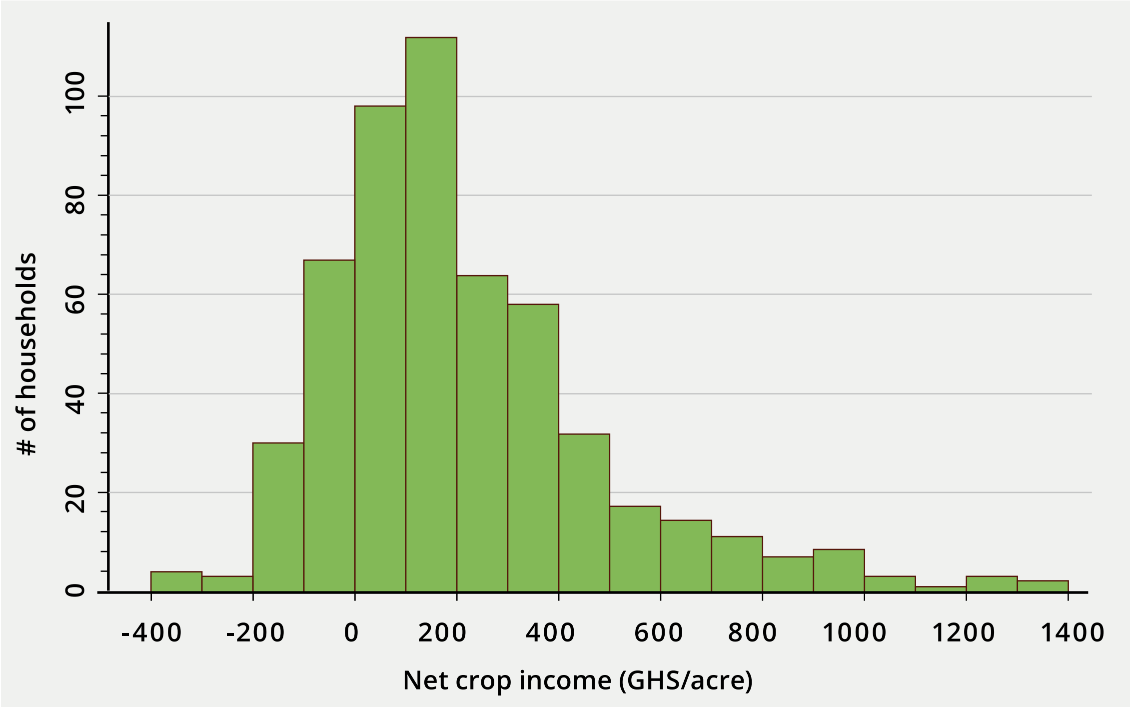
Net crop income 2018/2019 per acre

	Mean	Median	St dev	Min	Max	Uptake
Crop revenue	**392**	**300**	**290**	**35**	**2,040**	
Cost (GHS/acre)						
Tractor services	71	80	62	0	360	81%
Purchased seeds	9	0	19	0	120	38%
Fertiliser	62	0	88	0	540	48%
Pesticides	2	0	22	0	450	5%
Hired labour income						
Weeding	22	10	38	0	500	69%
Land preparation	13		20	0	100	51%
Harvesting	9		14	0	83	52%
Total hired labour	68	53	54	1	280	76%
Total costs	**191**	**162**	**142**	**0**	**790**	
Net crop income	**200**	**150**	**270**	**-400**	**1400**	

The distribution of net crop income within our household sample is shown in Figure 3. It ranges from negative GHS 400/acre to GHS 1400/acre (EUR 160/hectare to 560/hectare), which is a considerable difference. It tells us that there is a large potential for farmers to improve their productivity. In the remaining part of the report, we will look closer at what contributes to explaining the wide differences in net crop income among farmers, and the role of conventional farming inputs and SLM practices.

FIGURE 3:

Histogram of net crop income per acre (whole sample, n=483 households)

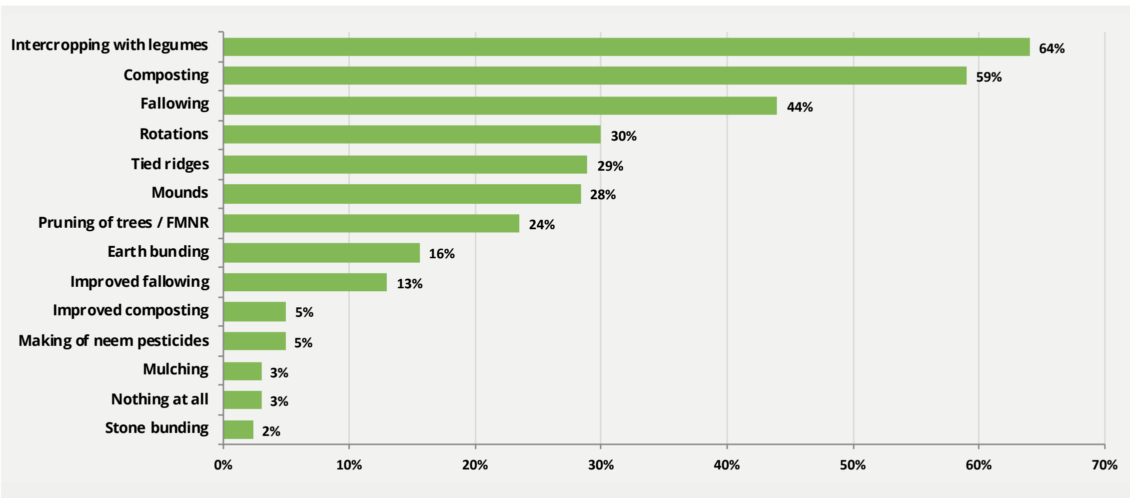


5.5 Understanding drivers of crop productivity

Farmers engage in a range of SLM practices on their farming plots independently or in association with one another. The application of these practices helps explain the dispersion in per acre crop income observed in Figure 3. Only 3 per cent of sampled farmers claim to do nothing at all. In Figures 5a through to 5l, we compared net crop income among farmers adopting a specific SLM strategy and farmers that do not take up that specific SLM.

FIGURE 4:

Degree of adoption of Sustainable Land Management practices in case study area (Lawra district)

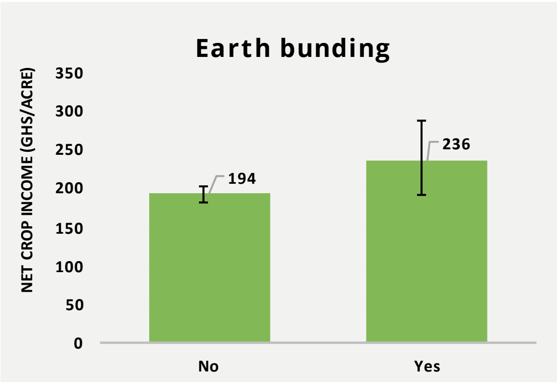


5.5.1 Sustainable Land Management and net crop income

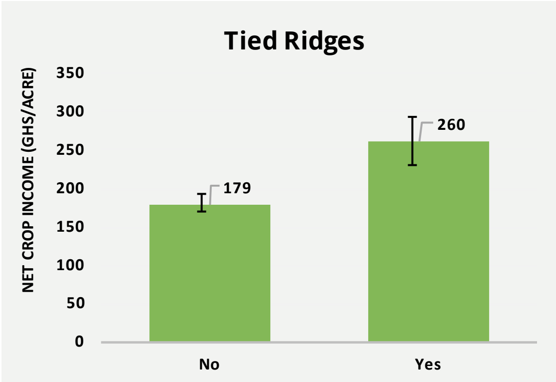
Statistically different means are proven using a t-test (t) and a Kruskal-Wallis (kw) non-parametric test. Only those practices for which there were sufficient observations to make meaningful inferences about differences in mean incomes are illustrated (see Figure 4). Overall, it can be observed that farmers practicing tied ridges, mulching, mounds, crop rotations, intercropping with legumes and tree pruning have higher tree density or mostly mature trees. When those farmers undertake FMNR, they gain higher incomes relative to those farmers that do not undertake that specific practice. On the whole, per acreage net crop income is about GHS 60-90/year (EUR 25-40/ha/year) higher among those using SLM practices. FMNR farmers in particular (with minimum eight trees per acre) who engage in pruning have substantially higher per acreage incomes. There is no statistically significant difference in net crop incomes among farmers undertaking fallowing, improved fallowing and earth bunding.

FIGURE 5A TO 5L:

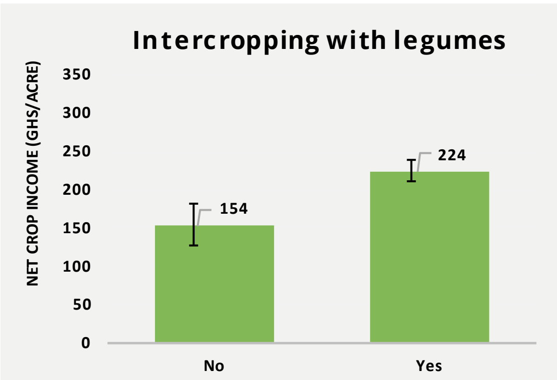
Splits showing average net crop income among adopters and non-adopters of 12 SLM and FMNR techniques. Bars show standard errors.



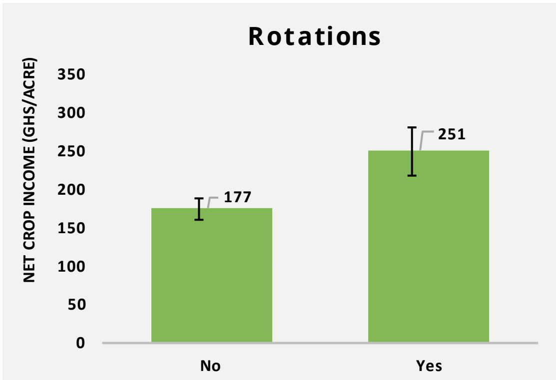
No significant difference in means



t+kw tests significant

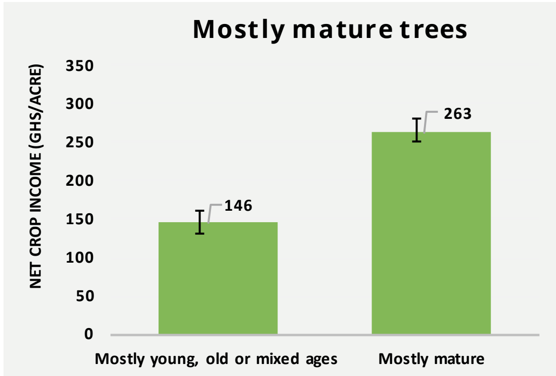


t+kw tests significant

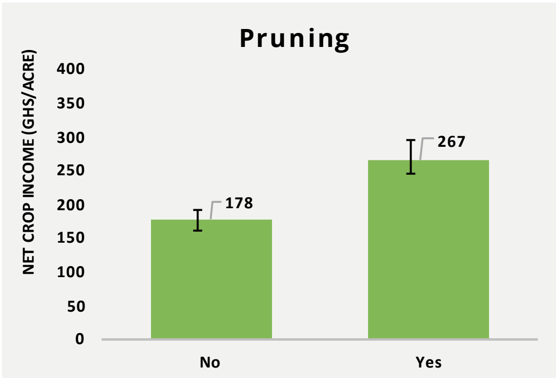


t+kw tests significant

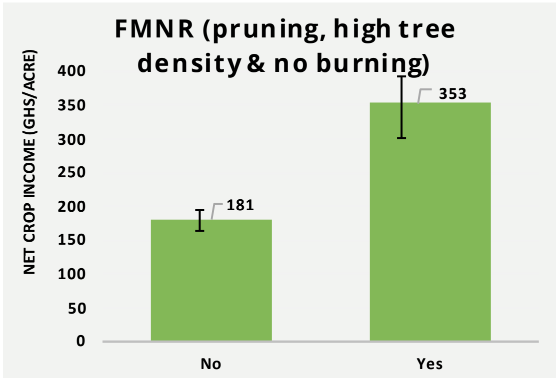
t+kw tests significant



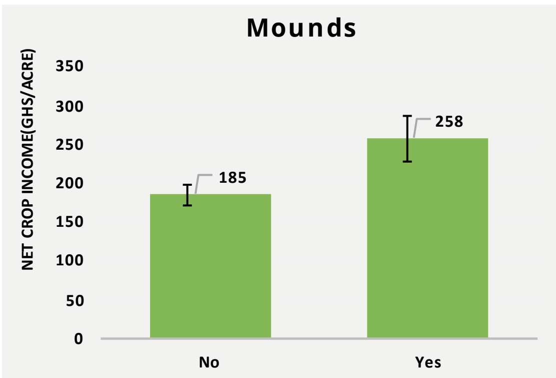
t+kw tests significant



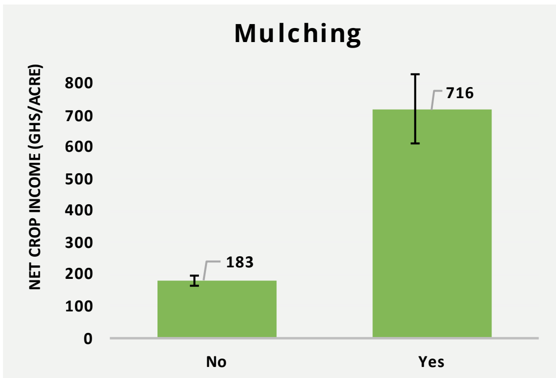
t+kw tests significant



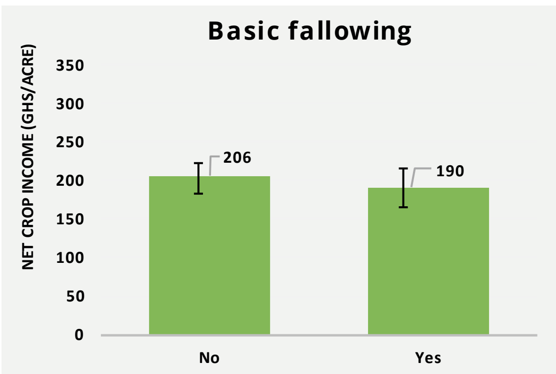
t+kw tests significan



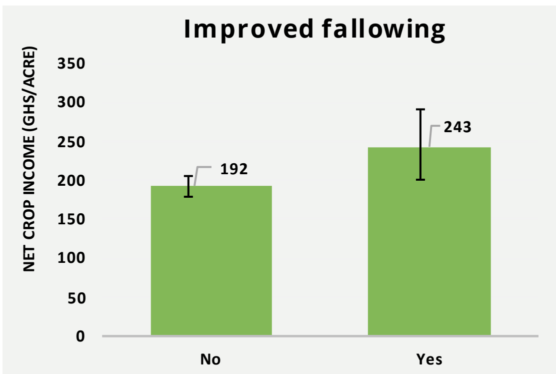
t+kw tests significant



t+kw tests significant



Not significant



Not significant

However, these per acre net income comparisons should not be used to make definite conclusions about what is the economic benefit of undertaking one practice over another because we are not controlling for all the other factors that may be explaining outcomes. For example, among farmers doing ridges, there is also a high proportion doing FMNR. Consequently, higher income attributed to ridges may be driven in part by FMNR adoption or higher use of fertilisers for instance. In order to control such influences and determine which practices are most important in explaining differences in agricultural productivity, a production function analysis is performed in the following section.

5.6 Production function analysis

In the presence of these multiple management practices and varying levels of input use among farmers, it is relevant to perform a production function analysis. It can enable us to understand the contribution of each farming input and activity to agricultural productivity. In essence, the production function is a statistical analysis (regression analysis) which describes how inputs affect farmland productivity. In our model, productivity is captured through consideration of crop revenue (as explained in Section 5.3). The estimated function allows us to observe how changing input variables affect the crop revenue per acre of our sampled farmers. Therefore, it gives us an understanding of both the statistical significance of individual inputs and the magnitude of which of these variables affect outcomes (i.e. the coefficient size). Thus, we use the following semi-log estimation:

Equation 10

$$\ln(Rev)_i = \alpha + \beta 1 \ln(T)_i + \beta 2n(P)_i + \beta 3n(SLM)_i + \gamma X_i + \varphi(C)_i + \epsilon_i$$

The outcome variable *In(Rev)* represents crop revenue per acre of each farmer *i* and is in log form, allowing us to observe nonlinearities. Variable *T* represents the tree density of individual farmer plots (in logs) and is an important component in determining to which scenarios our sampled farmers belong. The binary variable *P* equals one if a farmer engages in pruning and zero otherwise. *SLM* is a set of other (binary) sustainable land management measures, indicating whether or not farmers carry out crop rotations, intercrop cereals with legumes or have mostly mature rather than young and old trees on their cropland. Variable *C* is a set of community dummy variables that are aggregated into four areas: CIKOD communities, northeast, northwest, southeast, and southwest. These areas are analysed relative to the control communities (Oribli, Tabier, Kouwob). Community groupings can be found in Table 8. We control four areas in order to see how the location of individual communities impact crop productivity revenues. Finally, *X* is a set of farm characteristics and inputs; variable descriptions are included in Table 7.[4]

4 Other SLM measures (specifically, the making of tied ridges, earth bunding and the use of manure) are also included in the model. All of these SLM measures proved to be insignificant.

TABLE 7:

Explanatory variables used in the production function

Farm Characteristics/ Inputs	Description	Mean observed	Std dev	Min / Max
Tree density	Number of trees per acre (in logs)	8.7	6.5	1-40
Pruning	=1 if household engages in pruning and related FMNR activities	24%	0.4	0-1
Mature trees	=1 if trees are in majority mature, as opposed to young and old, or mixed	46%	0.5	0-1
Legume intercropping	=1 if farmer intercrops sorghum, millet, or maize with legumes (soya, beans, and groundnuts)	64%	0.4	0-1
Rotation	=1 if farmer engages in crop rotations	31%	0.4	0-1
Num. family members	Number of family members	7.4	3.4	1-29
ln(fertilizer spending)	Spending on fertilizer per acre (in logs)	62	88	0 - 540
ln(tractor spending)	Spending on tractor services per acre (in logs)	71	62	0 - 360
Labour cost	Spending on hired labour per acre	48	52	0 - 280
Northeast	=1 if respondent lives in Zukperi, Faalu, or Kondopie	12%	0.3	0-1
Northwest	=1 if respondent lives in Tangpuor, Naagagn, Pavuu, or Nyafinyor	18%	0.3	0-1
Southwest	=1 if respondent lives in Deboziir, Dagne, Tanchara, or Susu	12%	0.3	0-1
Southeast	=1 if respondent lives in Koro 1, Koro 2, or Koro 3	11%	0.1	0-1
Control	=1 if respondent lives in either of the control villages, Oribli, Tabier, Kouwob, where CIKOD has not had any intervention.	47%	0.5	0-1

We hypothesise:

1. Higher tree density will lead to higher revenues with diminishing returns as we add more trees;
2. Pruning will have a positive impact on revenues; and
3. Farm inputs will have an overall positive impact.

Our results from Equation 10 are presented in Table 8. With an adjusted-R^2 of 0.32, the model fit is strong and the model results are robust, with highly significant variable coefficient estimates in the expected directions. Despite being based on one-year observations, simple interviewer techniques and a limited number of observations, our model explains 32 per cent of the variation in crop productivity in the area.

In terms of our findings, the tree density coefficient is positive and significant and shows that as the number of trees per acre increases by 1 per cent and revenue per acre increases by about 11 per cent. Figure 6 illustrates the resulting marginal effects of each additional new tree on crop revenues.

Farmers engaged in pruning and FMNR activities[5] also have higher per acreage crop revenues, everything else being equal. The variable capturing the age of trees – whether farmers have mostly mature trees as opposed to young and old ones – is also positive and significant. This demonstrates that trees have a more pronounced positive impact on crop productivity as they mature or when a farmer has practiced FMNR for some years.

5 Pruning is the main variable – from the household survey – that is used to capture if the farmer practices FMNR or not, in combination with tree density.

The variables capturing whether farmers undertake rotations and/or intercropping with legumes are also positive and significant. Jointly, the large coefficient of all the SLM and FMNR related variables (tree density, pruning, maturity of trees, crop rotations, intercropping with legumes) illustrates the importance of preserving trees and pruning them, avoiding bush or man-made fires and deploying SLM practices in order to improve agricultural productivity.

TABLE 8:

Regression estimation results from production function (Eq. 10)

Ln(revenue)	Coef.	t	P>t
Ln(Trees^{-acre})	0.11	2.48	0.01
Pruning	0.25	3.58	0.00
Mature trees[6]	0.32	5.51	0.00
Legume intercropping	0.38	6.31	0.00
Rotation	0.12	1.82	0.07
Num. family members	0.02	2.01	0.05
Ln(Fertilizer cost^{-acre})	0.05	3.69	0.00
Ln(Tractor cost^{-acre})	0.06	3.73	0.00
Labour cost^{-acre}	0.002	3.87	0.00
Northeast	0.20	2.01	0.05
Northwest	-0.12	-1.47	0.14
Southwest	-0.24	-2.52	0.01
Southeast	0.23	2.41	0.02
Constant	4.47	34.3	0.00

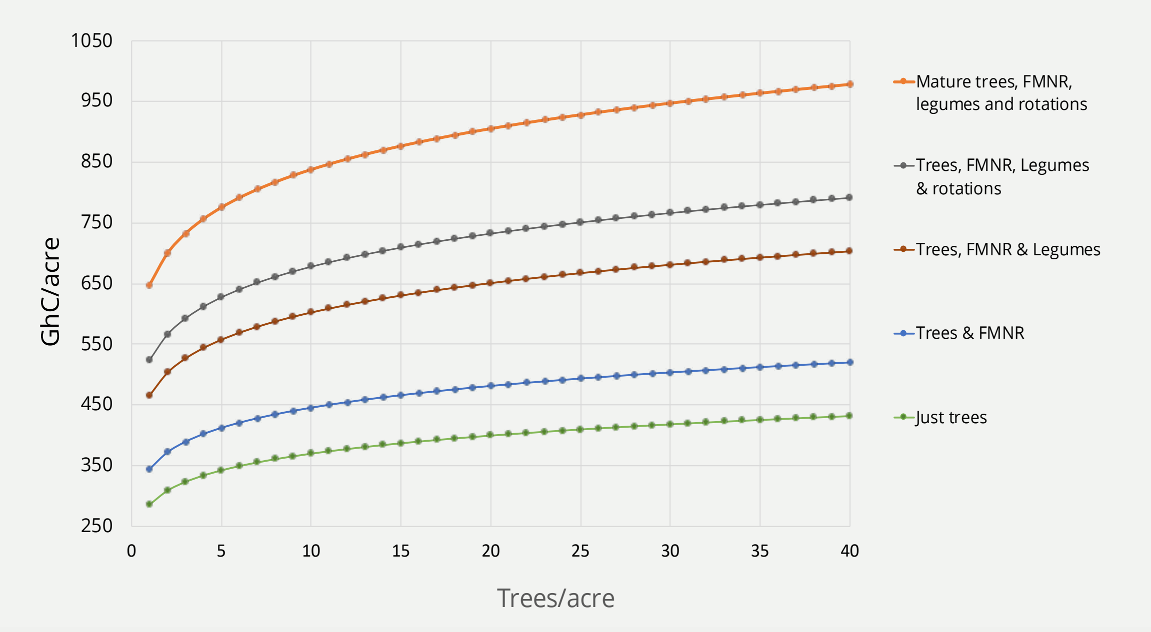
MODEL FIT: Number of obs = 483, Prob > F = 0.0000, Adj R-squared = 0.3206, Root MSE= .604

Independent control variables include: number of mature trees, intercropping legumes (=1 if yes, 0 otherwise); crop rotation (=1 if yes, 0 otherwise); number of family members, log of fertiliser expenditures, log of expenditures on tractors, and total expenditures on labour. The use of tied ridges, earth bunding, and manure are also controlled for and are insignificant.

6 *Farmers were asked in the questionnaire if their trees were predominantly young, mature, old or mixed. It is on the basis of this qualitative appreciation that we analysed the contribution of tree ages to crop productivity and revenues.*

FIGURE 6:

Crop revenues and their relation to varying levels of tree density, SLM, and FMNR practices.



As for conventional farming inputs, it may be noted that all variables are positive and significant.

Figure 7 highlights the effect of fertiliser spending and hired labour in our sample. We observe a positive impact of fertiliser spending with diminishing returns as fertiliser spending increases, as does tractor spending. Specifically, as farmers spend 1 per cent more on fertilisers or tractor services, revenues increase by 0.05 per cent and 0.06 per cent respectively.

What is noteworthy with respect to fertiliser use is that at low levels of spending, farmers enjoy a high return. When increasing NPK expenditures from GHS 0 to GHS 10 per acre, crop revenues increase by GHS 50. This results in a net gain of GHS 40 per acre. However, beyond GHS 10 per acre, further spending no longer pays off, i.e. revenues rise at a lower rate than spending (see Figure 7).

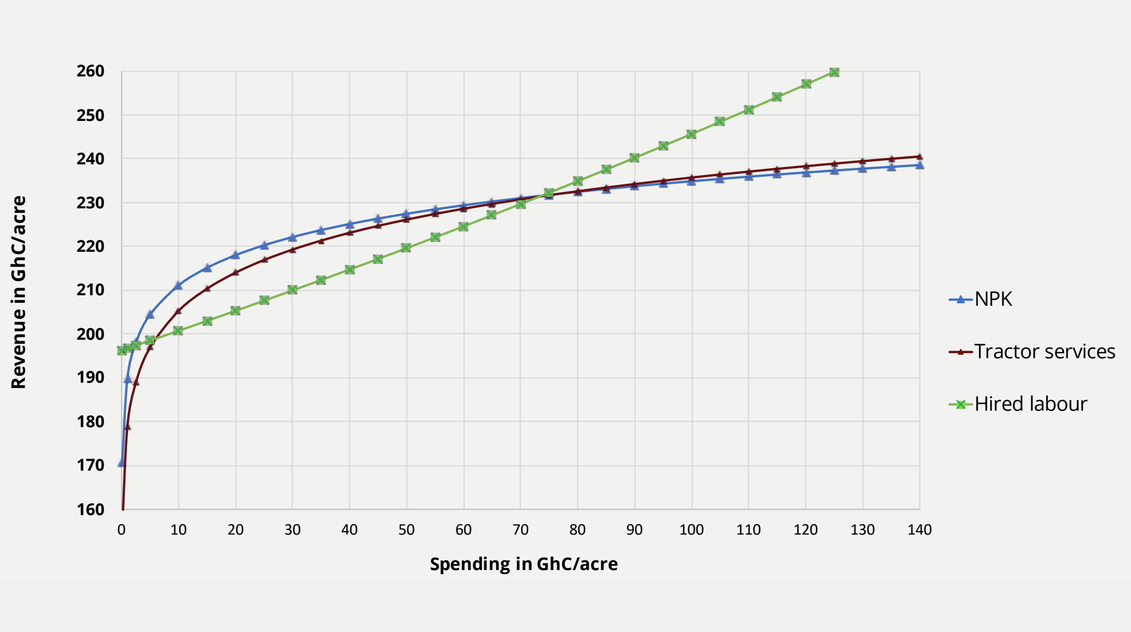
The returns to tractor spending also show diminishing returns. Nevertheless, we believe that increasing per acreage costs is likely to reflect supply and demand conditions or price discrimination on the part of the tractor rental agency, rather than more hours being spent to plough a given piece of land.

The amount spent on hired labour per acre (for land preparation, weeding or harvesting) shows no diminishing return (Figure 7). As farmers spend more on hired labour, crop revenue rises. It must be noted that non-hired family labour is not included in our estimation, but the number of family members (some of whom may be helping with farming) is positive and significant in our production function. When interpreting that coefficient, we conclude that as the household size increases by one member, per acreage crop revenues increase by 2 per cent.

Regarding the location variables, control villages are used as our base variable. Therefore, all community variables are being compared to the revenues in these control villages. When observing the coefficients and keeping everything else equal, we see that crop productivity – and thus agricultural revenues – are higher in the northeast and southeast (including Kondopie) relative to the control villages where CIKOD has not had any intervention. This makes sense, in that farmers or villages that have benefited from CIKOD interventions for a longer time and are closer to the CIKOD conservation centre will have higher levels of skills and general training opportunities relative to villages

FIGURE 7:

Relationship between crop revenue, hired labour, fertiliser and tractor service expenditure



that are further away and have received training more recently. The dummy variable for 'northwest' (including the villages of Tangpuor, Naagagn, Pavuu, and Nyafinyor) is insignificant, showing that there is no statistically significant difference between these communities and the control communities where CIKOD has not had any intervention.

Finally, crop revenues in the southwest are lower than in the northwest and control communities. This may potentially be explained by a higher prevalence of fires, and being further away from the CIKOD conservation centre (described in Appendix 1). However, we emphasise that even when controlling for location, the variables trees, pruning, and crop rotations all have a positive and significant impact on crop revenues.

In the next chapter we look closer at the kind of farming practices that farmers use, the site-specific effects, and the resulting impacts on farmers' crop revenues and incomes. In Chapter 7, we estimate income from on-farm forest products, and in Chapter 8 we compare the per acre income of a farmer that adopts FMNR and SLM practices to a conventional non-FMNR farmer.

06 Estimating the contribution of FMNR to net crop income

In this chapter we use the results from the production function from Chapter 5 to analyse how the adoption of Farmer Managed Natural Regeneration (FMNR) and Sustainable Land Management (SLM) influences the productivity and farmers' income from crop production.

6.1 Defining FMNR farmers

In this study, a FMNR farmer is defined as someone who engages in pruning and has a minimum of eight trees per acre. In fact, tree density becomes a statistically significant determinant of crop revenue once a plot has eight trees per acre or more, and is no longer significant with a tree density of seventeen trees per acre or higher. This is determined by observing the effect (i.e. the statistical significance) of tree density directly on revenues, everything else being equal. Table 9 displays how average crop revenue of farmers who have seven to seventeen trees changes. We observe that tree density has a significant effect (at the 95 per cent level) from eight trees per acre, and is no longer significant at seventeen trees. However, we note that the sample size decreases substantially with higher levels of tree density.

TABLE 9:

Tree density and income

Tree density	Crop revenue	Std Error	N
7	222.8	(19.39)	260
8	232.1**	(20.88)	229
9	245.3***	(23.16)	202
10	252.0***	(24.60)	189
11	311.3***	(36.96)	108
12	312.8***	(37.27)	107
13	324.8***	(39.89)	98
14	330.0***	(41.78)	93
15	307.0***	(43.19)	85
16	318.9**	(47.00)	47
17	295.0	(61.03)	41
	Significance * p<0.1, ** p<0.05, *** p<0.01		

Among farmers who have at least eight trees per acre, the mean tree density is thirteen trees per acre. In our sample, 47 per cent of farmers (229 out of 483) have at least eight trees per acre. Nevertheless, as argued in Chapter 3, pruning is integral to new FMNR practices as promoted by CIKOD.

Therefore, the farmers who have a tree density high enough and who also prunes are referred to as FMNR farmers. They comprise 11 per cent of the sample population (52 out of 483)[7] as summarised in Table 10. The control group (i.e. the non-FMNR farmers) who does not engage in pruning has an average of five trees per acre.

7 There is no difference in per acreage tree densities between those who prune (8.3 trees per acre) and those who do not prune (8.2 trees per acre). Therefore, pruning in itself is not an indicator of the number of trees found on the farms.

TABLE 10:

Tree density among FMNR and non-FMNR farmers

Tree density per acre	mean	median	std dev	min	max	%
Non-FMNR farmers	4.5	5	1.6	1	7	53%
Tree lovers (>7 trees/acre)	13.5	10	6.6	8	80	47%
FMNR farmers (>7 trees/acre and pruning)	13	13	3.1	8	20	11%

6.2 FMNR farmers and basic farm production costs

In contrast to non-FMNR farmers, the basic 'tree lovers' do not have higher labour and land preparation costs, even with an average tree density of 13 trees per acre. However, farmers engaged in pruning and associated FMNR activities have statistically higher labour and land preparation costs (Table 11). This is expected, as mentioned in Chapter 3, because it is more laborious to use tractors in areas dedicated to FMNR. For FMNR & SLM farmers who also rotate crops, tractor costs and hired labour costs are even higher.

Nonetheless, higher tractor service costs and hired labour costs are associated with higher crop revenues, so the production function is parameterised with these inputs. Finally, since the majority of farmers intercrop legumes with sorghum and maize, this is included in all the farming scenarios.

TABLE 11:

Average spending on tractor services and hired labour by farmer category

Average spending (GHS/acre)	Conventional farming	Tree lovers 13 trees/acre	FMNR 13 trees/acre + pruning	FMNR & SLM 13 trees/acre + rotation + pruning
Tractor service costs	60 (50)	**70 (90)**	**115 (100)**	**125 (110)**
Hired labour costs: land prep, weeding and harvesting.	45 (30)	45 (25)	**70 (60)**	**90 (70)**

Note: T-test and KW-test prove statistically different means, where data is highlighted in bold. Medians are provided in parenthesis.

6.3 Crop revenue by household location

By using these levels of explanatory data of farming costs in the production function, we can estimate the crop revenues for the different farming scenarios and across the different locations in our study area. The results for all of the five case study areas (northwest, northeast, southwest, southeast and the control villages) are shown in Table 12. All other factors influencing the profitability of crop farming – notably, the level of fertiliser use and the number of family members – are held constant in the different scenarios, using average spending levels across the sample population (Chapter 4).

TABLE 12:

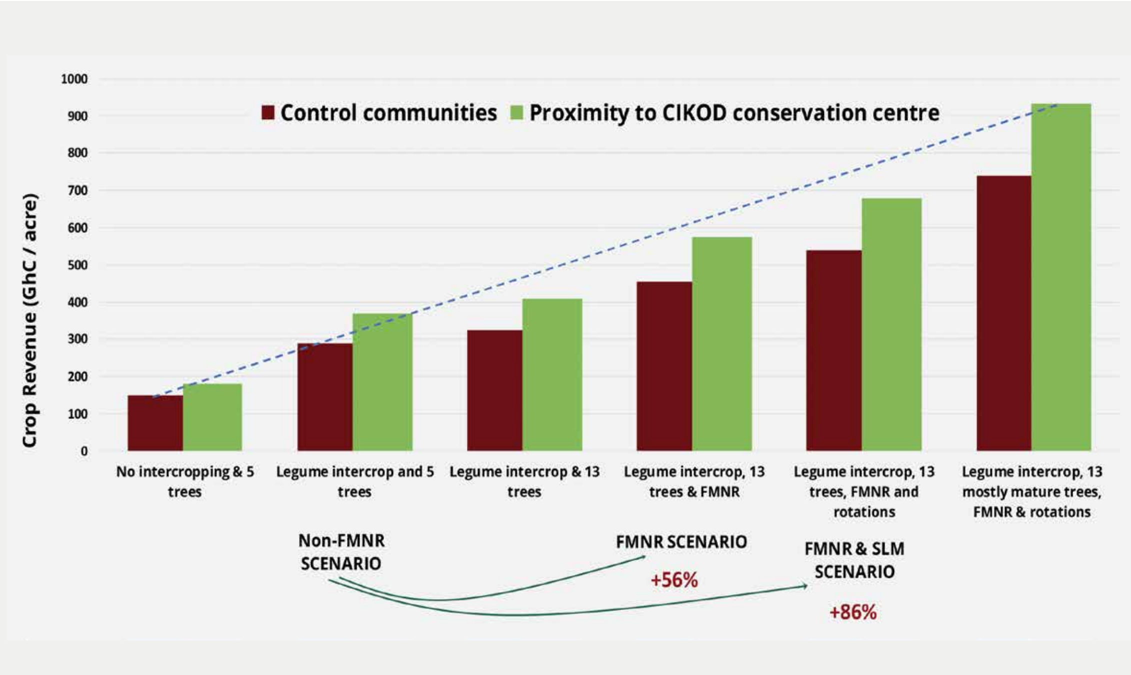
Revenue per acre by farming practice and household location

Revenue in GHS per acre	Non-FMNR		Tree lovers	FMNR	FMNR & SLM	FMNR & SLM+
Tree density	**5 trees/acre**	**5 trees/acre**	**13 trees/acre**			
	No intercropping	**Legume intercropping**	Legume intercropping	**Legume intercropping + pruning**	**Legume intercropping + pruning + rotations**	Legume intercropping + rotations + pruning + mostly mature trees
Control villages & northwest	150	**290**	325	**455**	**540**	740
Northeast	180	357	396	557	657	903
Southwest	120	230	255	359	423	581
Southeast	190	370	409	575	679	933

Note: Scenarios retained for cost benefit analysis are highlighted in grey.

FIGURE 8:

Crop revenue according to farming practice and village location



Note: The dashed line shows the potential for increasing crop revenues when moving from a low tree-cover and no intercropping, to a higher tree cover, farmer managed natural regeneration and crop rotations. The figure also indicates that if farmers in control communities were to receive the same quality of training as farmers located closer to the CIKOD conservation centre, their crop revenues would increase even further

(dark brown to green). It can also be observed that in the major CIKOD intervention zones (northeast and southeast), farmers have higher per acre revenues in comparison to the farmers in the control villages, everything else being equal. For example, the villages in the northeast (Kondopie, Zukperi and Faalu) that are found adjacent to the CIKOD conservation centre actually earn GHS 150 more per acre compared with the control villages, independently of whether or not they engage in FMNR and SLM practices.

As mentioned earlier, this may be attributed to the fact that they have benefited from other knowledge promoted by CIKOD and that the communities may be better at collectively managing key elements of FMNR, as evidenced in the fire-occurrence analysis in Appendix 1 and Figure 8. For example, focus group discussions revealed that fires are still recurrent in Tanchara (the southwestern part of the case study area) because some farmers deliberately set fire on other farmers' plots to obstruct FMNR efforts.

In this remaining analysis, we focus on:

1. **Bold highlighted scenarios (i.e. conventional farmers, FMNR farmers, and FMNR & SLM farmers) to simplify take-home messages.** As it is not possible to determine exactly how many years it takes for a tree to be 'mature' in the view of the farmers, we do not account for the enhanced benefits from having mostly mature trees. Thus, our results are lower bound estimates of the true benefits of FMNR adoption.
2. **Farmers in the control groups (first row in Table 12) resemble best the average farmer in the Upper West Region who do not have the privilege of living in proximity to a conservation and training centre.** However, it should be said that if the training and farming practices taught by CIKOD were to be scaled up across the districts, the net benefits of FMNR & SLM adoption could potentially be similar to those of the northeast. Therefore, farmers would enjoy a potential crop revenue increase according to the dashed line of Figure 8.

6.4 Costs of adopting FMNR

6.4.1 Pruning and thinning

In addition to regular farm production costs, farmers also incur costs related to their dedication to FMNR practices. The average labour costs of undertaking pruning and thinning are shown in Table 14 and are based on the results from focus group discussions across the five communities. The costs are derived by estimating the labour needs and the minimum wage (GHS 10 per day) that workers would be willing to accept to perform a given activity.

6.4.2 FMNR training costs, firefighting and equipment

To implement the FMNR activities, CIKOD engages in the training of lead farmers who serve to implement FMNR activities on their farms and teach other community members what they have learned. Fire volunteers are also trained. Their main role is to prevent fires by supporting farmers in their communities to create fire belts around their farms. Their other role is to support any fighting against fires that may be occurring. Finally, they also support regreening efforts through awareness raising on the effects of bush burning and tree felling, as well as on the importance of tree planting and regeneration. Each community typically has 100 households, comprising of 20 lead farmers and 20 fire volunteers nominated by the community. The standard practice is to have 10 women and 10 men among the lead farmers, and the same ratio for the fire volunteers (Rexford Yamdong 2019, personal communication). Within each community, the ratio is one lead farmer and one fire volunteer to five households. The costs associated with the training of lead farmers and volunteers, which are financed by CIKOD, are in the order of GHS 160 per year per person (see Figures 9a and 9b from the CIKOD conservation centre). With five households benefiting from the training directly or indirectly, the societal cost is GHS 32 per year per household. The gear is bought in the first year and the implied costs per household benefiting are in the order of GHS 41 for lead farmers and GHS 15.2 for fire volunteers. Since each household has approximately an average of two acres of main plots, the implied per acreage costs are half of this.

Non-lead and non-fire volunteer farmers who decide to take up FMNR practices have to purchase their own equipment and tools. At minimum, this involves the purchase of wellington boots, cutlasses, pruning knife and sickles for a total cost of GHS 80 per household (or GHS 40 per acre of main plot). We assume that the farmers spread their costs over two years and renew their equipment every five years. The average annual (non-discounted) cost to famers across a 20-year time horizon is thus GHS 30 per acre. These costs are summarised in Table 13.

TABLE 13:

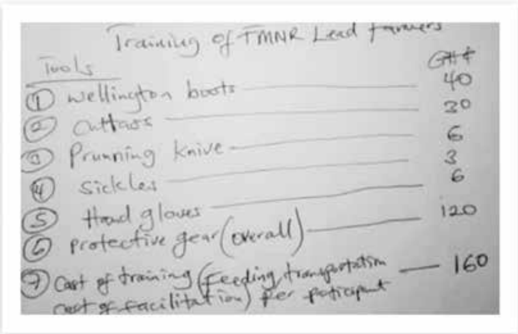
FMNR training, equipment, and labour costs

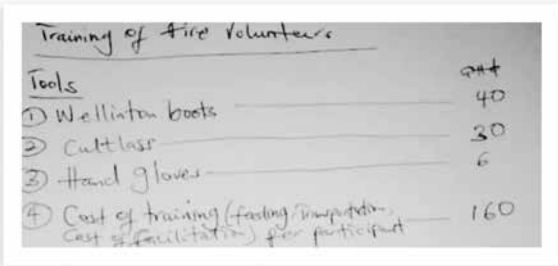
Cost per household or acre	GHS/household	GHS/acre	GHS/acre
	CIKOD expenses (Annually)	CIKOD expenses (Annually)	Farmers' expense
Training of fire volunteers	32	16	
Training of lead farmers	32	16	
Equipment for fire volunteers	15.2	7.6	
Equipment for lead farmers	41	20.5	
Equipment for villagers (year 1 and 2)			20
Pruning (years 1 to 3)			40*
Thinning (years 4 and onwards)			20
Average annual cost (GHS/acre)		**40**	**30**

*Example: Four man-days at 10 cedis per day to prune a cluster of trees on one acre of land

FIGURE 9A AND 9B:

Quick sketches of training cost for lead farmers and fire volunteers





6.5 Household income by farming practice

Finally, using cross-sectional data from the household survey, we account for all revenues and costs of FMNR at one moment in time for three types of farmers in control communities (Table 14). This budget shows that farmers have the potential to nearly double their income from food crops (despite higher production costs associated with FMNR) if they move from conventional/non-FMNR farming to FMNR farming with crop rotations.

TABLE 14:

Average annual net income from crop production (GHS/acre)

	Non-FMNR / traditional	FMNR	SLM & FMNR
Tree density	**5 trees/acre**	**13 trees/acre**	
Farming scenario	**5 trees/acre Legume intercropping**	**Legume intercropping + pruning**	**Legume intercropping + pruning + crop rotations**
Crop revenue	**292**	**456**	**538**
Production function inputs			
Fertiliser costs	60	60	60
Tractor service costs	60	115	125
Hired labour costs	45	70	90
Number of family members	7	7	7
Other costs – Seeds	7	22	22
Other FMNR costs – Average (fire prevention, pruning, equipment, and training)	0	30	30
Net crop income	**127**	**171**	**223**

We will further explore the impact of tree density, pruning and crop rotations on the flow of benefits and costs in the cost benefit analysis in Chapter 8.

CHAPTER

07

On-farm forest income among FMNR and non-FMNR farmers

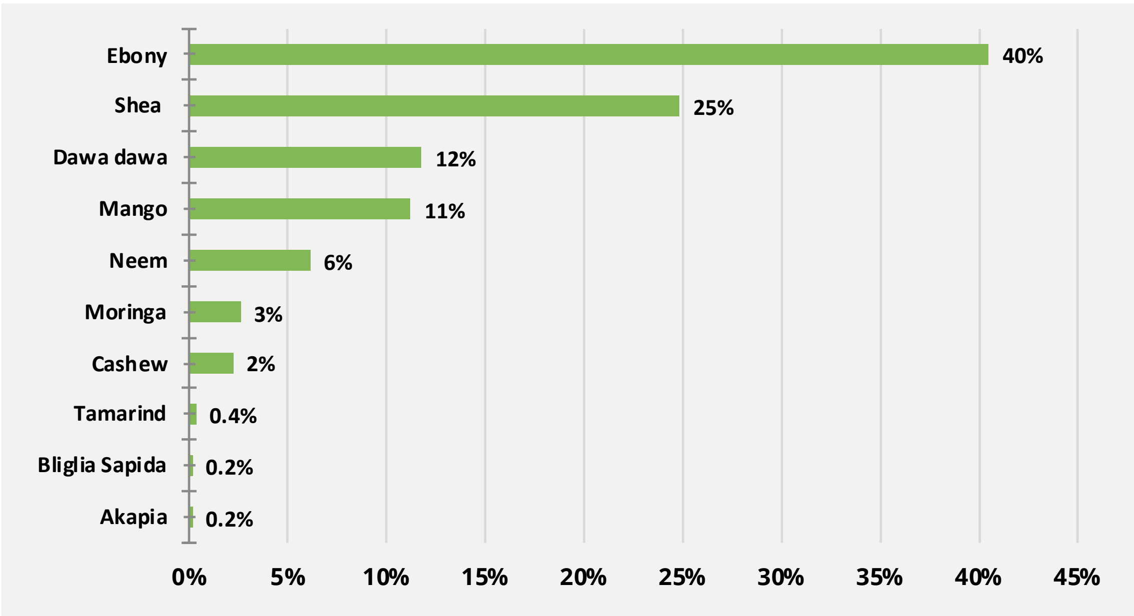
Farmers preserve and tend to a large range of different native and introduced tree species that have various densities. The comprehensive range of tree species was disclosed during the focus groups in the case study area and is provided in Appendix 2 (Damyang et al. 2019). In the following section, we consider the contribution of on-farm forest regeneration to farmer incomes and livelihoods.

7.1 Dominant tree species found on-farm

As reported by the household survey, the major trees species found on farmland in the case study area are ebony, shea, dawadawa, moringa, cashew, neem and tamarind. The proportion of farmers considering a given species as the most important (=1) is shown in Figure 10. To make the Cost Benefit Analysis (CBA) tractable, we also assume that the number of trees that the farmers retain within their fields is proportional to their predominance. As such, FMNR farmers who have an average of 13 trees per acre are thus assumed to have 5 ebony trees (40 per cent of 13 trees), 3 shea trees, 2 dawadawa trees, and so forth (Table 15). There is no significant difference in tree species diversity between FMNR and non-FMNR farmers. Accordingly, the economic valuation focuses on five major tree species and the cash and non-cash income that farmers derive from them.

FIGURE 10:

Prevalence of tree species on farmer's land, by order of importance



7.2 Valuation of on-farm forest income

In analysing the case for adopting FMNR practices, we assume that non-FMNR farmers have five trees per acre in their farming system at the outset of the accounting horizon. As a result of adopting FMNR, they increase tree cover to thirteen trees. Thus, the additional eight trees are young trees that will not provide substantial timber and NTFP for the first years of their lives. To estimate the value of on-farm forest income, we use information from focus groups, household survey responses,

CIKOD expert interviews and secondary literature on the production values of the different trees. The data and assumptions that we use for each tree and its product are presented in the following and summarised in Table 16.

TABLE 15:

Number and types of tree species per acre, for a typical non-FMNR and FMNR household

# of TREES	FMNR farmers	Non-FMNR farmers (baseline)	FMNR adopters Additional young trees
Ebony	5	2	3
Shea	3	1	2
Dawadawa (Parkia biglobosa)	2	1	1
Mango	2	1	1
Neem	1	0	1
Total	**13**	**5**	**8**

7.2.1 Ebony fruit

Ebony (*Diospyros crassiflora*) is endemic to Western Africa. It is slow-growing and produces very hard and durable heartwood which is highly demanded for exports. It is used to make sculptures, door knobs, musical instruments, etc. Its bark decoction is used in the treatment of ovarian problems. It can also be used against yaws and sores (Pfaf 2019).

In the Lawra and Nandom districts, ebony is particularly appreciated for its fruit (called 'lieme' and 'kpagra') that ripen in the dry season and are appealing, sweet, and juicy. The fruits are soft and delicate (National Research Council 2008) which means that they are not traded in markets, but rather "*support households in the fruiting season as children tend to eat less food at home because they get these fruits to supplement their diet*" according to focus group members (Damnyag et al. 2019). According to data from the household survey, households harvest an average of 0.75 maxibags[8] per tree, with a minimum of 0.3 and a maximum of 1.5 maxibags per tree per year.

Ebony trees grow slowly and take about 15 years to yield fruit (Damnyag 2019b). Therefore, we assume that as of year 15, the yields would increase by 0.1 maxibag per tree per year, rising from 0.3 to 1.5 bags per year. The focus groups revealed that farmers value one bowl of ebony fruit at GHS 1 to 5 per bowl (on average GHS 1.17 per bowl). About 40 bowls can fit in one maxibag. The implied value of a maxibag of ebony fruit is GHS 47.

8 Maxibags are used to trade crops. A maxibag holds approximately 80 kg of maize.

7.2.2 Shea nut

Shea trees form the dominant tree species of agroforestry parklands in Sudanian Savannas where it is associated with other species such as *Acacia senegal*, *Annona senegalensis*, *Parkia biglobosa*, and *Terminalia avicennioides* (Boffa 1999; Hall et al. 1996). Farmers maintain shea on farms primarily for its kernel, which is rich in fatty acids and is used locally for food and internationally for chocolate, as well as pharmaceutical and cosmetic products (Teklehaimanot 2004). Shea is the second most important oil crop in Africa after palm oil, and assumes primary importance in West Africa, especially in regions where annual precipitation is less than 1,000 mm (Hall et al. 1996).

Shea trees are reportedly less productive in fallows and natural forests. However, it bears fruit abundantly in cultivated fields of the Sahelian parklands and for this reason it is characterised as an anthropic species that benefits from the close care given to it by local communities (Lovett and Haq 2000a). Women are primarily engaged in the collection of fruits and in processing the kernels into shea butter.

To assess shea yields, we rely on field measurements recorded as part of the ELD evergreening study in the region of Bougouni, Mali which has a similar climate (Sudano-Sahelian) to the Upper West Region in Ghana. In Bougouni, Draman (2019) conducted a productivity assessment on farmland during the shea harvesting season (May to July). He found that young to mature trees yield an average of 13 kg of dried shea nuts (after *dépulpage*, the pulping process) whereas older trees beyond 25 years of age yield an average of 19 kg of dried shea nuts per tree, resulting in an average annual harvest of 15 kg per mature trees (Draman 2019).

These results are similar to those found in the scientific literature. Aleza et al. (2018) in Benin found a similar average of 17.4 kg per tree on farmland. In Sudan, Ruyssen (1957) found an average of 22.4, 5.3 and 17.2 kg per tree across 3 locations in Sudan. It takes about 15 years before a shea tree begins to fruit and about 25 years before it is fully mature, after which it will produce fruit for about the next 200 years (natural homes 2018). A coco bowl of dried shea nuts sells for GHS 8, and a shea coco bowl typically weighs 4.2 kg. Thus, shea nuts sell for about GHS 1.9 per kg (Damnyag 2019).

7.2.3 Dawadawa

Dawadawa *(Parkia biglobosa),* also known as the locust bean tree and 'néré' in Francophone West Africa, is a multipurpose tree indigenous to sub-Saharan Africa (Hopkins 1983). It is particularly typical of agroforestry parklands. Dawadawa is highly valued for its seeds which are ground into a pungent nutritious spice or condiment added to soups and stews (Campbell-Platt 1980). Fruit pulp, foliage, and seeds of the African locust bean can be used to feed livestock (Heuze et al. 2019). The usefulness of the tree is heightened by the fact that dawadawa can be harvested during the dry season, when feed is scarce. The tree is important for improving soil fertility and for use in traditional medicine (Teklehaimanot 2004).

Production also varies from year to year. According to CIKOD field staff, it takes 16-20 years for a dawadawa tree to begin to fruit. One mature dawadawa tree that has fruited for more than five years provides one maxibag of fresh dawa seeds. One bag contains 40 coco bowls. After drying the seeds, the remaining volume is 35 coco bowls. This is equivalent to approximately 90 kilograms of dawadawa seeds. Since it takes at least five years after fruiting started to achieve this harvest level, we assume that dawadawa seed yields increase by 10 kilograms per year, from year 16 to 25. Eventually it would reach an average annual harvest level of 40 kilograms by year 20, and 90 kilograms by year 25. A coco bowl with dawadawa sells for GHS 6-9. With roughly 2.5 kilograms of dawadawa seeds in one coco bowl, the average price is GHS 3 per kilogram of seeds.

7.2.4 Mango trees

Mango is one of the most important fruit crops of the tropics and subtropics (Chaudhri 1976). It is longlived (80 to over 100 years) and belongs to the *Anacardiaceae* family. In agroforestry, mango trees are well-suited for use on terraces and as dispersed trees on pasture or farmland (Musvoto et al. 1995)

Research from Uganda shows that local mango varieties yield about 200 fruits per tree per year (Recha et al., 2017), which is equivalent to approximately 120 kilograms per mango tree of the Kent variety, which is mostly used in Ghana.[9] This is an average, indubitably depending on management, variety and age of the trees. Mango trees start producing fruit in their third year and already achieve full production in the seventh or eighth year (ProductiveProduce 2018). For the calculation of the CBA, we assume that the harvestable volume increases linearly from 10 fruits in year three to 200 fruits in year eight (i.e. a marginal annual yield of 38 fruits per tree) after which it stabilises.

With that being said, improved varieties of mango can yield an average of 600 fruits per tree (Recha et al. 2017) and yields can be as high as 1,000 kg per hectare according to Dembélé et al. (2013). Thus, 120 kg per year is a conservative lower bound estimate. In local Ghanaian markets, three mangoes sell for GHS 2.5 in total. With an average weight of 0.6 kilograms per fruit, the market price is in the order of GHS 1.8 per kilogram or GHS 0.8 per fruit (Damnyag et al. 2019).

7.2.5 Biomass harvest for fuelwood

Any part of a tree can be used for energy, including the tops, branches, crowns, foliage, stumps, and roots (Röser et al. 2008). The periodic

9 *The average weight of the Kent variety is 0.57 kilogram per fruit (Okorley et al. 2014).*

thinning of trees to reduce resource competition can be used as fuelwood. Pruning also helps to enhance the quality of timber and to stimulate biomass production. Njenga et al. (2019) have shown that farmers who practice agroforestry can be entirely self-sufficient in fuelwood and produce surplus that they sell to neighbours as a source of income.

According to CIKOD, one mature tree (between 10 and 30 years of age) provides five to seven headloads of fuelwood. Pruning of a cluster of immature trees (i.e. saplings) on one acre can provide one or two headloads of fuelwood. Thus, we assume that non-FMNR farmers gain six headloads per tree per year from existing mature trees, whereas FMNR farmers obtain fuelwood from both mature trees and one headload per young tree. One headload sells for GHS 5 (Damnyag et al. 2019).

7.2.6 Potential and actual collection rate of fruits, nuts, and seeds

It is fair to assume that not all fruits, nuts and seeds are harvested and some fruits may perish before being collected or reaching markets. For example, in Burkina Faso, Boffa et al. (1996) found that total nut harvest over two years amounted to less than half of nut production on farmland. Therefore, we weight the potential forest income from dawadawa, ebony, shea and mango trees by a factor of 0.5 to produce a conservative estimate of actual forest income that farmers can obtain.

Summary statistics for these assumptions are shown in Table 16 and used to calculate average forest income for a typical non-FMNR and FMNR farmer. The cash flow for these farmers are provided in Appendix 3.

TABLE 16:

On-farm forest production values per tree per year, used in the Cost Benefit Analysis

	Unit	Mean yield tree/year	Min	Max	Price/unit (in GHS)
Ebony fruit, young, yr 1-14	Bags	0	0	0	47
Ebony fruit, mature, yr 15-30		0.75	0.3	1.5	
Marginal yearly increase, yr 14-20		0.1			
Shea nuts, young, yr 1-14	Kg	0	0	0	1.9
Shea nuts, mature, yr 15-30	Dried nuts	15	7	26	
Marginal yearly increase, 14-20		1			
Dried dawadawa seed, yr 5-15	Kg	0	0	0	3
Dried dawadawa seed, yr 16-20	Dried nuts	40	10	90	
Marginal yearly increase, yr 16-20		10.0			
Mango fruit, young, yr 3 -7	Kg of fruits	105	10	200	0.8
Mango fruit, mature, yr 8 -20		200	200	200	
Marginal yearly increase, yr 3-7		38			
Fuelwood from pruning of FMNR sapling, yr 1-3	Headloads	1.5			
Fuelwood from pruning, yr 10-20		6	5	7	5
Marginal yearly increase from FMNR, yr 6-9		2			
Thinning from FMNR, yr 4-10		2			

08 Cost Benefit Analysis results: FMNR versus status quo cropping practices

The analysis previously conducted in this study shows that at one moment in time, farmers who employ Sustainable Land Management (SLM) techniques and engage in Famer Management Natural Regeneration (FMNR) have significantly higher incomes as a result of improved soil fertility and on-farm forest income. However, because of the time value of money,[10] it is important to account for the flows of benefits and costs over time. For this purpose, a cost benefit analysis (CBA) is necessary.

8.1 CBA scenarios and assumptions

The CBA compares three farming scenarios.

- In the **FMNR farming scenario,** farmers employ intercropping with legumes, have a high tree density and deliberately engage in FMNR practices associated with pruning, thinning, and reduction of burning.
- In the **FMNR & SLM farming,** farmers undertake crop rotations in addition to FMNR.
- These two scenarios are compared to the **non-FMNR scenario,** in which farmers intercrop cereals with legumes, but have low tree densities and do not use rotations.

When estimating on-farm forest income, it is assumed that the average non-FMNR farmer has an average of five trees per acre as revealed in section 6.1 and with the species composition as shown in Table 16. We further assume that these five trees are mature and yield fruits throughout the 20-year accounting period. In contrast, FMNR farmers have an average of thirteen trees per acre, but at the time of adopting FMNR, the additional eight trees are young and will not yield forest income until maturity, as per the assumptions explained in Chapter 6.

Forest products may be consumed by the household (non-cash) or sold on markets (cash income) and are valued according to their farm gate market price or barter price as explained in Chapter 6.

10 *It is a basic financial concept where money available at the present time is worth more than the identical sum in the future due to its potential earning capacity.*

While FMNR farmers have higher crop yields, it takes time for soil fertility to regenerate. Since CIKOD interventions started in 2014, it is fair to assume that the crop revenues observed from the 2019 household survey for FMNR farmers have been achieved over the five years since CIKOD started their interventions. Thus, we assume that revenues increase progressively from GHS 290 per acre to GHS 455 per acre (i.e. GHS 33 per year) when an average non-FMNR farmer decides to adopt FMNR practices, and from GHS 290 to 550 per acre when going from non-FMNR to FMNR & SLM farming.

As shown from the production function results, crop revenues may increase further when farmers have predominantly mature trees, or where FMNR has been practiced for longer time. This reflects other literature. According to Patrice Savadogo from ICRAF:

> *"Where you find a very limited number of trees, you find low production of cereals – maybe 200 kg/ha. As tree density increases, yield reaches 300 kg/ha. The most we found was 500 kg, usually where FMNR had been for quite some time. That doubling of yield is due to trees (in Mongobay 2018)"*

We have not included this additional gain in our estimates, since it is difficult to determine when a tree can be considered mature.[11] Nevertheless, **the implication is that we are showing the lower bound profitability of FMNR farming systems.** It is assumed that the flow of income from on-farm forest production and crop production is constant for non-FMNR farmers, as we do not have any data on yields and productivity over time in the baseline situation without FMNR uptake.

8.2 CBA results on the case for FMNR and crop rotations

The case for adopting FMNR
Figure 11 shows the non-discounted cash flow of income to FMNR and non-FMNR farmers. For

11 *Farmers were asked in the questionnaire if their trees were predominantly young, mature, old or mixed. It is on the basis of this qualitative appreciation that we analysed the contribution of trees' ages to crop productivity and revenues.*

nonFMNR farmers, income is constant, reflecting a lack of investment into soil and forest improving activities. In contrast, FMNR farmers face some additional costs in the first years, notably related to the undertaking of pruning, thinning, fire-breaks, land preparation and the purchase of new equipment. However, the flow of income from both forest and crop revenues increases rather rapidly, as shown in Figure 11. Farmers practicing crop rotations in addition to FMNR can expect an additional income of approximately GHS 100 per acre, while FMNR farmers can expect the additional new trees to provide

FIGURE 11:

Non-discounted cash flows for illustration (GHS/acre)

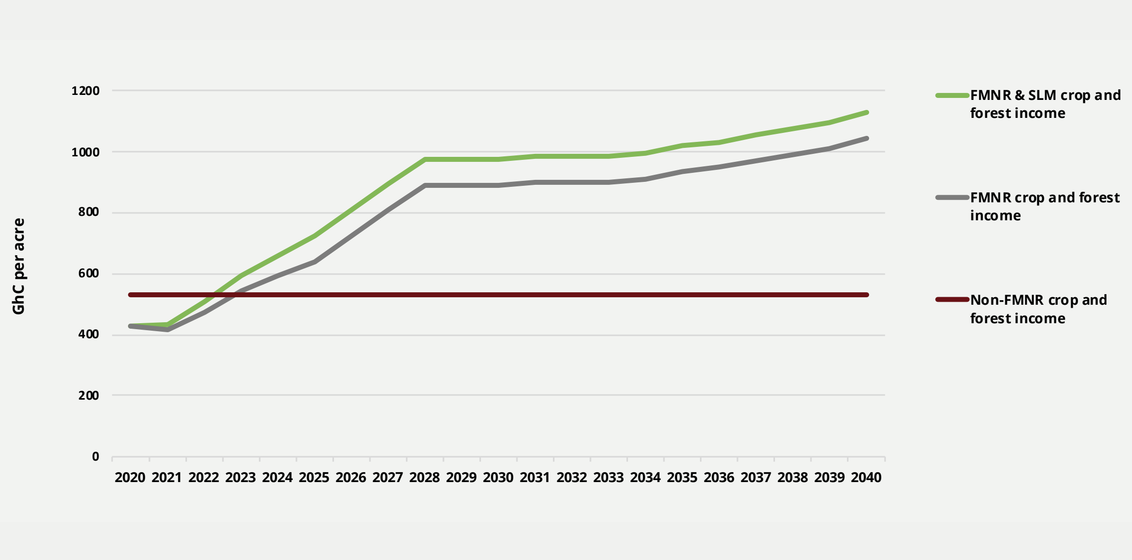
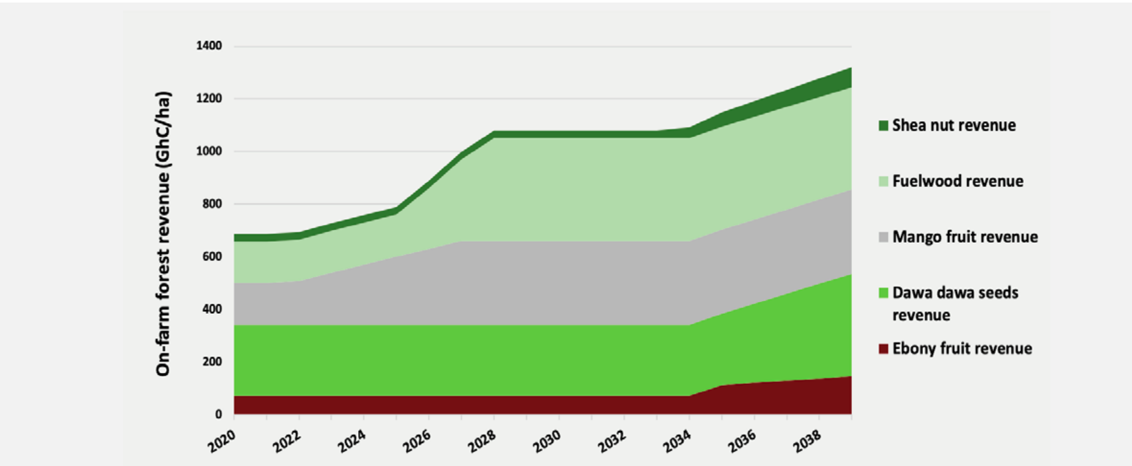


Figure 12b shows the breakdown of the flow of forest revenue for a typical FMNR farmer as the additional eight trees per acre begin to mature and provide more nuts, fruits and fuelwood. The flow of forest products is assumed to remain constant for non-FMNR farmers, although in reality it may be declining as existing trees grow older.

FIGURE 12

Flow of FMNR on-farm forest revenue



The net present value (NPV) of the three farming systems are shown in Table 17 for a time frame of 20 years and a discount rate of 5 per cent. As non-FMNR farmers adopt FMNR, the NPV of crop produce rises from GHS 1,518 to GHS 1,813 per acre. If farmers additionally engage in crop rotations, the present value of crop revenue increases to GHS 2,304 per acre. Forest income includes both cash and non-cash incomes. As such, a typical non-FMNR farmer can expect a total income of GHS 6,942 per acre in present value terms over 20 years, or in other words GHS 557 per acre per year. In comparison, a FMNR farmer can expect GHS 9,633 per acre in present value terms over 20 years or GHS 770 per acre per year. Finally a FMNR & SLM farmer can expect a total of GHS 10,123 per acre in present value terms over 20 years.

The NPV benefit of taking up SLM & FMNR farming is the difference between this scenario and the nonFMNR scenario, as shown in Table 18. FMNR combined with crop rotation will provide the typical farmer with an additional income of **GHS 255 per acre per year (EUR 102 per hectare)** in present value terms, or GHS 587 per household per year (EUR 94), since households have an average of 2.3 acres dedicated for the main plots. In order words, this sums up to four cedis of benefit to farmers from every cedi invested. The payback period (or break-even point) is 3.3 years, which is the amount of time required for cash inflows generated by a FMNR adoption to offset the initial cash outflow. The expected compound annual rate of return (earned by the farmer when investing in FMNR and crop rotations) is 33 per cent. Also known as the Internal Rate of Return (IRR), it is the discount rate that brings the NPV of a project down to zero. This implies that FMNR is financially viable at the discount rates that are used for project appraisal of land-use projects by the African Development Bank or World Bank. Even for the smallholder farmers – who require a 23 per cent rate of return to forgo present consumption for future consumption as evaluated in Chapter 4 – FMNR is worthwhile.

From a societal perspective, there are also some training costs associated with teaching farmers about FMNR. When accounting for these, the payback period is slightly above four years and the IRR is 26 per cent. This is substantial, considering that we have not accounted for other environmental co-benefits such as the enhanced carbon sequestration associated with improved tree cover.

TABLE 17:

Net present value of on-farm forest and crop incomes (GHS/acre) from non-FMNR, FMNR, and FMNR & SLM farming systems, r=5%, T=20 years

Net present value of on-farm forest and crop production (r=5 per cent)	Non-FMNR farmer	FMNR farmer	FMNR & SLM farmer
Total NPV (GHS/acre), of which	6,942	9,633	10,123
NPV from crop production (GHS/acre)	1,518	1,813	2,304
NPV from on-farm forest products (GHS/acre)	5,424	7,820	7,820
Net benefit per year per acre (GHS/acre)	557	770	810
Net benefit per year per farm (GHS/farm)	1,281	1,770	1,865

TABLE 18:

Cost benefit analysis results of adopting FMNR and FMNR & SLM farming systems, r=5%, T=20 years

Evaluation criteria	FMNR adoption	FMNR & SLM adoption	FMNR & SLM adoption
Who	**Farmer**	**Farmer**	**Society**
Present value, additional revenues (GHS/acre)	4,624	5,164	5,164
Present value, additional costs (GHS/acre)	-1,600	-1,982	-2,769
Net Present Value (GHS/acre)	**3,025**	**3,182**	**2,395**
Net benefit per year per farm (GHS/farm/year)	488	587	442
Net benefit per year per acre (GHS/acre/year), of which:	212	255	192
Crops (GHS/acre/year)	24	63	NA
Forest products (GHS/acre/year)	192	192	NA
Internal rate of return	23%	33%	26%
Payback period (years)	3.8	3.3	4.1
Benefit Cost Ratio	3.3	3.8	2.7

The flow of additional income (in present value terms) associated with adopting FMNR is shown in Figure 13. As mentioned earlier, farmers forgo income in the first years, but within four years they earn above and beyond what they would have earned by not doing FMNR.

FIGURE 13:

Non-FMNR to FMNR, additional income from on-farm forest and crop produce (non-discounted, T = 2020-2040)

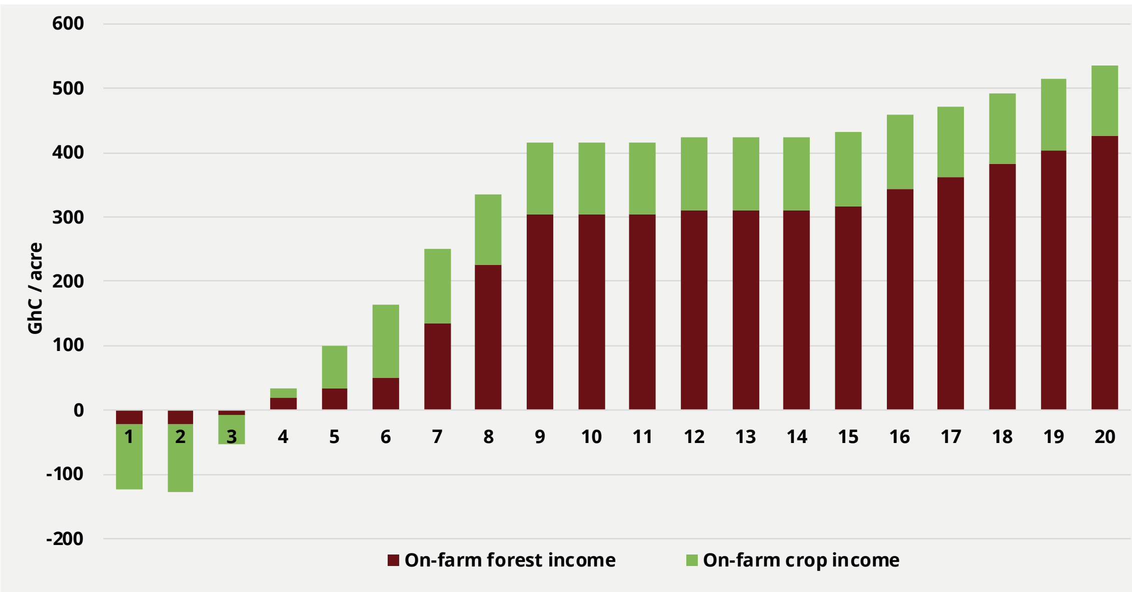
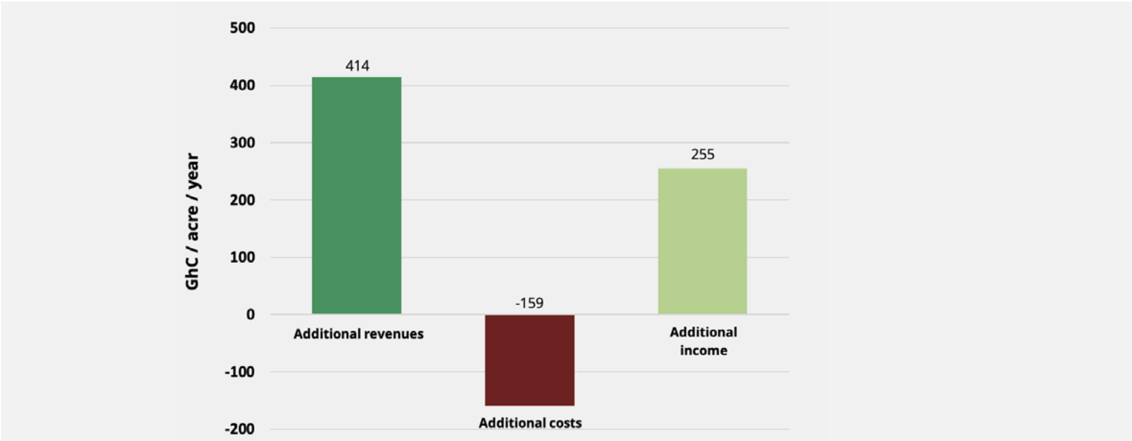


Figure 14 shows the present value of the additional revenues (from crop and forest products), the present value of the addtiona implementation and management costs associated with FMNR and crop rotations, and the difference between the two, i.e. the average additional income to farmers, in present value terms.

FIGURE 14:

Figure 14: Additional revenues, costs and income in present value terms from implementing FMNR and crop rotations, farmer perspective (discounted at r=5%)

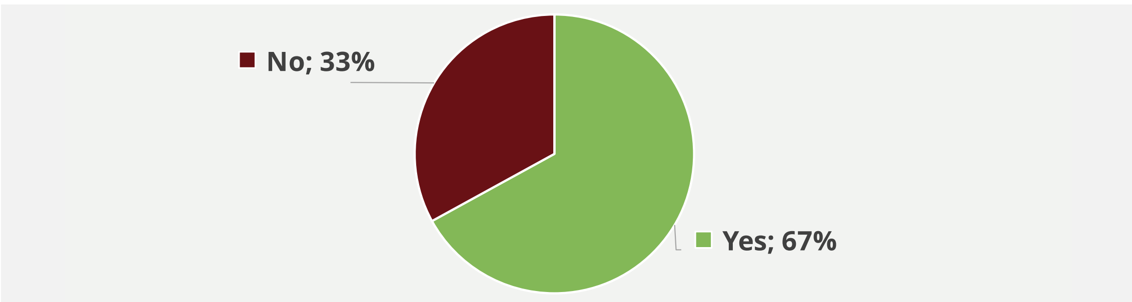


8.3 Sensitivity analysis and rural finance

Above presented results have been calculated using a 5 per cent discount rate, assuming that funding for the FMNR practices is provided through a mixture of grants and loans. However, the reality varies from farmer to farmer and one of the main constraints to further upscaling FMNR is insufficient access to rural funding. Among the households interviewed for this study, 33 per cent claim not to be able to take out any loan for farming (Figure 15). The 67 per cent who have access to financing mostly use family relations, credit unions, and/or rural banks (Figure 16). According to the ELD household survey results, annual interest rates among relatives are in the range of 0 per cent to 50 per cent, for a median of 20 per cent. Money lenders charge typically between 10 to 35 per cent interest rates, and saving clubs propose rates between 5 and 60 per cent. However, 10 and 20 per cent are the most common rates. Among credit unions, rates range between 5 to 25 per cent, but 10 per cent is the norm. Among rural banks, 20 per cent is the usual standard (table 19). These interest rates are aligned with farmers' lower discount rates as reported in Chapter 3. Loan duration ranges

FIGURE 15:

Access to credit. "If your household wished to invest in farming, would you be able to take a loan from the family, a formal, or an informal institution?"



from two months and up to thirty-six months in some rare cases. To reflect the opportunity costs of capital, we have performed the NPV analysis using 5 per cent, 10 per cent and 23 per cent interest rates.

TABLE 19:

Interest rates applied by lending institutions in the Lawra district

Interest rates	Most common rate(s)	Range of rates
Relatives	20 %	0 - 50 %
Money lenders	10 - 35%	10 - 35%
Saving clubs	10 % and 20%	5 - 60%
Credit unions	10 %	5 - 25%

FIGURE 16:

If you are able to take a loan, from what institution?

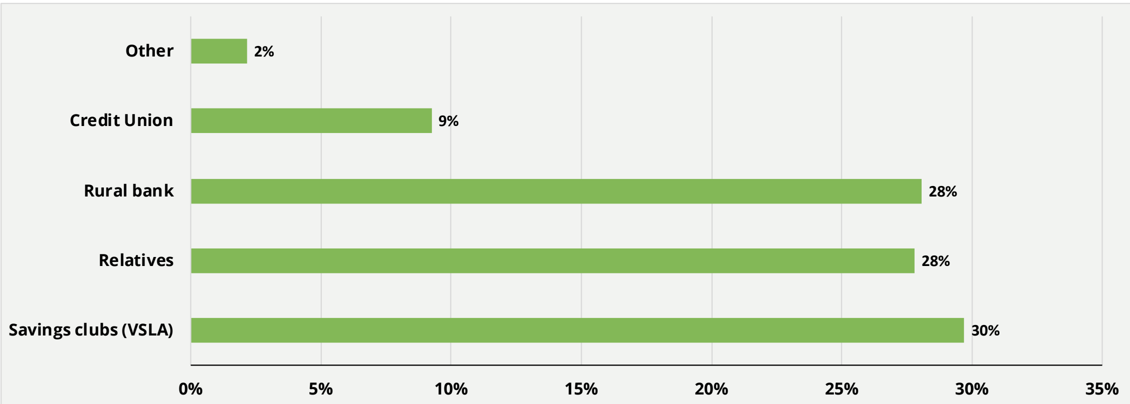


Table 20 shows the NPV returns associated with adopting FMNR and SLM. The overall net benefit of FMNR farming and crop rotations over traditional cropping are robust to differences in discount rates. Even if farmers had their own funds and could earn a 23 per cent rate of return on investment, they are better off investing their resources in FMNR. At a 23 per cent discount rate, farmers will enjoy a NPV benefit of GHS 547 per acre over a 20 year time period.

TABLE 20:

Net present value benefits of taking up FMNR & SLM at different discount rates, 20 years

Sensitivity analysis	Opportunity cost of capital (grants and loans)	African development bank reference rate	Farmers' personal discount rate
Discount rate	**5%**	**10%**	**23%**
NPV Farmers (GHS/acre)	**3,515**	**2,005**	**547**
NPV Farmers and society (GHS/acre)	**2,395**	**1,204**	**96**

8.4 Limitations: forest and crop revenues not considered in the CBA

Farmers enjoy a wide range of products as a result of FMNR, some of which were not accounted for due to the difficulty to attribute a given product to a designated farm. This includes the greater availability of bush meat, medicinal plants, poles (e.g. from neem trees), mushrooms, as well as canes and thatch to make 'kasog' baskets and 'kpakyang' chicken cages and so on. For instance, canes are often harvested in community land subject to FMNR. Canes were almost extinct, but thanks to land regeneration, those people with skills are back in the business of weaving and selling handmade crafts. In the Talensi district, Weston (2015) also showed that rafter or poles hewn from the tree trunk of a young tree are worth around GHS 4. However, it was not possible to quantify the availability of poles and their value in our case study area due to lack of data.

Additionally, we base our analysis on a typical FMNR farmer (five trees per acre) and a typical non-FMNR farmer (thirteen trees per acre). Yet, there are farmers with higher and lower tree densities and other species compositions, including *Faidherbia albida* (Gozan) and *Ficus gnaphalacarpa* (Kankang), for example. Such farmers enjoy a different level of forest-based revenue than what was considered in our calculations.

It is also assumed that non-FMNR farmers do not regenerate trees and maintain a constant level of forest income over the 20-year time horizon. However, in reality it is possible that the harvestable quantities of fruits and nuts will decline as trees get older. In the absence of accurate data on the actual ages of trees that are kept on farmland, we did not account for this.

Finally, the production function results (Tables 7 and 8, and Figure 7) demonstrate that when farmers have mostly mature trees on their farmland, crop productivity and revenues from sorghum, maize, groundnuts, and beans are the highest. In the CBA, we have not accounted for the enhanced income which is provided as trees mature because it is difficult to determine quantitatively what year trees become mature.

The implication is that the CBA provides a conservative, lower bound estimate of the true profitability of adopting FMNR farming.

PHOTO

A lady in Pavuu carrying a bundle of thatch from the community conservation area

09 Discussion and conclusion

The Upper West Region of Ghana belongs to the Sahelian zone in West Africa. Due to its geographic location and the dependence of its population on natural resources, rainfed agriculture and transhumance systems, the region is highly vulnerable to environmental degradation and climate change (ARF100). However, the current study shows that Farmer Managed Natural Regeneration (FMNR) can be a key contributor for the regreening of farmland affected by land degradation and can offer significant livelihood benefits to rural populations. Considering the exponential population growth rate and the rising competition for land (for the purposes of farming, mining and livestock rearing), it is of crucial importance to improve the production efficiency of existing farming systems.

TABLE 21:

Main constraints to adopting FMNR practices

What are the main constraints to adopting FMNR practices, in order of priority?	First or second most important reason
Lack of farm implements (pruning knife, pickaxe, etc.)	64%
Lack of labour	43%
Wild animal raids on crops	38%
Fear of expulsion (weak tenure)	26%
Lack of safety clothing and work gear	27%
Farmers habits	1.3%
Other (laziness, did not know about it)	1%

Our study results show that within only five years of implementing FMNR, farmers can expect a 56 per cent increase in the productivity of farm crops and an 86 per cent rise in crop productivity as long as they also implement crop rotations. In addition, farmers engaging in natural tree regeneration will enjoy a wider income base from on-farm forest products. According to UNDP (2011), there is a chronic food shortage in the Lawra district every year between the months of April to June when many households cannot afford two meals a day. Yet, this is the exact season when many indigenous trees (e.g. shea, ebony, dawadawa, and mango) provide nuts and fruit, thus supplementing farm income and helping them meet nutrition needs.

Our results show that an average farming household can increase its income from enhanced on-farm forest and crop production by GHS 650/year (EUR 106/year) in present value terms over a 20-year time horizon. This is in accordance with other findings in the literature. For example, a study involving 1,080 households in the Sahelian and Sudano-Sahelian ecozones of Burkina Faso, Niger, Mali and Senegal showed that FRMR increased household income by an average of USD 72 (EUR 65) per household per year (Binam et al. 2015). Considering crop production only, Haglund et al. (2011) found that annual crop revenue among 400 Nigerian farmers was EUR 40 higher for farmers practicing regeneration (EUR 110 for FMNR and EUR 70 for non-FMNR farmers). Finally, in the Upper East Region of Ghana, Weston et al. (2015) demonstrated that FMNR can increase household income up to USD 887 per year (EUR 710), which captures the value of social, health, environmental and economic benefits.

9.1 Constraints to the adoption of regreening practices

In light of these results, it may be questioned why the adoption of FMNR is not more widespread in the Upper West. As shown in Tables 22 and 23, the lack of farming implements, labour and financial resources needed to afford these inputs are considered to be among the main constraints of the farmers in our household survey.

TABLE 22:

How to facilitate the adoption of sustainable land management, ELD household survey

What would be needed to adopt more SLM practices, in order of priority?	Most important determinant
Access to equipment (wellington boots, cutlasses, wheelbarrows, pickaxe, etc.)	60%
Access to credit	40%
Other (extension services)	5%

In addition, Chapter 5 shows that farmers spend an average of GHS 60/acre/year on inorganic fertilisers (corresponding to 43 kg/ha). However, it has been proven that beyond GHS 10/acre/year[12] (=10 kg NPK/ha), it is no longer worthwhile to spend more on fertilisers as revenues will increase at a lower rate than the rise in costs. Thus, it makes sense for farmers to switch financial resources from fertilisers into hired labour, which does not show diminishing returns to scale as illustrated in our production function. At the same time, it is worth stating that almost 50 per cent of farmers spend nothing at all on fertilisers. This is also not recommendable as there are significant returns to spending marginally more than GHS 0/acre.

From a societal perspective, there is also scope for prioritising public expenditures differently. The Ghanaian National Fertiliser Subsidy Programme under the Ministry of Food and Agriculture (MoFA) was launched at the beginning of the year 2015 and is aimed at enhancing food production and security.[13]

The programme subsidises fertiliser bags at an average of 21 per cent (2014 data). With the full implementation of the programme, it is the expectation of MoFA that the application rate of 12kg/ha will increase to 20kg/ha, according to the Abuja declaration on Fertilizer Use by the African Green Revolution (Government of Ghana 2019). From our findings, it appears recommendable to lower spending[14] on fertiliser subsidies, in favor of the provision of low interest rate loans or conditional grants, which could help farmers acquire equipment that facilitates sustainable land management practices.

From the perspective of CIKOD, the input subsidy programme is also not targeting smallholders and the programme should be restructured to support this group. Other promising reforms involve improving farmers' access to capital and equipment. For example, farmers need access to water to make high quality compost. This means that farmers either need to carry residues and animal dung back to the homestead to allow for composting, or dig small water reservoirs closer to the fields. According to the CIKOD's Deputy Executive Director, Daniel Banuoku, financial support for equipment and assets such as donkey charts and wheel burrows or labour to help with the digging of water holes closer to the fields would have a considerable impact (Banuoko 2019, personal communication).

12 NPK fertiliser in our study area cost an average of GHS 3.6/kg, as one bag of 25kg sells for GHS 90.

13 The target is to increase the fertiliser use rate to at least 50 kg/ha (20 kg/acre) by 2020 as suggested in the Medium Term Agricultural Sector Investment Programme of the Ministry of Food and Agriculture.

14 From 2008 to 2013, a total of 724,055 metric tons of fertiliser were subsidised for the cost of GHS 345,244 million (Government of Ghana 2019).

Regarding constraints, it should be mentioned that FMNR makes the mechanisation of farming more complicated. In particular, ploughing the land with tractors is more laborious and consequently it is not compatible with the Ghanaian government's 30-year long push for mechanisation. For this reason, some argue that agroforestry (i.e. the deliberate planting of trees in ways that do not obstruct tractors – is a more promising regreening strategy (Ellison 2019, personal communication). While such arguments may be made, this study has shown that FMRN farmers remain overall significantly more profitable than conventional non-FMNR farmers. However, it is an area that requires further research, in case there are regreening strategies that can be done more cost-effectively.

Wild animal raiding is also considered a constraint to FMNR. There is, as of present, no effective way to address this; it is a consequence that FMNR farmers have to live with but in exchange they get to enjoy more opportunities from the hunting of wildlife. For example, it used to be near impossible to hunt rabbits, but now they have returned to farmland in our case study area (Damnyag et al. 2019).

A sizeable number of farmers also consider that weak land and tree tenure is a constraint to investing in FMNR (Table 21). This is despite the fact that 95 per cent of farmers consider that they have strong farming rights to land (Table 23). Although a smaller percentage of the farmers report moderate to weak farming rights (5 per cent), attention needs to be paid to this group. This group may be the shared cropland farmers in the area that find it difficult to retain higher tree densities on their farmlands. Blay and Damnyag (2008) observed higher degradation on land subject to share-cropping and lower tree density. Only two species (*Azadirachata indic* and *Mitragyna inermis*) were found compared to twelve tree species on family lands in the Lawra and Nandom districts. The low density of tree species on these shared croplands was attributed to the continuous cultivation which disturbs the recruitment and growth of most regenerating species, thus leading to reduced growth rate and death of some species (Blay and Damnyag 2008). It is interesting to note that the results of the soil sample analysis in Blay and Damnyag (2008) showed that the highest nutrient content in soils was in fallow family land, while the lowest levels were on shared crop land.

TABLE 23:

Perceived land tenure and farming rights, ELD household survey

To what extent do you have rights over your farmland	%
Strong farming rights...»I can farm the land forever»	95%
Moderate farming rights...»I can farm land for a long time to come.» e.g borrowed land	3%
Weak rights...»I could be told to leave at any time»	2%

9.2 Co-benefits of FMNR, keys to success, and scaling-up interventions

In terms of the perceived benefits of FMNR, the focus group discussions and our economic analysis revealed enhanced crop productivity and availability of forest products. However, another less tangible co-benefit is that of improved community togetherness, as shown from the household responses in Table 24. This is noteworthy because community cohesion is also a condition for the long-term success of FMNR. As argued in Chapter 4, increased community cohesion allows for effective implementation of FMNR and suppression of **uncontrolled bushfire.** When there is a greater degree of fire reduction in communities, FMNR uptake becomes cheaper.

Community cohesion can be promoted through the creation of 'communal conservation areas', as done by CIKOD in an area between the Kalsagri and Pavuu communities where the FMNR practices were first piloted on highly degraded communal land. This serves as test ground and a learning site, which has attracted the interest of farmers from different communities. This interest was further manifested when thatch (which had almost gone extinct) returned to the area in abundance (as seen in Figure 17).

TABLE 24:

Benefits of FMNR, ELD household survey

What are the perceived benefits of FMNR?	Most important %	Important %	Least important
Community togetherness	51%	38%	11%
Better soil quality	42%	52%	6%
Reduced farming costs	8%	10%	82%

The successful creation of this conservation area has helped to resolve land disputes between the Paavu and Kalsagre communities.

The Gozori community in the Upper West also provides an impressive example of a community that has managed to control the incidence of fire for over 30 years. While Ghana developed a national wildfire management policy in 2006 (MLFM 2006), Goziri remained one of the few communities in the Upper West Region where vegetation is not burned (EPA Upper West 2010). The key to the success of their effectiveness is transformational leadership, community engagement, a clear and well-understood purpose of fire management, an active anti-wildfire committee, and finally a set of 11 binding rules that the community developed with the leadership of the chiefs and sub-chiefs, attributing responsibility to every individual of the community.[15] Every community member is also responsible for fighting wildfire if it occurs. As a result of these efforts, community members have been able to regenerate biomass for cattle and sheep and establish a healthy forest cover. As such, the expectations of their engagement were met (Lignule 2017).

To allow for the scaling up of this experience, Lignule (2017) advises that:

1. leadership skills training should be made available for local leaders;
2. community members should be engaged in setting the rules for wildfire management; and
3. There is a clearly stated purpose so that expectations can be met.

15 For example, individual adults are responsible for preventing wildfires and will be fined in the case of having set fire. Then they shall explain to the community the circumstances under which it occurred. Every community member is also responsible for fighting wildfire if it occurs.

To do so, it is important that the wildfire management is adapted to local contexts using participatory processes. For now, this a skill that the staff of public fire management agencies currently lack.

The development of effective wildfire management and the expansion of FMNR and SLM practices align with the commitments of Ghana under UNFCCC and UNCCD. The Nationally Determined Contribution under the UNFCCC has both land-based mitigation plans (including wildfire management in the transition and Savanna drylands in Ghana) and land-based adaptation priorities (including communitybased conservation agriculture). The National Voluntary Land Degradation Neutrality of Ghana targets under the UNCCD include a 66 per cent increase in soil organic carbon of degraded croplands and rangelands and the rehabilitation and sustainable management of sparsely vegetated areas for improved production and reduction in bush and wildfires by 2030.

In conclusion, FMNR offers a promising low-cost strategy for regreening northern Ghana. It meets national and international commitments while also improving farmer livelihoods and resilience. It is community driven and non-political, and it provides biomass, livestock, fuelwood and better soil fertility. On-farm forest products and enhanced crop production improve farmers' food security and income levels throughout the year. In districts (Lawra, Wa West, Nadawli) where farmers have little access to tractor services because of poverty and small field sizes, FMNR is a promising option for improving agricultural productivity. This study has contributed to building on the existing evidence base for FMNR, confirming that there are significant improvements in crop productivity to be made when controlling for other influential land management practices that farmers are taking up. This is an important contribution to the existing literature.

References

Asian Development Bank (ADB), 2013. Cost/Benefit Analysis for Development: A Practical Guide Visit https://www.adb.org/sites/default/files/institutional-document/33788/files/cost-benefit-analysis-development.pdf.

Asian Development Bank (ADB), 2017. *Guidelines for the Economic Analysis of Projects*. Philippines: ADB. Visit www.adb.org/sites/default/files/institutional-document/32256/economic-analysis-projects.pdf.

Agra (2019). Planting for food and jobs revolutionizes agriculture in Ghana agriculture. February 22nd. Visit https://agra.org/planting-for-food-and-jobs-revolutionizes-agriculture-in-ghana-agriculture/.

Akapme, C. K. 2016. "Development of a Framework on Tree Tenure and Benefit Sharing Scheme (Legal Reform Proposals)." Final Report, Government of Ghana, Ministry of Lands & Natural Resources.

Aleza, Koutchoukalo, Villamor, Grace, Nyarko, Benjamin, Wala, Kperkouma and Akpagana, Koffi. 2018. "Shea (Vitellaria paradoxa Gaertn C. F.) fruit yield assessment and management by farm households in the Atacora district of Benin." *PLoS ONE* 13(1): e0190234.

Amoako, E. E., Asante, W. J., Cobbinah, S., Kuuder, C. J. W., Adongo, R. and Lawer, E. A. 2015. "Tree tenure and its implications for sustainable land management: The case of *Parkia biglobosa* in the Northern Region of Ghana." *Journal of Natural Resources and Development* 5: 59-64.

Angelsen, A., H. O. Larsen, J. F. Lund, C. Smith-Hall and S. Wunder. 2011. Measuring livelihoods and environmental dependence: methods for research and fieldwork. Center for International Forestry Research (CIFOR), Bogor, Indonesia: 1-15.

Ansley, R. J., Button, T.W. and Skjemstad, J. O. 2006. "Soil organic carbon and black carbon storage and dynamics under different fire regimes in temperate mixed-grass savanna." *Global Biochemical Cycles* 20(3).

Ansley, R.J., Button, T.W., Skjemstad, J. O., (2006). Soil organic carbon and black carbon storage and dynamics under different fire regimes in temperate mixed-grass savanna. Global Biochemical Cycles. Vol. 20, Issue 3.

AFR100 (2019). Ghana's restoration commitment. Visit https://afr100.org/content/ghana.

Asian Development Bank (ADB). 2013. *Cost/Benefit Analysis for Development: A Practical Guide*. Philippines: ADB.

Banuoku (2019) Personal communication. Daniel Faabelangne Banuoku. Deputy Executive Director at Centre for Indigenous Knowledge and Organizational Development (CIKOD) i.banuoku@gmail.com.

Bayala, J., Heng, L. K., Van Noordwijk, M. and Ouedraogo, S. J. 2008. "Hydraulic redistribution study in two native tree species of agro-forestry parklands of West African dry savanna." *Acta Oecologica* 34(3): 370–378.

Bayala, J., Sanou, J., Bazié, H. R., Coe, R., Kalinganire, A. and Sinclair, F. L. 2019. "Regenerated trees in farmers' fields increase soil carbon across the Sahel." *Agroforest Systems*: 1 – 15.

Bayala, J., Sileshi, G.W., Coe, R., Kalinganire, A., Tchoundjeu, Z., Sinclair, F. and Garrity, D. 2012. "Cereal yield response to conservation agriculture practices in drylands of West Africa: a quantitative synthesis." *Journal of Arid Environments* 78: 13–25.

Bayala, J., Teklehaimanot, Z. and Ouedraogo, S. J. 2002. "Millet production under pruned tree crowns in a parkland system in Burkina Faso." *Agroforest Systems* 54(3): 203–214.

Bayala, J., Teklehaimanot, Z. and Ouedraogo, S. J. 2003. "Effects of pruning on production of Vitellaria paradoxa and Parkia bi-globosa and yield of associated crops in parklands." In *Improved Management of Agro- forestry Parkland Systems in Sub-Saharan Africa*, edited by Teklehaimanot, Z., 85 – 100. EU/INCO Project Contract IC18-CT98-0261, Final Report, University of Wales Bangor, UK.

Bayala, J., Teklehaimanot, Z. and Ouedraogo, S. J. 2004. "Fine root distribution of pruned trees and associated crops in a parkland system in Burkina Faso." *Agroforest Systems* 60: 13–26.

Binam, J.N. Place, J.N, Kalinganire, A., Hamade, S., Boureima, M., Tougiani, A., 2015. Effects of farmer managed natural regeneration on livelihoods in semi-arid West Africa. Environmental Economics and Policy Studies 17 (4), 543-575.

Blašković, Teo. 2019. "At least 28 killed, 286 homes destroyed as severe flooding hits Upper East Region, Ghana." *The Watchers*. 18 October 2019. Visit https://watchers.news/2019/10/18/flood-upper-east-region-ghana-october-2019/.

Blay, D. and Damnyag, L. 2008. "Land tenure systems and land degradation in Ghana." Institute of Statistical, Social and Economic Research (ISSER), Technical Paper No. 80, University of Ghana, Accra.

Boffa, J. M. 1999. *Agroforestry parklands in sub-Saharan Africa*. Rome: Food and Agriculture Organization of the United Nations.
Visit http://www.fao.org/3/x3940e/X3940E00.htm.

Boffa, J. M., Yaméogo, G., Nikiéma, P. and Knudson, D. M. 1996. "Shea nut (Vitellaria paradoxa) production and collection in agroforestry parklands of Burkina Faso." Purdue University, West Lafayette (USA), Dept. of Forestry and Natural Resources.
Visit www.hubrural.org/IMG/pdf/etudekariteburkina.pdf.

Cavendish, W. 2000. "Empirical regularities in the poverty environment relationship of rural households: evidence from Zimbabwe." *World Development* 28 (11): 1979–2003.

Cemansky, Rachel. 2015. "Africa's Indigenous Fruit Trees: A Blessing in Decline." *Environmental Health Perspectives* 123(12): A291–A296.

Center of International Forestry Research (CIFOR). 2006. "Poverty Environment Network (PEN) Technical Guidelines, Version 4." Visit https://www.cifor.org/pen/the-pen-technical-guidelines/.

Chevalier, A. 1946. "L'arbre à beurre d'Afrique et l'avenir de sa culture." *Oléagineux* 1: 7–11.

Citypopulation. 2019. "The population of the regions and districts of Ghana according to census results and latest official projections."
Visit www.citypopulation.de/en/ghana/admin/.

Cook, C. and Grut, M. 1989. "Agroforestry in Sub-Saharan Africa. A Farmer's perspective." World Bank Technical Paper No. 112.
http://documents.worldbank.org/curated/en/252981468770061239/pdf/multi-page.pdf

Damnyag, L., Saastamoinen, O., Appiah, M. and Pappinen, A. 2012. "Role of tenure insecurity in deforestation in Ghana's high forest zone." *Forest Policy & Economics* 14(1): 90–98.

Damyag, L., (2019b). Personal communication. Senior Researcher at the Council for Scientific and Industrial Research. Email: ldamnyag@yahoo.com.

Delolme, A. 1947. "Etude du karité à la station agricole de Ferkéssédougou." *Oléagineux* 4: 186-200.

Draman, A. 2019. "La production du shea dans la commune de bougouni." Results obtained upon request from Vanja Westerberg,
vanja@altusimpact.com.

Eckel, C., Johnson, C. and Montmarquette, C. 2005. "Saving Decisions of the Working Poor: Short- and Long-Term Horizons." In *Field Experiments in Economics*, edited by Carpenter, J.P., Harrison, G.W. and List, J.H, 219 – 260. Amsterdam: Elsevier, 1st edition.

ELD Initiative 2017. ELD Fact sheet on Africa. The costs of land degradation and benefits of sustainable land management in Africa.

Ellison, J., GIZ. Personal communication. *Advisor to TECAS (Training & Extension for Conservation Agriculture in the Savannahs). Development Worker under supervision of the Market Oriented Agriculture Programme (MOAP), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Regional Department of Agriculture Wa, Upper West Region, Ghana.*
james.ellison@giz.de

EPA Upper West. 2010. "Baseline Survey on the Status of Environmental Resources Degradation in Northern Ghana" (unpublished). In Lignule, Emmanuel. 2017. *Self-Mobilization for Wildfire Prevention in the Goziri Community, Upper West Region, Ghana*. United Nations University, Land Restoration Training Programme.

FAO, IFAD and WFP. 2015. "The State of Food Insecurity in the World 2015. Meeting the 2015 international hunger targets: taking stock of uneven progress." Rome: FAO.
Visit www.fao.org/3/a-i4646e.pdf.

FAO. 2011. "Community based fire management: A review." FAO Forestry Paper No. 166. Rome: FAO.
Visit http://www.fao.org/3/i2495e/i2495e.pdf.

Food and Agriculture Organisation of the United Nations (FAO). 2002. "Ghana: General Information."

Forest Commission (FC). 2017a. "Ghana Cocoa Forest REDD+ Programme: Emission reduction programme document (ERPD)."
Visit www.forestcarbonpartnership.org/system/files/documents/GCFRP_Carbon%20Fund_Final%20Draft_April%2022%202017-formatted.pdf.

Forest Commission (FC). 2017b. “Ghana’s National Reference Level.” Report, Ghana National REDD+ Secretariat,Accra Visithttps://redd.unfccc.int/files/ghana_national_reference__level_01.01_2017_for_unfccc-yaw_kwakye.pdf.

Forest Commission Ghana. “2016. Ghana REDD+ strategy, 2016-2035.” Accra: Government of Ghana.
Visit https://www.fcghana.org/userfiles/files/REDD%2B/Ghana%20REDD%2B%20Strategy.pdf.

Ghana Statistical Service. 2018. “Poverty trends in Ghana, 2005-2017.” Accra: Ghana Survey Living Standards Round 7.
Visit www2.statsghana.gov.gh/docfiles/publications/GLSS7/Poverty%20Profile%20Report_2005%20-%202017.pdf .
Global Forest Watch (2019). Forest Cover Loss in Ghana. Visit https://www.globalforestwatch.org/dashboards/country/GHA.

Haglund, E., Ndjeunga, J., Snook, L. and Pasternak, D. 2011. “Dry land tree management for improved household livelihoods: farmer managed natural regeneration in Niger.” *Journal of Environmental Management* 92(7): 1696–1705.

Hall, J. B., Tomlinson, H. F., Oni P. I., Buchy, M. and Aebischer, D. P. 1997. “Parkia biglobosa: A Monograph.” School of Agricultural and Forest Sciences Publication No. 9, University of Wales Bangor, UK.

Illukpitiya, Probohd and Yanagida, John. 2010. “Farming vs forests: Trade-off between agriculture and the extraction of non-timber forest products.” *Ecological Economics* 69(10): 1952–1963.

International Renewable Energy Agency (IRENA). 2018. *Sustainable Rural Bioenergy Solutions in Sub-Saharan Africa: A Collection of Good Practices*. Abu Dhabi: IRENA.

Jamnadass, R. H., Dawson, I. K., Franzel, S., Leakey, R. R. B., Mithöfer, D., Akinnifesi, F.K. and Tchoundjeu, Z. 2011. “Improving livelihoods and nutrition in sub-Saharan Africa through the promotion of indigenous and exotic fruit production in smallholders’ agroforestry systems: a review.” *International Forestry Review* 13(3): 338–354.

Karbo, N., Bonye, S. Z. and Domozoro, C. Y. F. 2014. “FMNR Baseline survey in Lawra and Nandom districts.” Draft report. Ghana: Center for Indigenous Knowledge & Organizational Development (CIKOD).

Kessler, J. J. 1992. “The influence of karité (Vitellaria paradoxa) and néré (Parkia biglobosa) trees on sorghum production in Burkina Faso.” *Agroforestry Systems* 17(2): 97–118.

Kranjac-Berisavljevic, G. 2018. “Report of the scoping mission for ‘Reversing Land Degradation in Africa through Scaling-up EverGreen Agriculture’ Project – component 1 (economics of land degradation) in Ghana.” Ghana: University of Development Studies.

Laris, P., Wardel., D. 2006. Good, bad or ‘necessary evil’? Reinterpreting the colonial burning experiments in the savanna landscapes of West Africa. The Geographical Journal, Vol. 172, No. 4, December 2006, pp. 271–290.

Larwanou, M., Abdoulaye, M. and Reij, C. (2006). Etude de la régénération naturelle assistée dans la région de zinder (niger): Une première exploration d’un phénomène spectaculaire. International Resources Group for the U. S. Agency for International Development.

Lawrance, Emily C. 1991. “Poverty and the rate of time preference: evidence from panel data.” *Journal of Political Economy* 99(1): 54-77.
Lawrence, personal communication.

Lignule, Emmanuel. 2017. “Self-Mobilization for Wildfire Prevention in the Goziri Community, Upper West Region, Ghana.” United Nations University, Land Restoration Training Programme. Visit www.unulrt.is/static/fellows/document/lignule2017.pdf.

Lovett, P.N. Haq, N. 2000. Evidence for anthropic selection of the Sheanut tree (Vitellaria paradoxa). Agroforestry Systems 48: 273 - 288.

Mariam, D., Bernadin, T. C. A. and Inoussa, T. M. 2013. “Inventaire des vergers de mangues dans la cercle de Bougouni au Mali.” *Journal of Applied Biosciences* 66: 5095–5105.

McKay, J. K., Christian, E., Harrison, S. and Rice, K. 2005. “How local is local? A review of practical and conceptual issues in the genetics of restoration.” *Restoration Ecology* 13(3): 432–440.

Ministry of Food and Agriculture (MOFA). 2011. “Agriculture in Ghana: Facts and figures.” Statistics, Research and Information Directorate (SRID), Accra.

Ministry of Food and Agriculture (MOFA). 2019. “Upper West Region, Info.”

Ministry of Lands, Forestry and Mines (MLFM). 2006. “National wildfire management policy.”
Visit www.fire.uni-freiburg.de/intro/2015/update-1054/Ghana-Wildfire-Policy-2006.pdf.

Mongabay 2018. Farmer-managed natural regeneration: the fastest way to restore trees to degraded landscapes? Cathy Watson on 29 June 2018.

Visit https://news.mongabay.com/2018/06/farmer-managed-natural-regeneration-the-fastest-way-to-restore-trees-to-degraded-landscapes/.

Moseley, W. G. 2001. "African evidence on the relation of poverty, time preference and the environment." *Ecological Economics* 38(3): 317–326.

Musvoto, C. and Campbell, B. M. 1995. "Mango trees as components of agroforestry systems in Mangwende, Zimbabwe." Agroforestry Systems 32(3): 247–260.
Visit https://doi.org/10.1007/BF00711713.

National Research Council. 2008. *Lost Crops of Africa: Volume III: Fruits*. Washington DC: The National Academy of Sciences.

Natural Homes. 2018. "Building and living with shea tree: A 200 year long relationship."
Visit http://naturalhomes.org/naturalliving/shea-butter.htm.

Nikiema, A., van der Maesen, L. J. G. and Hall, J. B. 2003. "The impact of parkland management practices on plant resources diversity." In *Improved Management of Agro- forestry Parkland Systems in Sub-Saharan Africa*, edited by Teklehaimanot, Z. 43–50. EU/INCO Project Contract IC18-CT98-0261, Final Report, University of Wales Bangor, UK.

Okorley, E. L., Acheampong, L. and Abenor, M. T. 2014. "The current status of mango farming business in Ghana: A case study of mango farming in the Dangme West District." *Ghana Journal of Agricultural Science* 47(1): 73-80

Okullo, J. B., Hall, J.B. and Masters, E. 2003. "Reproductive bio- logy and breeding systems of Vitellaria paradoxa." In *Improved Management of Agro- forestry Parkland Systems in Sub-Saharan Africa*, edited by Teklehaimanot, Z. 66–84. EU/INCO Project Contract IC18-CT98-0261, Final Report, University of Wales Bangor, UK.

Pender, J. L. 1996. "Discount rates and credit markets: Theory and evidence from rural India." *Journal of development Economics* 50(2): 257–296.

Pfaf (2019). Diospyros crassiflora – Hiern. Plants For a Future.
Visit https://pfaf.org/user/Plant.aspx?LatinName=Diospyros+crassiflora.

Government of Ghana (2019). NATIONAL FERTILIZER SUBSIDY PROGRAMME ON COURSE. By Phelomina Nkasia, O. Can be downloaded from:
www.ghana.gov.gh/index.php/media-center/features/2404-national-fertilizer-subsidy-programme-on-course.

Place, F. Binam, J.N., 2013. End of project technical report for the Free University Amsterdam and IFAD. The World Agroforestry Centre, Nairobi, Kenya

Plants for a Life. 2019. "Diospyros crassiflora – Hiern."
Visit https://pfaf.org/user/Plant.aspx?LatinName=Diospyros+crassiflora.

Productive Produce. 2018. "Mango Trees." 21 April 2018.
Visit *https://www.productiveproduce.org/articles/2018/2/25/mango-trees*.

Pye-Smith C. 2013. "The Quiet Revolution: How Niger's farmers are re-greening the parklands of the Sahel." ICRAF Trees for Change No. 12. Nairobi: World Agroforestry Centre.
Visit http://old.worldagroforestry.org/downloads/Publications/PDFS/BL17569.pdf.

Quansah, Charles, 2017a. "Key Policy-technical measures to achieve LDN." Ministry for Environment, Science, Technology and Innovation Environmental Protection Agency, Accra.

Quansah, Charles, 2017b. "LDN National Targets." Ministry for Environment, Science, Technology and Innovation Environmental Protection Agency, Accra.

Quansah, Charles, 2017c. "Identification of LDN Transformative projects in Ghana." Ministry for Environment, Science, Technology and Innovation Environmental Protection Agency, Accra.

Recha, J., Kimeli, P., Atakos, V., Radeny, M. and Mungai, C. 2017. *Stories of Success: Climate-Smart Villages in East Africa*. Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).
Visit https://ccafs.cgiar.org/blog/intercropping-mango-trees-benefits-farmers-albertine-rift#.XVrMdpMzagw.

Reij, C. and Garrity, D. 2016. "Scaling up farmer-managed natural regeneration in Africa to restore degraded landscapes." *BIOTROPICA* 48(6): 834–843.

Ruyssen, B. 1957. "Le karité au Soudan." *Agronomie Tropicale* 12(2): 143-172.

Sheil, D. and Wunder, S. 2002. "The value of tropical forest to local communities: complications, caveats, and cautions." *Conservation Ecology* 6(2): 9.

Sidibé, Y., Myint, M. and Westerberg, V. 2014. "An economic valuation of agroforestry and land restoration in the Kelka Forest, Mali. Assessing the socio-economic and environmental dimensions of land degradation." Report for the Economics of Land Degradation Initiative,

Kenya: International Union for Conservation of Nature.
Tanaka, T., Camerer, C. F. and Nguyen, Q. 2010. “Risk and time preferences: Linking experimental and household survey data from Vietnam.” *American Economic Review* 100(1): 557–71.
Teklehaimanot, Z. 1997. “Germplasm Conservation and Improvement of Parkia biglobosa (Jacq.) Benth. for Multipurpose Use.” EU/INCO Project Contract TS3*-CT92-0072, Final Report, UK: University of Wales Bangor.
Teklehaimanot, Z. 2004. “Exploiting the potential of indigenous agroforestry trees: Parkia biglobosa and Vitellaria paradoxa in sub-Saharan Africa.” *Agroforestry Systems* 61: 207–220, 2004.
United Nations Development Programme (UNDP). 2011. “Lawra District. Human Development Report: Resource Endowment, Investment Opportunities and the Attainment of MDGs.” Accra: UNDP.
Visit www.undp.org/content/dam/ghana/docs/Doc/Inclgro/UNDP_GH_INCGRO_DHDR2011_Lawra-District.pdf.
UNSD (2008). Designing household survey samples: Practical guidelines’, Studies in Methods Series F, No 98, Department of Economic and Social Affairs, Statistics Division, United Nations, New York
Vedeld, P., Angelsen, A., Sjaastad, E. and Berg, G. K. 2004. “Counting on the Environment: Forest Incomes and the Rural Poor.” World Bank Environment Department Paper No. 98. Washington DC: World Bank.
Westerberg, V., Costa, L. and Ghambashidze, G. 2016. “Reducing Wildfires in Georgia: CBA of Agricultural Burning Practices in the Dedoplistskaro Municipality, Georgia.” GIZ Caucasus.
Weston, P., Hong, R., Kabore, C. and Christian, A. K. 2015. “Farmer-Managed Natural Regeneration Enhances Rural Livelihoods in Dryland West Africa.” *Environmental Management* 55(6): 1402–1417.
Yesuf, M. and Bluffstone, R. 2008. “Wealth and time preference in rural Ethiopia.” Environment for Development Discussion Paper Series No. 08-16.
Zhuang, Juzhong, Liang, Zhihong, Lin, Tun and de Guzman, Franklin. 2007. “Theory and Practice in the Choice of Social Discount Rate for Cost-Benefit Analysis: A Survey.” ERD Working Paper No. 94. Asian Development Bank.
Visit www.adb.org/sites/default/files/publication/28360/wp094.pdf.

Appendix 1. Fire occurrence analysis in the case-study area, Lawra district

Figure A1 shows the number of fires that have occurred from 2014 to 2019 within a 3500 metre radius of the CIKOD conservation center. The data is derived from the Copernicus land area burned 300 meters" at a 300x300 metre resolution. This means that fires which are smaller than 300x300m are not captured. Figure A1 shows that areas closer to the CIKOD conservation centre have a lower occurrence of fires. There is no evidence of a visible decrease in the number of fires over time, for any one of the three perimeters. A longer time series would be needed to make such an assertion. In terms of the total area burned, Figure A2 shows that the total area burned has declined since 2016. In mid-November 2019, only 98 hectares of land burned. Considering that most of the fires start in November and December (corresponding to about 40 per cent of the total burnt area in a year), our prediction of total burned area for the 2019 fire season is of 213.5 hectares, which is 18 per cent lower than that of 2018 (252 hectares), thus reinforcing the negative trend.

FIGURE A1:

Frequency of fires

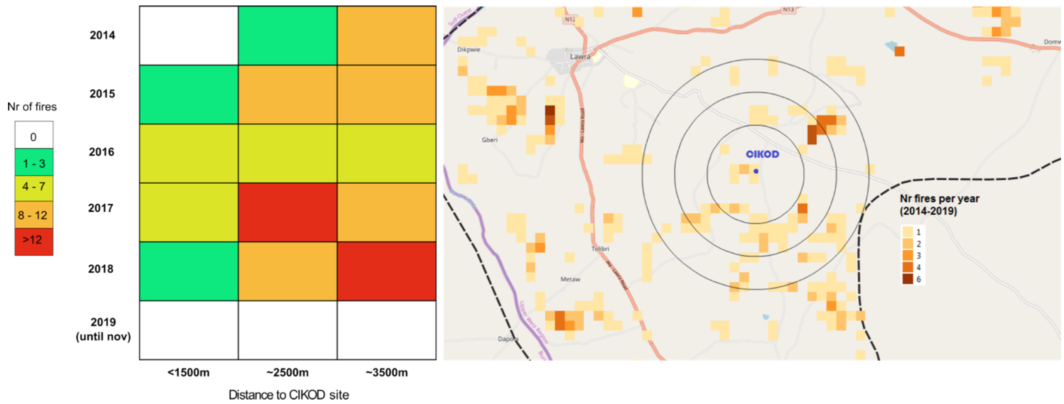
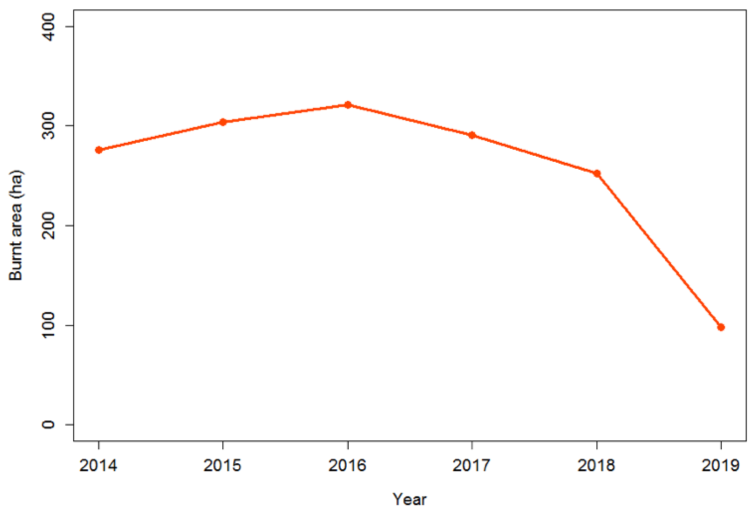


FIGURE A2:

Total area burned around the 17 CIKOD intervention villages



Appendix 2. Tree species found on farmland in the case study area

TABLE A2:

Tree species found in the Lawra district, focus group findings

Scientific name of tree/shrub	Common name	Name in local language (Dagara)
Diospyros mespiliformis	Ebony	Gaa tie
Azardiracta indica	Neem tree	Nalsaalle suge
Vitellaria paradoxa	Shea tree	Tang tie
Lannea acida		Suge
Saba senegalensis		Ore
Parkia biglobosa	Dawadawa	Dua tie
Faidherbia albidia	Apple-ring acacia	Gozan
Adansonia digitata	Baobab tree	Tuo
Ximenia americana		Lieme
Vitex doniana	Black plum	Gbaara/Bagnigbe
Balanites aegyptiaca	Desert date / soap berry	Sangsang
Ficus gnaphalacarpa	Ficus tree	Kangkang
Annona senegalensis	African custard apple	Bataame
Detarium senegalense	Tallow tree	Kpagra
Erythrophleum guineese	Tali/protodom	Kankyelle
Khaya senegalensis	Mahogany	Kogo
Gardenia erubescens	French gardenia femelle	Kalzuge
Magnifera indica	Mango	Mango
Moringa oliefera	Moringa	Opnyukuo

Appendix 3a: Assumptions used in the cash flow analysis

Conventional farming / Non-FMNR

Benefits, crop production	
	GhC/acre
Crop Revenue	**290**

Costs	
Variable	
Tractor services (year 1-30)	60
Seeds (year 1-30)	7
Fertilizer (year 1-30)	60
Pesticides (year 1-30)	2
Total hired labour (year 1-30)	45
Pruning (year 1-3)	
Thinning (year 4-30)	
Fixed	
Training of fire volunteers	
Training of lead farmers	
Equipment fire volunteers	
Equipment lead farmers	

FMNR & SLM scenario

Benefits, crop production	
	GhC/acre
Crop revenue, at outset	**290**
Crop revenue, after 5 years	**540**
Annual increase in crop revenue (year 0-4)	50

Costs			
Variable			
Tractor services (year 1-30)	125		
Seeds (year 1-30)	22		
Fertilizer (year 1-30)	60		
Pesticides (year 1-30)	2		
Total hired labour (year 1-30)	90		
Pruning (year 1-3)	40		
Thinning (year 4-30)	20		
			Note
Fixed, CIKOD	**Per acre**	**Per household**	
Training of fire volunteers	16	32	Costs borne by CIKOD
Training of lead farmers	16	32	
Equipment fire volunteers	7,6	15,2	
Equipment lead farmers	20,5	41	
Fixed, farmers	40	80	

On-farm forest production (Conventional farming / Non-FMNR)

Trees per acre, by species	Mature	Young
# ebony tree per acre	2	0
# shea tree per acre	1	0
# dawadawa tree per acre	1	0
# mango tree per acre	1	0
# neem tree per acre	0	0
Total trees	**5**	**0**

Benefits, forest products

	Mean yield/tree/year	**Min**	**Max**	**Price**
Ebony fruit, young, yr 1-14 (bags)	0	0		47
Ebony fruit, mature, yr 15-30 (bags)	0,75	0,3	1,5	
Marginal yearly increase, yr 14-30 (bags)	0,1			
Shea nuts, young, yr 1-14 (kg)	0	0		1,9
Shea nuts, mature, yr 15-30 (kg)	15	7	26	
Marginal yearly increase, 14-30 (kg)	1			
Dried dawadawa seed, yr 5-15 (kg)	0	0		3
Dried dawadawa seed, yr 16-30 (kg)	90	10	90	
Marginal yearly increase, yr 16-25 (kg)	10,0			
Mango fruit, young, yr 3 -7 (fruit)	105	10	200	0,8
Mango fruit, mature, yr 4 -30 (fruit)	200			
Marginal yearly increase, yr 3-7 (fruit)	38			
Fuelwood				
From prunings, mature trees, yr 10-30 (headloads)	6	5	7	5
From prunings, cluster of sapling, yr 1-3 (headloads)	0			
Marginal yearly increase, yr 6-9 (headloads)	0			
From thinnings of young trees, yr 4-10 (headloads)	0			
	Conversion factor			
Potential -> Realistic harvesting of fruits and nuts	0,5			

On-farm forest production (FMNR & SLM scenario)

Trees per acre, by species	Mature	Young/newly nourished
# ebony tree per acre	2	3
# shea tree per acre	1	2
# dawadawa tree per acre	1	1
# mango tree per acre	1	1
# neem tree per acre	0	1
Total trees	**5**	**8**

Benefits, forest products

	Mean yield/tree/year	**Min**	**Max**	**Price**
Ebony fruit, young, yr 1-14 (bags)	0	0	0	47
Ebony fruit, mature, yr 15-30 (bags)	0,75	0,3	1,5	0
Marginal yearly increase, yr 14-30 (bags)	0,1	0		
Shea nuts, young, yr 1-14 (kg)	0	0	0	1,9
Shea nuts, mature, yr 15-30 (kg)	15	7	26	
Marginal yearly increase, 14-30 (kg)	1,4	0		
Dried dawadawa seed, yr 5-15 (kg)	0	0		3
Dried dawadawa seed, yr 16-30 (kg)	90			
Marginal yearly increase, yr 16-25 (kg)	10,0			
Mango fruit, young, yr 3 -7 (fruit)	105	10	200	0,8
Mango fruit, mature, yr 4 -30 (fruit)	200			
Marginal yearly increase, yr 3-7 (fruit)	38			
From prunings, mature trees, yr 10-30 (headloads)	6	5	7	5
From prunings, cluster of sapling, yr 1-3 (headloads)	1,5	1	2	
Marginal yearly increase, yr 6-9 (headloads)	2			
From thinnings of young trees, yr 4-10 (headloads)	2			
	Conversion factor			
Potential -> Realistic harvesting of fruits and nuts	0,5			

Appendix 3b: Non-FMNR cash flow

20 years, r=5%

NON-FMNR scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Revenue food crops																				
Crop revenues	290	290	290	290	290	290	290	290	290	290	290	290	290	290	290	290	290	290	290	290
Revenue on-farm forest products																				
Ebony fruit, existing trees	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5
Ebony fruit revenue	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5
Shea nuts, existing trees	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Shea nut revenue	28,5	28,5	28,5	28,5	28,5	28,5	28,5	28,5	28,5	28,5	28,5	28,5	28,5	28,5	28,5	28,5	28,5	28,5	28,5	28,5
Dawa dawa seeds, existing trees	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
Dawa dawa seeds revenue	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270
Mango fruit, existing trees	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Mango fruit revenue	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160
Fuelwood, mature trees	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Fuelwood revenue	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
On-farm forest income (potential)	679	679	679	679	679	679	679	679	679	679	679	679	679	679	679	679	679	679	679	679
On-farm forest income (realistic)	415	415	415	415	415	415	415	415	415	415	415	415	415	415	415	415	415	415	415	415
Input costs - crops																				
Tractor services	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Seeds	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Fertilizer	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Pesticides	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Hired labour	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45
Crop input costs	**174**	**174**	**174**	**174**	**174**	**174**	**174**	**174**	**174**	**174**	**174**	**174**	**174**	**174**	**174**	**174**	**174**	**174**	**174**	**174**
Income / cash-flow per acre																				
Crop income	116	116	116	116	116	116	116	116	116	116	116	116	116	116	116	116	116	116	116	116
On farm forest income	415	415	415	415	415	415	415	415	415	415	415	415	415	415	415	415	415	415	415	415
On farm forest and crop income	**531**	531	531	531	531	531	531	531	531	531	531	531	531	531	531	531	531	531	531	531
Discounted cash flow																				
Net crop income	116	110	105	100	95	91	87	82	79	75	71	68	65	62	59	56	53	51	48	46
Forest income	415	395	376	358	341	325	309	295	281	267	254	242	231	220	209	199	190	181	172	164
Net forest and crop income	**531**	**505**	**481**	**458**	**436**	**416**	**396**	**377**	**359**	**342**	**326**	**310**	**295**	**281**	**268**	**255**	**243**	**231**	**220**	**210**
Cumulative cash flow	**531**	**1036**	**1517**	**1975**	**2412**	**2827**	**3223**	**3600**	**3959**	**4301**	**4627**	**4937**	**5232**	**5514**	**5782**	**6037**	**6280**	**6511**	**6732**	**6942**
Discounted costs, forest and crop	174	166	158	150	143	136	130	124	118	112	107	102	97	92	88	84	80	76	72	69
Discounted benefits, forest and crops	705	671	639	609	580	552	526	501	477	454	433	412	392	374	356	339	323	307	293	279

Discount rate	**5,00%**
Financial appraisal criterion	**NPV**
PV Forest Income	5'424
PV Net crop income	1'518
PV costs	2'277
PV benefits	9219
Net Present Value	**6'942**

Appendix 3c: FMNR & SLM cash flow

FMRN & SLM scenario	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Food crops																				
Crop revenues	290	340	390	440	490	540	540	540	540	540	540	540	540	540	540	540	540	540	540	540
Revenue on-farm forest products																				
Ebony fruit, young trees	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,9	1,1	1,2	1,4	1,6
Ebony fruit, existing trees	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5
Ebony fruit revenue	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	112,8	120,9	128,9	137,0	145,0
Shea nuts, young trees	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	14	16,7	19,4	22,1	24,9
Shea nuts, existing trees	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Shea nut revenue	29	29	29	29	29	29	29	29	29	29	29	29	29	29	42	55	60	65	71	76
Dawa dawa seeds, young trees	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	20	30	40
Dawa dawa seeds, existing trees	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
Dawa dawa seeds revenue	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	300	330	360	390
Mango fruit, young trees	0	0	10	48	86	124	162	200	200	200	200	200	200	200	200	200	200	200	200	200
Mango fruit, existing trees	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Mango fruit revenue	160	160	168	198,4	228,8	259,2	289,6	320	320	320	320	320	320	320	320	320	320	320	320	320
Fuelwood, young trees	1,5	1,5	1,5	2	2	2	16	32	48	48	48	48	48	48	48	48	48	48	48	48
Fuelwood, mature trees	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Fuelwood revenue	157,5	157,5	157,5	160	160	160	230	310	390	390	390	390	390	390	390	390	390	390	390	390
On-farm forest income (potential)	687	687	695	727	758	788	889	999	1079	1079	1079	1079	1079	1079	1092	1148	1191	1234	1278	1321
On-farm forest income (realistic)	422	422	426	444	459	474	559	655	735	735	735	735	735	735	741	769	791	812	834	855
Input costs per acre - crops																				
Tractor services	70	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125
Seeds	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
Fertilizer	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Pesticides	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Hired labour	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
Crop input costs	**244**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**
Farmer input costs - FMNR																				
Pruning	40	40	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thinning	0	0	0	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Wellington boots, gloves, cuttlas, knifes, sickles	20	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Equipment renewal	0	0	0	0	0	0	0	10	10	10	10	0	0	0	0	0	10	10	10	10
FMNR Management costs	**60**	**60**	**40**	**20**	**20**	**20**	**20**	**30**	**30**	**30**	**30**	**20**	**20**	**20**	**20**	**20**	**30**	**30**	**30**	**30**
Societal costs - FMNR																				
Training	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
Wellington boots, gloves, cuttlas, knifes, sickles	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
FMNR equipment and training costs	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**
Income / cash-flow																				
Net crop income	16	11	71	131	181	231	231	226	226	226	226	231	231	231	231	231	226	226	226	226
On-farm forest income	392	392	406	434	449	464	549	640	720	720	720	725	725	725	731	759	776	797	819	840
On-farm forest and crop income	408	403	477	565	630	695	780	866	946	946	946	956	956	956	962	990	1.002	1.023	1.045	1.066
Farmer - Discounted cash flow																				
Net crop income	16	10	64	113	149	181	172	161	153	146	139	135	129	123	117	111	104	99	94	89
Forest income	392	373	368	375	369	364	410	454	487	464	442	424	403	384	369	365	355	348	340	333
Net forest and crop income	408	384	433	488	518	545	582	615	640	609	580	559	532	507	486	476	459	446	434	422
Cumulative cash flow	408	792	1224	1712	2230	2775	3357	3972	4612	5222	5802	6361	6893	7400	7886	8362	8821	9267	9701	10123
	0	1	2	3	3	4	5	5	6	8	9	10	16	18	20					
Discounted benefits, forest and crop	712	726	740	763	781	795	820	849	863	822	782	745	710	676	647	630	610	590	571	552
Discounted costs, forest and crops	304	342	307	276	262	250	238	234	223	212	202	187	178	169	161	153	151	144	137	130
Discounted benefits, forest only	**422**	**402**	**386**	**383**	**378**	**371**	**417**	**465**	**497**	**473**	**451**	**429**	**409**	**390**	**374**	**370**	**362**	**354**	**346**	**339**
Discounted costs, forest only	**30**	**29**	**18**	**9**	**8**	**8**	**7**	**11**	**10**	**10**	**9**	**6**	**6**	**5**	**5**	**5**	**7**	**7**	**6**	**6**
Society - Discounted cash flow																				
Net forest and crop income	348	327	378	436	469	498	537	572	599	571	544	524	499	475	456	447	431	420	409	398
Cumulative cash flow	348	674	1053	1489	1957	2455	2992	3565	4164	4735	5278	5802	6300	6775	7231	7678	8109	8530	8939	9337
		1	2	2	3	4	5	5	6	7	9	10	0	0	0					
Discounted benefits, forest and crop	712	726	740	763	781	795	820	849	863	822	782	745	710	676	647	630	610	590	571	552
Discounted costs, forest and crops	364	399	362	327	312	297	283	277	263	251	239	222	211	201	191	182	178	170	162	154

Discount rate	**5,00%**
Farmer, financial appraisal criterion	**NPV**
PV crop income	2.304
PV forest income	7.820
PV costs	4259,0
PV benefits	14382,3
Net Present Value	10.123

Society, financial appraisal criterion	**PV cost society**
PV cost	5045,4
Net present Value	**9336,9**

Appendix 3d: From non-FMNR to FMNR & SLM

years, r=5%

From non-FMNR to FMNR & SLM scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Farmer, non-FMNR to FMNR & SLM																				
Additional benefits, crop & forest produce	182	220	259	305	344	379	424	472	504	480	457	435	414	395	379	374	367	358	350	342
Additional costs, crop & forest produce	130	176	150	125	119	114	108	110	105	100	95	85	81	77	73	70	71	68	64	61
NPV non-FMNR --> FMNR & SLM	-123	-121	-49	30	82	129	186	238	281	268	255	248	237	225	218	221	216	215	214	212
NPV, cumulative	-123	-244	-292	-263	-181	-52	134	372	653	921	1175	1424	1661	1886	2104	2325	2541	2756	2969	3182
Society, non-FMNR to FMNR & SLM																				
Additional benefits, crop & forest	182	220	259	305	344	379	424	472	504	480	457	435	414	395	379	374	367	358	350	342
Additional costs, crop & forest	190	233	204	177	169	161	153	153	146	139	132	120	114	109	104	99	99	94	89	85
NPV non-FMNR --> FMNR & SLM	-183	-179	-103	-22	32	82	142	195	240	229	218	213	203	194	188	192	188	189	189	188
NPV, cumulative	-183	-361	-464	-487	-454	-372	-231	-36	205	433	651	865	1068	1261	1449	1641	1829	2018	2207	2395

Financial appraisal criterion	
Farmer, non-FMNR to FMNR & SLM	**NPV**
Years with negative NPV	3
Fraction	0.28
Payback period	3.28
IRR	33%
Benefit Cost ratio	3.8
PV Additional benefits, 20 years	5'164
PV Additional costs, 20 years	1'982
NPV 20 years	3'182
Society, non-FMNR to FMNR & SLM	
Years with negative NPV	4
Fraction	0.1
Payback period	4.1
IRR	20%
Benefit Cost ratio	2.7
PV Additional benefits, 20 years	5'497
PV Additional costs, 20 years	2'769
NPV 20 years	**2'395**

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Food crops																				
Crop revenues	290	340	390	440	490	540	540	540	540	540	540	540	540	540	540	540	540	540	540	540
Revenue on-farm forest products																				
Ebony fruit, young trees	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,9	1,1	1,2	1,4	1,6
Ebony fruit, existing trees	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5
Ebony fruit revenue	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	70,5	112,8	120,9	128,9	137,0	145,0
Shea nuts, young trees	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	14	16,7	19,4	22,1	24,9
Shea nuts, existing trees	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Shea nut revenue	29	29	29	29	29	29	29	29	29	29	29	29	29	29	42	55	60	65	71	76
Dawa dawa seeds, young trees	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	20	30	40
Dawa dawa seeds, existing trees	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
Dawa dawa seeds revenue	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	300	330	360	390
Mango fruit, young trees	0	0	10	48	86	124	162	200	200	200	200	200	200	200	200	200	200	200	200	200
Mango fruit, existing trees	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Mango fruit revenue	160	160	168	198,4	228,8	259,2	289,6	320	320	320	320	320	320	320	320	320	320	320	320	320
Fuelwood, young trees	1,5	1,5	1,5	2	2	2	16	32	48	48	48	48	48	48	48	48	48	48	48	48
Fuelwood, mature trees	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Fuelwood revenue	157,5	157,5	157,5	160	160	160	230	310	390	390	390	390	390	390	390	390	390	390	390	390
On-farm forest income (potential)	687	687	695	727	758	788	889	999	1079	1079	1079	1079	1079	1079	1092	1148	1191	1234	1278	1321
On-farm forest income (realistic)	422	422	426	444	459	474	559	655	735	735	735	735	735	735	741	769	791	812	834	855
Input costs per acre - crops																				
Tractor services	70	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125
Seeds	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
Fertilizer	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Pesticides	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Hired labour	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
Crop input costs	**244**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**	**299**
Farmer input costs - FMNR																				
Pruning	40	40	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thinning	0	0	0	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Wellington boots, gloves, cuttlas, knifes, sickles	20	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Equipment renewal	0	0	0	0	0	0	0	10	10	10	10	0	0	0	0	0	10	10	10	10
FMNR Management costs	**60**	**60**	**40**	**20**	**20**	**20**	**20**	**30**	**30**	**30**	**30**	**20**	**20**	**20**	**20**	**20**	**30**	**30**	**30**	**30**
Societal costs - FMNR																				
Training	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
Wellington boots, gloves, cuttlas, knifes, sickles	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
FMNR equipment and training costs	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**
Income / cash-flow																				
Net crop income	16	11	71	131	181	231	231	226	226	226	226	231	231	231	231	231	226	226	226	226
On-farm forest income	392	392	406	434	449	464	549	640	720	720	720	725	725	725	731	759	776	797	819	840
On-farm forest and crop income	408	403	477	565	630	695	780	866	946	946	946	956	956	956	962	990	1.002	1.023	1.045	1.066
Farmer - Discounted cash flow																				
Net crop income	16	10	64	113	149	181	172	161	153	146	139	135	129	123	117	111	104	99	94	89
Forest income	392	373	368	375	369	364	410	454	487	464	442	424	403	384	369	365	355	348	340	333
Net forest and crop income	408	384	433	488	518	545	582	615	640	609	580	559	532	507	486	476	459	446	434	422
Cumulative cash flow	408	792	1224	1712	2230	2775	3357	3972	4612	5222	5802	6361	6893	7400	7886	8362	8821	9267	9701	10123
	0	1	2	3	3	4	5	5	6	8	9	10	16	18	20					
Discounted benefits, forest and crop	712	726	740	763	781	795	820	849	863	822	782	745	710	676	647	630	610	590	571	552
Discounted costs, forest and crops	304	342	307	276	262	250	238	234	223	212	202	187	178	169	161	153	151	144	137	130
Discounted benefits, forest only	**422**	**402**	**386**	**383**	**378**	**371**	**417**	**465**	**497**	**473**	**451**	**429**	**409**	**390**	**374**	**370**	**362**	**354**	**346**	**339**
Discounted costs, forest only	**30**	**29**	**18**	**9**	**8**	**8**	**7**	**11**	**10**	**10**	**9**	**6**	**6**	**5**	**5**	**5**	**7**	**7**	**6**	**6**
Society - Discounted cash flow																				
Net forest and crop income	348	327	378	436	469	498	537	572	599	571	544	524	499	475	456	447	431	420	409	398
Cumulative cash flow	348	674	1053	1489	1957	2455	2992	3565	4164	4735	5278	5802	6300	6775	7231	7678	8109	8530	8939	9337
		1	2	2	3	4	5	5	6	7	9	10	0	0	0					
Discounted benefits, forest and crop	712	726	740	763	781	795	820	849	863	822	782	745	710	676	647	630	610	590	571	552
Discounted costs, forest and crops	364	399	362	327	312	297	283	277	263	251	239	222	211	201	191	182	178	170	162	154

Discount rate	**5,00%**
Farmer, financial appraisal criterion	**NPV**
PV crop income	2.304
PV forest income	7.820
PV costs	4259,0
PV benefits	14382,3
Net Present Value	10.123
Society, financial appraisal criterion	**PV cost society**
PV cost	5045,4
Net present Value	**9336,9**

For further information and feedback please contact:

ELD Secretariat
info@eld-initiative.org
Mark Schauer
c/o Deutsche Gesellschaft für Internationale Zusammenarbeit
(GIZ) GmbH
Friedrich-Ebert-Allee 36
53113 Bonn, Germany

Co-Funded by the European Union (EU) and the German Federal Ministry for Economic Cooperation and Development (BMZ).

www.eld-initiative.org

ISBN 978-92-808-6063-4