GOVERNANCE OF PEOPLE-CENTERED FOREST-AGRISCAPES RESTORATION IN MALAWI: INSTITUTIONAL AND MODELING APPROACHES

By

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A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Geography—Doctor of Philosophy
Environmental Science and Policy—Dual Major

2021

ABSTRACT

GOVERNANCE OF PEOPLE-CENTERED FOREST-AGRISCAPES RESTORATION IN MALAWI: INSTITUTIONAL AND MODELING APPROACHES

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This doctoral dissertation embodies an interdisciplinary inquiry of human-environment interactions approached from a geospatial perspective. It investigates some socio-institutional dimensions of ecosystem restoration, focusing on the Forest Landscape Restoration (FLR) paradigm. FLR is a people-centered ecosystem restoration approach that advances a holistic landscape approach to restoring degraded natural resources. FLR's implicit landscape approach to environmental management requires sectoral interactions and policy integration in implementing restoration interventions in interlocking agricultural and forested landscapes – forest-agriscapes. As such, FLR seeks to address, holistically, the interlinked challenges of land degradation, deforestation, biodiversity loss, climate change, livelihood insecurity, and unsustainable supply of multiple socio-ecological benefits. The research analyses specifically how to achieve integrated and sustainable governance of landscape-scale restoration of lands, trees, and forests by deepening understanding of the related institutional, socio-economic, cultural, and behavioral dimensions. It employs an analytical approach that blends qualitative analysis, econometric modeling, and spatial agent-based modeling (ABM) to explore forest-agriscapes restoration as a complex socio-ecological system (SES).

Using Malawi as a country case study in sub-Saharan Africa (SSA), the research *first* investigates what potential context-appropriate governance system—including governance model, institutional arrangements, and regulatory framework—would adequately promote effective integrated implementation of landscape restoration. The research adopts a polycentric governance perspective based on the Ecology of Games Theory (EGT). Using the EGT, it explores the structural and functional dimensions of an appropriate integrated governance system by examining four specific governance parameters: collaboration arrangements, social learning mechanisms, coordination processes, and institutional externalities. *Second*, the research draws on an econometric perspective and an environmental behavior perspective rooted in social psychology to examine the local patterns and socio-cultural determinants and

the decision-making processes of local individual and collective resources restoration efforts. Through a mixed qualitative and quantitative methods approach, it addresses why and how local smallholder farmers and resource users engage in restoration activities, including the driving and constraining factors for their restoration efforts. *Finally*, the research uses ABM, a bottom-up computational modeling approach to SES, to explore the aggregate landscape-level dynamic patterns and environmental impacts of local restoration decisions and consequent activities, with different simulations of management and policy scenarios.

The research offers diverse knowledge contributions and practical insights for effective forest-agriscape restoration. It advances knowledge on framing ingredients of a contextualized polycentric governance system to successfully operationalize an integrated landscape approach to resources management and restoration in Malawi and contributes to testing the EGT as a novel theory of polycentric governance. Moreover, the research illuminates the nature, level, diversification features, and areal extent of local restoration, and uncovers associated main drivers and challenges. It also offers more social understanding of individual and collective restoration behaviors, notably insights on local farmers' and resources users' decision-making processes for land, tree, and forest restoration. This improves knowledge on empirically capturing such behavioral components and integrating them into computational modeling. Further, the research uncovers a forward-looking 10-year trend and spatially explicit patterns of potential restoration extent, intensification, participation level, and resulting landscape regreening. The dynamics of the potential aggregate environmental impacts of local, bottom-up restoration efforts suggest empowering them, shedding light on likely propitious management and policy options to operationalize. This contributes insights for spatially targeted and evidence-based restoration implementation in Malawi, exemplifying how to enhance the use of ABMs to support restoration management and policy. Overall, the research shows the promise of using mixed integrative research approaches to better inform effective FLR interventions and the practical insights for Malawi are also relevant for other similar SSA contexts.

Broadly, the dissertation illustrates effective socio-ecological governance as one way to approach the persistent challenge centered on a complex co-existence issue: how to balance competing goals of attaining sustainable natural resource-based livelihoods, food security, and poverty reduction while protecting biodiversity and ecological integrity within a changing climate context.

This dissertation is dedicated to:
God, my Savior and Protector.
My daughter, Edna, may this path inspire you.
My husband, Edouard Romeo Mensah, may this testify for the worthiness of your untold sacrifices.
My father, Andre Jonas P. Djenontin, and my mother, Eudoxie Houegbelo.
Thank you all for allowing me to embrace and successfully end this PhD journey

ACKNOWLEDGEMENTS

I benefited from diverse support from various sources throughout my PhD study and dissertation research, which I loudly acknowledge in the following lines, although simple words would not measure to how deeply grateful I am to each of them.

My unmeasurable gratitude goes to my advisor, Dr. Leo C. Zulu, for the untold and invaluable support, both academic and beyond, that I benefited from him. Beyond just an academic mentor, Dr. Zulu and his family has extended to me (and my family) their true humanity in many respects.

I am equally grateful to the other members of my academic committee for their specific guidance. I thank Dr. Arika Ligmann-Zielinska, Dr. Robert B. Richardson, and Dr. Pascal Nzokou for the critical and constructive feedback, and overall collaboration throughout the research and its publication processes.

My dissertation research benefitted from funding and institutional support through several institutions to which I am grateful. I thank the College of Social Sciences of Michigan State University (MSU) for awarding me in 2019 a Research Scholars Award, which contributed tremendously to my field work and other research expenses. Likewise, I extend my gratitude to the Environmental Science and Policy Program (ESPP) of MSU for financially supporting my studies and some aspects of the dissertation research dissemination. I also extend my gratitude to the Graduate Women International (GWI) for awarding me a GWI Recognition Award in support of my PhD dissertation research. Finally, I am indebted to the Department of Geography, Environment, and Spatial Sciences of MSU for its various institutional funding and other support throughout the journey of my PhD study and research.

My dissertation research has also necessitated some external collaborations. In that regard, I am indebted to the colleagues at the Lilongwe University of Agricultural and Natural Resources (LUANAR), specifically *Dr. Judith Kamoto*, for her invaluable assistance in making my field work a success. In addition, partnership with the Forestry Department of the Ministry of Natural Resources was a cornerstone to successfully conduct my field work. I thank *Ms. Tangu Tumeo* and *Mr. Teddie Kamoto* for their respective and invaluable support, in many respects and forms.

I also thank particularly all members of my research team in Malawi for their invaluable support in collecting the data for this dissertation research. I am indebted to *Gabriel Sajeni*, who served as my research assistant for all the qualitative data collection, translation, transcription, and quality assurance. I also deeply recognize the commitment of my enumerators for administering the household survey questionnaire and collecting associated geospatial data – *Pemphero Phiri-Nganga*, *Noel Limula*, *Rhoda Micheal*, and *Mwayiwawo Chitsamba* embraced the countless field work obstacles with me in collecting the primary data that offer the empirical evidence in this dissertation research.

I would also like to mention my research subjects in Dedza and Ntchisi Districts in Central Malawi, including their local authorities and traditional leaders, who did not hesitate to spend their precious time with me to answer my research questions. Equally, I am thankful to all national-level practitioners and managers that I interviewed across the spectrum from government, non-government organization, to international organization officers.

Finally, I am grateful to all my colleagues and friends within and outside the Department of Geography, Environment, and Spatial Sciences for making this tricky and challenging journey attainable and pleasant. I am expressly thankful to the collegiality that I benefitted from Dan Wanyama, Thomas Bilintoh, and particularly Judith Namanya with whom I share more than a professional relation, bonding through our common motherhood experience and struggles in balancing parental responsibility toward our respective daughters.

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KEY TO ABBREVIATIONS

AEC	Area Executive Committee
BMCs	Block Management Committees
CBFM	Community-based Forest Management
CBNRM	Community-based Natural Resources Management
CCC	Catchment Conservation Committee
DADO	District Agriculture Development Officer
D&D	Deforestation and Degradation
DESC	District Environment Sub-Committee
DoF	Department of Forestry
EDO	Environment District Officer
EGT	Ecology of Games Theory
FGDs	Focus-Group Discussions
FLR	Forest Landscape Restoration
FR	Forest Reserve
GVHs	Group Village Heads
HHS	Household Survey
HH	Household
IAD	Institutional Analysis and Development
IFMSLP	Improved Forest Management for Sustainable Livelihoods Program
KIs / KIIs	Key Informants / Key Informants Interviews

LESC	Local Environment Sub-Committee
LFMB	Local Forest Management Board
LRC	Land Resources Conservation
LWRC	Land and Water Resources Conservation
MLFR	Mua-Livulezi Forest Reserve
NFR	Ntchisi Forest Reserve
NGOs	Non-Governmental Organizations
NRM	Natural Resource Management
PERFORM	Protecting Ecosystems and Restoring Forests in Malawi
PGS	Polycentric Governance Systems
RGBs	Resource-Governance Bodies
RUGs	Resource-User Groups
SSA	sub-Saharan Africa
TLC	Total Land Care
UP	United Purpose
VAC	Village Agriculture Committees
VDC	Village Development Committee
VFAs	Village Forest Areas
VFCs	Village Forest Committees
VNRMCs	Village Natural Resource Management Committees

1 CHAPTER 1: Introduction

Introduction: Research Background; Problem; Goal, Objective, Questions; Methodological Framework; and Organizational Structure

1.1 Research Background

Sub-Saharan Africa (SSA) continues to experience severe land degradation and deforestation, herein termed *"environmental degradation"* (Johnson et al., 1997). SSA accounted for 17% of the global 3.623 billion ha of degraded land during 1982-2006, with Eastern, Central, and Southern sub-regions most severely affected (Le et al., 2014). SSA's acute degradation of croplands (about 350 million ha) (Vlek et al., 2010) fuels hunger and poverty because it is linked to decline of land fertility and low agricultural productivity (Tully et al., 2015). Further, the significant degradation of grasslands (40%) and forests (26%) biomes in the region (Nkonya et al., 2016) results in considerable biodiversity and ecosystem services loss. Economically, SSA bears a disproportionately large share (26%) of the total global cost of degradation due to land-use conversion, and addressing this tragedy is more beneficial and profitable than taking no action (Nkonya et al., 2016). However, the rigid sectoral approach traditionally deployed to deal with environmental degradation tends to be ineffective and results in undesirable trade-offs (Ros-Tonen et al., 2018). Notably, the institutional fabric governing environmental conservation activities is fragmented and this remains a major concern (Mansourian 2017; 2016). One reason is that the interactions among sectors that contribute to environmental degradation are not thoughtfully addressed in a holistic way. In particular, the agriculture and the forestry sectors often affect each other adversely. Agricultural activities remain major drivers of deforestation in SSA (FAO, 2016), which in turn undermines croplands productivity. Besides, wood fuel and charcoal production are important drivers of deforestation despite their modestly positive contributions to livelihoods and poverty reduction (Zulu and Richardson, 2013; Chidumayo and Gumbo, 2013). Another reason is that the inherent mosaic nature of many landscapes in SSA, which are made of interconnected agricultural and forested lands – here referred to as *forest-agriscapes*[1] – is not fundamentally considered for integrated management. Such a situation underscores calls for the need to foster positive sectoral interactions with improved coordination of the policies and interventions (FAO, 2016).

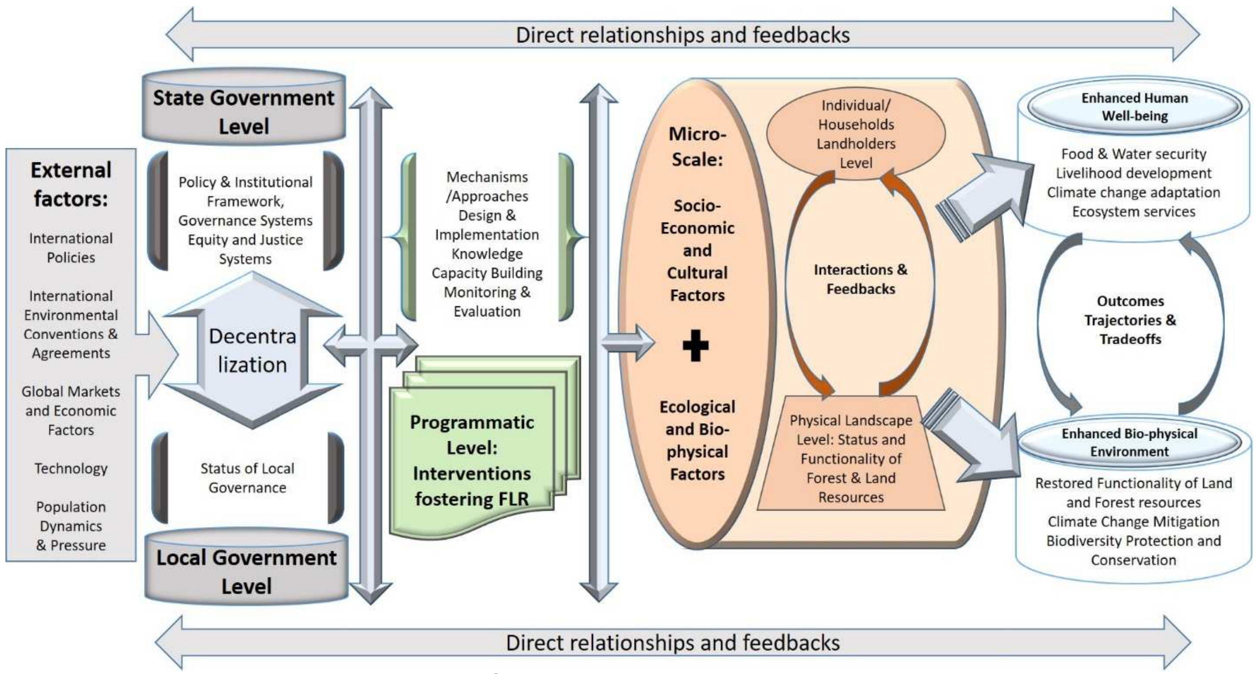
As response, scholars tout the necessity of alternative environmental problem-solving paradigms that transcend the prevalent fragmented and rigid sector-based approaches. The suggested path is to

[1] Although we have used "forest-agri**c**scape" in some publications drawn from this dissertation, we have adjusted the spelling of the composite phrase to "forest-agriscape" throughout this document to align with recorded uses of the term "agricscape" in the literature of agricultural landscape.

embrace integrated landscape approaches to environmental management and governance that reconcile biodiversity conservation, food security, and sustainable livelihoods goals in a changing climate (Sayer et al., 2013; Reed et al., 2016). One such emerging landscape approach fostering integration is embodied in *"Forest Landscape Restoration (FLR)"* – a paradigm that seeks to restore degraded forest-agriscapes and address environmental degradation. FLR is a planned process that aims to regain ecological integrity and enhance human well-being in deforested and degraded landscapes by generating greater socio-ecological benefits (Sabogal et al., 2015; Laestadius et al., 2015; Chazdon and Laestadius, 2016). It integrates agricultural, biomass-based energy, and other environmental priorities to address interlinked challenges of land degradation, deforestation, biodiversity loss, livelihood insecurity, and adverse climate-change impacts in a holistic way. Such features emphasize the distinctive, unique, and complex nature of FLR as an approach tackling more than one policy issue, cutting across sectors, to handle hitherto opposing objectives spanning the environment-development realm. Given its landscape scope, FLR embroils a constellation of actors straddling different land-tenure and land-use types and harmonizing their disparate interventions (implementation strategies, programs, and practices, diverse policies, and laws) on the complex and multi-faceted degradation drivers is critical to enhance restoration outcomes at the landscape level. Further, FLR advances a people-centered approach, advocating for strong involvement of local communities, including smallholder farmers, and other local stakeholders in restoration endeavors according to its principles articulated by Besseau et al. (2018).

In assessing the prospects for FLR success, Djenontin et al. (2018) offers a contextual clarification of key concepts related to the FLR paradigm and a synthesis of interacting factors that could influence the outcomes of FLR and alike restoration interventions in SSA. Specifically, their review of FLR constraints and opportunities in SSA comprehensively articulates some multilevel factors at the household, project, and government scales that may influence the success or failure of such integrated approach to land restoration (Figure 1.1). These include: (1) micro-scale factors that enable or limit local participation (individually or collectively) in resources restoration; (2) intervention-design features and programmatic factors at implementation stages; and (3) institutional, governance, and policy factors that operate from the local to national government scales. Their early survey of the literature provided some necessary background for this dissertation research and helped to focus the current intellectual enquiry on the socio-institutional dimensions of landscape-scale restoration of land, tree, and forest resources in SSA, with Malawi, Southern Africa, as a country case study.

Figure 1-1. Multi-level and multi-scale influential factors related to FLR interventions



Source: Djenontin et al., 2018

1.2 Research Problem

The landscape approach to environmental management that is implicit in FLR requires substantial sectoral policy integration, with consideration of interconnections among different land cover types and interactions among attendant resource-management institutions and actors (Ros-Tonen et al., 2018). However, how to implement such an integrated landscape approach for resources restoration remains a major challenge (Chazdon et al., 2017). Fragmented management approaches and generally low take up of restoration compound with financial shortcomings to undermine success and jeopardize FLR promises (Faruqi and Landsberg, 2017; Djenontin et al., 2018). **First, the practical supporting governance arrangements necessary to translate the tenets of the landscape approach remain under-studied, as demands for adequate research show** (Chazdon et al., 2021). Governance challenges are already considerable for the existing and relatively well-studied sector-based and often single-goal environmental schemes (Berkes, 2007; Zulu, 2009; 2013; McLain et al., 2017). The challenges become more complex given the significant sectoral integration sought in FLR to address the multi-faceted nature of degradation drivers (Wilson and Cagalanan, 2016; Ros-Tonen et al., 2018). This is especially true because of the often-discrepant institutional arrangements implemented by diverse resource-governance structures operating at various scales. There is, thus, a pressing need to articulate appropriate governance systems to better inform implementation of an integrated-landscape approach for sound resources restoration. Very little research has examined the governance requirements of the emerging landscape-scale FLR approach generally (van Oosten, 2013; Mansourian, 2016; 2017), and in SSA particularly (Mansourian et al., 2016). The idea of polycentric governance (Ostrom, 2010), positing multi-layered and multi-scaled systems for managing environmental schemes, is conceptually compelling as a lens to guide articulation of FLR governance systems.

Second, researchers stress engagement of local stakeholders, particularly local smallholder farmers, landowners, and resource users—hereafter farmers—as a necessity for successful implementation of FLR (Mansourian, 2017). Despite such narratives that community involvement is critical, **how to enhance or improve local participation in order to address the low take up of restoration activities and maximize outcomes remains unclear.** Local participation is often taken for granted or assumed to occur spontaneously, reflecting the relative neglect of the social and behavioral dimensions that also drive local restoration efforts and shape outcomes. Local farmers engage in restoration in various ways, both on individual farmlands and in collectively managed land and forest resources; hence socio-political, institutional, and cultural considerations (values, norms, motives, rationales, incentives, capabilities, and sustaining policies) are key to addressing their needs and challenges as a means to increase their engagement (Galabuzi et al., 2014; Wilson and Cagalanan, 2016). Farmers' land-use decisions shape land-use changes and associated socio-ecological outcomes (Villamor et al., 2014). Therefore, understanding the drivers of farmers' decision-making and processes to engage with restoration activities is vital to promoting a people-centered forest-agriscape restoration.

Malawi is uniquely placed as a country to study the potential of FLR in SSA. The Global Land Outlook highlighted Malawi as one of the Southern African countries where degradation severely affects croplands (UNCCD, 2017). Annually, 29 metric tons of soil are lost per hectare, undermining fertility (MNREM, 2017a). Malawi lost 57% of its forest cover from 1972 to 1992, denoting a yearly deforestation rate of 2.8% (Kainja 2000), and 41% of its miombo ecosystem is degraded (Le et al., 2014). The ensuing degradation cost

Malawi an estimated $244 million in 2001-2009, which represents 6.8% of its GDP (Kirui, 2015). Following that, the country has extensively engaged in the use of participatory management models and institutional arrangements to govern its natural resources, mainly land, tree, and forest resources (Zulu, 2012; 2013; Kamoto et al., 2013). Malawi has therefore pledged to restore 4.5 million ha of degraded lands by 2030. Among the 31 African countries that have committed to restoring their forest-agriscapes, the country is one of the most advanced in FLR implementation. It has produced a national FLR strategy that identifies 7.7 million ha, representing 80% of the country's land area, as potential degraded areas to restore (MNREM, 2017a). The FLR strategy also outlines explicit intervention options for specific areas identified for restoration: (1) deforested and degraded forest reserves/natural forests and plantations outside reserves (36% of the country's area); (2) village forest areas and woodlots on degraded customary unallocated lands under collective action (8% of the country's area); and (3) agrarian areas on allocated or privately-owned customary lands (39% of the country's area) (MNREM, 2017a). The purposes of restoring such resources are mainly to increase forest resources, address land productivity decline to support crop production for sustained food security, and to provide sustainable ecosystem services. These services include biomass-based energy (firewood and charcoal), timber, poles and non-timber forest products, carbon sequestration, water regulation, and cultural and religious services.

Yet, uncertainties remain on how to meet these objectives effectively. Indeed, the extent to which current resource-governance schemes, institutional arrangements, and the policy and regulatory framework can adequately support restoration efforts remains unclear. Besides, the ensuing complexity from the different participatory management models being implemented involving diverse resources, management arrangements, and stakeholders creates institutional externalities; a significant challenge that requires innovative institutional solutions for FLR governance. The challenge of addressing institutional externalities stemming from prevailing governance fragmentation is particularly acute and mostly unresolved. Also, little is known about why and how farmers across Malawian forest-agriscapes decide to embrace restoration, what type of restoration activities they develop individually and/or collectively, and what enabling management and policy options would enhance their engagement and investments in restoration.

1.3 Research Goal, Objectives, and Questions

The goal of this dissertation research is to examine holistically the socio-institutional facets of the FLR paradigm, including its inherent landscape approach to resources restoration and management. The research will contribute knowledge to integrated governance of land, tree, and forest resources and will offer a deep and contextual understanding of the related socio-cultural, economic, and behavioral dimensions. This includes articulation of relevant governance and institutional configurations for successful resources restoration and enabling management and policy options for scaling up.

As such, there are two research objectives: 1) to investigate appropriate governance and institutional arrangements that can foster restoration efforts to achieve multiple socio-ecological benefits; and 2) to understand farmers' decision-making processes underlying resources restoration, nature and manifestations of local restoration efforts and their drivers, and the potential aggregate environmental impacts at the forest-agriscape level. Findings will specifically advance knowledge on a potential polycentric governance system that would adequately support landscape-scale resources restoration. They will also provide practical insights on local implementation of the FLR paradigm, including restoration practices, influential drivers, barriers, spatial extent of restoration outcomes, and management and policy options necessary to accelerate restoration delivery. Altogether, the research will generate empirical evidence on FLR potential in central Malawi, with lessons for other areas of Malawi and countries with similar contexts.

To achieve such goal and objective, the research addresses three questions articulated as follow:

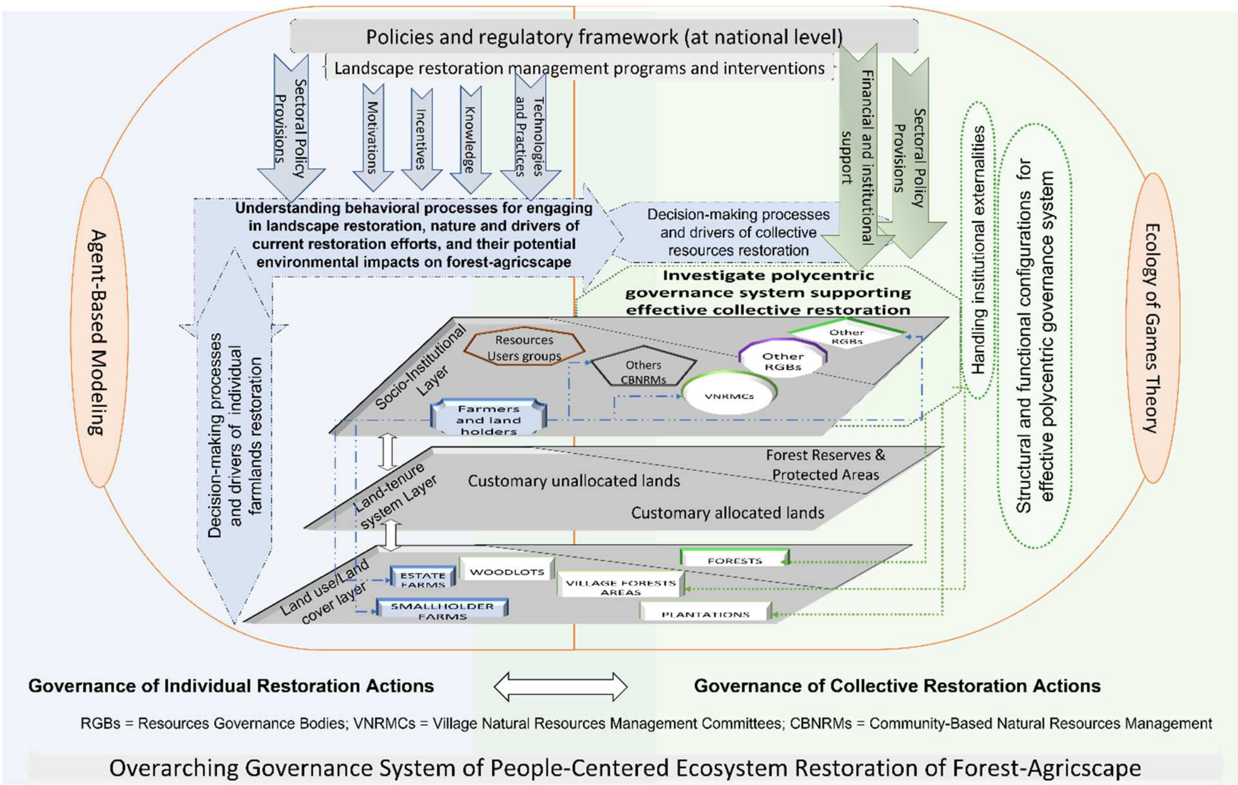
- **RQ1:** What structural and functional governance arrangements can enhance the contextual processes and positive outcomes of collective restoration of forest-agriscape?
- **RQ2:** What are farmers' decision-making processes and drivers of observed restoration of individual farmlands and collective resources in forest-agriscapes?
- **RQ3:** What are potential aggregate environmental effects of farmers' restoration decisions and investments and propitious management and policy options to accelerate restoration delivery?

1.4 Methodological Framework

1.4.1 Overarching Theoretical Lenses

This research is embedded in nature-society relationships studies and draws from two related bodies of literature holding several theoretical insights. The research is grounded in the polycentric governance perspective that emanates from the Institutional Analysis and Development framework (Ostrom, 2007). It adopts the Ecology of Games Theory (EGT) as a core theoretical lens to guide analysis of polycentric governance (Lubell, 2013) and to address the first central research question. The EGT provides a uniquely appropriate perspective to grasp the structure and functions of a polycentric governance system that can support processes of forest-agriscapes restoration to achieve positive outcomes. The research also adopts a systems-thinking perspective and use of ABM computational tool to examine the potential landscape-level impacts of social interactions and behavior that shape restoration as a land-cover conversion. ABM offers a pragmatic problem-solving method that allows a spatially explicit exploration of the potential impacts of farmers' restoration decisions and investments on forest-agriscapes and an empirical testing of enabling management and policy options for restoration. Combined insights from EGT and ABM will help to critically frame a suitable governance system and situated management options to advance restoration of forest-agriscapes. We elaborate in each chapter the further rationale for choosing the EGT and ABM and explain their use in the analyses. Figure 1-2 below illustrates the overarching framework that encapsulates the questions elaborated above, research gaps to fill, relationships across the key dynamics and dimensions, and theoretical perspective that inform the research.

Figure 1-2. The conceptual and theoretical framework of the research in Malawi



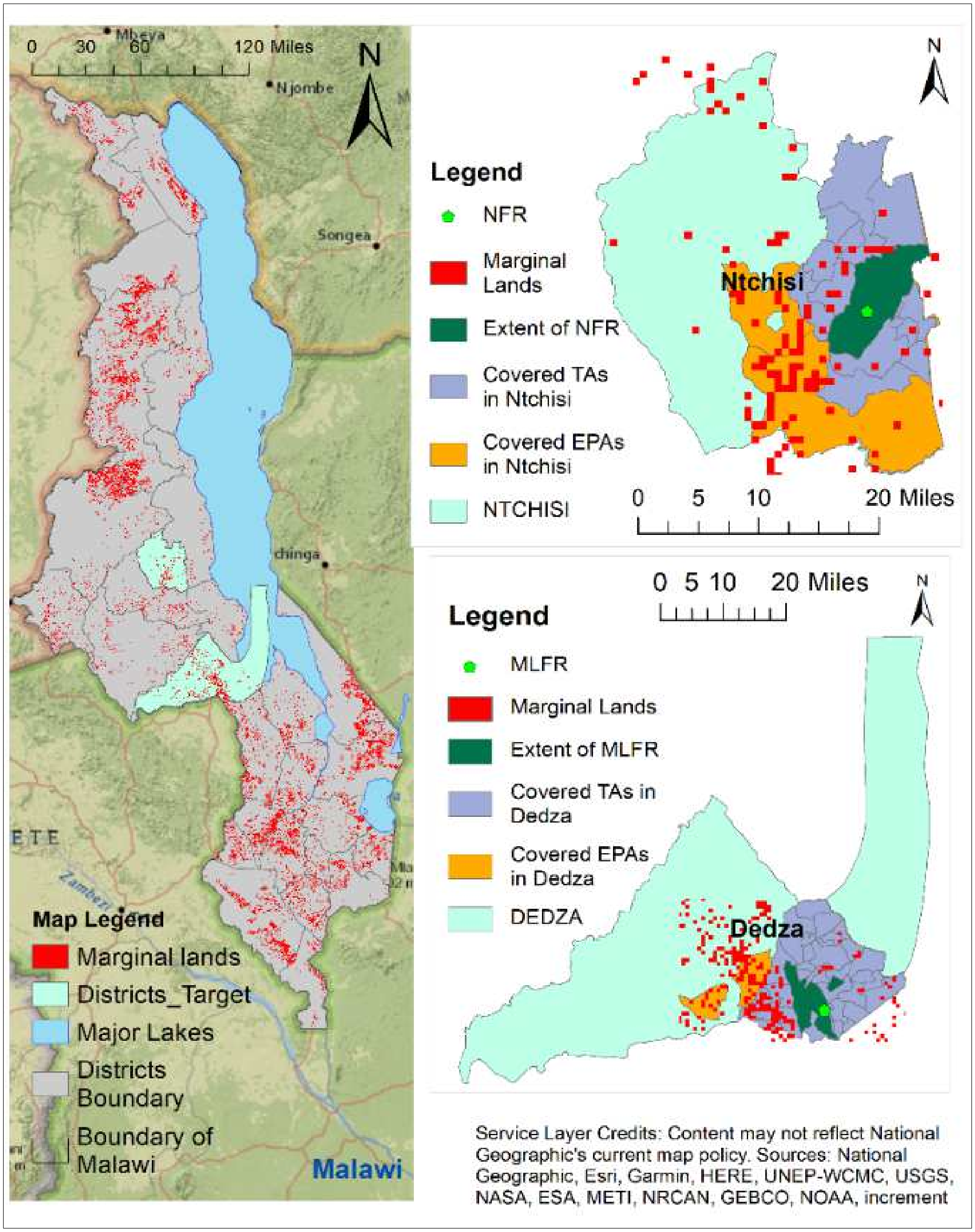
1.4.2 Study Areas

In Malawi, we draw on ongoing restoration efforts in Ntchisi and Dedza Districts in the central region (Figure 1-3). Compared to the North (with a high productivity) and the South (with a low productivity), Central Malawi displays a mix of high and low land productivity (Peter et al., 2018). We selected the districts using three criteria developed based on both a desktop review and preliminary fieldwork in summer 2018. *First*, we drew on a country-level restoration stocktaking analysis and mapping and selected districts with high functional degradation—loss of landscape functionality—within and around forest reserves, relative to other districts in Central Malawi (MNREM, 2017b, pp33-34). The spatially explicit measure of functional degradation was a composite index based on nine criteria: low soil fertility, high erosion, high slope, high poverty, canopy cover loss, sediment export, fire incidence, low evapotranspiration, and high population density. Population density affects pressures on resources and can shape restoration dynamics, thus offering contrasting dynamics in the two districts. Dedza is more densely populated than Ntchisi – 221 versus 186 (also the national average) persons per square km in 2018 (NSO, 2019). *Second*, conversations with forestry officials indicated that, given past experience with land management projects, both districts have higher levels of engagement with pro-environmental practices as potential sources of accelerated restoration, and have significant restoration opportunities—percentage of district area—relative to other districts in the region (MNREM, 2017b, pp30-32). *Third*, we considered the dynamic and extent of implementation of participatory community forest involving collective-action groups in order to capture variation between districts. Different participatory forest management (PFM) models have been implemented in both districts. The PFM models have changed format and geographic scale over time, from individual farmers and village-level CBFM outside protected areas to combined co-management and CBFM in both forest reserves (FRs) and adjacent customary areas at the scale of villages groups.

The specific research sites in the two districts are forest-agriscapes encompassing a forest reserve, adjacent communal forests and woodlands, and the adjacent agrarian lands on customary areas. For Ntchisi district, the Ntchisi Forest Reserve (NFR – 13° 19' 00" S and 34° 03' 00" E) covers 9,720 hectares and is located approximately 32 km east of the district town center. For Dedza district, Mua-Livulezi Forest Reserve (MLFR – 14° 22' 9" S and 34° 31' 51" E) covers 12,147 hectares. The trajectory and environmental state of each forest-agriscape are different, as are the underlying socio-political, cultural, and economic factors. NFR is located in a relatively sparsely populated rural setting that is likely to face growing pressures for restoration in the future. It is relatively well-managed and has better-established institutional arrangements for collective forest and tree management/restoration efforts within and outside the FR, and restoration efforts on agrarian lands (Zulu, 2013). In contrast, MLFR is in a more densely populated area that faces immense degradation pressures. It is a relatively poorly-managed FR (Senganimalunje et al., 2016). Although both were part of the earliest PFM endeavors spearheaded under the "Improved Forest Management for Sustainable Livelihoods Program" (IFMSLP), only the NFR is part of the more recent social forestry project, "Protecting Ecosystems and Restoring Forests in Malawi" that seeks to sustain the legacy of IFMSLP. This nuance may imply differences in the capacity for self-governance and sustainable management at the two sites. Geographically and jurisdictionally, NFR covers three traditional authority (TA) territories spanning two extension planning areas (EPAs), and MLFR covers two TAs spanning three EPAs in Dedza district.

In Malawi, 52.5% of the population live below the poverty line (UNDP, 2019). Subsistence rain-fed agriculture (practiced as the main livelihood by 85% of households) is primarily dominated by maize as the staple food and tobacco as the top commercial crop (Mangisoni, 2008). The crop-production system is mostly maize-based, often intercropped with legumes (Silberg et al., 2017). Other main food crops include groundnuts, beans, cassava, and potatoes. Forest-based livelihoods (22.7% of all livelihood activities) in Ntchisi district include timber sales and fuelwood production (Chinangwa et al., 2016). Charcoal production and timber harvesting exert much pressure on the vegetation cover in Dedza district (Senganimalunje et al., 2016). Besides, the forest-agriscapes in both districts provide important non-timber forest products (NTFPs), such as firewood, mushrooms, edible caterpillars, and water for irrigation (Chinangwa et al., 2016; Senganimalunje et al., 2016).

Figure 1-3. Research areas and study sites showing the forest-agriscapes.



Notes: NFR = Ntchisi Forest Reserve; MLFR = Mua-Livulezi Forest Reserve; TAs = traditional authority territories; EPAs = extension planning areas.

1.4.3 Research Design and Data Collection

We employ a mixed-methods approach for data collection and analysis. Such an approach addresses concerns over weaknesses of conducting purely qualitative or solely quantitative research, harnessing the analytical power of integrating data-collection methods, data sources/types, and data analyses to cross-validate core findings (Creswell, 2014). Given the complexities that characterize forest-agriscape restoration, such an approach provides the means to capture different ecological, social, and institutional facets of the issue, including connecting multiple stakeholders, their needs, level of power and influence on potential impacts at different scales. We use a several primary data collection approach (Doody and Noonan, 2013), including household survey (HHS), semi-structured key informant interviews (KIIs), and focus group discussions (FGDs). We also use Role-Playing Games (RPGs), following a constructivist approach to understanding environmental behavioral aspects (Redpath et al., 2018). We further integrate personal observations, review of secondary data, and use secondary data products. We elaborate in each paper specific details of data collection and analysis.

1.5 Organizational Structure of the Dissertation

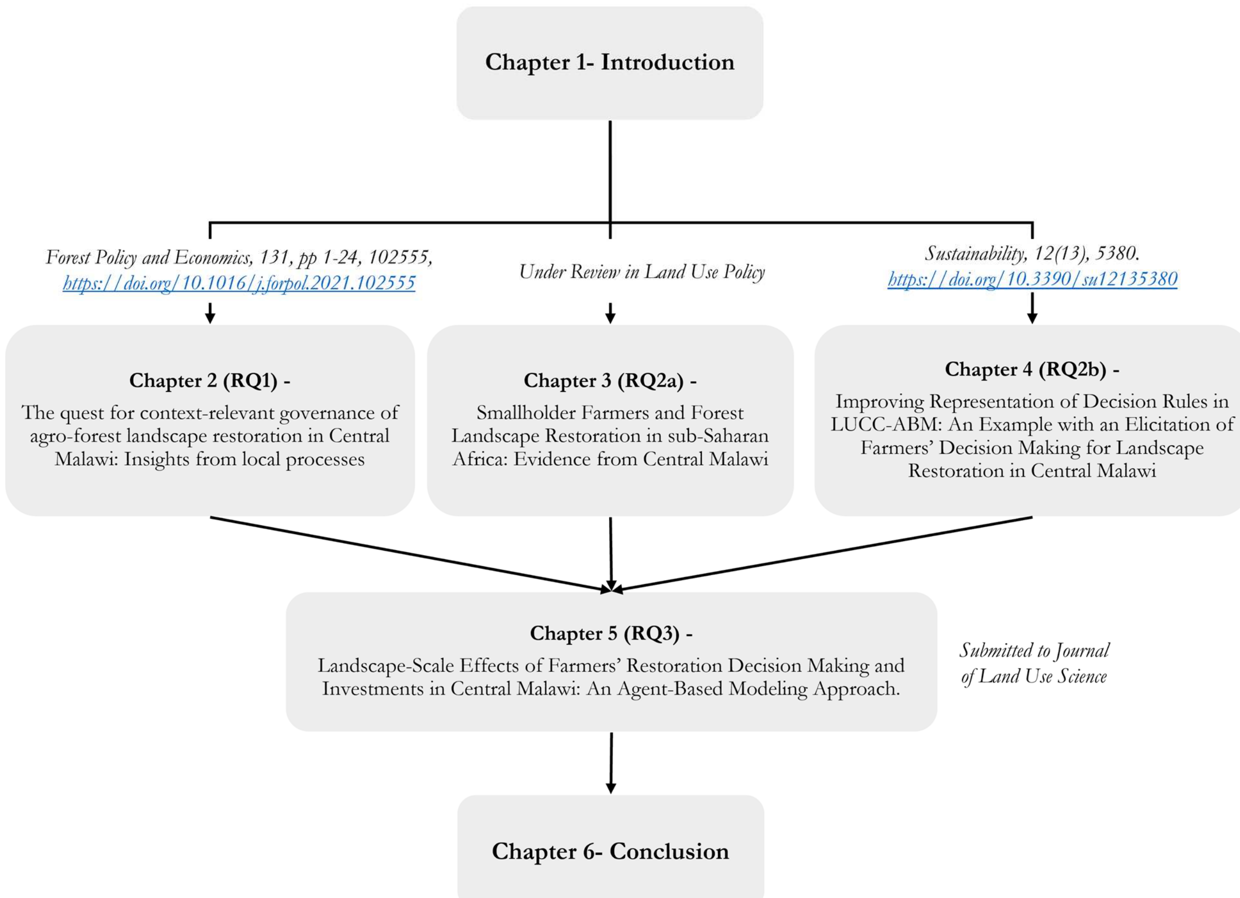
This dissertation document is structured based on a publishable paper format as follows (Figure 1-4). An introduction (this current Chapter 1) provides an overview and research background, including the problem; introduces the research goal, objective, and specific questions; articulates the methodological framework, encompassing the overarching theoretical lenses, the research areas, and the data collection and analysis approach; and maps the dissertation structure. Chapters 2, 3, 4, and 5 present the research findings through four papers as follow:

- *Paper 1 (Research Question 1): The quest for context-relevant governance of agro-forest landscape restoration in Central Malawi: Insights from local processes.* **(Published in Forest Policy and Economics 131, pp 1-24, 102555. https://doi.org/10.1016/j.forpol.2021.102555).**
- *Paper 2 (Part of Research Question 2): Smallholder Farmers and Forest Landscape Restoration in sub-Saharan Africa: Evidence from Central Malawi.* **(Under Review in Land Use Policy).**
- *Paper 3 (Part of Research Question 2): Improving Representation of Decision Rules in LUCC-ABM: An Example with an Elicitation of Farmers' Decision Making for Landscape Restoration in Central Malawi.* **(Published in Sustainability, 12(13), 5380. https://doi.org/10.3390/su12135380).**

- *Paper 4 (Research Question 3): Landscape-Scale Effects of Farmers' Restoration Decision Making and Investments in Central Malawi: An Agent-Based Modeling Approach.* **(Submitted to Journal of Land Use Science).**

We elaborate in each paper specific intellectual contributions while also articulating any limitations. We end with Chapter 6 that concludes and wraps up the entire dissertation research and its overall contributions to scholarship and broader impacts.

Figure 1-4. Overall structure of the dissertation research



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2 CHAPTER 2

Paper 1: The Quest for Context-relevant Governance of Agro-Forest Landscape Restoration in Central Malawi: Insights from Local Processes

Abstract

Failures of sectoral approaches to avert environmental degradation increase demands for integrated approaches that mitigate conflictual management of forest, tree, and land resources. Despite much agreement on the consequent need for a holistic landscape approach for a well-integrated governance system, the requisite governance interactions and processes remain under-studied. Under the idea of polycentric governance systems (PGS), we employ the Ecology of Games Theory (EGT) to investigate qualitatively the structure and functions of the current governance system supporting collective restoration of two agro-forest landscapes in central Malawi. The EGT offers theoretical grounding for context-appropriate assessment of the quality of a PGS, based on 35 focus group discussions with local-level resource-governance bodies leading restoration efforts, 21 key informant interviews (KIIs) with district-level officers and local traditional authorities, and 16 KIIs with national-level stakeholders. The current governance system shares some PGS attributes but does not foster adequate cooperation to address challenges of limited resource capacity, inequitable resource distribution, and negative institutional externalities. Social learning and coordination mechanisms helped to catalyze critical interactions to realize some PGS benefits, but need strengthening. Findings show promise for a PGS that can achieve inter-sectoral and cross-scale coordination, building on the effective operationalization of existing decentralization institutions offering multi-stakeholder platforms and coordination venues. Dynamizing relevant policy spaces, institutions, and processes that foster necessary deliberation, learning, and coordination is important to mitigate negative institutional externalities. Findings uncover challenges of governance integration and can inform necessary institutional arrangements for well-coordinated landscape-scale restoration in Malawi and similar contexts in sub-Saharan Africa.

Key words: *Polycentric governance system; Ecology of games theory; Coordination; Social learning; Institutional externalities; Forest landscape restoration; Malawi.*

2.1 Introduction

Growing understanding of the drivers of deforestation and degradation (D&D) in sub-Saharan Africa (SSA) and the ‘wicked’ nature of their interactions underscore the need for integrated approaches to govern and manage forest, tree, land, and water resources, hereafter termed *environmental resources*. A landscape approach is one advocated approach that allows cross-sector and cross-scale integration to address conflictual policies, priorities, interests, demands, and management over environmental resources (Sayer et al., 2013, Milder et al., 2014, Reed et al., 2020). Indeed, a sectoral approach to avert D&D has hitherto been ineffective, generating failures and negative trade-offs (Ros-Tonen et al., 2018). On one hand, a narrow sector approach fails to consider the inherent connectivity that characterizes landscapes made of interlocking agricultural and forest ecosystems, or *forest-agriscapes* (Djenontin et al., 2020a). On the other, a sectoral approach to manage these forest-farm mosaics results in the fragmentation of the institutional fabric governing those resources. It also fails to cohesively address interacting sectoral drivers of D&D. For instance, the agriculture sector remains a major driver of D&D in SSA, which in turn undermines cropland productivity and water supply (FAO-SOFO, 2016; Angelsen 2010, Laurance et al., 2014, Lawrence and Vandecar, 2015). Also, biomass-based energy needs are important drivers of D&D even as they contribute as safety nets to rural and urban livelihoods (Zulu and Richardson, 2013; Chidumayo and Gumbo, 2013).

The *Forest Landscape Restoration* (FLR) paradigm promotes integrated management and embodies a landscape approach to restoring degraded forest-agriscapes. It aims to attain multiple socio-ecological goals, including addressing interlinked challenges of D&D, biodiversity loss, and livelihood insecurity (Chazdon and Laestadius, 2016; Djenontin et al., 2020b). Thus, FLR is cross-sectoral, subject to multiple policies, and involves diverse actors straddling different land-tenure systems, land-use types, and social and jurisdictional scales. FLR carries governance complexities given its multidimensional nature and intents.

Despite growing appeals for FLR, much agreement on the value of the attendant landscape approach, and increasing understanding of the governance challenges and requirements (Ros-Tonen et al., 2018; Djenontin et al., 2020b; Chazdon et al., 2021), the practical governance mechanisms and processes for implementation remain under-studied, or at least the research is still evolving. Integrated resources management at landscape scale compounds known, daunting governance challenges (Berkes, 2007; Zulu, 2009; 2013; McLain et al., 2017). Targeting the often discrepant and incongruous institutional configurations, processes, and functions that undermine cohesion and produce negative externalities, FLR inherently demands significant integration and coordination of sectoral resource-governance institutions operating at various scales (Wilson and Cagalanan, 2016). To address these acknowledged but often neglected weaknesses (Mansourian, 2017), there is urgent need to develop or inform the development of suitable governance systems for sound landscape restoration and management (Ros-Tonen et al., 2018).

The literature on FLR governance and the landscape approach is growing. Early perspectives and review works raise awareness of governance needs for FLR (van Oosten, 2013; McLain et al., 2017; 2018; Djenontin et al., 2018). Some recent studies uncover theoretical and empirical challenges and opportunities for the landscape approach, (Ros-Tonen et al., 2018); discuss ways to operationalize the landscape approach (Arts et al., 2017); and question understandings of governance[2] under FLR (Mansourian, 2016; 2017; Mansourian and Sgard, 2019). Others works examine theoretical and practical governance and institutional innovations in FLR and other restoration undertakings (Wilson and Cagalanan, 2016; Mansourian et al., 2016; Zhang and Putzel, 2016; Long et al., 2018). New studies investigate specific governance challenges and potential solutions in implementing FLR projects, including institutional requirements and choices, and the challenge of geographic scale (Mansourian et al., 2019; Sapkota et al., 2018; Walters et al., 2019; Wiegant et al., 2020). These studies and other resource-governance studies advance polycentric governance as particularly suitable for socio-ecological systems (Ostrom et al., 1961; Ostrom, 2005; 2010; Andersson and Ostrom 2008; Nagendra and Ostrom, 2012; McGinnis and Ostrom, 2012; Chazdon et al., 2021). Nonetheless, the defining structural properties and functional processes of a suitable polycentric governance system (PGS) should be context-dependent (van Oosten et al., 2014) to meet place-specific demands of FLR interventions.

In this paper, we investigate the structural properties and functions of a potential PGS to effectively implement FLR using insights from two forest-agriscapes in Malawi's Central Region. The recently

[2]We define an FLR governance system as the set of institutions and ways through which individuals and entities at multiple scales and levels interrelate, exercise their rights and obligations, and mediate their needs and interests over time, to shape FLR processes and outcomes. This definition builds on the broader governance literature (Lemos and Agrawal, 2006; Paavola, 2007; Colfer and Pfund, 2011) and on FLR literature specifically (Mansourian, 2016; 2017; Mansourian and Sgard, 2019).

developed theory of polycentric governance—the Ecology of Games Theory (EGT - Lubell, 2013)—provides a compelling lens to analyze the configurations, interactions, and processes of the existing NRM governance system in the study sites, and to inform the ingredients of an improved and effective PGS for forest-agriscape restoration. We focus on the nature of cross-scale and multi-level configurations and the quality of collaborations, resources distribution, social learning, and coordination designed to foster sound collective resources restoration.

In the remainder of the paper, Section 2-2 presents a brief historical overview on resources governance in Malawi and the recent rhetoric of landscape-scale resource management. Section 2-3 describes the methods, including the guiding theoretical perspective, the study areas, and the data. Section 2-4 presents the results, which are discussed in Section 2-5. Section 2-6 concludes with a recap and some implications for FLR implementation in the Malawian and other similar contexts.

2.2 Historical dynamics of environmental-resources governance and the advent of the landscape approach to resources restoration in Malawi

Malawi's environmental governance evolved from traditional unwritten (oral) forms under the authority of local chiefs to more legal pluralistic forms that superimpose adopted and adapted science-based modern laws onto existing customary institutions (Kowero et al 2003; Kamoto 2009). Similar to most colonized African countries, the post-colonial Malawi government inherited a centralized governance approach to natural resource management (NRM) from independence (1964) to the 1990s (Ribot, 2005; Zulu et al., 2020). But from the mid-1990s, the country shifted from this top-down state-controlled model to a participatory, community-based one (Kalipeni and Zulu 2002; Shackleton et al., 2001; Blaikie, 2006). The participatory management model devolves negotiated NRM responsibilities and benefits to empowered local institutions to enhance livelihoods, governance, and forest condition (Agrawal and Gibson, 1999). Malawi now has nearly 25 years of implementing contemporary forms of participatory environmental resources management, although an earlier incarnation—the Village Forest Areas (VFAs) scheme—can be traced back to 1926 British colonial rule (Zulu, 2008). Selected major examples of community-based schemes implemented since 1999 include the Community Partnerships for Sustainable Resource Management program (1999-2009), the Improved Forest Management for Sustainable Livelihoods Program (IFMSLP - 2005-2014), and the Protecting Ecosystems and Restoring Forests in Malawi

(PERFORM) project (2014-2019). Malawi has engaged substantially with community-based natural resources management (CBNRM) policy and practice in the forestry, land and water resources, fisheries, livestock, and wildlife sectors (Zulu, 2012; Zulu 2013; Kamoto 2013; Remme et al., 2015; Senganimalunje et al., 2016; Chinangwa et al., 2016; Zulu et al., 2018).

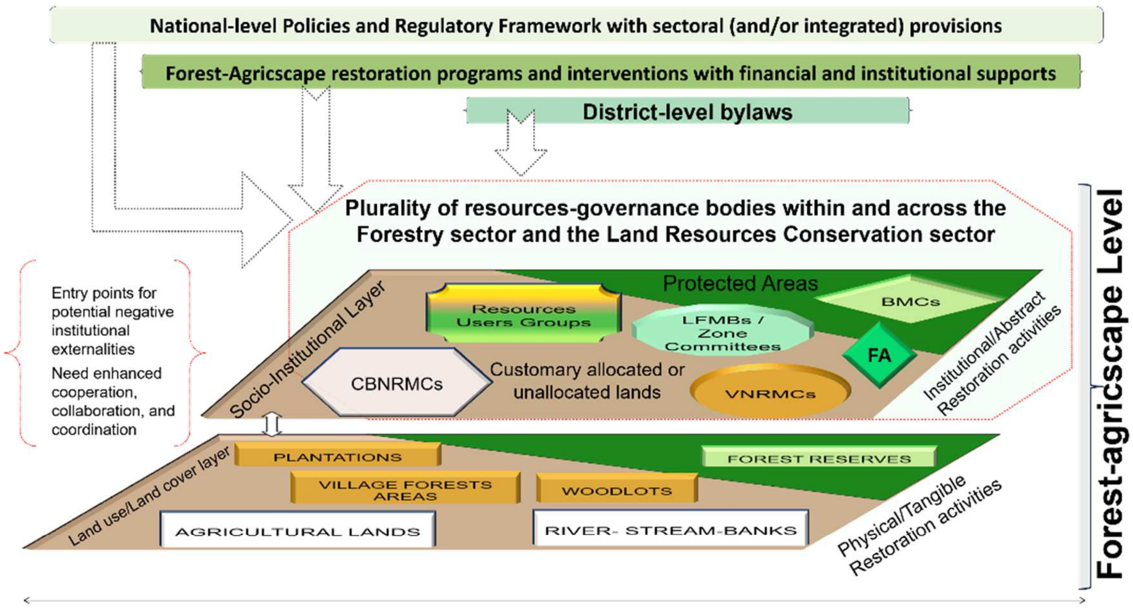
In the forestry sector, the participatory forest management models and their operating scale have changed over time. The model changed from individual farmers and village-level CBNRM outside protected areas to a people-government co-management model introduced in 2006 within selected forest reserves (FRs), and CBNRM on customary lands at the scale of village groups (Zulu, 2012; Zulu, 2013; Kamoto 2013; Remme et al., 2015). On customary unallocated lands, the community-based forest management (CBFM) approach promoted the establishment of VFAs managed by elected Village Natural Resource Management Committees (VNRMCs). Under forest co-management, the Department of Forestry (DoF) partnered with local communities organized into groups of villages as Block Management Committees (BMCs) consisting of elected members from constituent villages leading forest management in delineated FR blocks. A multi-stakeholder Local Forest Management Board (LFMB) composed of district officers for forestry, agriculture, fisheries, water, and community services, the district assembly chief executive, traditional authorities, and non-state actors coordinated management across FR blocks (Zulu, 2013). The LFMBs have had scant success and have been replaced with new arrangements in selected FRs supported under the PERFORM project. Further, a recent empirical comparison of forest condition in selected FRs between 1999 and 2018 showed higher forest cover decline (37%) in co-managed FRs than in DoF-managed FRs (11.6%) (Gondwe et al., 2019).

In the land resources conservation sector, other participatory efforts are noticeable, especially since the introduction of the Agricultural Extension Policy in 2000 (Kaarhus and Nyirenda, 2006). They include CBNRMs at the village or group-village level for managing land and water resources conservation and irrigation schemes; generally operating under a ‘model village’ concept,[3] but with differences in sectoral policy provisions. Overall, forest-specific resource-governance bodies (RGBs) cohabit with those of land and water resources conservation, and with various resource-user groups (RUGs), all holding diverse levels

[3] See some critiques of this concept in Kaarhus and Nyirenda (2006, pp25-26)

of control over the resources (Figure 2-1). Yet, Malawi continues to struggle with D&D, and at substantial socioeconomic costs (Kirui, 2015).

Figure 2-1. Institutional landscape governing collective restoration processes in Malawi's forest-agriscapes



BMCs: (Block–Forest Reserves–Management Committees) Co-managing forests in protected areas.
VNRMCs: (Village Natural Resource Management Committees) Managing forests & trees on villages customary lands
CBNRMCs: (Community-based natural resources management Committees) Managing land & water resources conservation actions ==➔ Land & Water Resources Conservation; Irrigation scheme; Gully reclamation; etc.
Zone Committees: Linked to protected areas and customary lands (new institution). These play part of the functions of formerly established **LFMBs** (Local Forest Management Boards) that no longer exist in any districts.
FA: Forest Association (new institution) – Not-formally-recognized institution; yet getting some recognition in few places.

Consequently, Malawi recently embraced the FLR paradigm to implement a landscape approach to resource restoration. Malawi is first, among 30 African countries, to elaborate a national FLR strategy and monitoring framework after pledging to restore 4.5 million ha of degraded lands by 2030 (MNREM, 2017a; 2018). A nation-wide restoration stocktaking and a participatory strategy elaboration process (MNREM, 2017b) identified 7.7 million ha (80% of the country's land area) as potential lands to restore. Identified restoration needs involving collective action include restoration of forest reserves, natural forests, and plantations; restoration of VFAs and woodlots; implementation of soil and water conservation measures; and river- and stream-bank restoration; constituting 36%, 8%, 11%, and 0.4% of the country's land area, respectively (MNREM, 2017a&b). These restoration interventions aim mainly to increase trees and forest cover, address D&D and biodiversity loss, and provide sustainable ecosystem services. The diversity of environmental resources targeted for restoration underscores the need for integration, particularly among forestry and agriculture sectors and non-government actors, for effective resource restoration.

Malawi seeks to capitalize on its experiences with participatory resource management to achieve FLR targets, but performance remains questionable. Challenges include institutional model and implementation limitations and low-morale issues among implementing civil servants (Zulu, 2012; 2013; Kamoto, 2013; Chinangwa et al., 2016). Other concerns include lack of knowledge mobilization and capacity strengthening, lack of beneficial relationships among key stakeholders and governance structures, and poor gender sensitivity (Remme et al., 2015). These highlight poor governance – principles and functions, learning mechanisms and coordination processes. Moreover, Zulu (2009 and 2012) has raised scale politics infused with power relations as challenges while also discussing how scale can be harnessed to strengthen institutional arrangements for governing these resources. With FLR, an additional major challenge is institutional externalities arising from the inherent pluralism of the institutional fabric (Figure 1). Implementation of sectoral participatory governance models generally involves diverse institutional arrangements, regulations, and policies across overlapping and sometimes competing jurisdictions, and stakeholders at different scales. This produces institutional fragmentation and 'stickiness' (Brockhaus and Angelson, 2012), and negative externalities – a mostly unresolved challenge that requires innovative solutions. Therefore, the question of how to achieve the inter-sectoral and cross-scale governance integration sought for forest-agriscapes restoration is paramount and remains unresolved. Our goal is to attempt an articulation of a context-suitable integrated PGS guided by the EGT.

2.3 Methods

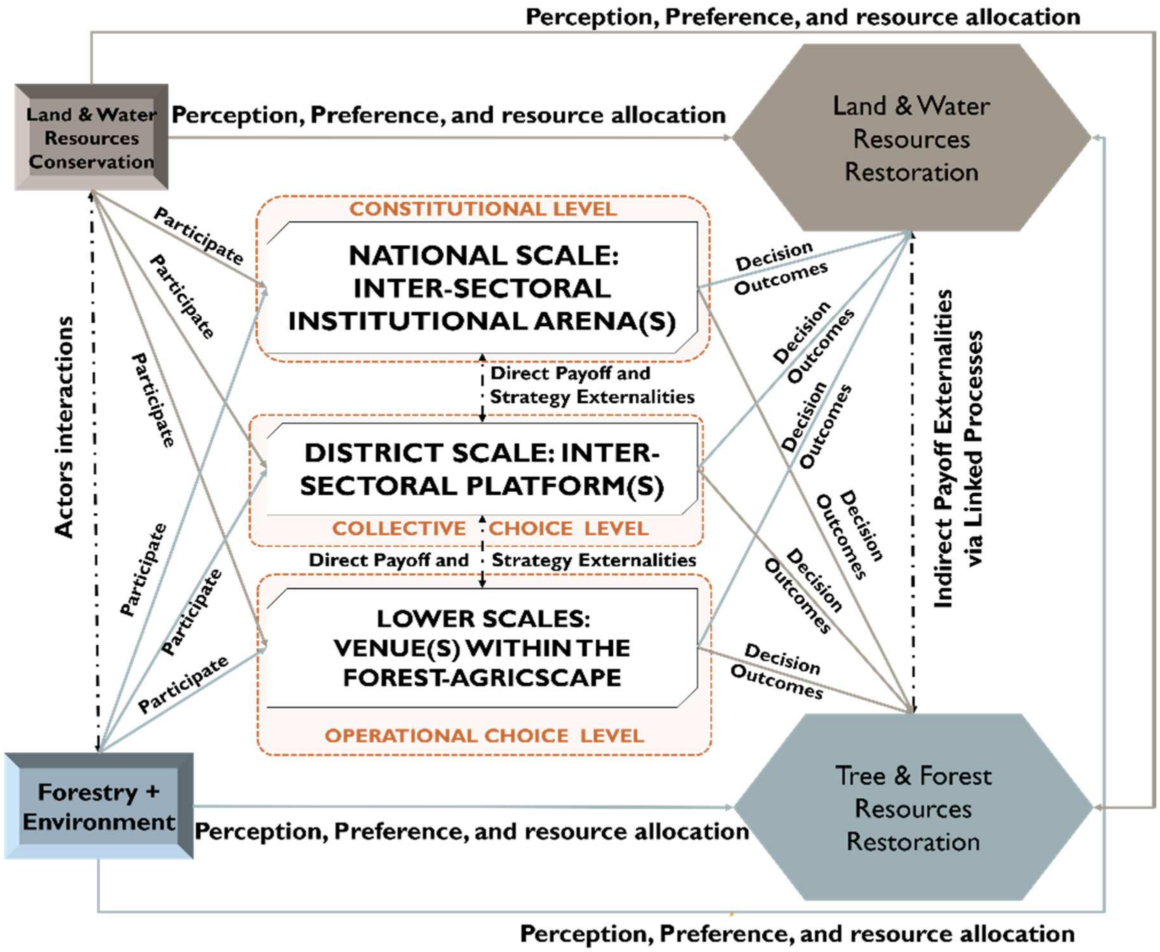
2.3.1 Theoretical perspective

The study employs the Ecology of Games Theory (EGT – Lubell, 2013), which offers a theoretical lens to analyze polycentric governance systems (PGS) empirically in order to draw real-world insights for improved and effective context-relevant governance. The original idea of a PGS translates horizontal cooperation, competition, and conflict resolution among multiple but (semi)autonomous governance structures (Ostrom et al., 1961; McGinnis, 1999). The notion's contemporary manifestation highlights the multi-scale and multi-level aspects of governance pluralism (Ostrom, 2010). In the governance of common-pool resources, polycentricity encapsulates the relationships among multiple entities with overlapping jurisdictions (Ostrom 1998; 2005; 2007; 2011; Andersson and Ostrom 2008; Blomquist and de Leon, 2011; McGinnis and Ostrom, 2012; Nagendra and Ostrom, 2012). Polycentric governance has inherent advantages, including an enabling adaptive management perspective, good institutional fit, and mitigation of risk through institutional redundancy (Berkes, 2002; Young, 2002; Cash et al., 2006; Schröder, 2018; Carlisle and Gruby, 2019). A polycentric regime requires adequate institutional interactions configured around necessary enabling arrangements and processes that enhance the functioning and effectiveness of complex, self-organizing governance system for solving collective-action problems (Carlisle and Gruby, 2019).

Uniquely, the EGT broadens the analytical lens of the Institutional Analysis and Development (IAD) framework (Ostrom 2011; McGinnis, 2011). It does this by adding hypotheses from other policy-science theories, including ones suitable for complex resources governance (Schlager and Weible, 2013; Petridou, 2014; Hamilton and Lubell, 2018). The EGT addresses the challenge of a narrow focus of the IAD framework on a single decision-making venue for a single collective action issue. As such, it wields compelling appeal to analyze the governance of forest-agriscapes restoration in two ways. First, the EGT allows for studying the real-world complexity of the governance of collective restoration featuring interconnectedness and interdependencies among diverse policy actors working to achieve shared restoration goals, through its notion of 'policy games' (Lubell, 2013; Berardo and Lubell, 2019; Lubell et al., 2014). A policy game involves a set of policy actors operating at diverse scales and participating in institutional processes of rule-governed collective decision-making over specific policy issues concurrently in a geographically-bounded policy system. The interdependencies and connectivity (via biophysical and/or social processes) among many policy games constitute an 'ecology of games', which requires relevant and effective interactions among policy actors to achieve positive outcomes (Lubell, 2013). Second, the EGT also allows the investigation of institutional externalities based on hypothesized mechanisms and functions to anticipate and avoid or mitigate externalities carrying negative governance and environmental implications. Such undermining externalities are major indicators of inadequate or lack of cohesion among different policies and coordination among actors. Externalities are instances where resource-management decisions and actions of one institution affect (positively or negatively) the efforts and outcomes of other institutions (Lubell, 2013; Mewhirter et al., 2018). They constitute spillovers arising from various interdependencies (Schröder, 2018). Lubell (2013) distinguishes payoff and strategy externalities. Payoff externalities are either direct, arising from overlapping jurisdictions or functionalities over a shared policy issue; or indirect, involving different but somehow interlinked policy issues that are affected by each institution's actions. Strategy externalities are commonly related to policy actors' strategies when they have multiple institutional affiliations, and tend to be positive (Zhou and Mu, 2019). Positive payoff and strategy externalities should be buttressed and promoted. However, the persistence of negative payoff externalities (mutually undermining resource-management decisions and actions across sectors and scales), is an inherent and core governance challenge that needs solutions.

To illustrate use of the EGT, we depict the overarching ecology of games of landscape-scale resource restoration in Malawi (Figure 2-2), considering ecological (forest-agriscape) and related socio-political and governance (national, district, and local) scales. Different policy actors share similar policy issues and some tackle different policy issues that are interconnected. This hints at the presence of direct and indirect interdependencies (Figure 2-2). Actors' potential interactions include participation in different arenas or platforms, yielding decision outcomes that affect the policy issues and lead to likely direct and indirect payoff and strategy externalities. These arenas occur at different socio-political scales and represent policy institutions within which multi-sectoral interactions can take place. They also depict institutional scales, or tiered levels of governance processes, associated with resource-restoration policy system in Malawi. The institutional scales include the constitutional level (national scale), the collective-choice level (district scale), and the operational-choice level (local scales in forest-agriscapes) where tangible collective restoration processes occur.

Figure 2-2. Ecology of games of collective resources restoration in the Malawian context



Overall, our use of the EGT focuses on the extent to which the essential interactions of cooperation, competition, conflict resolution, and institutional externalities mitigation, and the underlying processes across sectors and spatial scales make the existing governance arrangements for forest and tree management and restoration in both protected and communal areas operate as a sound PGS. Specifically, we focus on two EGT hypotheses, which emphasize explicit governance processes, to examine effective governance integration for forest-agriscape restoration at implementation levels, including district and sub-district administrative scales (while also linking to national processes). The two hypotheses listed below provide an organizing framework to examine what structural properties and functional arrangements can enhance restoration governance for positive outcomes, and to anticipate the implications of institutional change within the governance system.

1) *the degree of cooperation (collaborative arrangements), nature of resources distribution, and extent of social learning among the governance structures define the quality of the governance in forest-agriscapes restoration in Malawi.* Under this hypothesis, interconnections across policy issues; characteristics and institutional rules of policy structures and actors, and their relationships; and power relations are integral features and determinants of the governance interactions and processes. In particular, multiple types of power mediate interactions among stakeholders, the control of resources, the distribution of costs (time, materials, and physical burdens) and benefits (monetary or non-monetary), and institutional arrangements in a PGS (Morrison et al., 2019).
2) *Collaborative institutions mitigate the occurrence and magnitude of negative institutional externalities with emerging coordinative functions by some institutions of the complex system.* We explore the manifestation and nature of negative externalities, and coordination arrangements (what and/or who?) as solutions. Coordination processes remain a defining trait of a PGS (Schröder, 2018) and their effectiveness determines the PGS quality (Pahl-Wostl et al., 2012; Pahl-Wostl and Knieper, 2014).

2.3.2 Study Area

We draw on ongoing restoration efforts in Ntchisi and Dedza in the central region (Figure 1-3) as described in Section 1.3.2 in Chapter 1.

2.3.3 Data and analyses

Using purposive and proportional sampling (Palinkas et al., 2015), we conducted 35 focus-group discussions (FGDs) with diverse resource-governance bodies (RGBs) restoring tree, forest, and land and water resources. RGBs include BMCs, VNRMCs, other CBNRM structures, and RUGs from forest-agriscapes in both study sites. We also conducted 21 key-informant interviews (KIIs) with officers and local authorities at district and sub-district scales, and 16 KIIs with officers of both national and international agencies dealing with environmental resource management and governance (Table 2-1). Finally, we consulted national policy documents, district-level bylaws, and other relevant governance documents available at the level of the RGBs. We used interview guides approved through an official university IRB process. Besides general information on restoration objectives, activities, and approaches, we sought information required for our theoretical framework (described in Section 2.3.1). We also sought insights on the historical dynamics of resources governance in the research sites.

We transcribed the audio-recorded (in English and Chichewa) data and translated the *Chichewa* language ones into English. We analyzed the data using Nvivo Plus 12 qualitative data software. Content analysis commenced with a guided open coding of the different types of data using queries to uncover the major governance and related themes dictated by the EGT. Expanding with cross/axial coding, we identified emerging and recurring sub-themes along with illustrative excerpts. For instance, we sought specific information about how the RGBs are ordered across scales, on participation rules in collective actions, and incentives choices. We also noted other internal governance dynamics within the RGBs such as types of operational resources, benefits and their sharing, and resources monitoring processes. We further identified themes describing other policy actors, conveying horizontal and vertical relationships in the system, partnerships and contractual arrangements, knowledge mobilization, and learning. We noted narratives that describe the extent and nature of collaboration and resources capture among actors, learning mechanisms, forms of institutional externalities, inter-sectoral coordination of actions and decisions, and creative arrangements initiated to address emerging barriers and maximize restoration efforts.

Table 2-1. Sampling and sample size for FGDs and KIIs

District (FR)	Traditional Authorities	Group Village Heads (GVHs)	Sampled Resources-Governance Bodies for FGDs (35)		District-level KIIs (21)	National-level KIIs (16)
			Type	**Resources-Governance Bodies**		
Ntchisi (NFR)	Kassakula	Mpamila	Forestry	NFR (GVH level) VFA (Village level - Chimbalanga)	District Land Resources Conservation Officer (1) Agriculture Extension Development Coordinator (1) District Forestry Officer (1) Environmental District Officer (1) District Planning Development (1) TA Nthondo (1) GVH Ndinda (1) GVH Msankhire (1) GVH Kandodo (1) GVH Mgundana (1) Forest Association (1)	Forestry Sector (2) Energy Sector (1) Environmental Management Sector (1) National Parks and Wildlife Sector (1) Land Resources Conservation Sector (2) Water Resources Conservation Sector (1) Local Government (1) International Agencies (2) NGOs (4) Private Sector (1)
			LWRC	CCC: LRC & Afforestation (GVH level) Mpamira Circle (TA level)		
		Mponda (Galuntsuke)	Forestry	NFR (GVH level) VFA (Village level - Chamakwokwe)		
			LWRC	CCC: LRC & Gully reclamation (GVH level)		
		Chentche	Forestry	NFR (GVH level) VFA (Village level)		
			LWRC	CCC: LRC (GVH level)		
	Nthondo	Mandwe	Forestry	NFR (GVH level) RUG: Bee Keeping (GVH level)		
		Mpanang'ombe	Forestry	NFR (GVH level) VFA (Village level) VFA (Village level – Chingagnama)		
		Chifwerekete	Foresty	NFR (GVH level) VFA (Village level)		
			LWRC	CCC: Irrigation Scheme (Village level)		
	Vuso Jere	Nyanga	Forestry	NFR (GVH level) VFA (Village level - Tskonombwe)		
			LWRC	CCC: LRC & Irrigation (GVH level)		
Dedza (MLFR)	Kachindamoto	Kabulika	Forestry	MLFR (GVH level) VFA (Village level)	District Agriculture Development Officer (1) District Land Resources Conservation Officer (1) District Forestry Officer (1) Environmental District Officer (1) District Planning Development (1) TA Kamenyagwaza (1) GVH Songwe (1) GVH Kanyera (1) United Purpose NGO (1) MUA Mission (1)	
			LWRC	CCC: LRC (GVH level)		
		Mganja	Forestry	MLFR (GVH level) VFA (Village level – Youth group) RUG: Bee Keeping (Village level)		
			LWRC	CCC: LRC (GVH level)		
		Songwe	Forestry	VFA (GVH level)		
			LWRC	CCC: Irrigation Scheme (GVH level)		
		Bwanali	Forestry	MLFR (GVH level)		
			LWRC	CCC: LRC (GVH level)		
		Kafulama	Forestry	VFA (Village level) RUG: Bee Keeping (Village level)		
	Kamenyagwaza	Ngonoonda	Forestry	MLFR (GVH level) + VFA (GVH level)		

NFR = Ntchisi Forest Reserve; MLFR = Mua-Livulezi Forest Reserve; LRC = Land Resources Conservation; RUG = Resources Users Groups; VFA = Village Forest Area; LWRC = Land & Water Resources Conservation; CCC = Catchment Conservation Committee; NGO = Non-Governmental Organization

2.4 Results

2.4.1 Structural properties of the governance for forest-agriscapes restoration in the Malawian context

2.4.1.1. Policy actors, policies, and interdependencies in landscape-scale resources restoration

Key informant interviews revealed a diverse mix of key policy actors and entities holding direct and indirect influences on various NRM policies relevant to restoration policy games (Table 2-2), affirming the polycentric nature of forest-agriscape restoration governance and need for integration. Government actors, from at least seven sectors from two core ministries, and NGO and private-sectors actors, along with international development partners, exhibit interdependencies variously across at least 11 sets of NRM-based and three related policies and laws. More than half (55%) of the reported influences were direct, indicating a generally high level of interconnections. Forestry-sector actors were dominant in wielding influence across nearly all the NRM policy areas followed by Land Resources Conservation actors. Also, NGOs had influence in all the NRM areas and international agencies play a significant role (Table 2-2). Forest, land, and water resources policies/laws drew mostly the connectivity among actors from at least five sector/agency types. Although only few referred explicitly to the relatively new National FLR strategy, which shows influences primarily from DoF and some international agency actors, key informants emphasize the interconnectivity of resources degradation issues and NRM policies, and of restoration actions. A forestry-sector informant's perspective on observed interconnectedness epitomizes this: *"we strongly believe that forestry issues are interlinked to agriculture issues. We know that we are not the only players in the landscape, and if you look at degradation, you find that it is caused by different land uses."*

Further, several respondents highlighted cross-scale linkages as another main feature of landscape-scale resources restoration. They emphasized enabling inter- and multi-sectoral and cross-scale processes as means to foster cohesive collective restoration. Suggested future approaches included using existing or setting up new platforms for actions ranging from policy decisions and strategic agenda setting, joint planning, to intervention implementation.

> *"There should be a multi-sectoral approach; all sectors should come together … there should be joint formulation, planning, implementation, monitoring, evaluation and lesson learning" (KII, International Agency).*

> *"We need to ensure that there is landscape planning, budgeting, and implementing together based on the targets we have for resources restoration. When planning, we have to identify where the problem is and who is responsible for it" (KII, Forestry Sector).*

Respondents emphasized the importance of governance arrangements, specifically at district and sub-district implementation scales. One national-level informant from the forestry sector elaborated: *"… the most important is at district level because of decentralization. There are only few projects that are implemented at national level."* Highlighting operational collaboration, he continued: *"You need to work together, otherwise you can use two vehicles to go and implement projects in one area."* This commonly held perspective justifies our subsequent focus at the district and lower geographic scales in examining governance structures and functional mechanisms—actors/entities, institutional characteristics and rules, and interactions and underlying processes—that support implementation of forest-agriscape restoration.

Table 2-2. Types of policy actors and policies governing resources restoration and their interconnections

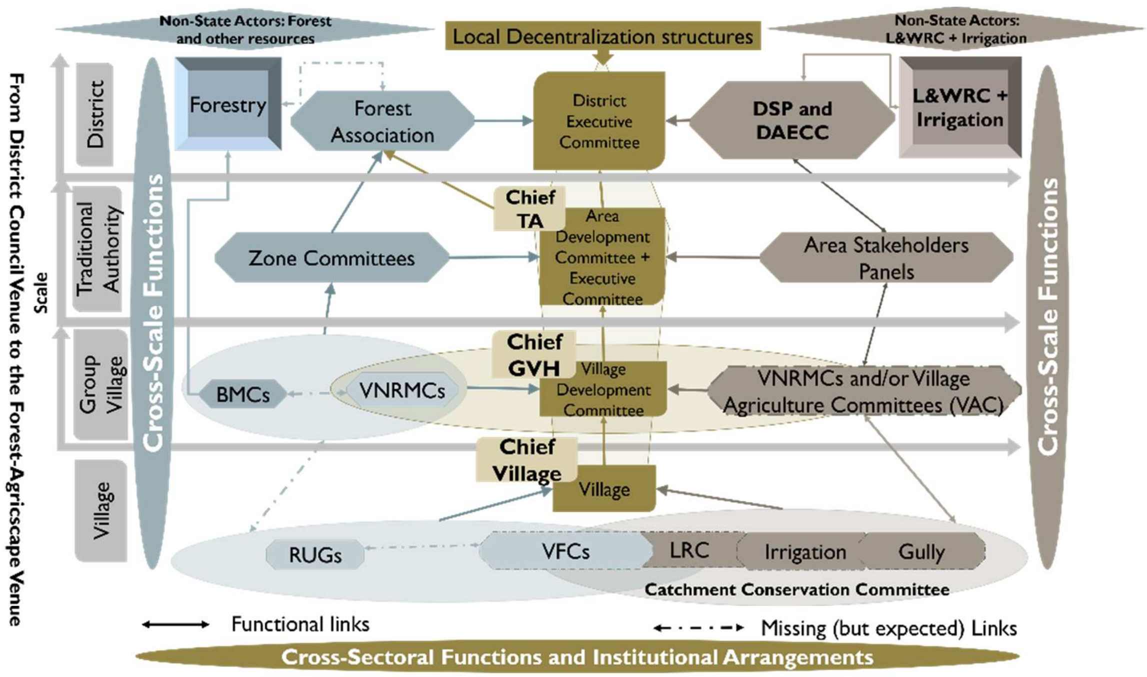
Types of Policy Actors		**Natural Resources-specific Policies and Laws**											**Other Broad Policies**		
Ministry lines	Sectors / Agencies	Forest Policy & Forest Act	National FLR Strategy	Environmental Management Policy & Act	National Energy Policy & Energy Acts	National Charcoal Strategy	National Parks and Wildlife Policy and Act & Regulations	National Agriculture Policy & National Agricultural Investment Plan	Land Resources Management Policy and Strategy	Land Act and Customary Land Act	Irrigation Policy and Development Strategy & Irrigation Act	Water Policy and Water Resources Act	Decentralization Policy and local government Act	National Climate Change Policy	MGDS
Ministry of Natural Resources, Energy and Mining (MNREM)	Forestry Sector Actors (FS)	XXX	XXX	XX	XX	XX	X	X	X	X		X	X	X	X
	Energy Sector Actors (ES)	X			XXX	XXX								X	
	Environmental Management Actors (EM)			XXX											
	National Parks and Wildlife Actors (NPW)	X					XXX	X				X			
Ministry of Agriculture and Food Security (MAFS)	Land Resources Conservation Actors (LRC)	X		XX					XXX	XX	X	X		X	
	Irrigation Sector Actors (IS)								X		XXX	XX			
	Water Resources Conservation (WRC) Actors			X							X	XXX			
Para-State	International Agencies (IA) (e.g. FAO; UNDP, etc.)	XXX	XX	XX				XXX						XXX	XXX
	NGOs Actors	XXX		XXX / X	XX	X	XXX / X	X	XXX / X	X	X	X	X		
	Private Sector							XXX	XX						

Keys: XXX= First degree (direct) influence; XX=Second degree (direct); X = Third degree (indirect) influence; MGDS = Malawi Growth and Development Strategy

2.4.1.2. Architecture and weaknesses of the governance framework at district and local scales

The governance architecture for forest-agriscape restoration in Ntchisi and Dedza districts combined interacting formal and informal structures and actors operating at nested village, village-group, Traditional Authority (TA), and district scales. The actors/structures fall into four categories (Figure 2-3): 1) government NRM-sector departments with district-level officers and frontline-extension agents; 2) non-state policy actors, comprising non-governmental organizations (NGOs) and the private sector; 3) decentralized local governance and development structures/actors at district and sub-district levels; and 4) diverse resource-governance bodies (RGBs) leading restoration activities.

Figure 2-3. Structural architecture of the governance framework in place for collective resources restoration

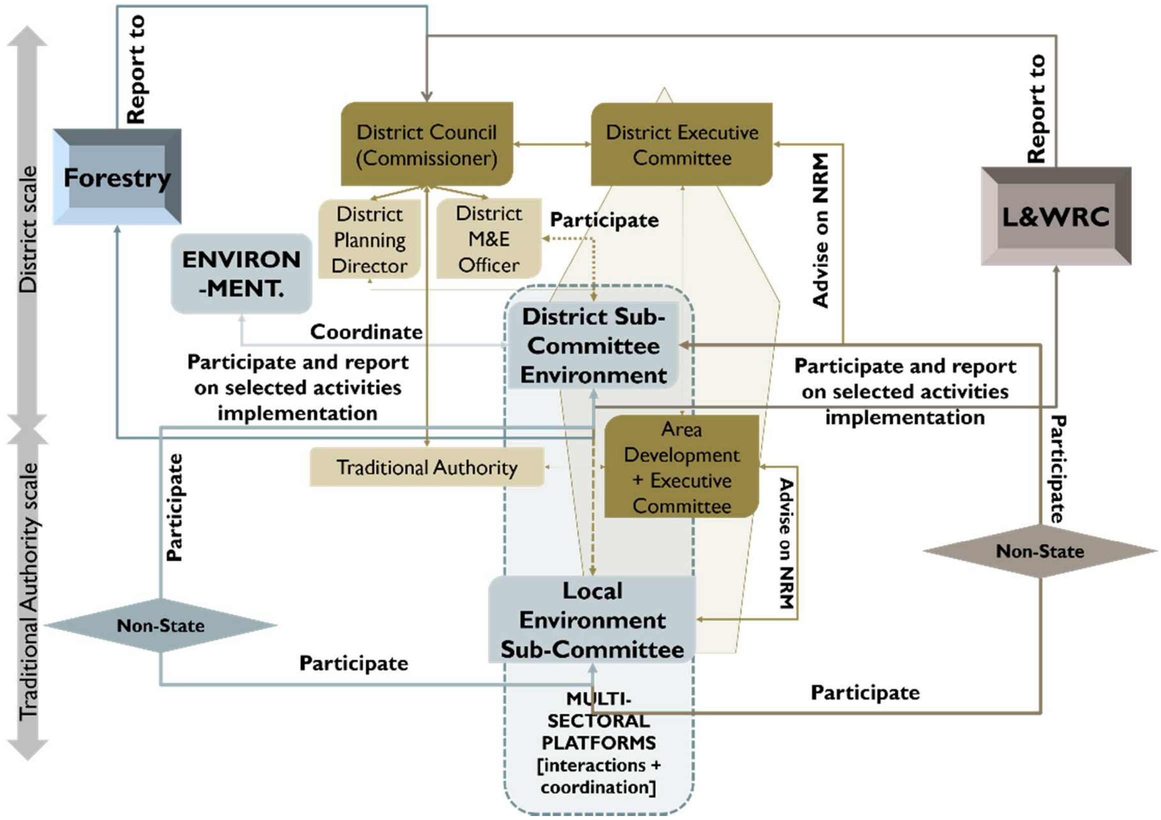


BMCs: (Block–[Forest Reserves]–Management Committees). Co-managing forests in protected areas
Zone Committees: Linked to Forest Reserves/Protected Areas (Co-Management) and forest on customary lands (VFAs)
VNRMCs: (Village Natural Resource Management Committees) Managing forests & trees on customary lands (VFAs) and other land-based resources at the Group-village level
VFCs: (Village Forest Committees) Managing forests & trees on customary lands (VFAs) at the village level
DSP/DAECC (District Stakeholders Panel / District Agricultural Extension Coordination Committee)
L&WRC: (Land and Water Resources Conservation)
CCCs: (Catchment Conservation Committees) Managing land & water resources conservation actions ==➔ **LRC** = Land Resources Conservation; **Irrigation** = Irrigation scheme; **Gully** = Gully reclamation
RUGs: Resources Users Groups ==➔ Bee keeping groups; Cookstoves + Briquettes Groups; Woven Furnitures Groups; etc.

Findings show that the organizational model for the RGBs and most of the local governance entities, regardless of sector, builds largely on principles of (democratic) representation. The four categories of policy actors/structures are interlinked functionally, both horizontally across sectors and vertically across geographic scales. The major institutional arrangements for cross-scale functional linkages are multi-stakeholder bodies, platforms, or committees, operating mainly at TA and district scales. Most channel activities either (i) of sectoral RGBs and user groups in a locally-driven manner but with some technical support (e.g., zone committees, forestry associations, or catchment conservation committees), or (ii) of combined community and technical (government, NGO, private) stakeholders (e.g., Area or District Stakeholder Panels and Development Committees). Some institutional forms channel activities across sectors (and scales), only among the technical agencies. These include, for instance, the Area and District Executive Committees (AEC, DEC), the District Environment Sub-Committee (DESC), and the Local Environment Sub-Committee (LESC) (see Figure 2-4). The 'co-management' model as applied in the two districts, is another and inherently cross-scale institutional form. This form uses the committee structure with inter-connections across scales, as described in section 2.2.

Conversations revealed that the platforms and functions provided under Malawi's decentralization policy were perceived to offer spaces for cross-sector and cross-scale processes among the set of actors, and are relevant for an integrated restoration governance (Figure 2-4). Specifically, stipulated DESC functions include coordination of all environment and NRM activities within a district; ensuring integration of environmental concerns in local plans, programs, and interventions; assisting in the development of bylaws; coordinating activities of VNRMCs; managing conflict resolution using bylaws; and generally providing technical guidance to the sectors and District Assembly (Environment Management Act, 2017 pp25-27). The DESC is chaired by the Director of Planning and Development (DPD) in each district, and the Environment District Officer (EDO) serves as the secretariat. The DESC reports key or outstanding issues to the DEC where technical agents across sectors address all development issues at district level. The LESC, composed of extension workers of active NRM sectors within a TA and the major TA chief, plays a similar role at TA scale, referring issues to the broader AEC, as articulated in the 2017 Environmental Management Act building on the 1998 Local Government Act (sections 15 and 16).

Figure 2-4. Decentralized institutional structures and arrangements for inter-sectoral interactions relevant for restoration processes at district and TA scales



Nevertheless, informants revealed structural weaknesses in the institutional elements and their characteristics, notably the RGBs and decentralization structures. First, some RGBs were absent, others were present but with purposively downgraded or upgraded spatial jurisdictions, and yet others were weak partly due to their informal or project-driven origins and lacking legal or policy mandate. For instance, on land and water resources conservation (LWRC), village agriculture committees (VACs) and VNRMCs are supposed to be the main organizational RGBs at the scales of individual or groups of villages. However, VACs/VNRMCs were sometimes missing, leaving the community-based LWRC activities under the leadership of the thematically broader village development committee (VDC). Another institutional entity for community land resources management is the catchment conservation committee (CCC) designed as a village-scale RGB. However, its sub-committees on land/soil, water, and forests, which are supposed to work together in a coordinated fashion, are often informal and ad hoc. Also, scalar mismatches and inconsistencies mean that the CCC sometimes operates across two or more villages (at GVH scale) to fit the spatial extent of particular catchments.

On the forestry side, VNRMCs managing VFAs on customary lands were also often missing, dysfunctional, or existed at mismatched scales between the ecological scale of the forest resources and the sociopolitical scale of the collective restoration arrangements. Such situations sometimes justified establishment of new RGBs with modified spatial jurisdictions. As a group village head from Ntchisi noted, *"it is better to have [sub]committees in the villages. Some chiefs just want to maintain powers."* Thus, Village Forest Committees (VFCs) are sometimes sub-committees of VNRMCs. Further, co-management structures and activities for state forest reserves were not present in Dedza, where block management committees (BMCs) established under a previous project were largely non-operational (only 3 of 14 BMCs remained functional). In Ntchisi, socio-structural and scalar mismatches prompted the restructuring and rescaling of co-management RGBs. Still, as some local chiefs affirmed, the rearrangements of BMCs remain inadequate and their current domination by elected members compared to local chiefs have resulted in ineffective enforcement, elite capture by executive members, and corrupt and non-sustainable resources extraction and sale. The temporary re-scaling, which is expected to enhance efficiency and accountability, includes having VNRMCs/VFCs to additionally control management of forest reserves immediately adjacent to them in an integrated manner, and two newly established RGBs: Zone Committees and Forest Associations. Zone Committees are set at TA scale (although replacing BMCs set previously at GVH scale) and Forest Associations, replacing former LFMBs, are set at district scale to guide and oversee forestry activities and policy implementation. However, despite being included in new co-management agreements between the Department of Forestry and participating communities, these new or re-scaled RGBs are not formally endorsed in current forest policy and law, making their legality, financing and future uncertain.

Second, findings revealed weaknesses in RGB institutional characteristics, particularly the quality of *internal cooperative rules* that guide collective-action operations. Challenges include lack of sustainable financing mechanisms and limited operational resources, which undermined their functioning; uncertain government capacity for effective support; weak resource-monitoring capacity; and inequitable costs and benefits sharing (Table 2-3). The chair of the Forest Association in Ntchisi complained that despite good intentions, promised financial resources supposed to come from the Department of Forestry and district assembly had not materialized and the ensuing lack of mobility had rendered the association dysfunctional. This resources challenge was paramount for all RGBs, prompting suggestions of the need for instituting partnership arrangements that would include resources sharing to enhance restoration efforts given their overlaps in restoration processes. *“NGOs just facilitate formation of committees, but they don’t provide enough operational resources. There is need to provide resources…”* suggested the District Agriculture Development Officer (DADO) for Dedza, along with sharing mechanisms for restoration tools/equipment among RGBs.

Third, many informants pointed to challenges with the decentralization structures and actors, including limited resource capacity (financial, human/skills, and accessibility to information) and incomplete or poor articulation of some sub-district structures. For instance, although the DESC has freedom for self agenda-setting and membership determination based on specific issues being addressed at any time, provisions on DESC roles, positions, how and who can join and/or withdraw, and meeting frequency tended to be unclear or misunderstood. District-level informants displayed differing local understandings of the DESC policy provisions, including for instance on its meeting frequency and functions potentially undermining their role in forest-agriscape restoration governance.

Table 2-3. Cooperative rules within resources-governance bodies in the forest-agriscapes of Dedza and Ntchisi

Common Trends About	***Collective Actions for Tree & Forest Resources [N=22: 8 focus groups in Dedza and 14 in Ntchisi]***	***Collective Actions for Land & Water Resources [N=10: 4 focus groups in Dedza and 6 in Ntchisi]***
Participation and commitment	Fair: but undermined by commitment limitations of volunteerism, especially in BMCs in Dedza.	Good: enhanced with incentives offered by NGOs; women are more committed.
Rules for internal management	Participate in monthly meetings and in resources management activities; Pay defined fine when late to meetings or absent for no valid reasons; Use democratic decision making; Conduct reporting duty; Replace non-committed members; Schedule and lead activities; Implements agreed forest management plan + Bylaws (in few cases)	Attend scheduled meetings; Implement (unwritten but often known) management plan; Conduct monthly reporting duty (by lead farmers) to Agricultural Extension Development Officers/Coordinators (AEDOs/AEDCs)
Transparency (check and balances)	Poor in former BMCs (in Dedza): Use of receipt books supplied by DoF and how money is used; Good in VFCs/VNRMCs: Reporting on produce sales and money use to community through VDC	Depended on democratic openness and practices of the organizations
Trust levels	Limited: members do not denounce other members or their relatives from the community who are involved in illegal tree harvesting; cliques develop because of/causing mistrust.	Good: with social capital building (sympathy to grieving members)
Monetary resources	Sales of forest resources (poles, trees, medicines, and firewood) – main source for VNRMCs/VFCs, insufficient due to declining resource availability and value; Membership fees; fines/penalties from late participation and unjustified absenteeism (K50-K500 ≈ $0.066-0.66) - insufficient; Fines/penalties from illegal harvesting (K10,000-K50,000 ≈ $13-67) - Not sufficient because rare.	Membership fees - Insufficient
Operational costs and needs	Time (moderate, voluntarism based); Working tools & materials (insufficient); Training needs (nurseries establishment and management, forest management, leadership skills – dependent on NGOs, government, projects); Mobility for resource monitoring and for sensitization campaigns (low, transport availability/costs); Food costs during management activities (low, can be abused).	Time; Working tools/materials (not enough); Training (technical knowledge on SLM, LWRC, trees planting); Mobility for sensitization/awareness campaign (low, transport availability/costs).
Cost sharing or saving features	Using existing monetary resources; Volunteer time commitment; Materials and training supplied by Projects/Programs & NGOs; In-kind contributions from members (personal materials); Personal monetary contribution from members (rare).	Materials and training supplied by Projects/Programs & NGOs; In-kind contributions from farmers (personal materials); Paid time with cash-for-work incentives
Types of benefits	Trees, bamboos, firewood, poles, medicines; fruits, thatch grass, mushrooms, grazing animals in specific zones; Opportunities of being part of RUGs; Tree seedlings to plant on individual farms; Incentives. (With BMCs managing FRs, forest resources are generally sold. With VNRMCs/VFCs managing VFAs, many benefits are often free by request from traditional leaders or during organized collection periods; some products are sold (e.g.K300 for a headload bundle of firewood)	Tree seedlings, vetiver grasses, Incentives from NGOs.
Benefits Sharing features	Variable in VNRMCs/VFCs – internally-defined as group constitutions with chiefs and include contribution to community development and social welfare/support (50-60%), Chief GVH (10%), food supply during collective activities and loans to individuals (30-40%). Formula based on the legacy of the IFMSLP with some adaptations over time. Most common patterns with BMCs -- 50-60% for VDC for community development; 30-40% for forestry department; 10% for either the BMC or the former LFMB	Sharing vetiver grass, manure, tree seedlings for use or planting on individual farms – no formalized mechanisms.
Types of Incentives	Training and operational support given by NGOs; Tree seedling handouts; Travel for exchange visits; In-kind handouts (food for work); Meeting allowances; Monetary handouts (cash for work: e.g. K14,400/24days).	Training; Free operational materials; Cash for work (K14,000/biweekly); Food for work; Meeting allowances.
Monitoring of physical resources	Mostly visual -- state of forests and trees in the landscape during patrolling and tree planting works; Some previous efforts of tree counting in collaboration with extension workers (with project support – participatory forest assessment).	Visual, no formal measurement -- appreciated via farm productivity observations; Site visits in collaboration with extension workers (More often with project support).
Types of conflicts	Disagreements over activities and schedules; Illegal harvesting of resources by individuals; Challenged fines and penalties enforced; Non-cooperative behaviors; Between-members personal conflicts.	Small quarrels over activities (workload sharing) and clashes of a personal nature.
Conflicts Frequency	Not common	Not common
Conflict-resolution mechanism	Internally-managed; Settled by traditional leaders (GVHs, TAs) based on established written and unwritten bylaws and customary law; final resort to the police/legal system on illegal harvesting or theft.	Settled at the VDC level, rarely escalate to the TA level
Challenges	Insufficient financial and other operational resources; Insufficient training (including on leadership); Inadequate incentives; Overdependence on volunteerism; Minimal costs (and time) sharing; Transboundary conflicts with neighboring villages sharing common resources; Illegal harvesting of resources for charcoal production and firewood; Forest encroachments and continual tree loss (in Dedza); Poverty and lack of alternative livelihoods to farming.	Reluctance of some farmers to participate; Tenure insecurity not supporting tree planting; Lack of relevant skills; Insufficient training; Low commitment when no incentives; Increasing poverty and land scarcity

2.4.2 Cooperation and competition interactions and related processes in forest-agriscapes restoration

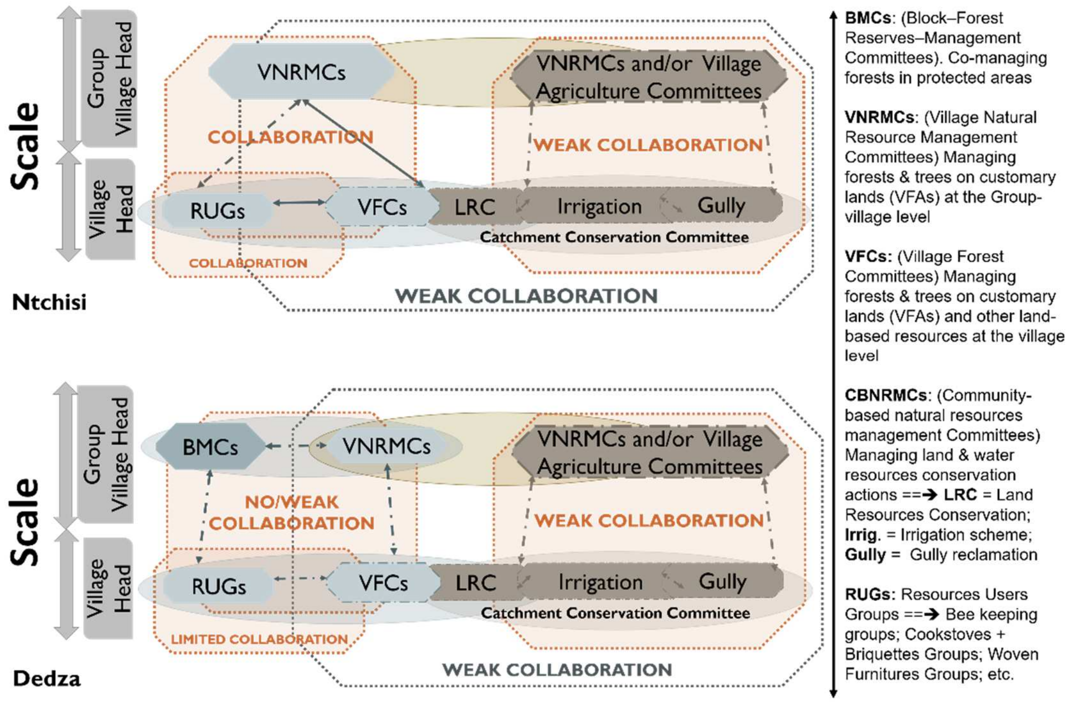
Following the EGT, we present findings of the quality of the existing collaborative arrangements within and across scales; the nature of resources sharing and distribution features; and social learning mechanisms that underpin adaptive and integrated resource restoration. We examined how these processes shape PGS interactions, including of cooperation and competition.

2.4.2.1. Collaborations within and across scales among resources-governance bodies

Findings show that the amount and quality of formal collaboration across sectors and scale was very limited although relatively more collaboration occurred through informal arrangements (Figure 2-5). *"No, we normally don't work together. We work together only when we are working on paid activities, for example, MASAF [Malawi Social Action Fund] …,"* explained a VNRMC member in Kabulika1 on local level activities, reflecting a common sentiment among RGB members and other informants on formal collaboration. Rare indirect collaborations were observed in cases of multiple group affiliation. A CCC member in Dedza explains: *"We don't work together or do joint activities as [we are] different committees, but some members of this committee are also members of those other committees."* Another nuance shows that horizontal, intra-sectoral collaborations were more evident among LWRC-related RGBs than forest-related ones in both districts. Some respondents attributed the observed, though limited, cooperation to rare leadership accommodating cooperation among groups (Table 2-4). Such leadership is yet to grow and effect all RGB relations, which remained less cooperative in apparent lose-lose relationships.

> *"There is no good relationship between us and other committees, and we don't wish each other well. There is no good relationship between people from different GVHs. Now there are more people and many chiefs, and no one wants to be inferior to another. Everybody works on his own. For instance, our friends from Kadewere had fruit seedlings, but all the seedlings did not do well and died because they did not want to come here to learn how to manage those fruit seedlings. If they had asked us, we could have helped them, and their seedlings would have survived" (FGD-VNRMC, Kabulika 1, Dedza).*

Figure 2-5. Collaboration among resources-governance bodies based on formal relations



Infrequent cases of informal partnerships emerged among RGBs operating on customary lands, including forestry ones. Collaborative arrangements were observed between interdependent beekeeping RUGs and VFCs or VNRMCs, which tended to share membership affiliation. Beekeepers placed beehives in VFAs and depended on sound forest management for honey production (Table 2-4). Other informal collaborations included shared monitoring and reporting of illegal activities, and reciprocity in activities such as firebreak maintenance among adjacent VFCs and between VFCs and VNRMCs (Ntchisi only). Further informal collaborations included technical knowledge and limited logistical exchanges within and across sectors. *"We share ideas, for example, on how to establish tree nurseries",* commented the GVH leader of Ndinda on such interactions among and between VFCs and other CCC groups. Such collaboration often involved harnessing the differentiated but complementary expertise across RGBs to compensate for internal capacity gaps. Occasionally, neighboring villages forged informal inter-village collaborations among VFAs in order to deal with cross-border conflicts or cases where a member of one village broke resource-use rules in another village (Table 2-4).

2.4.2.2. Resource distribution among resources-governance bodies

Because of limited valuation of the many costs and benefits involved in forest-agriscape restoration, our analysis focused on informal and formal arrangements to redistribute or share the scarce external resources to address identified intra-RGB resource challenges. First, FGDs indicated scant sharing arrangements over operational tools or materials (seedlings, panga knives, axes, boots, wheelbarrows, shovels, protective gear, etc.) among RGBs. Explanations included resource scarcity in virtually all groups, lack of a sharing culture, inadequate mutual trust, and fears of damage to equipment/tools lent out (Table 2-4). However, KIIs revealed some inter-RGB resource sharing, including labor pooling arrangements and seedling sharing among adjacent VFAs, and skill sharing among government field officers (Table 2-4). We found only one case in Dedza of an established tool-sharing system initiated by the GVHs and VDCs. The lending system had tacit basic rules for sharing tools, donated by NGOs, among CCC groups for conservation work, including the responsibility to repair or replace borrowed tools that were damaged.

> *"… We were given operational resources by CISP [Comitato Internazionale perlo Sviluppo Deipopoli - a Malawi-Italian NGO], and any committee that needs resources can borrow from the VDC. For example, we, Umodzi drama group, were not given materials, but if we want to do NRM activities, we go and borrow from VDC and we are given [the tools]. … Committees from other GVHs cannot borrow from the VDC of another GVH. … Borrowing is done on a first come first served principle. … Also, activities differ, and materials are shared based on the nature of activity. … A committee that damages the equipment replaces or repairs it, and we do not give money to the VDC to replace or maintain the equipment. The only disadvantage is that there is competition… one committee has to wait for the other committee that borrowed the materials first to finish [their work]. Some people just borrow the materials out of jealousy [to keep them out of circulation]" (FGD-CCC, Songwe, Dedza).*

Second, some participants decried the lack of mechanisms for fair benefit distribution. Local participants largely considered project supplied material support for restoration as incentives. However, such material support induced unintended perversities such as competition, asymmetrical power relations among some RGBs, and dependency on handouts (Table 2-4). Still, as the Land Resources Conservation officer for Dedza district explained, the resulting competition for the resources did not negate collaboration among RGBs: *"They want to enjoy benefits on their own, but technically I have seen them working together."* Findings also indicated that competition among NGOs to achieve quick results and donor-imposed targets drove the giving of material support and ensuing RGBs competition or dependency. One NGO actor (United Purpose - UP) in Dedza acknowledged, *"You know, sometimes we are dictated by donors."*

2.4.2.3. Social learning processes for resources restoration

Besides formal training, RGB members emphasized social learning through the sharing of knowledge and experiences in formal and informal collaborative relationships. Such learning happened at meetings involving several committees, through the use of poems and drama in various local stakeholder platforms, during demonstration field days, and during observation visits between RGBs as commonly promoted by frontline government and NGO extension agents. These social-learning processes and activities not only enhance mobilization of knowledge, but also trigger self-reflection and course correction based on learning from different experiences to enhance restoration (Table 2-4).

Another mechanism for promoting social learning to enhance restoration are small woodlands or woodlots established by or under the influence of some traditional leaders at household, village, GVH, or TA levels to demonstrate sound environmental management and behavior among their subjects. This was notable in Ntchisi. As a traditional leader affirmed: *"I asked people who have spare lands to create their own forests… There are some people who are resistant, but we try to engage them to understand benefits of trees"* (GVH, Mgundana). *"I also require all villages under my jurisdiction to have a village forest,"* echoed GVH Ndinda. Such exemplary leadership is a potentially effective governance "technology" that can reinforce restoration outcomes (Table 2-4).

The observed social-learning processes and mechanisms are, however, sporadic, and often incidental. The agriculture extension stakeholder platforms at GVH/TA and district levels on LWRC issues offer a good example for replication.

Table 2-4. Illustrative quotes on collaboration, resources distribution, and social learning processes

Collaboration among RGBs within and across scales	**Cross-scale features of resources distribution and sharing**	**Social learning mechanisms**
"We do not share knowledge because we have not received training to work with other committees in terms of sharing knowledge. We were not told to do that. Also, it cannot happen because leadership would be a problem. All committees have leaders and when we meet together, committee leaders do not want to listen to each other. Everyone wants to express his/her authority" (FGD-CCC, Bwanali, Dedza).	*"We don't have anything to share as a group because we use resources from our homes. We do not have resources that we can share with others. If we had the resources [physical tools], we would share because the materials would be at VDC level and every committee would have the opportunity to borrow and return them after use. We have discussed contributing money and buying resources [tools] for the VDC, but with this year's economic hiccups, we have not managed to do so; but there are those plans" (KII-GVH Ndinda, Ntchisi).* *"The committee that receives the resources take them as their own resources and hold on to them. ... [For example,] we tried to borrow shovels to use at our nurseries, but the other committee came and took back their shovels before we could even finish our work, and we were told to ask UP to give us resources. We have never shared tree seedlings also, and I do not think it is possible because we come from different committees and villages." (FGD – CCC Kabulika, Dedza).*	*"We share knowledge on how to raise tree seedlings and best soil for tree planting. After being trained by UP, we pass knowledge to our friends from youth clubs and from block committee. Knowledge is shared through drama plays and after that, committees continue with sensitizations of villagers. Sensitization through drama is done at GVH level. … For example, block committee shares bylaws with people, and they give drama group themes that they feel people should know, and we convey information through drama" (FGD-VFC, Songwe, Dedza).*
We keep bees in our village forest, which is in Mkwaila, GVH Mganja. … the objective is to keep beehives while protecting the village forest. It is called Mkwaila village forest. … The forest was not established for the purpose of bee keeping, rather it is for the village, and we just utilize the forest for… keeping bees. The agreement we have made with the VFA is that we participate in forest management activities such as planting trees and making fire breaks, and we do these activities together" (FGD-Beekeeping group, Mganja, Dedza).		*"Collaborative learning is encouraged, and it is done at district level through field visits. We strengthen collaboration through field days, exchange visits, farmer demonstration plots where farmers learn how others are doing; and we engage the clubs, extension people. We engage all the officers and we do exchange visits between farmers from Lilongwe and Mchinji. We also use model farmers with success stories and farmers share resources[knowledge] on their own" (Private Sector).*
"… They work together, these committees plant trees together and sometimes they help NFR committee to deal with dangerous people in the forest. There are some people who are very dangerous and need collective effort to catch them" (KII-GVH Msankhire, Ntchisi). *"There is more collaboration …For example, you find that irrigation committee involves forest committee to make sure that they are protecting the riverbanks. You will see that there is water-management committee, and then you find agriculture or crops-management committee [and] land-management committee working with them to make sure that what happens in the scheme is according to the regulations. In the villages, … if it is catchment management, the catchment-management committee will take the lead to ensure that things are done accordingly. If it is another activity, … another committee on tree management will take the lead and there is quite a number of collaborations" (KII-DADO, Dedza).*	*"Neighboring VFAs share resources if one village is having challenges. … There has been a case in Ntchisi where one village started conserving one side of 100ha hill and the other villages started working on the other side" (KII, NGO2).* *"If the graveyard-management committee has more resources, the VNRMC can borrow some from them. Committees can borrow money from each other. … Well established committees have some interest to ensure that other small committees are functioning" (KII-GVH Msankhire, Dedza).* *"For the tree seedlings we give committees to plant, we normally get them from Department of Forestry and we also use forestry extension workers when it comes to special skills like tree management" (KII-DADO, Dedza).*	*"We encourage learning from one another. …. You find that there are some people performing highly, and there will be some people lagging behind…We take those who are lagging behind to go and see what others are doing and they can learn… Sometimes we organize field days, open days and during these, all those that are doing different interventions are brought together to learn what others are doing and probably they adopt some of the interventions. [Also,] In training, we deliberately include some topics that are transformative in nature that relate to issues of ownership, issues to do with sustainability." (KII-UP, Dedza).*
"We are promoting villages to talk to each other, and we are promoting chiefs' forum and they set up a forum for that and they discuss when to meet and they discuss issues that are there such as encroachment, green belt initiative. TLC [Total Land Care] promotes that relationship. In landscape, you find a boundary between two villages and the chiefs develop a forum to be talking to each other" (KII, NGO2).	*"Most projects that have been implemented in the district have been using incentives … food and cash-based incentives: food for work or cash for work. We were giving out food and money before but now we do not do that anymore. We sometimes provided things like revolving loans, pass-on livestock programs, and we also provided irrigation and other materials" (KII-UP, Dedza).* *"… in fact, what has divided villages in our country are handouts. … Even the TAs have been divided, and that is why you hear about sub-TA or senior GVH. Sometimes you have one VNRMC in one village. At village level, those VNRMCs are called VFCs" (KII-DFO, Ntchisi).*	*"We encourage that every person has trees on his/her village. ... All chiefs [are] demanded to establish tree seedlings each and every year and that they should distribute the seedlings to the individuals and if anyone fails to comply and not planting a single tree, he/she is fined a chicken. … I also help them with advices on, for example, when to plant trees and how management of those trees can be done. I have my own committee that goes and monitor natural resources management activities" (KII-GVH, Msankhire, Ntchisi).*

2.4.3 Coordination processes and conflict-resolution mechanisms for forest-agriscapes restoration

Coordination and effective conflict resolution are essential mechanisms and processes of a sound PGS because they address the quintessential challenge of adverse institutional externalities and associated conflicts (first elaborated below). Many informants highlighted previously described, existing decentralization institutions as offering the best—albeit unfulfilled—opportunities for coordination and cross-sector integration at district and lower scales to enhance forest-agriscape restoration, as illustrated below:

> *"There has to be horizontal and vertical coordination. Local committees should report to relevant authorities. I think to us when we heard [instructions] from government to develop landscape restoration, we emphasized that people should see the importance of complementing sectors, and the DC [District Commissioner] and directors should facilitate the linkages" (KII, NGO1).*

2.4.3.1. Institutional externalities in forest-agriscapes restoration in Malawian context

The analysis revealed the presence of significant negative payoff externalities arising from conflicting or inconsistent policy and regulatory provisions and arrangements. Strategy externalities related to policy-actor strategies as they navigate multiple institutional affiliations, but their negative aspects appeared to outweigh the positive ones and constrained cohesive restoration efforts. We examine the nature, manifestations, and potential impacts of the externalities below.

a. <u>Payoff externalities in regulations</u>

Findings on the soundness and harmony across restoration-related policies and laws were mixed. Half of the national-level key informants (8/16) perceived them to be sound, well-articulated, and aligned with each other. An NGO actor affirmed that *"at policy level, there are no problems because the policies are fully articulated, except in minor cases."* However, a majority (9/16) of informants specified aspects that created negative externalities, including conflicts. They variously characterized the negative policy-related externalities as *"gaps," "not aligned"* or *"not talking to each other."* Informants also attribute the externalities to lack of coordination of policies and policy processes. A PERFORM Project officer surmises: *"To me, …coordination is what is lacking."* An informant from FAO elaborates: *"policies do not link …When policies are being prepared, the processes look like they are linked, but the policies [at the end] do not adhere to each other and they work in silos, not in collaboration."* The general observation was that policy gaps created inconsistencies, including inappropriate, outdated, and ineffective provisions, confusion, inadequate regulation to harmonize actors' efforts and practices at the implementation level, and low ensured accountability, as the following perspectives illustrate:

> *"We do not have regulatory framework that government was supposed to provide. Government should have documented approaches for NGOs to use. Communities are left confused. Government should elaborate documented approach[es] that government officers should oversee, including tree planting approaches. Government should regulate the behavior of all implementing partners. … There are so many NGOs working on similar activities but with different approaches. You will find that government officers are working with different NGOs in the same community, but with different approaches, and it creates so much chaos" (KII, NGO2).*

Concretely, three streams of regulatory incongruences are worth noticing. First, negative externalities emanated from incompatible provisions or language within and across certain sector policies. One example is discrepant provisions on riverbank protection across forest, environmental management, land resources conservation, water resources, and irrigation policies. While all promote riverbank protection, they are inconsistent on the buffer zone size (distance from the water's edge) to be protected. Further, irrigation policy promotes riverbank cultivation, conflicting with riverbank conservation policies (see Table 2-5 for detailed illustrative perspectives from KIIs). Non-alignment of penalties and fines within and across sectors is another manifestation of negative payoff externalities. For instance, similar offences in forest regulations attract different penalties in the wildlife regulations. Within the forest sector, penalties do not align across scales. Some bylaws at district scale are not consistent with national provisions, and those at TA scale are not reflected consistently at lower scales where they are either weak, poorly defined, or non-existent, as the following perspective captures.

> *"… for us to implement some of the possible approaches that we are coming up with, we need the legislation. That is why there is a need to review the Forest Policy and the Act. [Also,] in the current policy, penalties for degrading the forest do not match the extent of the damage because they are very low, and people are not afraid of damaging the environment" (KII, Forestry Sector)*

Second, negative payoff externalities were manifested with inconsistent policy interpretation, and selective or delayed implementation. A moderate share (7/16) of informants reported that different interpretations of policy provisions during implementation due to their vagueness caused mixed or negative outcomes. *"Sometimes, how you are interpreting these policies becomes an issue when implementing them,"* noted a PERFORM Project officer. Two manifestations are illustrative: selective implementation of lax provisions on riverbank protection among agriculture officials and disparate/disjointed approaches to resources conservation, including perverse incentives for collective resources management (Table 2-5). For instance, some (6/16) informants noted incoherence arising from delayed activation of laws and regulations supporting established NRM policy, causing a time lag in relevance, and from lack of or poor enforcement of existing ones.

Third, some policy provisions were non-applicable in practice or required excessive transaction costs. Some (5/16) informants affirmed this, especially in relation to resource tenure (in)security associated with significant power imbalances that get in the way or widespread resistance to implementing new customary land laws. Perceptions from catchment management and forests on customary land, respectively illustrate:

> *“The policies are advocating for a catchment approach and within the catchment there are different individuals owning land. It becomes difficult if in the same catchment others are not willing to restore the land because of the land ownership issues” (KII, NGO1).*

> *“I have no right to choose what type of trees to grow there because the traditional leader can come and choose who will use the land next year. This limits people’s investment on that land. … A farmer, when not sure of who will use the land next year, he can cut all the trees” (KII, Forestry Sector).*

Although some policy actors have tried to address this practical externality challenge by crafting locally innovative informal agreements based on the customary authority of traditional leaders, it remains a key regulatory issue to address more effectively for the sustainability of restoration actions and outcomes. An NGO informant from Dedza articulated how involving local leaders made it easier to circumvent temporarily the land-tenure insecurity issue and to sustain program works within a collective irrigation scheme. *“… now we do participatory agreements, where anyone owning land that side agrees that the land could be rented out to anybody [else] who is willing to use it during irrigation activities, and the owner commits the land to the irrigation activities. … It is not a legal document, but at community level, it has power to govern how the forest or irrigation schemes should be managed. When the Chiefs are there, the document is well recognized and when the TA has assented to the participatory agreement, it is given more power.”* An FGD participant from a CCC-based irrigation scheme in Songwe (Dedza) narrated more articulated arrangements for addressing land-tenure insecurity: *“…Every farmer pays K17,000 per acre of land as the rent fee, and if you do not want to cultivate under the scheme but your land is in the scheme, you receive the money and others use the land.… These rules were set by community members together with chiefs, and everyone follows [them].”*

b. Payoff externalities at the level of the resources-governance bodies

Local informants highlighted three negative payoff externalities among RGBs that illustrate material adverse impacts on collective restoration. First, and only in Dedza, discussants noted the negative effect of the activities of cookstove-making groups on land and forest degradation. They explained that extracting clay soil from surrounding forests sometimes leads to soil degradation, damaged tree roots, and tree felling. One participant elaborates: *"In making energy-saving cookstoves, we use soil and we dig a lot of soil which is not aligned with soil conservation …. We do cut a lot of trees, but … we also use dry wood …"* (FGD-VNRMC, Kafulama, Dedza). Second, discussants reported that illicit manipulation of water ways in irrigation schemes to divert water flow causes gully/soil erosion and undermines efforts to construct check dams to conserve water. One FGD participant explains: *"In Nakaingwa irrigation scheme, some people broke and blocked water [irrigation] canals at night using big stones, and water does not reach the irrigation scheme. This happens because of problems of water supply and every farmer wants water for his/her crops"* (FGD-Irrigation-CCC, Songwe, Dedza). Third, discussants cited perverse impacts from the disparate approaches on incentives and inconsistent technological practices promoted by non-state actors for resource management (Table 2-5) and called for a more coherent and harmonized approaches to community-based resources restoration.

In contrast, FGD participants also cited positive payoff externalities, mainly as complementarities of some restoration activities. Some perceived the promotion of efficient cookstoves and briquettes by some RUGs to lower pressure on forest resources by reducing firewood demand. Many affirmed advantages of keeping beehives in VFAs and in woodlots for reducing tree cutting (Table 2-5). FDG participants also underscored the multiple benefits of agroforestry practices in both increasing tree cover and improving soil fertility, and glorified the catchment-management approach for synergizing cross-sectoral restoration actions.

c. Strategy externalities

Notable strategy externalities stemmed from having multiple affiliations to RGBs. For instance, a discussant noted: *"… members are multi-affiliated; some members belong to VSL [Village Savings Loans] as well as irrigation scheme"* (Irrigation group, Songwe CCC, Dedza). Positive strategy externalities included avoiding conflictual activities and engaging in informal collaboration, given mutual awareness of ongoing activities in different RGBs (Table 2-5). Such positive strategy externalities also enhance social learning by drawing on the diverse knowledge each RGB offers. *"You learn a lot of things. For example, here at block management, I learn about environmental management and restoration, and from other committees, I learn some other things. I gain diverse knowledge,"* explained a BMC member in Dedza. *"It is very good because you get more knowledge through participation in many different groups",* remarked a beekeeping group member. Multiple membership also increases benefit sources, particularly cash to improve livelihoods, as an FGD participant from VFC Kabulika1 explains: *"…you get money from beekeeping, sale of tree seedlings, sale of energy saving cook stoves and briquettes."* However, participants rarely mentioned how strategy externalities would enhance ecological outcomes, besides the social benefits.

Discussants also reported disadvantages from some tactical double affiliations (Table 2-5). Most reported being overbooked, which undermines reported positive gains. *"Being a member of different committees is more time demanding. It makes people busier,"* expounded a member of BMC Mganja, Dedza. Another significant disadvantage is the elevated potential to mislead others: *"… when a member who has a double affiliation does not have listening skills, he is likely to mislead people from other committees,"* noted one member of Beekeeping Group of Mganja. Further, traditional leaders sometimes use their power to control the membership of RGBs under their jurisdictions and monopolize benefits, such as by inserting relatives. Nonetheless, some discussants dismissed inconveniences from strategy externalities. A member of BMC Mganja contended that with proper scheduling *"there are no disadvantages because we have set different times for the meetings. …, we meet only on Sundays for the other committee, and we meet Thursdays for the block management committee."*

Overall, while sectoral interactions offer opportunities to discuss and mitigate the negative externalities and accentuate the positive ones discussed above, this can only be achieved if conflicting or complementary activities and approaches are detected and debated, synergies harnessed, and duplication and negative spillover effects mitigated or avoided, through coordination processes and mechanisms.

Table 2-5. Selected illustrations on the manifestations of institutional externalities

<table>
<tr><th colspan="2">Payoff Externalities</th><th colspan="2">Strategy Externalities</th></tr>
<tr><th>Negative</th><th>Positive</th><th>Positive</th><th>Negative</th></tr>
<tr><td>“The one that I know is … when they are talking about buffer zone. Land resources policy say 15 meters for the riverbank protection while forest policy states about a 30 meters buffer zone” (KII, Forestry Sector).

“Forest policy promotes observation and protection of buffer zones while agriculture policy promotes cultivation in the buffer zone” (KII, FAO Malawi).

“Another gap is found with for example, green belt initiative and riverbanks protection. Agriculture policy does not match with programs in protected areas and sometimes issues of enforcement become a challenge” (KII, Parks and Wildlife Sector).

“The other gap is in EMA [Environmental Management Act]. … It just makes provision on buffer zones deliberately to protect riverbanks, but it does not say how many meters from the river should be protected. … Others say it is 15 meters, while water resources policy says 100 years’ flood return period mark” (KII, Land Resources Conservation Sector).</td><td rowspan="5">“… We have put beehives in the two forest areas and they [committees] go to check the hives. Currently, we have stopped selling trees because we are relying on the honey [that] we harvest from the forest. But previously we were selling some trees to raise funds for operations. [Now] We want to buy more beehives and put in the forests to prevent people from cutting down trees in the forests. Currently, we have five beehives in each forest.” (KII-GVH Kandodo, Ntchisi).</td><td>“… in the communities, they know all the committees and you find that members have multiple affiliation. And they make sure that they do not conflict much because if there is something harmful, it affects the whole community, so they make sure they do in collaboration” (KII-DADO, Dedza).

“Mganja is so special than any other place. … people that run from one committee to another are the same. … So, if they are the same people, can they have conflicts? They do not need to tell someone because they know when to do things” (KII-LRC, Dedza).</td><td rowspan="5">“It is difficult to attend meetings of different committees scheduled at the same time” (FGD-LRC, Mganja, Dedza)

“Time allocation is difficult when committees meet at same time. For example, if you are chairperson for two committees and two NGOs want chairpersons to attend the meetings scheduled at same time it is very difficult for you to choose which meeting to attend or not” (FGD-VNRMC, Songwe, Dedza).

“It is difficult when there are more than one activity taking place at the same time. Some people insult members with multiple affiliation claiming that they are greedy for positions and money. Problem is that people do not accept community leadership and responsibilities” (FGD-VNRMC, Kafulama, Dedza)</td></tr>
<tr><td>For example, Local Government Act says one can formulate bylaws, including for Forest Act. But in their [local] bylaws, the penalties for violating environmental norms is K2000 and that is the maximum. While in the Forest Act of 2005, including what they call Fines and Convention Acts, the violation fine is 20 times that K2000. It looks like one policy is superior to the other. This should not be the case and it is the issue of coordination because these policies were supposed to speak to the other” (KII, PERFORM Project).

“… Forest Act is weak compared to Wildlife Act and these policies are not talking to each other. Penalties in Forest Act are not stiffer. However, when the policies were being improved, they engaged us” (KII, Parks and Wildlife Sector).</td><td rowspan="2">“We learn a lot of things through trainings and we inform other committees. Other committees that did not attend meetings get information through other committees. What is gotten from one committee should be shared to other committees” (FGD-VNRMC, Songwe, Dedza).

“We learn different things and information that we cannot have through our committee we get it from another committee. We become faster learners than people who belong to one committee. … People who are in many committees are the same people who hold positions because they are always ready to lead people while other people run away from leadership positions” (FGD-LRC, Mganja, Dedza)</td></tr>
<tr><td>“… People have just conflicting perceptions over irrigation and land resources policies. They say the policies talk different things on how many meters from the riverbank should not be cultivated. No! … the only problem was the technology for irrigation; the treadle pumps had short pipes and these forced farmers to cultivate in riverbanks because they did not have money to buy pipes to extend the shorter ones. There was a provision of the pipe as a package and if the pipe is short, you are supposed to buy extra. Farmers who do not have money to buy the extra pipe are forced to cultivate in the buffer zone” (KII, Land Resources Conservation Sector).

“Another problem is that most policies are implemented by NGOs using different approaches. For example, as NGO, I go to implement policies that talk about buffer zone while another NGO that don’t know about the buffer zone protection policy is issuing treadle pumps to the farmers … you will see that there are no guiding rules that prevent farmers from doing that” (KII, NGO1).</td></tr>
<tr><td>“If you have project on conservation agriculture there should not be conflicting approaches and we need to have joint supervision and make recommendations. We do not want to take conflicting messages to farmers. As government, we are policy holder and anybody doing project on agriculture or land resource related, we should control that” (KII-LRC,Dedza).</td><td rowspan="2">“…somebody can be in bee keeping and also benefiting from other interventions. It can be VFC and irrigation scheme or a member of VSLs and that is how we feel you can easily improve livelihoods if you are engaging in multiple interventions rather than one single entity” (KII-UP, Dedza).</td></tr>
<tr><td>“There is need to revise the incentives and they are not well articulated in the policies. They are somehow articulated in the policies although not exhausted. The incentives should be relevant with the current situation. Policies give the room for the implementers to see what to do” (KII, NGO2).

"Incentive approaches differ because it depends on design of the project. However, we encourage not to give handouts because sustainability is questioned. … The problem is that when you are giving handouts and you go; people associate that with your project” (KII-DFO, Ntchisi).</td></tr>
</table>

2.4.3.2. Coordination functions and processes at the district scale

All key informants identified the District Environment Sub-Committee (DESC) as the most promising multi-sectoral policy platform at district scale (Figure 2-4) for operationalizing sectoral interactions that could lead to joint planning (including budgeting), implementation, and monitoring. Many also affirmed the DESC as a suitable coordination arena where NGO and private sector activities are reviewed according to district-specific plans for resources restoration (Table 2-6). In both Ntchisi and Dedza, coordination processes using decentralized institutions have been initiated but proceed at different paces. Dedza was in the second year of implementation. Discussants and informants narrated examples of the positive coordination roles of the DESC as a catalyst to bring two or more related sectors, state, and non-state, together on an important issue. One informant lauds the value of the district development planning process and framework as a useful coordination tool for forest-agriscape restoration.

> *It is just yesterday that we were discussing, and we were looking at plans because sectors have come up with issues when trying to come up with the DDP [District Development Planning] framework. Sectors have activities that have been submitted and we noted that there are some activities that need to be done jointly. …We have noted some activities that are similar for forest, health, and environment [sectors]. For example, there was an issue from forest and environment sectors. They came up with an issue of deforestation, and looking at strategies that have been put in place, they were different. … [The]issues are crosscutting, and we just have to discuss. Yesterday, I was telling the DFO [District Forest Officer] that we need to sit down and see how we can implement our strategies." (KII-EDO, Dedza).*

Nonetheless, the DESC is yet to engage in meaningful joint planning, implementation, and monitoring of interventions fully. Although there is a designated district planning framework led by the Director of Planning and Development to allow joint planning, conversations showed that the planning was mostly limited to compilation of sectoral plans (Table 2-6). In particular, joint budgeting is yet to happen to guide resources allocation to the policy actors according to their respective roles and tasks. Interviews indicated that the DESC currently functions more as an information exchange platform than for joint planning and implementation. The Environment District Officer (EDO) for Ntchisi explains: *"What we do is just to share what we are implementing. Its information sharing on what other sectors are doing. We do different activities. For example, wildlife does its own things and we cannot make one working plan. We do not do joint work planning because sectors have different activities."* Others characterized the lagging behind of these coordination processes for government activities as a general function of incomplete governance decentralization. *"I think we have not reached that level yet. These days we are decentralized, and as a Council we have not sat down and planned together,"* noted the LRC officer in Dedza. Recognizing this problem, some informants called for properly funded coordination processes that go beyond mere sector-plans compilation to including interactions that allow true institutionalized and required joint planning and actions that actualize and strengthen the legal cross-sector mandate invested in the DESC (Figure 2-4).

Several reasons explain the limited coordination functioning and effectiveness at district level. First, the DESC is crippled with lack of resources that prevent effective coordination and interactions that can foster operational joint planning and implementation. *"It [DESC] is mandated to meet every month, but you see they do not meet because they do not have resources… it has got no specific resources,"* noted the Ntchisi LRC, echoing other state and non-state informants. This funding problem explains the common complaint that the DESC becomes vibrant only when there is a donor-funded project with multi-sectoral components involving non-state actors. Some informants viewed the inadequate and inequitable resources endowment at NRM sector level (rather than the DESC) as another barrier to coordination and joint implementation (Table 2-6). Second, the DESC suffers from low participation, and is at times inactive. *"The main challenge is low turn-out of DESC members. For example, today we had only 10 people out of a possible 25. People are overcommitted with other activities in their offices,"* complained the EDO from Ntchisi. Third, there is an unwillingness to collaborate, which suggests need for transformation in the work culture from the silo model to a collaborative one. An NGO agent in Dedza narrated an inspiring example of the functioning of the DESC for inter-sectoral integration but decried challenges of clashes in work culture, especially what he termed "a culture of allowances" (Table 2-6). In sum, findings suggest that if supported with adequate, dedicated operational resources to meet as mandated, and sound leadership, the DESC can serve the coordination function needed for a pluralistic, but integrated governance that can tackle noticed negative institutional externalities.

Table 2-6. Illustrative quotes on coordination processes with the DESC platform at district scale

DESC as institution for coordination	Advantages of coordination	Nature of coordination processes	Challenges to coordination processes	NGO-led coordination
DESC is the one that brings together all the players; all sectors that have similar mandates such as agriculture, health, youth, fisheries, forestry, and under agriculture we have two key departments; irrigation and land resources, and fisheries and these are the ones in the committee…We are working with those whose mandates are related to environmental management. … Actually, we do come up with joint work plans for the whole year, which means all sectors bring plans under DESC, and DESC consolidates the whole district plan, and we are able to follow what NGOs and government sectors are doing. We follow up on the implementation of those plans. When it comes to reporting on environmental issues, DESC is the first place to report because it is the custodian of all the plans. DESC can also come up with projects based on issues that have been identified, and these can be multi-sectoral projects" (KII-EDO, Dedza).	*"Yes, conflicting activities happen, but that is the goodness of harmonization to see where we are conflicting, because when you uncover conflicts you find ways and means of doing away with them. For example, irrigation farming versus forestry: you see there is a river, and where there is water, that is where you do farming. But there are cases where that area is good for [planting] trees [because] of degradation. So, if you do not harmonize, an irrigation officer will go forefront encouraging people to do farming, but it will be painful to the forestry officer because he will see that if we do that [cultivate] we will see a lot of degradation. These conflicts happen and that is why we say forestry and agriculture should come and discuss [in order] to have one message to give to the farmers, and this is how we harmonize our messages" (KII-DADO, Dedza).*	*"…we want sectors to have joint work plans, and it is in the process…We want to come with one work plan for the district. We ask them to send[their plans] and we are going to compile…it will help in efficient use of resources and also to share what other departments are doing. Everyone should know what others are doing. … This is why we want joint work plans … and we want to start little by little because…we have never done this before. We are starting this month and by September we will be able to be harmonized" (KII-DPD, Ntchisi)* *"We have individual plans and then at district level we analyze these plans through presentations at DESC, and we harmonize these plans. We look at commonalities; what is in agriculture that is related to what forestry and other sectors are responsible for, and we bring those together and see how all together can be involved based on our capacities and expertise." (KII-DADO, Dedza)* *"We do joint planning by bringing sector plans, including the budget together. We also look at time frames. The reason we have time frames is to see how best we can coordinate the activities. We want to do things in coordinated ways, and we do not want to bring duplication. On budgets, we need to know how much has been invested in environmental conservation per year. And on time, we need to know when, and also within the plans we need to know where, we are implementing projects. For 2018-2019, we have done that [planning] (KII-EDO, Dedza).*	*"…Government says it does not have resources for DESC meetings. Private sector [representatives] incur costs when attending DESC meetings…DESC does not have resources to cover expenses… You have to cover transport costs, allowances, refreshments. We do not often meet because of lack of resources. …if you go to DESC officers, you hear they do not have resources to convene the meetings. Sometimes, private sector [representatives] are not [even] invited to the meetings" (KII, Private Sector).* *With the resources that are put in, we are limited. For example, in the spirit of doing joint activities with forestry, as Department of Land Resources we are able to procure polythene tubes while the forest [colleagues] could not afford anything. Because of that we may go to the site just to put conservation structures without the forestry folk. We will do our part and leave the other part. The only limiting factor is the amount of resources … even though the ideas for coordination are there." (KII-LRC, Dedza).*	*"We have a project with UP, and we have disaster management, environment, forestry, nutrition. Last year, they developed a plan and all sectors involved in the project came with plans, which were consolidated. Implementation was following the plans, and no one implemented activities outside the plan. …If I had an activity that is related to forests, I did coordination and forestry[colleagues] did actual implementation of the plan, and next year we are going to do a review of the plans and it works perfectly" (KII-EDO, Dedza).* *"…There are conflicting priorities where we feel they [public sectors] can support those interventions. They have their own priority mandate that probably may not be effective with our institution. …We as NGOs, we may have resources and a time frame, but our [public sector] friends work under a very slow pace. And with this culture of allowances, people work and want to get lunch or night allowance. NGOs do support [such claims] but that should be periodic ... If you are doing normal work, you do not need to get an allowance. These are some challenges we meet when taking somebody on board to work on certain issue" (KII-UP, Dedza).*
"NGOs go to DESC firstly to present their idea, and from their presentation you know who will be involved…From their presentations, you already know which sector the NGO is going to work with…and we even advise them to work with particular sectors. For example, we work with United Purpose and we help them with our expertise, and when they go for implementation we go together, and we tell them to work in areas that need support. And tomorrow there is joint planning and review with them. They normally implement through our staff. We discuss, for example, [if]to move resources from area A to area B where there is no support" (KII-DADO, Dedza).	*"On complementarity, we have cases where farmers that we are working with in agriculture could also be involved in things to do with forestry, and we refer them to forestry officers because they are experts and better with tree planting. Also, there are cases to do with community training … and we can work with forestry people. In terms of fisheries, where we have aquaculture, we have ponds in areas where there are forest zones. We encourage farmers doing fish farming to be good in tree planting, tree management. And we work with forestry people, and they also encourage those with ponds … to plant trees instead of vandalizing trees" (KII-DADO, Dedza).*		*"… We have serious problems when it comes to government officers to collaborate. I have seen this before where we can sit down and plan, and when the resources come, coordination breaks [down], and each sector does what it wants, and this happens even after joint planning." (KII-EDO, Dedza).* *"We do this[collaboration] if we are being supported by an organization, not as individual departments, because we might have different directions and we plan differently. We plan through our sectors but for the NGOs, because they have interest points and they want immediate impact, they pull us together to work in that area, and we don't want to conflict when we work in one area" (KII-LRC, Dedza).*	

2.4.3.3. Coordination processes and conflict-resolution mechanisms at the TA and the other lower scales

As with the DESC's coordination at district level, the Local Environment Sub-Committee (LESC) is designated to coordinate environmental issues across sector technicians operating at TA scale, but this role is generally weak, underfunded and not fully actualized. An encouraging case of extension workers from multiple sectors collaborating well in Kachindamoto TA, Dedza district (Table 2-7) demonstrates the locally recognized potential of an empowered and strengthened LESC to enhance coordinated planning, reporting, and implementation of restoration activities across sectors. However, in reality, interviews indicated that the AEC is yet to use the LESC to engage in fostering cooperation and joint implementation among RGBs.

Coordination arrangements at sub-district socio-political scales from TA to GVHs and villages were limited to designated reporting processes: 1) from RGBs to the traditional leaders and to extension workers; and 2) within the traditional leader hierarchy (Table 2-7). The reporting content and efforts include internal sanctions taken for breach of resource rules (free-riding behaviors), requests for more sanctions or conflict resolution, and progress reporting. The superiority of local bylaws is determinant. Discussants noted efforts to strengthen resource-use and management rules by stiffening sanctions for illegal behaviors in the bylaws at TA, GVH, and village scales as positive trends, notably in TA territories in Ntchisi (Table 2-7). For conflict-resolution mechanisms, the impartiality of traditional leaders in duly applying the sanctions and resolving conflicts is important but not given. NGOs occasionally provide leadership training to address these challenges (Table 2-7).

Interviews, however, indicated that periodic reporting activities were often weak, sometimes only oral, irregular, and limited in content. For instance, when asked how they report to the next level up the traditional leadership hierarchy, one RGB from Kandodo, Ntchisi answered: *"We just tell him [the GVH], and he sends the report to the TA. We report once a month and sometimes after a month. We report after an activity, for example after making fire breaks, making forest boundaries, and after harvesting honey."* An FGD participant from VFC Songwe, Dedza illustrates another report channeling: *"we … directly report to our group village headman and he reports to the forest extension worker. Reporting is done in writing but sometimes it is done verbally."* In Dedza, poor relationships between the RGBs and traditional leaders, or between village and GVH leaders, undermined the reporting function, as noted in Kamenyagwaza TA. Even with the generally good relationships between RGBs and traditional leaders in Ntchisi, coordination efforts remained oral or weakened by lack of appropriate resources, particularly for RGBs on customary lands.

Table 2-7. Selected respondent characterizations of coordination processes at the Traditional Authority and lower scales

Coordination processes across scales	**Bylaws, sanctions, and conflicts resolutions across scales**	**AEC as policy institution for coordination at TA level**
“We have deliberately put an arrangement that the committee reports to the senior GVH and we follow right procedures to manage the case if someone is suspected of being found on the wrong side. The senior GVH reports to the extension worker and the extension worker reports to forestry office and reporting is done per every activity” (KII-GVH, Msankhire, Ntchisi). *“We report to forest department, and we also report to chiefs. Chiefs know what we are doing and after every activity we do, we report to the chiefs through VDC. The VDC then sends report to the forest extension worker, and we send the chairman and vice to go and present a report at the VDC meeting. The report is in written form. We report on the activities.” (FGD-BMC, Mganja, Dedza)* *“Normally with PFM, all activities that are done will be coordinated by VFC, and VFC collaborates with VNRMC and VFC reports to VNRMC. Everything that is related to natural resources management, whether trees, water, forests, soil has to be reported to VNRMC.” (KII-UP, Dedza)*	*“We also have bylaws which say that no one is allowed to go into the forest without permission from chiefs, and if somebody goes there without permission, he/ she is fined.” (TA Nthondo, Ntchisi)* *“These are rules that I set with my chiefs. Senior GVH, GVH and all village heads, and after writing them in our book, we tell the community so that they should know. For example, there are rules that anyone who burns somebody else’s maize stocks [that were meant] for mulching, is fined a goat. We have fined people last year at Mbalale village because children burn maize stocks that were meant for mulching…The committee treasurer is the one that keeps the money, and we penalized the parents for what their children did, and they paid K12,000.” (KII-Senior GVH, Mgundana, Ntchisi)*	*“The structure we have here [district level] is almost the same at TA level because we have ADC and within that there is Area Executive Committee (AEC), and there are all extension workers in that committee, and they work in collaboration. You find that sometimes we house them in one office at EPA level. There is someone from forestry office, and various organizations. We take what we agree here to them and communities” (KII-DADO, Dedza).*
“They [the committee] report to me and when they do that, I pass information to other village heads, and they provide people to help the committee. When they have finished their work, they give me a report with names of people who have participated, and if there is someone who did not participate, I ask him or her and if no valid reasons are given, I penalize that person. I do this because village forest is for us all, not only few people, and that [offending] person pays chicken.” (KII-GVH, Mgundana, Ntchisi) *“… we also have a big committee at senior GVH level (VDC) and it is this committee that coordinates activities of all other sub-committees. The big committee calls all the sub-committees to discuss issues of interest, and this is done at senior GVH, and it is done once every month. … They do report at VDC level and reports go to cluster [zone] committee. From cluster [zone] committee, reports go to the TA. Before the report is sent to the TA, we look at it and suggest solutions to some of the problems that we can manage to solve without involving the TA. After we have cross-checked the reports, we send them to the TA.” (KII-GVH, Ndinda, Ntchisi)* *“If it is an issue concerning land resources, management will refer that issue to land resources committee; similarly, when the issue is from irrigation or water. These committees report to the main committee and main committee takes issues to VDC, and VDC takes issues to ADC, which is umbrella, and the ADC takes the issues to full council.” (KII-LRC, Ntchisi)*	*“When there are issues, GVH takes it to the TA, and normally they [issues] end there because there are bylaws which are very tough, and no one can bypass them. If they can deal with the issues on their own, they do not go to the ADC; it ends there.” (KII-DFO, Ntchisi)* *We take them for adjudication and if found guilty, we fine them, and money [the fine] is kept at the treasury of the committee so that they can use the money for operational purposes. People from other sides of the forest e.g., the Nkhotakota side, encroach into the forest and when they want to catch them, they resist violently but we try to manage the conflicts, and no one has been hurt so far. Issues of bordering villages managing resources in NFR.” (KII-GVH, Msankhire, Ntchisi)* *“… I have received training in leadership and conflict management, and training sessions were conducted by TLC, PERFORM and World Vision.” (KII-GVH, Ndinda, Ntchisi)*	*“…all extension workers from forestry and agriculture, and NGOs have a committee called AEC…and these extension workers within the EPA converge monthly or quarterly in a meeting, which is always chaired by the AEDC. They share their activities and whatever they have been doing…they even plan together...issues from ADC are also reported, and there is time the TA and AEDC also convene a meeting which is attended by members of AEC and ADC, and they share the reports.” (KII-DFO, Dedza)*

2.5 Discussions: Opportunities, challenges, and actions for effective governance integration

2.5.1 Attributes and intrinsic advantages of PGS in place

The governance system studied through the EGT shares key attributes of a PGS, although the architecture was not consistent across the two forest-agriscapes. Specifically, how the multiple policy actors and policy institutions are organized across hierarchical socio-political (from district to village) and ecological scales varies. *First*, consistent with recent PGS conceptualizations (Carlisle and Gruby, 2019; Berardo and Lubell, 2019; Schröder, 2018), findings affirm the presence of multiple standalone RGBs with internal rules for collective action, interacting within and across scales, and dealing with connected policy issues within the system's boundary. Indeed, multiple RGBs pursue the same goal while exhibiting task specificity (e.g., the sub-committees of the CCC). Also, RGBs utilize institutionally overlapping features to achieve their respective goals. These include multiple affiliations of individuals, horizontal territorial overlaps (e.g., BMCs and VNRMCs, and sub-committees of the CCC), and vertical functional overlap (e.g., VFCs vs. VNRMCs). Further, RGBs are connected through vertical and horizontal relationships and are supported by other actors, including local authorities, government officers, and non-state actors interacting through the decentralization policy institutions. The ecological connectivity that characterizes the two main sectoral policy issues—forest resources restoration and LWRC activities (Figure 2-2)—underlies the interlinked functionality and necessity of a landscape approach.

Second, findings of forms of cooperation and competition among RGBs and among non-state actors, and sanctions (increasing in severity up levels of the traditional hierarchical) and conflict-resolution mechanisms articulated in both the internal governance rules of RGBs and bylaws at traditional authority level were generally consistent with the second attribute of a PGS that articulates the nature of interactions and rules – multiple autonomous decision-making units interacting through cooperation, competition, conflict, and conflict resolution (See Schröder, 2018; Carlisle and Gruby, 2019). Although low in degree, cooperation was manifest in both formal and informal collaborative partnerships among RGBs. Lack of (re)distribution arrangements of scarcely available resources for RGB operations, incongruent approaches to incentives, and unfair distribution of direct costs and benefits of restoration activities generated unintended detrimental conflicts and competition. Also, reported sanction and conflict-resolution features are encouraging, but more systematic and consistent enforcement and strengthening of internal rules is needed to ensure PGS effectiveness.

Findings reveal the presence of some adaptability mechanisms involving scale, stemming from the interplay of the governance functions and structural properties, to realize some inherent PGS advantages. There were indications of both the specificity of RGBs to particular geographic scales and the agency to address observed scalar mismatches through rescaling processes involving the downscaling or upscaling of RGB spatial jurisdictions. Such adaptive rearrangements of the socio-political scale of RGBs to fit the ecological scale better, as Ostrom's design principles 'prescribe' (Cox et al., 2010), can enhance institutional fit and risk mitigation through redundancy (See Carlisle and Gruby, 2019). Our emphasis on the necessity of institutional fit of local RGBs leading restoration actions also responds to growing calls for multi-scale governance in FLR implementation to realize national commitments (Wiegant et al., 2020). Nonetheless, efforts to achieve closer institutional and ecological fit are permeated and influenced by differential power relations that need more attention. In the studied forest-agriscapes, traditional leaders are instrumental actors in mitigating competition for resources and incentives and balancing relations of power arising from altered jurisdictions of RGBs. This reflects previously raised politics of scale (Zulu 2009) in community forestry and illustrates how power infuses and affects the configuration of the PGS structures and policy decisions and choices for resources restoration (Morrison et al., 2019). Further, the adaptive scalar rearrangements can provide the meaningful redundancy needed to mitigate the risk of failure in the PGS, by enhancing vertical functional overlap. That said, the rescaling of forest co-management responsibilities from former BMCs to VNRMCs being piloted in Ntchisi can jeopardize the ability to mitigate potential risk of failure to manage and restore forests and trees, sustainably. Lubell (2013) cautions that consolidating all decision-making authority into a single institution (already busy with village forests) might counteract benefits of specialization in specific governance functions.

2.5.2 Functional quality of the current governance system: challenges and potential actions

Findings support our *first EGT hypothesis that the low degree of cooperation, the asymmetrical resources distribution, and the low level of social learning demonstrate a weak governance that needs enhancement for successful forest-agriscapes restoration.* First, limited cooperation among RGBs and deleterious competition over incentives and benefits undermine attainment of restoration socio-ecological goals. It exacerbates internal RGB capacity challenges, including limited operational funding and other resources, and inequitable benefit (re)distribution. The problem of limited resource capacity for conservation activities has been raised previously (for Malawi, Zulu 2009; 2012; Kamoto 2013), as has the demotivating effect of competition for distributional resources on collaboration and adverse impact on governance outcomes (da Silveira and Richards, 2013; Poteete and Ostrom, 2004). These distributional issues need to be addressed as a priority because unfair allocation of such costs and benefits is a potent killer of collective resources management (Lindhjem et al., 2010; Pham et al., 2013; Zulu, 2013). Our findings suggest two institutional fixes as avenues to addressing the distributional and collaboration challenges. One way is to strengthen existing informal collaborative arrangements and establish new formal ones to fill identified gaps. This could include encouraging more informal arrangements and spaces to boost co-operation levels and expanding and formalizing existing sharing arrangements to address the operational resources shortages among RGBs. Another way is to address the sustained, but unproductive, levels of competition over handouts, privileges, and benefits from participating in collective restoration efforts. Some NGOs showered incentives on local beneficiaries to obtain quick results to impress their funders, demonstrating another form of competition. While competition of ideas, methods and other forms can enhance efficiency in governance (Ostrom et al., 1961; Olsson et al., 2007), current levels were unhealthy and non-conducive to cooperation and sustainability of restoration activities. Therefore, harmonizing incentives mechanisms for collective restoration efforts becomes paramount, possibly through changes in district-level bylaws and ultimately in higher level policies and regulations. Such harmonization should accommodate resource users' preferences for incentives, which are crucial for the decision to participate in collective restoration (Djenontin et al., 2020a).

Second, findings show that current social learning processes are promising but remain insufficient to strengthen current and future governance outcomes. Reported current formal and informal activities and processes fostering social learning among RGBs provide enabling conditions to realize further functional advantages of a PGS with respect to learning and adaptive management (Carlisle and Gruby, 2019). However, the deliberation processes promoting social learning at the community level, mainly built around particular extension activities and unintentionally through relatively common multiple affiliation of individuals in RGBs, appeared incidental rather than strategically planned and formalized as needed. On the technical side, the value and unique promise of multi-stakeholder platforms, offered by the DESC and LESC policy institutions, to enable interactions among state and non-state policy actors and senior traditional leaders across scales involving deliberation, learning, and harmonizing information, knowledge, and approaches is recognized locally, and elsewhere (Galaz et al., 2012). Still, the DESC and LESC are not yet fully or meaningfully operationalized to materialize PGS functional benefits for forest-agriscape restoration. There is need for transformation, including a more explicit mandate and improved functioning of the District Assembly to enhance such cross-sector processes; strengthened political will to implement them; and institutional-managerial support from external agents, at least initially. Further, observed innovative leadership promoting positive environmental behavior through forest-patch or woodlot establishment observed among Ntchisi communities can be institutionalized as part of learning to reinforce the making of environmental stewards (Agrawal, 2005). Previous findings in the districts affirm that good local leadership is motivating farmers' engagement in collective restoration efforts (Djenontin et al., 2020a). Enhancing such local leadership with more training and necessary resources would be beneficial.

Findings also support our *second EGT hypothesis that policy institutions providing interface to realize inter-sectoral and cross-scale linkages can take on coordination functions for governance integration. However, the coordination processes ought to be meaningful and effective to help anticipate, mitigate, and address negative institutional externalities, including other types of conflicts.* Findings showed emergence of coordinative functions to preempt the occurrence or reduce the magnitude of the negative externalities and conflicts although they remained inadequate. Negative institutional externalities affecting forest-agriscapes restoration were manifest at the regulatory level, arising from inconsistent policies and laws guiding resource restoration efforts; thus, confirming these as real challenges (Ostrom, 2010). By uncovering such externalities, we provide a way to examine how a reformed inter-sectoral regulatory framework could re-articulate discrepant provisions affecting resources management, tenure rights, and incentives schemes. At implementation level, entry ports for negative externalities included the lack of or weak formal collaboration among sectoral RGBs, and the shaky, fragmented implementation of restoration interventions. Understanding the nature, drivers, and implications of negative institutional externalities on the functional governance processes for forest-agriscape restoration is important to further envisage how to re(shape) coordination arrangements and enhance their advantages for delivering enhanced resources restoration outcomes (Mewhirter et al., 2018; Lubell et al., 2017).

While highlighting the need for stronger and persistent cross-sectoral coordination processes, findings also suggest that observed weaknesses in both studied districts are partly due to the novelty of the arrangements and more time is needed to attain and demonstrate success. First, findings showed that DESC and LESC platforms are also relevant policy institutions to perform necessary inter-sectoral coordination functions for the coherent implementation of forest-agriscape restoration at district and sub-district scales, consistent with EGT's assumptions (Lubell, 2013; Zhou and Mu, 2019). Therefore, strengthening the capacity of these local policy institutions and rearticulating their steering functions (and institutional rules and capacities) would reduce the observed weaknesses that render them inactive and ineffective in meaningfully mitigating negative institutional externalities and enhancing needed inter-sectoral integration. Strengthening would include creative and effective financing mechanisms for the coordination functions. Second, notable efforts have been initiated in the DESC at the district-council level, but more is needed in terms of joint planning, joint decision□making, procedures, and voluntary and mandatory processes including joint implementation and monitoring (Schröder, 2018). Importantly, enhancing the quality, regularity and formalization of the coordination processes would serve to catalyze synergies within the PGS. For that, overcoming divided loyalties of district officers and institutional inertia and resistance of sectoral leadership to allow decentralization processes the necessary space to flourish is paramount. Indeed, fear of professional disempowerment undermines political will (Blaikie, 2006; Zulu, 2012). Also, power imbalances and domination of some actors in terms of views, approaches, and resource endowment often influenced the coordination processes. Third, the observed weak and limited coordination and accountability functions through current reporting mechanisms across scales and within sectors should be enhanced and made more systematic to support integrated coordinative functions.

Altogether, a countrywide re-operationalization of true, full, and government and politically empowered decentralization policy and its institutions is essential to achieve needed inter-sectoral and cross-scale integration for forest-agriscape restoration in Malawi. Demonstration of decentralization institutions' potential to govern restoration effectively, preferably through ongoing or new pilot FLR projects in selected districts, is a necessary starting point.

2.6 Conclusion and recommendations

Using the EGT, this research has provided an in-depth qualitative assessment of current institutional arrangements supporting the restoration of land, tree, and forest resources in Malawi to prospect for a contextually-relevant PGS fostering cross-sector integration in implementing the FLR paradigm. Using the cases of Dedza and Ntchisi districts, analysis of the core structural attributes and functional processes of a PGS has offered insights into context-appropriate institutional configurations that can support a landscape approach to resources restoration at district and local scales.

Our analysis reveals that although fragmented, the current governance system shares the attributes of a PGS, featuring a nested multi-level model ordering multiple and independent sectoral governance institutions across different scales. Cooperation is limited, inadequately fostered, and incongruent approaches to collective resources restoration with respect to incentive and direct benefit levels and distribution fuel counterproductive competition. A district-level harmonization of incentives approaches to collective restoration that considers farmers' preferences would be beneficial. Further, the structure of the PGS is subject to rescaling processes in the search for fit between RGB institutional scales and ecological scales of the resources being managed but the infused power relations and practical merits should be examined further to mitigate adverse impacts. Solutions should go beyond merely increasing or reducing the number of RGBs to include balancing power relations among RGBs and with other key stakeholders to mitigate the risk of failure.

Existing multi-stakeholder platforms within decentralization structures, particularly the DESC and LESC, offer room for meaningful inter-sectoral coordination and collaboration across scales, as integration mechanisms and means to anticipate and mitigate negative externalities that undermine cohesive forest-agriscape restoration. Barriers included limited financial resources, informality, competing interests, and incomplete actualization of joint planning, implementation, and monitoring functions across sectors. Formal and informal social learning mechanisms were reported as enabling processes, but they need significant enhancement, including more effective formal deliberative processes among supporting policy actors to harmonize information, knowledge, and RGB approaches, to foster adaptive landscape restoration.

Overall, insights suggest that a PGS encompassing strengthened rules and institutions coordinated and operationalized through the processes and structures of Malawi's decentralization policy is most promising for effective forest-agriscapes restoration in Malawi. Lessons show that meaningful decentralization must strengthen all three dimensions—political, financial, and administrative—if its offered policy institutions are to meet anticipated benefits of reinforced coordination, cooperation, and social learning among and across policy actors and RGBs, and support forest-agriscape restoration effectively. Further, significant enhancement of the quality of existing enabling conditions and conflict-resolution mechanisms by district and local authorities, and appropriate checks-and-balances, can maximize PGS's inherent advantages in the current governance system. Our research contributes knowledge to the quest for suitable governance system for forest-agriscape restoration in Malawi, with lessons for similar contexts in SSA. The EGT provides a uniquely appropriate lens to examine the structural properties and functions of a real-life PGS that can support integrated governance for implementing effectively FLR interventions. Findings reveal material manifestation of challenges to governance integration, with insights on potential ways to realize or improve inter-sectoral and cross-scale interactions and mitigate negative institutional externalities.

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3 CHAPTER 3

Paper 2: Smallholder Farmers and Forest Landscape Restoration in sub-Saharan Africa: Evidence from Central Malawi

Abstract

Malawi is a sub-Saharan African country at the forefront of the contemporary forest landscape restoration movement that places local smallholder farmers and resources users at the center of restoration actions. However, the specific local dynamics and determinants of efforts at individual and collective levels, and how they add up to landscape-scale restoration outcomes remain understudied. Using a multivariate Tobit regression model and a Poisson model on a 2019 household survey (N=480 households) from Central Malawi's Dedza and Ntchisi Districts, we 1) estimate the nature, level, and areal extent of restoration efforts across interlocked forest and agricultural landscapes, and 2) examine the drivers of and challenges to restoration. We reinforce our analyses with qualitative insights from seven focus group discussions. Results indicate restoration diversification patterns whereby farmers generally combine two or more land-management practices based on their complementarities in achieving specific livelihoods, food security, and ecological goals of restoration, and on their compatibility in terms of labor and other inputs demand. The mean estimated total area of restored farmlands was 1.10 (±0.76) and 1.07 (±0.72) acres in Dedza and Ntchisi, respectively – less than half the average total landholdings in the area. Land configuration mattered. Land plots that were spatially consolidated and tenure-secured were associated with higher restoration efforts. Therefore, restoration policies should center on strategies that improve land-ownership security while minimizing fragmentation within landholdings. Drivers of collective restoration of forests and trees include sound local leadership, perceived tangible benefits in ecosystem goods and services, secure resources rights, and perceived balanced between payoffs and socio-ecological goals. These can inform restoration programs involving collective actions and their governance. The findings also offer insights and inputs for future computational modeling for analyzing the aggregated landscape-level outcomes of restoration efforts spatially and over time.

Keywords: *Land restoration; Forest restoration, Restoration drivers; Restoration challenges; Smallholder farmers; Sub-Saharan Africa; Malawi*.

3.1 Introduction

Many countries in sub-Saharan Africa (SSA) have pledged to restore more than 100 million hectares of degraded forest-agriscapes by 2030 as part of their national commitments to the Bonn Challenge seeking to restore 350 million hectares globally (Djenontin et al., 2020a). Malawi offers an excellent case study among countries that have comparable restoration strategic interventions and actions within the African Forest Landscape Restoration Initiative (AFR100), the SSA regional implementing initiative for the Bonn Challenge. With an estimated 7.7 million hectares (ha) of degraded land (80% of the country's land area), Malawi has pledged to restore 4.5 million ha by 2030 (MNREM, 2017a&b). The country's approach to forest-agriscape restoration is multi-faceted and multi-purpose. In agrarian landscapes, the goals are to increase tree cover on degraded farmlands and pastures, to stabilize the soil, ameliorate soil fertility, reduce productivity decline, and sustain food security. In deforested and degraded forested areas, the aim is to restore forest resources and biodiversity and to provide sustainable ecosystem services, such as biomass-based energy (firewood and charcoal), timber, non-timber forest products, water regulation, carbon sequestration, and cultural/religious services. Improving forest cover and enhancing the collective management of forests on customary lands (village forest areas, woodlots, plantations, and natural forests) is part of planned interventions for forest-agriscape restoration in Malawi (MNREM, 2017a&b).

Rural smallholder farmers and forest-agriscapes resource users (hereafter 'farmers') and local authorities are considered as key local-level agents of restoration, and their combined individual and collective actions are essential for successful restoration at the landscape level (Mansourian, 2017). Even before the contemporary restoration movement, farmers across SSA have continued to reclaim degraded farmlands using resourceful combinations of restoration practices and technologies (Pye-Smith, 2013; Reij and Garrity, 2016; Etongo et al., 2018). Likewise, farmers often engage in collective tree-planting and forest-regeneration activities. Activities implemented collectively in forested ecosystems are also an important contribution to the regeneration of degraded forest-agriscapes (Chang and Andersson, 2019). However, from a technology-adoption perspective, studies have increasingly shown that relatively few farmers adopt and apply restoration practices and technologies despite their demonstrated promising results (Galabuzi et al., 2014; Cordingley et al., 2015; Meijer et al., 2015; Nigussie et al., 2017; Ward et al., 2018).

Still, the specific local dynamics of farmers' restoration efforts–both at individual and collective levels–remain poorly understood. First, at individual farmland level, existing studies on farmers' uses of different restoration practices and their drivers were conducted in different contexts, and mostly focused narrowly on individual technologies and practices (Shiferaw and Holden, 1998; Ajayi et al., 2007, de Graaff et al., 2008, Fenske, 2011; Adimassu et al., 2012; 2016, Galabuzi et al., 2014; Ayamga et al., 2016; Silberg et al., 2017; Legesse et al., 2018; Musa et al., 2018). Few studies have considered how farmers implement several of these restoration practices/technologies in combination, and what the underlying drivers are (Etongo et al., 2018; Ward et al., 2018). Also, there is a dearth of knowledge about the extent of farmlands restored from such local efforts. Second, at a collective level, tree planting is generally considered the sole collective restoration activity in forested areas (Chang and Andersson, 2019). This narrow focus on tree planting neglects other important restoration activities implemented collectively such as farmer-managed natural regeneration and conservation and management activities (Djenontin et al., 2020b).

Therefore, taking stock of the nature and spatial extent of restoration efforts by farmers and understanding their driving factors in a holistic manner is essential to inform effective management and policy actions for forest-agriscape restoration. This requires better insights on: (1) how forest-agriscapes restoration unfolds locally, (2) how farmers tailor and package various land-management practices to meet specific restoration goals, (3) the barriers to farmers' restoration efforts, and (4) the critical leverage points for policies to accelerate restoration. Thus, considering farmers' restoration of land, forest, and tree resources using land-management practices, we assess 'how much' restoration and 'what and how many' restoration practices are being implemented. Specifically, we estimate (i) the areal extent of land restored in the agrarian landscapes, and (ii) the nature (type, configuration, and number) of restoration practices and activities implemented on land plots and in collective resources management.

We adopt an econometric method with an input-metric (rather than output or impact-based) approach to estimate restoration efforts on individual farmlands and in collectively-managed agrarian and forest lands, and to determine the location-based drivers using the case of central Malawi. Chang and Andersson (2019) use such an econometric method to examine the enabling factors for participating in forest restoration in eight developing countries, four in SSA. However, their study does not include Malawi and they focus solely on tree planting, leaving other forest-agriscapes restoration practices and activities unaccounted for. Our study adopts a more holistic perspective considering the sum of restoration actions deployed by diverse farmers in the mosaic farm-forest ecosystems of rural landscapes, as promoted under the contemporary forest landscape restoration (FLR) approach and its initiatives. We use quantitative data from a household survey (N=480 farmers) conducted in 2019 in Central Malawi and complement the analysis with insights from qualitative analysis of data from seven focus group discussions (FGDs) on the questions.

The study can inform effective forest-agriscapes restoration governance, policy, and programming as it reveals critical leverage factors and points to improve the tailoring of appropriate technology packages to local contexts, and to boost farmers' contributions necessary for achieving restoration objectives and pledges. Also, the improved understanding of local restoration patterns can guide how to strengthen local participation to maximize restoration outcomes while also informing future modeling work.

In the remainder, Section 3-2 describes the conceptual approach to forest-agriscapes restoration practices and the drivers of their application. Section 3-3 describes the mixed quantitative and qualitative data collection and analysis methods used. Section 3-4 presents the findings. First, it focuses on the areal extents of farmlands restored in agrarian landscapes and their driving factors. Second, it presents the results on the nature of restoration and the underlying drivers, both on farmlands and in collective resources management. Third, it describes restoration challenges that farmers face. Section 3-5 discusses these findings and Section 3-6 concludes the chapter, highlighting some implications.

3.2 Review of restoration practices and the underlying drivers

3.2.1 Restoration practices

There are no silver bullet practices for restoring degraded forest-agriscapes (Mansourian et al. 2005a&b). In their review, Djenontin et al. (2018) noted that the range of practices and technological infrastructure for restoring agrarian ecosystems in SSA is context oriented. Efforts to increase tree cover and restore agroecological functionalities include tree planting, farmer-managed natural regeneration (FMNR), and agroforestry practices (Asaah et al., 2011; Weston et al., 2015; Amadu et al., 2020). FMNR emerged as a major restoration technique implemented at the farm scale in many SSA countries (Weston et al., 2015; Reij and Garity, 2016). The practice consists of promoting trees and shrubs regrowth on farmlands serving the primary function of agricultural production. Through pruning and active protection, farmers assist the natural regeneration from resprouting tree stumps, root-system stock, or from seeds recruited from the soil or dispersed into the field (Lohbeck et al., 2020). FMNR offers the potential to address concomitantly food production, soils conservation, and biodiversity protection (Haglund et al., 2011; Lenhardt et al., 2014). Non-tree-based technologies are also important for restoring agrarian farmlands (Pye-Smith, 2013; Schwilch et al., 2011). They include diverse sustainable land management (SLM) practices (Ajayi et al., 2007; Adimassu et al., 2012; Galabuzi et al., 2014; Nyanga et al., 2016; Kimiti et al., 2017), including soil and water conservation (SWC) techniques and conservation agriculture (CA) practices. In general, SWC techniques are used in reclaiming degraded lands and they involve small water retention and soil stabilization techniques and infrastructures, including techniques for rainwater harvesting or infiltration into soils for cultivated crops (Shiferaw and Holden, 1998; de Graaff et al., 2008; Pye-Smith, 2013; Kabore and Reij, 2004). The practices of CA include no/minimum tillage, mulching with cover crops or crop residues, crop rotation, and intercropping, which may be bundled or implemented individually (Ward et al., 2018; Holden et al., 2018). This diverse repertoire of pro-environmental land-management practices and technological packages is adopted selectively and according to specific objectives and contexts in forest-agriscapes restoration (Djenontin et al., 2018).

Both tree- and non-tree-based restoration are critical for Malawi, where environmental degradation remains a major development challenge. At the household level, restoration efforts include the use of agroforestry systems, FMNR, CA practices, and SWC techniques (MNREM, 2017a&b). Collective activities for communal land regeneration center on SWC techniques and collective tree and forest regeneration (Malawi's most prominent restoration program) include tree-seedling production, tree planting, natural regeneration promotion, and related support activities. These support activities include firebreak maintenance, environmental awareness/outreach activities against deforestation, and forest-protection activities such as monitoring and patrolling.

3.2.2 Drivers of adoption of restoration practices

The diverse portfolio of restoration practices, spatial scales of restoration, and varied socio-cultural, economic, and ecological contexts complicates understanding of factors influencing restoration efforts. While farmers' decisions to restore their degraded lands and implement specific practices and technologies vary widely, recurring influential factors are observed mainly at two levels: the farm-household and plot levels. Common drivers in the literature are socio-cultural, economic, cognitive, biophysical or ecological, and geographic in nature (Fenske, 2011; Adimassu et al., 2016; Ayamga et al., 2016; Nigussie et al., 2017; Silberg et al., 2017; Legesse et al., 2018; Djenontin et al., 2018). Further, the drivers can be clustered as capability-related, motivational, institutional, and technological. Because institutional factors extend beyond the farm-household realm and can apply to land plots, we distinguish a third level: institutional level. Our synthesis of the driving factors that show broad agreement across the literature (Table 3-1) informs the choice of explanatory variables in estimating our models for farmland restoration at individual level.

Table 3-1. Literature-informed potential driving factors of restoration efforts

Level	Nature	Actual Factors	Description	Variable type
Farm-household	Social-cultural	Age	Age of household head or the land manager	Continuous
		Education	Education level of the household head or the land manager	Discrete/Dichotomous
		Farming experience	Farming experience of the household head or the land manager	Continuous
		Gender	Sex of the household head or the land manager	Discrete/Dichotomous
		Ethnicity	Ethnicity of the household head or the land manager	Discrete/Dichotomous
		Marital status	Marital status of the household head or the land manager	Discrete/Dichotomous
		Membership of association	Membership in local institutions	Discrete/Dichotomous
	Economic	Household size	The total number of family members	Continuous
		Active member (Labor)	The number of economically active member in the household	Continuous
		Land holdings size	Total land size of the household (ha)	Continuous
		Number of plots	Number of plots per household	Continuous
		Income generating activities	The number of economic activities	Continuous
		Off farm income	Access to off-farm income	Discrete/Dichotomous
		Livestock holdings	Total livestock size	Continuous
		External labor	Number of external active workforce	Continuous
		Income	Monthly or Annual income (reported)	Continuous
		Assets wealth	Value of consumer assets and housing goods	Continuous
	Cognitive	Perception of land degradation	Perception of household head or the land manager on land degradation as a problem/threats	Discrete/Dichotomous
		Perception of the importance of the restoration practices	Perception of household head or the land manager on the values and contributions of the practices or technologies	Discrete/Dichotomous
Field/Plot	Cognitive/ Biophysical	Level of fertility	Fertility of plots (perceived or measured)	Discrete/Dichotomous
		Value/contribution to livelihoods goals	Importance (perceived or measured) of a plot to food security, income, etc.	
	Biophysical/ ecological	Size	The size of a plot	Continuous
		Slope	Slope characteristic of a plot	Discrete/Dichotomous
	Geographical	Distance plot to household	The distance from home of household head to each plot (walking minutes)	Continuous

Table 3-1 (cont'd)

Level	Nature	Actual Factors	Description	Variable type
Institutional level	Institutional support	Land tenure	Land security based on ownership type or acquisition mode	Discrete/Dichotomous
		Extension service	Access to extension services	Discrete/Dichotomous
		Training/Knowledge	Access to training services on the technologies or practices	Discrete/Dichotomous
		Credits/loans	Access to credit services	Discrete/Dichotomous
	Territorial	Jurisdictional location/residence	Territory of residence	Discrete/Dichotomous

For collective restoration, we draw on the institutionalist approach to the governance of collective management of the commons that advocates for using rules and norms to regulate human behavior, particularly the propensity of individuals to free ride in the management of common-pool resources (CPR), which accelerates their depletion and degradation (Ostrom, 1990; Baland and Platteau, 1996; Agrawal, 2001; Cox et al., 2010). Institutionalist scholars offer institutions (rules in use) as the solution, and design principles as a practical guide to craft successful collective institutions under common property-rights regimes (Ostrom, 1990). Using insights from this institutionalist literature, we focus on four main sets of factors that potentially influence farmers' involvement in collective restoration efforts, and ultimately shape restoration outcomes. These are resource property rights, specific community attributes, farmers' socio-economic and cultural characteristics, and the values and attributes of particular resources.

First, resource property rights, specifically appropriation and provision rules, are a critical factor influencing farmers to conserve, restore, and use forest resources sustainably (Nagendra, 2007; Robinson et al., 2018; Chang and Andersson, 2019). Tenure rights over collectively held resources (the commons) in rural contexts of SSA are multi-faceted and complex. The issue is not so much about ownership rights, but rather about the rules regulating access often encoded in locally-defined exclusion rights to the shared resources (Schlager and Ostrom, 1992; Sikor et al., 2017). Therefore, attention to local and contextual arrangements for resources rights is important because it can affect farmers' motivation to engage in collective restoration (McLain et al., 2018; Djenontin et al., 2018).

Second, consideration of some community attributes (sometimes termed social capital) can help to explain involvement in collective restoration (Cardenas, 2000; Pretty, 2003; Bouma et al., 2008). Specifically, elements of trust, reciprocity, communication, and community cohesion and reputation that shape individual behaviors also influence group-level outcomes. These factors serve as indicators of community loyalty, civism, and local leadership over group actions. The perceived quality of local leadership associated with collective resources management and other local community development groups (e.g., farmer cooperatives or associations, youth organizations) has been found to be particularly important in shaping conservation and development outcomes in Malawi (Zulu, 2008; 2013).

Third, farmers' social characteristics affect their motivation to engage with collective restoration activities (Nagendra, 2007). These include household-specific social factors enumerated in Table 1. More important is the influence of these characteristics on the cultural values and economic benefits associated with the collective restoration activities. The perceived value of ecosystem services—the tangible harvests and benefits—that farmers gain from participating in collective restoration actions can motivate and incentivize their involvement (Etongo et al., 2015; 2016; Chang and Andersson, 2019).

Fourth, this perceived resource value is relative, rather than absolute, often expressed in relation to attributes of the resource and in terms of opportunity costs. Indeed, the perceived capacity of the resources to reduce the opportunity costs of partaking in collective restoration activities compared to the value of the benefits they could gain if they had used their efforts in other ways, is more important than the absolute benefit values. Farmers' perceived payoffs in meeting livelihoods needs and environmental goals have been shown to influence their engagement in collective actions (Meijer et al., 2015). Specifically, the perceived relative importance of the resources being restored to food security, income generation, energy needs, and adaptation and mitigation to climate change are important farmer considerations for the decision to restore them.

3.3 Methods

3.3.1 Study area

The study took place in Central Malawi in Ntchisi and Dedza Districts (Figure 1-3) as introduced in Chapter 1, section 1.3.2. Additional information relevant for this chapter is that the Chewa ethnic group is the dominant one in Ntchisi, but Dedza is predominantly Ngoni, with some few Chewa.

3.3.2 Data collection

We used mixed research methods to examine the areal extent, nature, and drivers of restoration. We conducted a household survey in July-August 2019 using a questionnaire entered in the Qualtrics survey software and administered offline on computer tablets (Leisher, 2014). The sample frame is the population of farm households (HHs) in the covered TA territories. We use a multi-stage clustered sampling design with household-level outcomes. HHs are nested into villages, which are nested into group-village territories under group-village heads (GVHs), and GVHs are nested into TA territories. We determine the sample size based on a power analysis of 80% (Snijders, 2005; Maas and Hox, 2005). Following Scheaffer et al. (2011), the number of GVHs we included per TA in the sample is proportional to their number in each TA. The resulting sample size of 480 HHs covers 70% of the GVHs in the sample frame (Table 3-2).

Table 3-2. Sample size by Traditional Authority territories, Group Village Heads, and Households

District (FR)	**Sample frame (Population)**			**Sample (Survey)**		
	Traditional Authorities	Number of GVHs	Percentage of GVHs	Number of GVHs	Percentage of GVHs	Number of HHs
Dedza (MLFR)	Kachindamoto	18	31.58%	13	32.50%	13*12 = 156
	Kamenyagwaza	5	8.77%	3	7.50%	3*12 = 36
Ntchisi (NFR)	Kassakula	14	24.56%	10	25.00%	10*12 =120
	Nthondo	13	22.80%	9	22.50%	9*12 = 108
	Vuso Jere	7	12.28%	5	12.50%	5*12 = 60
Total	5	57	100	40	100.00	480

The proximity of the GVHs and villages to the forest reserve guided their respective selection within TAs and GVHs because households use of forest resources is significantly associated with distance to the nearest forest area (Senganimalunje et al., 2016). HHs were selected randomly within villages, from village rosters that we obtained from the village heads. We collected information on the practices and technologies adopted to restore land plots at the farm-household level and activities implemented for collective restoration of land, tree, and forest resources. In addition, we collected information on farmers' sociodemographic characteristics, assets and financial, social, and natural capitals. Other information included restoration challenges and community-level factors shaping restoration activities.

We also conducted seven focus group discussions (FGDs) of 15-20 participants during which we assessed the challenges to restoration activities at both individual farm-household and collective-action levels, among other topics. In the first four FGDs, participants were representatives of collective-action restoration groups. The other three FGDs constituted representatives of farm households who apply restoration practices on their individual lands.

3.3.3 Specification of the econometric models

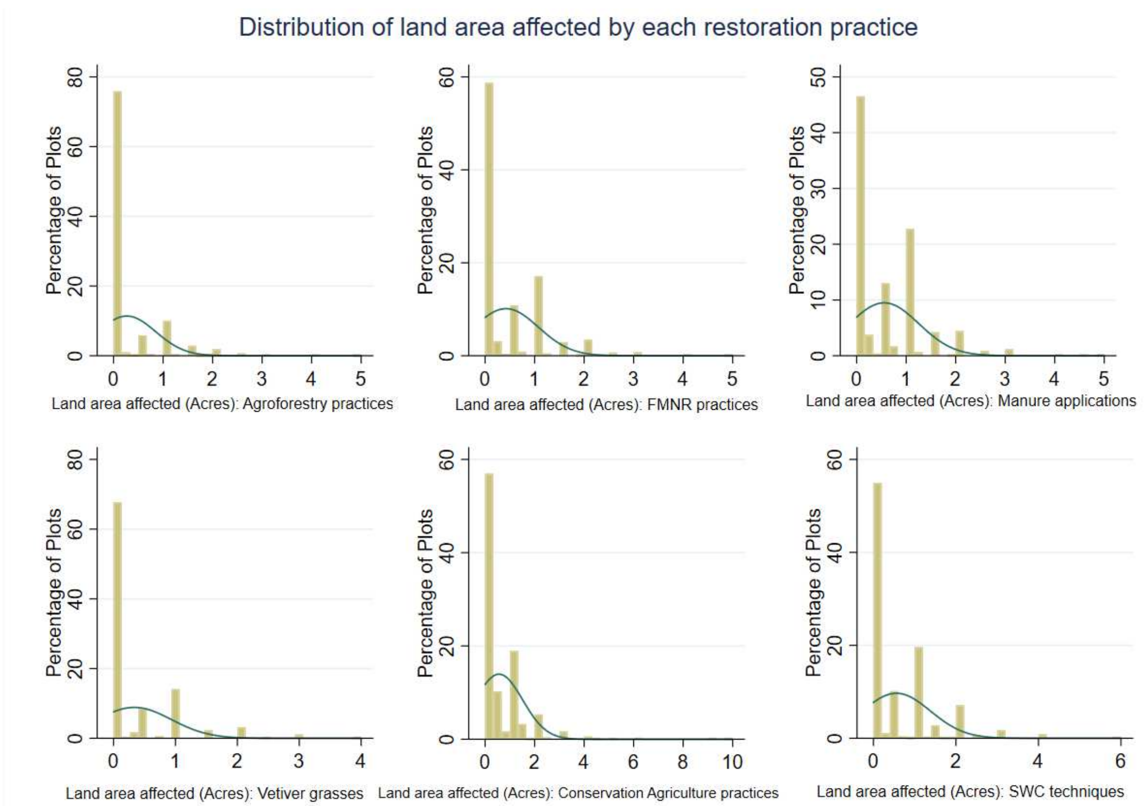
To estimate the areal extent of restoration in agrarian landscapes and the nature of restoration efforts in the forest-agriscapes, we consider two separate econometric models following the definition of two distinct proxy variables.

3.3.3.1. Multivariate Tobit model

The first proxy variable reflects the amount (area in acres) of agrarian lands under restoration at farm-household level, estimated using a multivariate Tobit model. First, we consider a multivariate model because restoring degraded land plots at farm-household level involves multiple, likely interrelated, decisions on using different practices. While there are no formally-promoted packages of restoration practices, the configurations of existing land-management practices observed empirically on-farm lead us to consider the potential interrelations among farmers' choices and the influencing factors. This would help to determine which/if combinations of technologies or practices are perceived compatible or not. Recent similar studies have used multivariate regression models, notably multivariate probit, to shed light on complexities of the choice of land-management technologies and practices (Nigussie et al., 2017; Ward et al., 2018; Etongo et al., 2018). They have also attempted to address one critical shortcoming of previous studies — the challenge of untangling determinants of using particular targeted technology(ies) or practice(s) (Andersson and D'Souza, 2014). Insights from these studies and our conceptualization of the dynamics involved make a multivariate model appropriate to estimate the set of equations representing the use of specific restoration practices on land plots based on the survey data. However, we go beyond measuring the probability of using the restoration practices to also consider the resulting areal extent of land restored using the particular practices.

Second, a Tobit regression with Maximum Likelihood (ML) estimation appears more appropriate for our study than an Ordinary Least Squares (OLS) estimation. The Tobit model (Tobin, 1958; Amemiya, 1973; Greene, 2005) is a corner solution model often used when the dependent variable being estimated shows a limited distribution with strong endpoints (on left or right; in our case left on zeros) determining optimal choices. It is also appropriate to estimate outcomes (areal extent of land under particular restoration practices) that depend on an intermediate decision (to use the restoration practice or not) as a condition to their observance. Our data suggest that the area of land restored with the identified restoration practices can at times be zero because all farmers do not implement restoration practices, and those who do implement, do not do so on all their land plots; leading the dependent variables to display a cornered distribution at zero (see frequency histograms in Figure 3-1). With such limited dependent variables, an OLS regression provides biased and inconsistent estimates, and some scholars have therefore used the Tobit model (e.g., Dolisca et al., 2007; Etongo et al., 2015). Further, a seemingly unrelated regression or multi-stage least squares model is also inadequate because it assumes that the "zero" observations and the positive non-zero ones are generated by the same process (Anastasopoulos et al., 2012).

Figure 3-1. Distribution of land area under restoration at farm-household level in the study area



Following the reasoning above, we apply a multivariate Tobit regression model (Amemiya, 1974). The equation T of the multivariate Tobit model (mvtobit) is:

$$Y_{it}^{*} = X_{it}'\beta_t + \varepsilon_{it}, \; i = 1, 2, \dots . N, \qquad t = 1, 2, 3, 4, \dots, \; T \qquad (1)$$

$$\text{with } \; Y_{it} = \begin{cases} Y_{it}^{*}, & if \;\; Y_{it}^{*} > 0 \\ 0, & if \;\; Y_{it}^{*} \leq 0, \end{cases}$$

where Y_{it}^{*} is the latent dependent variable for the restoration practice t on plot i, X_{it}' is a vector of explanatory variables, β_t is a vector of unknown coefficient parameters to be estimated, and N is the number of observations. It is assumed that the disturbance terms of the equations for areas under restoration are correlated with ρ representing the correlation coefficient, and that these disturbance terms are distributed as multivariate normal and independent of the explanatory variables (Wooldridge, 2002). ε_{it} are multivariate error terms that are normally and independently distributed $N\ (0, \sigma^2)$, and the variance-covariance matrix has values 1 on the leading diagonal and ρ as off-diagonal values.

The model represents an extension of the univariate tobit model that allows more than one equation of land plots under a specific restoration practice. Each tobit equation explains both the probability of applying a restoration practice and the extent of its application in terms of area covered, and the explanatory factors. Each dependent variable is continuous and the set of explanatory factors in each equation can be different. Thus, the multivariate model consists of t univariate tobit equations, which can be estimated separately with a simulated maximum likelihood (SML) (Greene, 2000; Wooldridge, 2007). Following these assumptions, the multivariate tobit distribution is:

$$F(Y_1, Y_2, Y_3, \ldots, Y_T) = C[F_1(Y_{i1}|X_{i1}'\beta_1), F_2(Y_{i2}|X_{i2}'\beta_2), F_3(Y_{i3}|X_{i3}'\beta_3), \ldots, F_T(Y_{iT}|X_{iT}'\beta_7);\ \theta]\ . \quad (2)$$

The log-likelihood function for the multivariate tobit, defined as:

$$L = \sum_{i=1}^{N}\sum_{t=1}^{T} ln f_{ik}\ (Y_{it}|X_{it};\beta_t)\ +$$

$$\sum_{i=1}^{N} C_{1-T}\ [F_1(Y_{i1}|X_{i1};\beta_1), F_2(Y_{i2}|X_{i2};\beta_2), F_3(Y_{i3}|X_{i3};\beta_3), \ldots, F_T(Y_{iT}|X_{iT};\beta_T);\ \theta]\ , \quad (3)$$

depends on the multivariate standard normal distribution function $C_{1-T}(.)$. The maximum likelihood estimation method of Geweke, Hajivassiliou, and Keane (GHK) allows calculation of such cumulative joint normal distributions of higher dimension (Greene, 2011; Cappellari and Jenkins, 2003; Gates, 2006). We implement our mvtobit using the conditional mixed process estimator ('cmp' command) in Stata. This estimator eases the high computational demand for fitting the log-likelihood and achieving convergence. The 'cmp' command starts by fitting each equation separately to obtain a good starting point for the full model fit (Roodman, 2011). A Wald test or likelihood ratio test is used for the null hypothesis that the correlations ρ among the areas covered by each implemented restoration practice, along with the diverse determining factors, are either equal to zero or nonexistent. Rejecting the null hypothesis implies that the decision to apply the restoration practices on certain areas of lands are interrelated, as are the factors affecting such decisions.

3.3.3.2. Poisson Model

The second proxy variable emulates the count of restoration practices implemented on land plots and in collective restoration, each estimated separately with a Poisson model. It depicts the total number of land-management practices that farmers implement for regeneration purposes, as part of restoration diversification patterns in the area. The Poisson model (Cameron and Trivedi, 2005; 2009; 2010; 2013; Greene, 2009) for such count data Y_i is:

$$E[Y_i|X_i] = \lambda_i = \exp(X_i'\beta) = \exp(\beta_1 + \beta_2 X_{2i} + \cdots \beta_k X_{ki}) \ ,$$

where λ is the mean number of occurrences. The model is estimated most often as a log-linear model as part of a generalized linear model written as:

$$lnE[Y_i|X_i] = ln\lambda_i = X_i'\beta = \beta_1 + \beta_2 X_{2i} + \cdots \beta_k X_{ki}$$

The Poisson model restricts the conditional variance to equal the conditional mean (i.e., equi-dispersion). The non-observation of an over-dispersion (variance exceeds the mean) for each of the dependent variables considered (one for plot level and one for collective-action level) justifies our use of the Poisson model over a potential negative binomial model that corrects for such biases. In addition, as graphed in Figure 3, we do not encounter an excess of zeros that would require a zero-inflated model. We use robust standard errors of the parameter estimates to control for mild violation of the model's underlying assumptions (Cameron and Trivedi, 2009).

3.3.4 Data Analysis

We use Stata 15 to run the statistical descriptive analyses and the econometric models from which we inferred the driving factors. We use Nvivo Pro 12 to analyze the qualitative data from the FGDs, focusing on recurrent themes and sub-themes that describe restoration challenges, and deriving some representative excerpts.

We registered 1,015 land plots in total for the 480 farm households, with 350 and 665 land plots in Dedza and Ntchisi, respectively. In the area, a farm household may own more than one land plot and the number of plots per farm household ranged from 1 to 7, with 45.7% of farmers reporting owning two land plots and 29.6% owning three. On average, plot size was 1.03 (±0.67) acres, with 0.99 (±0.62) and 1.04

(±0.70) acres in Dedza and Ntchisi, respectively. The total area of landholdings was 2.48 (±1.52) acres, with 1.96 (±0.96) and 2.76 (±1.68) acres for farmers in Dedza and Ntchisi, respectively.

Likewise, farmers may participate in more than one collective restoration scheme. On average farmers participate in 1 to 3 collective resources-restoration actions, with most engaging in only one among the 5 types registered. Collective resources restoration included restoration of designated village forest areas (VFAs) (74.3%), community woodlots (8.4%), natural forest patches (usually around graveyards) (12.4%), land and water resources (3.7%), and riverbanks (1.2%). Survey respondents differentiated these restoration efforts from the ones occurring in the state-owned protected forests.

Farmers reported 13 distinct land-management practices adopted to restore land plots. Guided by our literature review, we regrouped the practices into seven categories (Table 3-3).

Table 3-3. Restoration practices and activities implemented in the study area

Restoration Practices Disaggregated – All Dummy	**Obs.**	**Percentage* (%)**	**Restoration Practices Regrouped – All Dummy**	**Percentage* (%)**
Farm-household (land plots) Level				
Agroforestry	1,015	24.1	Agroforestry	24.1
Farmer-managed natural regeneration (FMNR)	1,015	41.6	Farmer-managed natural regeneration (FMNR)	41.6
Manure Making & Application	1,015	54.0	Manure	54.0
Intercropping	1,015	9.5	Conservation Agriculture (CA) Components	45.6
Mulching	1,015	37.5		
Minimum Tillage	1,015	2.7		
Rotation	1,015	0.2		
Swales	1,015	7.2	Soil and Water Conservation (SWC) Components	45.2
Contours Ridges	1,015	37.7		
Box Ridges	1,015	9.0		
Vetiver Grass (Chrysopogon zizanioides)	1,015	32.4	Vetiver Grass	32.4
Pits Planting (like *Zai* practices)	1,015	1.4	Other Practices	1.8
Fallowing	1,015	0.4		
Collective-Actions Level				
Tree Planting	323	73.7	Tree Planting	73.7
Natural Regeneration	323	73.7	Natural Regeneration	73.7
Forest Protection Activities	323	89.2	Forest Protection Activities	89.2
Activities bring Awareness about Tree Cutting	323	56.0	Activities bring Awareness about Tree Cutting	56.0
Firebreak	323	91.3	Firebreak	91.3
Manure Making & Application	323	7.7	Other Restoration Activities	22.6
Swales	323	9.9		
Ridges	323	1.2		
Pit Planting (like *Zai* practices)	323	7.7		
Vetiver Grass (Chrysopogon zizanioides)	323	6.5		
Riverbank Protection	323	3.4		
Gully Plugs (Building & Management)	323	3.4		

* Percentage of farmers adopting and implementing the restoration practices and activities

We dropped the category “Other Practices”, given that these practices were adopted on less than 2% of the sampled plots. Likewise, we regrouped seven of the 12 restoration activities that farmers reported to implement in collective restoration into a new category, “Other Restoration Activities”, thereby reducing the number of categories to six (Table 3-3).

For the mvtobit, we calculated the corresponding land area under each of the six practices as the dependent variables to be estimated. We could not apply this approach to the collective restoration. Farmers did not privately own a portion of the collective resources and all the resources-restoration activities could not be measured with such an area-based metric. This justified focusing the mvtobit analysis on individual farmland restoration only. For the Poisson model, we computed the number (count) of restoration practices as the dependent variable to be estimated, separately for land plots and for collective resources restoration in the forest-agriscapes.

Insights from the summary statistics of the potential explanatory variables in our regression estimations (see appendix Tables 3-A and 3-B) and an analysis of their multicollinearity enabled us to select a final subset of the variables to use as regressors. In addition, for the mvtobit estimation, we used the ‘*pdslasso’* regularization method (Ahrens et al., 2019) to select more meaningful control variables for each of the univariate equations. The *pdslasso* routine employs the Least Absolute Shrinkage and Selection Operator (*lasso*) approach of Tibshirani (1996) combined with the "post-double-selection" methodology of Belloni et al. (2012; 2014) for such regularization. When using only the selected explanatory variables from the *pdslasso* routine does not improve the robustness of the model and estimates, we report the full model with all relevant explanatory variables.

3.4 Results

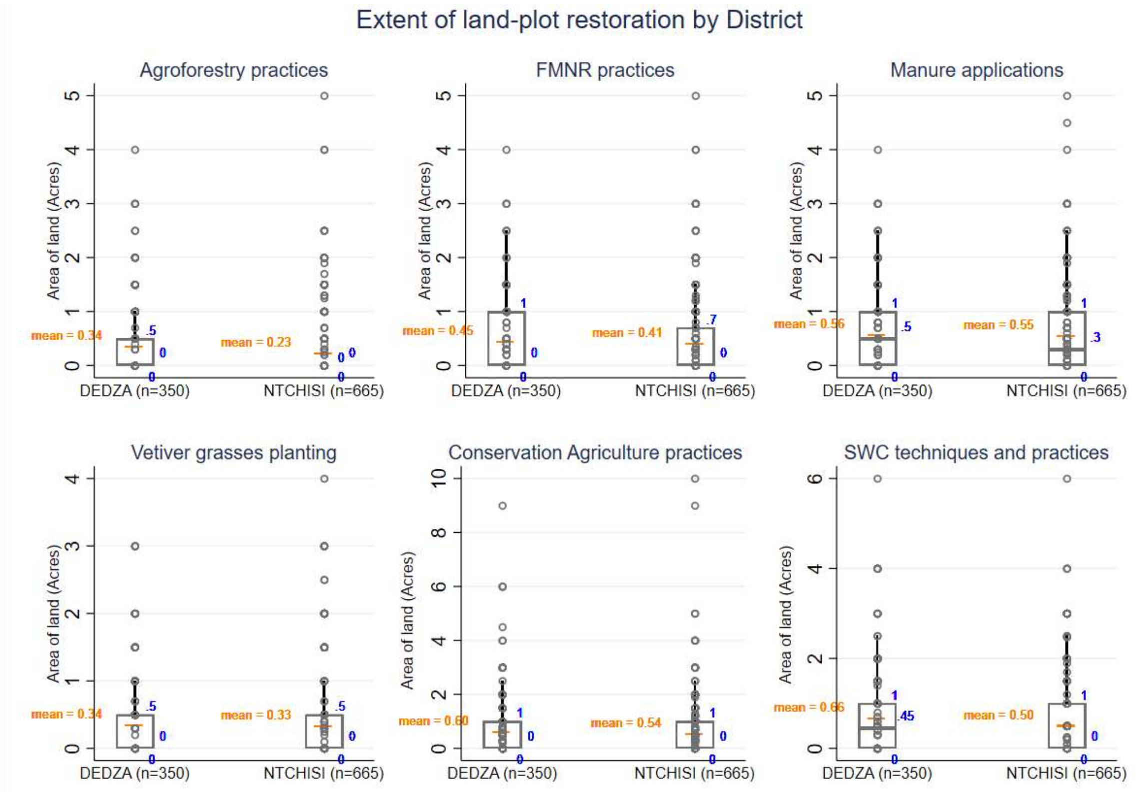
3.4.1 Areal extent of restoration and driving factors

3.4.1.1. Areal extent of farmlands restored

At household level, 1.10 (±0.76) acres and 1.07 (±0.72) acres were restored on average in Dedza and Ntchisi, respectively. These represent less than half of the average total household landholdings in the study area. For each restoration practice adopted, the disaggregated data in Figure 3-2 indicate that on average farmers applied manure, CA practices, and SWC techniques on at least a half-acre of land while

FMNR, vetiver grass (*Chrysopogon zizanioides*), and agroforestry practices are implemented on less than a half-acre of land.

Figure 3-2. Areal extent of land-plot restoration at farm-household level in the study area



Note: Each strip-plot displays the quartile-based dispersion of the areal extent of farmland restored with each practice, by district. The boxes indicate the interquartile range, and we display the value of the first quartile, the median, and the third quartile (in blue); the lines (whiskers) show the minimum and maximum range outside the quartiles; and beyond the whiskers are extreme values (outliers). The orange line displays the mean value of the areal extent of restored land.

While the pattern is similar in both districts, land areas being restored through agroforestry practices or SWC techniques showed a statistically significant difference (*p-value=0.0025*) between the two districts (Figure 3-2). Agroforestry- and SWC-based restoration in Dedza covered more land—0.34 (±0.6) acres and 0.66 (±0.9) acres respectively—than in Ntchisi, 0.23 (±0.6) acres and 0.50 (±0.8) acres, respectively. Field observations affirm the relatively extensive growing of agroforestry-fertilizer trees, notably Faidherbia trees (*Faidherbia albida*), following an agroforestry-system approach in Dedza agrarian landscapes.

3.4.1.2. Driving factors for farmland restoration

The econometric results confirm the appropriateness of the multivariate model to estimate the determinants of the decision to restore some land areas with particular restoration practices. First, the Wald test p-value (*p<0.01*) confirms the statistical significance of the overall model (Table 3-4). This supports the rejection of the null hypothesis that postulates no correlations among the adoption and extents of application of the restoration practices. Second, the likelihood ratio test of the estimated correlation *atanhrho* among the different equations of land areas under restoration (Table 3-4) are significantly different from zero ($p<0.01$). Thus, overall, the results suggest strong correlations among the decisions to restore some allocated land areas with specific restoration practices. Third, it is worth noticing that, although the multivariate model does not show clear-cut superiority regarding the robustness of the estimates β and the robust standard errors when compared with the univariate models (Table 3-C in appendices), the latter provides large absolute values for the error terms. Also, the univariate models predicted a lot of out-of-range values while the predicted values from the multivariate model emulate the observed values better (Figure 3-A in Appendices).

Several factors contributed significantly to explain the estimated areal extent of farmland restored, including factors at household, plot, and institutional levels. Influential household-level factors were socio-cultural, social capital, economic, and perceived values and actual gains (Table 3-4). First, the predicted areas of land restored with SWC techniques increase in male-headed households compared to female-headed ones and increase also with older household heads. Similarly, the predicted areas of land restored with manure and vetiver grass planting increase among educated farmers compared non-educated ones.

Second, when farmers are part of an association or cooperative, the predicted areas of land restored with agroforestry, FMNR practices, manure application, and CA practices increase, while the predicted restored land areas with SWC techniques decrease. The increase with agroforestry and the decrease with SWC techniques are true for those involved in cooperatives dealing with environmental matters and/or with economic activities, including village savings and loans (VSLs) groups. For manure application, the increase in restored areas is observed among farmers who belong to associations where the main activities involve both social and economic issues. Predicted restoration with FMNR and CA practices increase among farmers who are part of associations centered on economic activities.

Third, the predicted areas of land with planted vetiver grass increase when there are more productively active members. Similarly, with more external labor, the predicted areas restored using agroforestry increase as opposed to areas restored with CA practices. This denotes that with more labor availability, farmers are less likely to practice CA, indicating that CA practices are favored during low labor availability. Further, an increase in the total area of landholdings is associated with a decrease in the predicted areas of land restored with manure and SWC techniques. Also, an increase in the number of plots owned decreases the predicted areas of land restored with agroforestry while it increases the predicted areas of land reclaimed with SWC techniques and with vetiver grass planting.

Fourth, concerning perceptual values and tangible extra harvests, findings indicate that the predicted areas of land restored increase when farmers harvest additional products from their farms besides their main crops. This is particularly true for lands restored with FMNR practices and manure given the potential of NTFPs and firewood harvesting. It is also true for lands restored with agroforestry, SWC techniques, and vetiver grass planting for the potential to harvest timber and/or firewood. The predicted areas of land under agroforestry practices, manure application, CA, and SWC techniques increase when farmers perceive the land as important for food security (from the standpoint of what is cultivated on it). Likewise, when farmers perceive their field as providing important strategies for mitigating and/or adapting to climate change, the predicted areas of land restored with FMNR and manure increase. Also, perceived importance for supplying energy materials and generating income enhances land areas restored with SWC techniques.

The geographical and biophysical characteristics of land plots were also important determinants. An increase in the distance between the plot and the homestead decreases the predicted fraction of land allocated to almost all of the restoration practices. An increase in plot size increases the predicted areas of land restored, for all the restoration practices. The predicted areas of land restored with agroforestry, FMNR practices, and manure application increase when farmers perceived the land plots as highly degraded.

Table 3-4. Multivariate tobit estimates of the areal extent of restoration in agrarian landscapes in Central Malawi

VARIABLES	Agroforestry	FMNR	Manure	CA	SWC	Vetiver Grass
Gender of the Household Head (1=Male, 0=Female) = 1, Male	0.150	0.0896	-0.0193	0.183	0.783***	-0.146
	(0.185)	(0.118)	(0.0920)	(0.147)	(0.157)	(0.153)
Age (Years)	-0.00617	0.00275	0.00267	0.000375	0.00952*	0.00753
	(0.00591)	(0.00413)	(0.00348)	(0.00524)	(0.00522)	(0.00515)
Education (1= Educated, 0=Not Educated) = 1, Educated	0.113	0.108	0.220**	0.0242	-0.0815	0.230*
	(0.158)	(0.0997)	(0.0871)	(0.126)	(0.128)	(0.131)
Association with Environmental Activities other than resources restoration (1=yes, 0=no) = 1, Yes	0.603*	0.176	0.0962	0.389	-1.633***	-0.520
	(0.321)	(0.241)	(0.171)	(0.271)	(0.553)	(0.343)
Association with Social Activities (1=yes, 0=no) = 1, Yes	-0.112	0.128	0.256**	0.222	0.313	0.269
	(0.267)	(0.187)	(0.129)	(0.214)	(0.211)	(0.213)
Association with Economic Activities & VSL (1=yes, 0=no) = 1, Yes	0.413**	0.203*	0.345***	0.528***	-0.710***	-0.0736
	(0.163)	(0.114)	(0.0858)	(0.125)	(0.143)	(0.140)
Number of Active Household Member (Count)	-0.0180	-0.0365	0.00237	-0.0528	0.00851	0.107***
	(0.0384)	(0.0265)	(0.0218)	(0.0332)	(0.0321)	(0.0317)
External Labor Use (Count)	0.0446***	0.00716	-0.00336	-0.0294**	0.00390	-0.000856
	(0.0146)	(0.0103)	(0.00914)	(0.0143)	(0.0123)	(0.0137)
Total Farmlands (Acres)	0.0585	-0.00735	-0.0933**	0.0220	-0.132**	-0.0738
	(0.0711)	(0.0466)	(0.0442)	(0.0605)	(0.0613)	(0.0597)
Number of Plots (Count)	-0.299***	0.0341	0.0274	-0.0678	0.132*	0.231***
	(0.0948)	(0.0568)	(0.0474)	(0.0700)	(0.0740)	(0.0765)
Livestock: Ruminants & Pigs (Count)	-0.00303	0.00124	0.0116	0.000243	0.0164	0.0286**
	(0.0166)	(0.0115)	(0.0110)	(0.0164)	(0.0143)	(0.0146)
Livestock: Poultry (Count)	0.00791	-0.00576	0.00131	-0.000273	0.00717	0.0122*
	(0.00759)	(0.00544)	(0.00379)	(0.00633)	(0.00597)	(0.00699)
Off Farm Income (1=yes, 0=no) = 1, Yes	-0.0662	-0.0523	-0.118	0.200*	0.0253	-0.175
	(0.144)	(0.0985)	(0.0826)	(0.118)	(0.123)	(0.124)
Kachindamoto Traditional Authority Area (1=yes, 0=no) = 1, Yes	0.668***	0.136	0.0374	0.642***	0.136	0.601***
	(0.233)	(0.134)	(0.118)	(0.218)	(0.166)	(0.199)
Kamenyagwaza Traditional Authority Area (1=yes, 0=no) = 1, Yes	0.105	-0.390**	-0.224*	0.637***	-0.0125	-0.0704
	(0.256)	(0.158)	(0.133)	(0.224)	(0.176)	(0.229)
Kassakula Traditional Authority Area (1=yes, 0=no) = 1, Yes	-0.157	-0.264*	-0.177	0.605***	-0.395***	0.466**
	(0.237)	(0.138)	(0.116)	(0.191)	(0.152)	(0.196)
Nthondo Traditional Authority Area (1=yes, 0=no) = 1, Yes	-0.0406	-0.727***	0.0465	0.451**	-0.621***	-0.165
	(0.233)	(0.148)	(0.117)	(0.196)	(0.160)	(0.210)
Household Head is the plot manager (1=yes,0=no) = 1, Yes	-0.0213	0.219*	0.195*	-0.0349	0.0470	0.210
	(0.181)	(0.120)	(0.110)	(0.168)	(0.159)	(0.155)
Number of Years of utilization of the plot	0.0104	-0.00802*	-0.00296	0.00548	-0.00341	-0.00210
	(0.00671)	(0.00448)	(0.00370)	(0.00599)	(0.00589)	(0.00570)
Distance Plot to household (Km)	-0.141***	-0.105***	-0.0888***	-0.208***	0.111***	0.00781
	(0.0528)	(0.0304)	(0.0249)	(0.0443)	(0.0235)	(0.0300)
Plot size (Acres)	0.403**	0.552***	0.671***	0.851***	0.662***	0.442***
	(0.160)	(0.129)	(0.140)	(0.197)	(0.152)	(0.144)
Plot is on high slope (1=yes,0=no), = 1, Yes	0.0734	-0.0438	0.00548	0.455***	-0.0639	-0.354***
	(0.149)	(0.0998)	(0.0826)	(0.132)	(0.117)	(0.133)
Plot is on low slope (1=yes,0=no), = 1, Yes	-0.0858	-0.131	0.0789	0.285**	-0.628***	-0.172
	(0.159)	(0.0947)	(0.0855)	(0.132)	(0.134)	(0.123)
Plot land is perceived as highly degraded (1=yes, 0=no), = 1, Yes	0.259*	0.194**	0.166**	-0.0539	-0.246**	-0.0877
	(0.140)	(0.0907)	(0.0767)	(0.124)	(0.112)	(0.117)
Plot land is perceived as slightly degraded (1=yes, 0=no), = 1, Yes	0.145	-0.0231	-0.150	-0.0517	-0.157	0.239
	(0.190)	(0.129)	(0.107)	(0.164)	(0.144)	(0.148)
Land Type: Main rain-fed Agriculture field (1=yes, 0=no), = 1, Yes	0.260	0.115	0.108	0.595	0.357	0.0641
	(0.374)	(0.247)	(0.228)	(0.378)	(0.266)	(0.228)

Table 3-4 (cont'd)

VARIABLES	Agroforestry	FMNR	Manure	CA	SWC	Vetiver Grass
Land use: Fresh vegetables Garden (1=yes, 0=no), = 1, Yes	0.0979	0.205	0.604***	0.739**	-0.243	-0.313
	(0.424)	(0.264)	(0.217)	(0.370)	(0.285)	(0.287)
Plot Tenure: Customary Allocated land with documented letter/agreement (1=yes,0=no) = 1, Yes	0.765***	0.861***	-0.00470	0.259**	0.0124	0.282**
	(0.139)	(0.0927)	(0.0743)	(0.115)	(0.109)	(0.117)
Plot Tenure: Leasehold land with some form of legal document (1=yes,0=no) = 1, Yes	0.198	0.702***	-0.230	-0.123	-0.193	-0.271
	(0.343)	(0.178)	(0.175)	(0.258)	(0.264)	(0.294)
Plot Acquisition mode: Inherited land (1=yes,0=no) = 1, Yes	0.0862	0.353	-0.0685	0.492	1.605***	0.231
	(0.496)	(0.256)	(0.248)	(0.342)	(0.512)	(0.331)
Plot Acquisition mode: Land acquired from/allocated by local leader (1=yes,0=no) = 1, Yes	0.261	0.175	-0.0671	0.410	1.927***	0.151
	(0.514)	(0.268)	(0.259)	(0.355)	(0.519)	(0.357)
Plot Acquisition mode: Purchased land (1=yes,0=no) = 1, Yes	2.139***	1.032***	0.543	0.988*	-	0.132
	(0.599)	(0.383)	(0.473)	(0.554)	-	(0.649)
Plot Acquisition mode: Rented or Borrowed Land (1=yes,0=no) = 1, Yes	-0.328	0.129	-0.273	0.322	1.761***	0.153
	(0.650)	(0.348)	(0.289)	(0.405)	(0.552)	(0.397)
NTFPs as Additional Harvest (1=yes, 0=no), = 1, Yes	0.105	0.407***	0.172**	-0.0135	-0.135	0.113
	(0.154)	(0.0953)	(0.0853)	(0.131)	(0.138)	(0.132)
Timber as Additional Harvest (1=yes, 0=no), = 1, Yes	-0.226	0.226	0.0506	-0.647*	0.647***	0.719***
	(0.370)	(0.236)	(0.188)	(0.345)	(0.211)	(0.260)
Firewood as Additional Harvest (1=yes, 0=no), = 1, Yes	0.996***	0.862***	0.362***	0.0874	-0.0635	0.232**
	(0.136)	(0.0884)	(0.0735)	(0.120)	(0.119)	(0.117)
Plot land is perceived as highly important for Food security (1=yes, 0=no), = 1, Yes	0.274*	0.0759	0.472***	0.490***	0.271**	-0.0392
	(0.140)	(0.0899)	(0.0803)	(0.120)	(0.114)	(0.116)
Plot land is perceived as highly important for Energy needs (1=yes, 0=no), = 1, Yes	0.0994	0.0323	-0.0592	0.0198	0.634***	0.00949
	(0.181)	(0.110)	(0.0992)	(0.164)	(0.144)	(0.146)
Plot land is perceived as highly important for Climate Change A&M (1=yes, 0=no), = 1, Yes	0.0760	0.308***	0.178**	-0.135	-0.201	0.155
	(0.148)	(0.0922)	(0.0772)	(0.127)	(0.127)	(0.120)
Plot land is perceived as highly important for Income (1=yes, 0=no), = 1, Yes	0.0464	-0.0309	-0.0475	0.0139	0.563***	0.0212
	(0.139)	(0.0955)	(0.0799)	(0.123)	(0.121)	(0.119)
Constant	-2.575***	-2.206***	-1.249***	-2.931***	-3.686***	-3.003***
	(0.787)	(0.481)	(0.415)	(0.690)	(0.740)	(0.582)

Likelihood-ratio test for all null correlations (atanhrho_12 = atanhrho_13 = atanhrho_14 = atanhrho_15 = atanhrho_16 = atanhrho_23 = atanhrho_24 = atanhrho_25 = atanhrho_26 = atanhrho_34 = atanhrho_35 = atanhrho_36 = atanhrho_45 = atanhrho_46 = atanhrho_56 = 0) : **LR chi2(15) = 139.42 (Prob > chi2 = 0.0000)**

Wald chi2 (239) = 1565.86

Prob > chi2 = 0.0000

Log pseudolikelihood = --5598.8352

Observations = 1,015

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Institutional factors surrounding land-tenure security, especially when combining plot-tenure types and acquisition modes, and the residence or location were also influential. The predicted areas of land restored with agroforestry, FMNR and CA practices, and vetiver grass planting increase in customary allocated lands that have some documented agreement. The predicted areas of land restored with SWC techniques increase when the land is inherited and allocated by a local leader. Also, the predicted areas of land restored with FMNR practices increase in leasehold lands. Further, the predicted areas of land under agroforestry and FMNR practices increase when the land is purchased. Finally, on residential location, Kachindamoto within Dedza District had the greatest areal extent of restoration over Kamenyagwaza, notably for agroforestry, CA practices, and planted vetiver grass. For Ntchisi District, Kassakula had the greatest areal extent of restoration over Nthondo, particularly for CA practices and planted vetiver grass. Both locations exhibit decreased areal extent of restoration with FMNR and SWC techniques.

3.4.2 The diversity and configuration of local restoration practices and technologies

Beside evidence of a variety of restoration practices registered and described earlier, their association patterns (as suggested by the correlations of the decision supporting their implementation) and total counts on land plots and in collective restoration also illustrate some configural aspect and diversity in restoration. First, in terms of association of restoration practices, the areas of land restored with agroforestry techniques is statistically positively linked to those restored with FMNR, manure application, and vetiver grass planting (Table 3-5). Likewise, the areas of land where farmers practice FMNR is statistically positively associated with the areas of land where they apply manure and where they implement CA techniques, with the last two also showing an association. Further, the areas of land restored with SWC techniques is more likely associated with the areas of land being recovered with vetiver grass. However, land areas where farmers implement CA techniques and FMNR practices are less likely linked to land areas where they implement SWC techniques as the extent of restored land areas with these practices are statistically negatively interrelated. Such associative patterns illustrate that farmers likely combine several of compatible restoration practices on the same lands, indicating an integrated approach in which both tree-based and non-tree-based restoration practices are combined to enhance restoration outcomes.

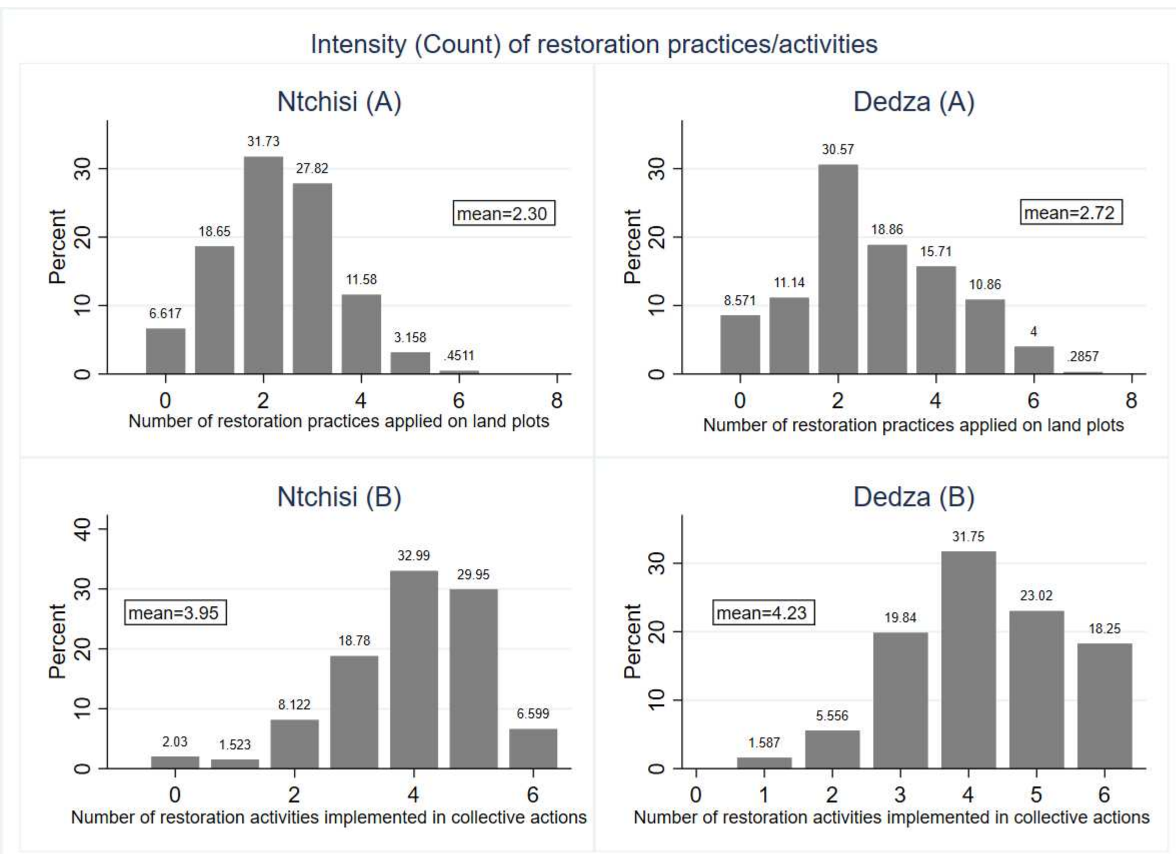
Table 3-5. Correlations between the different restoration practices used on plots

	Agroforestry	FMNR	Manure	Conservation Agriculture	SWC	Vetiver Grass
Agroforestry	1					
FMNR	0.103* (0.0567)	1				
Manure	0.107** (0.0527)	0.227*** (0.0540)	1			
Conservation Agriculture	0.0397 (0.0525)	0.105** (0.0527)	0.259*** (0.0538)	1		
SWC	-0.0227 (0.0480)	-0.0856* (0.0517)	-0.0617 (0.0480)	-0.183*** (0.0453)	1	
Vetiver Grass	0.140** (0.0549)	0.0712 (0.0512)	0.0378 (0.0497)	0.0649 (0.0527)	0.203*** (0.0537)	1

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Second, in terms of number, farmers implement on average 2-4 restoration practices in varied configurations. The number of restoration practices on individual land plots averaged 2-3 (mean=2.45; $\sigma^2 = 1.84$) while that implemented in collective resources management averaged 4 (mean=4.07; $\sigma^2 = 1.53$) (Figure 3-3). Overall, restoration efforts in Dedza surpass those in Ntchisi (Figure 3-3).

Figure 3-3. Intensity (count) of restoration practices on plots (A) and activities in collective actions (B)



Farmers in Dedza implement significantly more restoration practices than those in Ntchisi both on individual land plots (*p=0.0000,* Figure 3-3, panel A) and in collective resources restoration (*p=0.0448,* Figure 3-3, panel B). In Dedza, most collective restoration occurred in designated VFAs on customary lands and less in the state-owned forest reserve. In contrast, in Ntchisi more restoration effort was observed in the protected forest areas than in community forests on customary lands.

3.4.2.1. Factors influencing the number of restoration practices applied on farmlands

Each estimation for plot-level restoration practices displays highly statistically significant *($p<0.01$)* Poisson model for Ntchisi, Dedza, and the full sample (Table 3-6). The goodness-of-fit chi squared tests indicate that each model fits the data well.

Compared to women, the log count of restoration practices applied by men increases for Ntchisi district and for the whole area, indicating that male-headed households invest more in restoration than female-headed households. Older farmers also applied more restoration practices in Ntchisi. Moreover, being a member of an association or cooperative dealing with social or economic activities, including VSLs, increased the number of restoration practices applied on farms in Ntchisi and in the whole study area. This denotes that farmers possessing such social capital are likely to invest more in restoration on their farmlands. Further, farmers' residential location (TA) also mattered. In Ntchisi, the log count of restoration practices for farmers residing in Nthondo is less than that of farmers living in Kassakula. For the entire study area and compared to residing in Kachindamoto (Dedza), the log count of restoration practices for residents of Kamenyagwaza (Dedza) and of Kassakula, Nthondo and Vuso Jere (Ntchisi), is fewer also.

An increase in the size of the plots was associated with an increase in the log count of restoration practices for Ntchisi and for the whole study sample. However, an increase in households' total landholdings area decreases the log count of restoration practices for Ntchisi and for the whole study sample. Further, an increase in the distance between the plot and the homestead is critically associated with a decrease in the log count of restoration practices for both districts and for the entire study area, denoting that more restoration practices are implemented on plots closest to homesteads. Also, an increase in the use of external labor and in the number of poultry increased the log count of restoration practices for Ntchisi and for Dedza, respectively.

Table 3-6. Poisson model: Number of restoration practices on plots at the individual household level

VARIABLES	Ntchisi District	Dedza District	WHOLE SAMPLE
Age (Years)	0.00384**	-0.00166	0.00240
	(0.00195)	(0.00260)	(0.00148)
Gender of the HH Head (1=Men, 0=Women) = 1, Men	0.128**	0.132	0.125**
	(0.0647)	(0.0819)	(0.0490)
Education (1= Educated, 0=Not Educated) = 1, Education	0.0802	0.0517	0.0760*
	(0.0543)	(0.0670)	(0.0422)
Association with Environmental-related Activities (1=yes, 0=no) = 1, Yes	-0.132	-0.239	-0.184**
	(0.100)	(0.149)	(0.0880)
Association with Social-related Activities (1=yes, 0=no) = 1, Yes	0.176**	0.0616	0.153***
	(0.0732)	(0.113)	(0.0580)
Association with Economic-related Activities & VSL (1=yes, 0=no) = 1, Yes	0.195***	-0.0748	0.144***
	(0.0489)	(0.0729)	(0.0403)
Number of Active Household Member (Count)	-0.00586	0.0124	-0.00121
	(0.0127)	(0.0164)	(0.00978)
External Labor Use (Count)	0.00854**	-0.00964	0.00277
	(0.00406)	(0.00856)	(0.00342)
Total Farmlands (Acres)	-0.0406**	-0.0690	-0.0381**
	(0.0197)	(0.0486)	(0.0179)
Number of Plots (Count)	0.0318	0.0557	0.0260
	(0.0230)	(0.0564)	(0.0211)
Livestock: Ruminants & Pigs (Count)	0.00438	0.00562	0.00654
	(0.00483)	(0.00846)	(0.00415)
Livestock: Poultry (Count)	0.00157	0.00784*	0.00313
	(0.00269)	(0.00406)	(0.00234)
Off Farm Income (1=yes, 0=no) = 1, Yes	-0.0139	-0.0115	-0.00903
	(0.0430)	(0.0667)	(0.0364)
Traditional Authority Areas (TAs - Location): TAs = 2, Kamenyagwaza	NA	-0.266***	-0.290***
	-	(0.0649)	(0.0575)
TAs = 3, Kasakula (Reference level for Ntchisi District)	NA	NA	-0.239***
	-	-	(0.0477)
TAs = 4, Nthondo	-0.125***	NA	-0.346***
	(0.0429)	-	(0.0496)
TAs = 5, Vuso Jere	0.00336	NA	-0.238***
	(0.0600)	-	(0.0597)
Household Head is the plot manager (1=yes,0=no) = 1, Yes	0.224***	0.0263	0.122**
	(0.0656)	(0.0802)	(0.0494)
Number of Years of utilization of the plot	-0.00167	0.00107	-0.000752
	(0.00230)	(0.00297)	(0.00177)
Distance Plot to household (Km)	-0.0381***	-0.0570**	-0.0387***
	(0.0128)	(0.0227)	(0.0114)
Plot size (Acres)	0.0726*	0.0763	0.0694*
	(0.0435)	(0.0653)	(0.0376)
Plot is on high slope (1=yes,0=no) = 1, Yes	0.00693	-0.0662	-0.0275
	(0.0468)	(0.0648)	(0.0373)
Plot is on low slope (1=yes,0=no) = 1, Yes	0.00468	-0.0370	-0.0113
	(0.0553)	(0.0643)	(0.0413)
Plot land is perceived as highly degraded (1=yes, 0=no) = 1, Yes	0.0248	0.0629	0.0378
	(0.0448)	(0.0586)	(0.0355)
Plot land is perceived as slightly degraded (1=yes, 0=no) = 1, Yes	0.00311	-0.101	-0.00415
	(0.0557)	(0.0964)	(0.0477)
Land type: Main rain-fed agriculture (1=yes, 0=no) = 1, Yes	0.330**	-0.0146	0.0959
	(0.146)	(0.0889)	(0.0769)
Land use: Fresh vegetables garden (1=yes, 0=no) = 1, Yes	0.372**	0.0416	0.130
	(0.152)	(0.114)	(0.0866)
Plot Tenure: Customary Allocated land with documented letter/agreement (1=yes,0=no) = 1, Yes	0.186***	0.340***	0.254***
	(0.0459)	(0.0591)	(0.0348)
Plot Tenure: Leasehold land with some form of legal document/title (1=yes,0=no) = 1, Yes	0.104	-0.148	0.0598
	(0.111)	(0.238)	(0.102)
Plot Acquisition mode: Inherited land (1=yes,0=no) = 1, Yes	0.344**	0.280	0.356**
	(0.172)	(0.294)	(0.157)
Plot Acquisition mode: Land acquired from/allocated by local leader (1=yes,0=no) = 1, Yes	0.322*	0.456	0.356**
	(0.176)	(0.301)	(0.161)
Plot Acquisition mode: Purchased land (1=yes,0=no) = 1, Yes	0.733***	0.593*	0.702***
	(0.208)	(0.309)	(0.181)
Plot Acquisition mode: Rented or Borrowed land (1=yes,0=no) = 1, Yes	0.222	-0.0153	0.182
	(0.196)	(0.321)	(0.176)
NTFPs as Additional Harvest (1=yes, 0=no) = 1, Yes	0.0551	0.0959	0.0762*
	(0.0490)	(0.0765)	(0.0402)
Timber as Additional Harvest (1=yes, 0=no) = 1, Yes	0.107	0.0809	0.0995
	(0.0706)	(0.234)	(0.0650)
Firewood as Additional Harvest (1=yes, 0=no) = 1, Yes	0.236***	0.351***	0.306***
	(0.0450)	(0.0588)	(0.0350)
Plot land is perceived as highly important for Food security (1=yes, 0=no) = 1, Yes	0.178***	0.174**	0.182***
	(0.0423)	(0.0697)	(0.0364)

Table 3-6 (cont'd)

VARIABLES	Ntchisi District	Dedza District	WHOLE SAMPLE
Plot land is perceived as highly important for Energy needs (1=yes, 0=no) = 1, Yes	0.0253 (0.0570)	0.117* (0.0705)	0.0861** (0.0429)
Plot land is perceived as highly important for Climate Change A&M (1=yes, 0=no) = 1, Yes	0.137*** (0.0479)	0.151** (0.0637)	0.0901** (0.0372)
Plot land is perceived as highly important for Income generation (1=yes, 0=no) = 1, Yes	0.0560 (0.0445)	-0.0134 (0.0724)	0.0284 (0.0380)
Constant	-0.782*** (0.245)	0.141 (0.392)	-0.223 (0.199)
Observations	665	350	1,015
Wald chi2(38; 37; 40)	269.70	344.76	491.89
Prob > chi2	0.0000	0.0000	0.0000
Log pseudolikelihood	-1044.5536	-578.90821	-1635.6818
McFadden's Pseudo R2	0.047	0.108	0.067
Maximum Likelihood (Cox-Snell) R2	0.144	0.331	0.207
Cragg-Uhler (Nagelkerke) R2	0.149	0.339	0.214
Deviance goodness-of-fit (Prob > chi2(626; 312; 974))	400.5962 (1.0000)	235.7977 (0.9995)	660.8339 (1.0000)
Pearson goodness-of-fit (Prob > chi2(627; 312; 974))	334.9548 (1.0000)	186.3037 (1.0000)	544.6274 (1.0000)

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Regarding institutional factors, findings from plot tenure type and source indicate that owning more customary allocated land plots that have a documented agreement increases the number of restoration practices implemented in both districts and in the whole study area. Owning more inherited lands boosted the number of restoration practices, as observed also for lands allocated by a local authority in Ntchisi and in the whole study area. However, purchased lands seem to be the most conducive factor for a greater number of restoration practices applied in both districts and in the whole study area. Together, these findings suggest that tenure security associated with (i) customary allocated lands inherited or acquired from a local authority, and most importantly, (ii) purchased land or land acquired with a documented agreement/arrangement enhances the number of restoration practices applied on plots.

Furthermore, while additionally harvesting NTFPs from land plots marginally increased the number of restoration practices applied in the whole study area, harvesting firewood significantly increased restoration efforts on plots in both districts and when considering the entire study area. Also important are the cognitive values farmers place on their plots. Perceiving the plot as highly important for food security, for energy needs, and for helping to mitigate or adapt to climate change, increases the conditional mean of the number of applied restoration practices for Ntchisi, Dedza, and the whole study sample.

3.4.2.2. Factors influencing the number of restoration activities implemented in collective restorations

As at household level, the overall Poisson models for Ntchisi, Dedza, and the aggregate sample are highly statistically significant *($p<0.01$)* (Table 3-7). The goodness-of-fit chi squared tests indicate that each model fits the data well.

Table 3-7. Poisson model: Number of restoration activities implemented in collective resources restoration

VARIABLES		Ntchisi District	Dedza District	WHOLE SAMPLE
Age (Years)		0.00126	-0.000690	0.000204
		(0.00186)	(0.00144)	(0.00122)
Gender of the HH Head (1=Male, 0=Female) = 1, Male		-0.0634	-0.00384	-0.0511
		(0.0697)	(0.0700)	(0.0519)
Education (1= Educated, 0=Not Educated) = 1, Education		0.0192	-0.0445	-0.0189
		(0.0560)	(0.0634)	(0.0439)
Ethnicity (1= Chewa, 0=Not Chewa) = 1, Chewa		-	-0.0190	-0.0408
		-	(0.0508)	(0.0477)
Membership of association/group/cooperative (1=yes, 0=no) = 1, Yes		0.0454	-0.134	-0.0269
		(0.166)	(0.205)	(0.126)
Association with Environmental Activities other than resources restoration (1=yes, 0=no) = 1, Yes		-0.0125	-0.0375	-0.0578
		(0.142)	(0.139)	(0.0842)
Association with Social Activities & VSL (1=yes, 0=no) = 1, Yes		-0.155	0.156	-0.0488
		(0.167)	(0.159)	(0.118)
Association with Economic Activities (1=yes, 0=no) = 1, Yes		-0.0340	0.0724	-0.000113
		(0.162)	(0.191)	(0.120)
Traditional Authority Areas (TAs - Location)	TA = 2, Kamenyagwaza	NA	-0.133***	-0.134***
		-	(0.0447)	(0.0494)
	TA = 3, Kasakula (Reference level for Ntchisi District)	NA	NA	-0.130**
		-	-	(0.0540)
	TA = 4, Nthondo	0.0137	NA	-0.112*
		(0.0563)	-	(0.0601)
	TA = 5, Vuso Jere	0.0411	NA	-0.0881
		(0.0552)	-	(0.0545)
Types of Collective Actions (CAs)	CA = 2, Community Woodlots	-0.188*	-0.00566	-0.103*
		(0.0966)	(0.0680)	(0.0605)
	CA= 3, Natural Forests (around Graveyards)	-0.0510	-0.337***	-0.121**
		(0.0711)	(0.0901)	(0.0582)
	CA= 4, Land & Water Resources Conservation & Other CA (Riverbank Protection groups)	-0.538**	-0.359*	-0.361**
		(0.262)	(0.191)	(0.158)
Perceived payoffs: CA as highly important for Food security (1=yes, 0=no) = 1, Yes		-1.027**	-	-0.737***
		(0.435)	-	(0.278)
Perceived payoffs: CA as highly important for Energy needs (1=yes, 0=no) = 1, Yes		0.0854*	0.155***	0.121***
		(0.0479)	(0.0506)	(0.0339)
Perceived payoffs: CA as highly important for Climate Change A&M (1=yes, 0=no) = 1, Yes		0.304***	-0.0906	0.110*
		(0.111)	(0.0767)	(0.0666)
Perceived payoffs: CA as highly important for Income generation (1=yes, 0=no) = 1, Yes		0.0874	0.162	0.185**
		(0.0940)	(0.102)	(0.0735)
Leadership of local Authority over CA is perceived as good (1=yes, 0=no) = 1, Yes		0.0772	0.216***	0.138**
		(0.0737)	(0.0689)	(0.0550)
Leadership of local Authority over CA is perceived as bad (1=yes, 0=no) = 1, Yes		0.325***	0.0846	0.165**
		(0.117)	(0.0902)	(0.0810)
Tangible Benefits: NTFPs collection (1=yes, 0=no) = 1, Yes		0.0296	0.0821	0.0225
		(0.0534)	(0.0796)	(0.0451)
Tangible Benefits: Firewood collection (1=yes, 0=no) = 1, Yes		0.199	0.0891	0.143*
		(0.126)	(0.0942)	(0.0754)
Tangible Benefits: Timber harvesting (1=yes, 0=no) = 1, Yes		-0.0668	-0.0494	-0.0614
		(0.0718)	(0.0638)	(0.0478)
Tangible Benefits: Free access to specific zones for livestock grazing (1=yes, 0=no) = 1, Yes		-	-0.219	0.217**
		-	(0.161)	(0.0912)
Tangible Benefits: Granted tree tenure/use rights (1=yes, 0=no) = 1, Yes		-0.164**	-0.118*	-0.120*
		(0.0813)	(0.0617)	(0.0667)
Tangible Benefits: Actions for Community Development (1=yes, 0=no) = 1, Yes		0.160	-0.0600	-0.0264
		(0.210)	(0.175)	(0.142)
Tangible Benefits: Cash money (1=yes, 0=no) = 1, Yes		-	0.0571	0.0692
		-	(0.0964)	(0.0835)
No Harvest Benefits (1=yes, 0=no) = 1, Yes		0.179	0.124	0.157
		(0.140)	(0.108)	(0.0851)
Constant		0.824***	1.387***	1.225***
		(0.229)	(0.149)	(0.157)
Observations		197	126	323
Wald chi2 (24; 25; 29)		44.403	112.164	80.338
Prob > chi2		0.007	0.0000	0.0000
Log pseudolikelihood		-348.714	-222.131	-576.127
McFadden's Pseudo R2		0.031	0.033	0.024
Maximum Likelihood (Cox-Snell) R2		0.108	0.114	0.085
Cragg-Uhler (Nagelkerke) R2		0.111	0.117	0.087
Deviance goodness-of-fit (Prob > chi2 (172; 100; 293))		73.73476 (1.0000)	31.48244 (1.0000)	115.781 (1.0000)
Pearson goodness-of-fit (Prob > chi2 (172; 100; 293))		64.25747 (1.0000)	30.1238 (1.0000)	103.8261 (1.0000)

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

The residential location and local leadership attributes are influential. As with household-level restoration, the log count of collective restoration activities for residents of Kamenyagwaza, Kassakula, and Nthondo decreases compared to farmers residing in Kachindamoto when considering the whole study area. Local leadership also matters, though findings were mixed. Perceived good local leadership increases the log count of predicted collective restoration activities for Dedza and for the entire study area. Interestingly, perceived poor leadership does not decrease the log count of restoration activities for Ntchisi and for the entire study area, suggesting that even weak leadership might not discourage restoration efforts. Compared to designated village forest areas, the log count of collective restoration activities decreases for community woodlots (in Ntchisi notably), for natural forest patches around graveyards (in Dedza notably), and for land and water resources for both districts and for the whole study area.

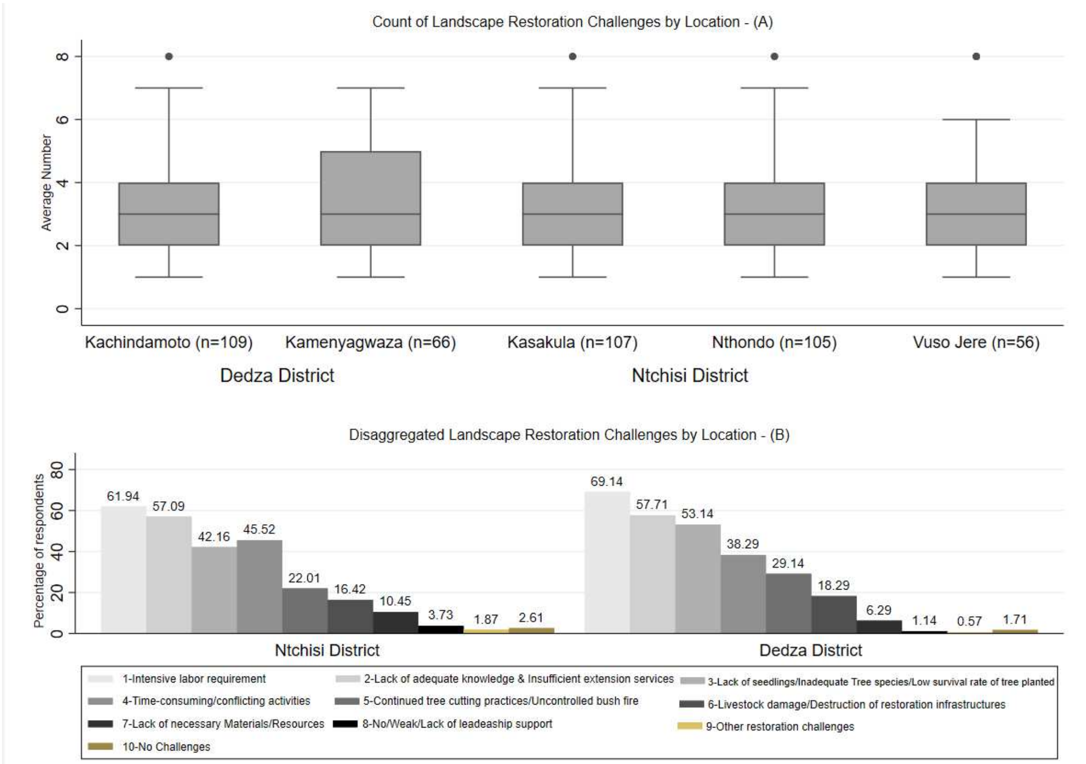
Perceptual factors in relation to the value of the collective restoration were also determinant. Perceiving the resources managed collectively as highly important for meeting energy needs increases the conditional mean of restoration activities for both districts and the entire study area. Likewise, when the collective restoration is perceived as highly important for mitigating climate change or adapting to its impacts, and for income generation, the log count of restoration activities increases for Ntchisi and for the whole study area. In contrast, perceiving the resources collectively managed as highly important for individual food security lessens the restoration activities, denoting potential conflicts between the two goals.

Actual benefits from participating in collective restoration are influential. Collecting firewood from the collectively-managed resources and getting free access to specific zones for livestock grazing increase the log count of restoration activities for the whole study area. In contrast, being granted some tenure or use rights over tree resources decreases the conditional mean count of restoration activities for both districts and for the whole study area, suggesting a false sense of private rights that lessen collective efforts.

3.4.3 Restoration challenges faced by farmers

Farmers reported facing many challenges (3±1.6, on average) in their restoration efforts at collective and individual levels (Figure 3-4).

Figure 3-4. Reported number of challenges faced by farmers engaged in restoration efforts (N=443) in the



study area

Note: **Panel A** - Each box-and-whisker diagram depicts the quartile-based dispersion of the number of restoration challenges faced per location (TAs and Districts). The boxes indicate the interquartile range; the lines (whiskers) show the minimum and maximum range outside the quartiles; and the dots are extreme values (outliers). **Panel B** – Disaggregated figures showing the different types of restoration challenges and the percentage of survey respondents citing them (depicting their relative importance).

The most recurrent challenges were the intensive labor requirement of restoration practices (64.8%); inadequate knowledge about restoration practices and technologies, including the insufficiency of extension services to provide the necessary knowledge and guidance (57.3%); and limited availability of seedlings of suitable tree species (46.5%). The time-consuming or conflicting nature of restoration activities (42.7%) was another challenge, particularly for collective restoration.

Findings from the focus group discussions affirm these challenges. Although the quantitative data indicated no statistical difference from one location to another, farmers provided differentiated substantiations for these challenges. For collective restorations, farmer respondents stressed the intensive labor requirements and the time constraints of restoration activities. Varying commitment levels exacerbated the collective-action challenges, with some participants decrying late coming and selective participation of community members – preference was for activities that were less demanding physically.

"When we call one another to do collective actions, some people do not keep time, and this demotivates others from committing themselves. Others prefer tree planting and management activities to swales making because swales making activities are tough and labor intensive compared to tree management activities. They choose what activity they should participate in" (FGD collective restoration, Kamenyagwaza, Dedza)

Other farmers complained that extension workers did not guide them since they, in turn, were not motivated by the government. Farmers attributed the tendency of many of them ignoring the benefits of restoring the resources to lack of training.

Furthermore, some farmers noted the intentional destruction of restoration infrastructure by some community members, such as the removal of planted vetiver grass (*Chrysopogon zizanioides*). Other farmers indicated not having the necessary operational resources and being demotivated from having no remuneration for their participation in collective-restoration activities.

"Others do not allow us to make swales in their fields, and if we plant vetiver, they remove [it]. *They do this with the fear that these technologies attract mice and rats. It is true that vetiver attracts mice, but it depends on the management activities of vetiver."* (FGD collective restoration, Kamenyagwaza, Dedza)

"We do participate in these activities on voluntary basis, and we lack operational resources such as slashers, and safety boots." (FGD collective restoration, Kassakula, Ntchisi)

Reported challenges to individual-level restoration included the lack of tree seedlings and other necessary inputs, high labor demand for many restoration activities, and poor trees species or soil type match. The following statement is illustrative:

"…we do not have enough tree seedlings to plant despite having the willingness to plant trees. We rely on NGOs who provide us with seedlings but often very late…More people want to participate but they do not have operational resources [to produce tree seedlings], such as watering canes and tubes. Other restoration activities are more labor intensive than others, for example managing natural regenerants is easier than planting trees." (FGD individual-level restoration, Ntchisi)

Further challenges included the damage of tree nurseries by livestock and the ensuing conflict with cattle owners. This challenge points to the tradeoff between using vegetation biomass for mulching on farm plots and using it as fodder for livestock. FGD participants in Dedza articulate this:

"In tree management, challenges include livestock destroying our nurseries, and sometimes our forests catch fire when fire breaks are not made on time. For land-conservation technologies, the challenge comes with cattle herders. They feed animals on maize stock we have laid in our gardens for mulching." (FGD individual-level restoration, Kachindamoto, Dedza)

"Cattle herders also feed their animals in our gardens where we have already put maize stocks for mulching, forcing us to do the same work more than once." (FGD individual-level restoration, Kamenyagwaza, Dedza).

Some farmers noted they use some traditional knowledge-based responses to address livestock damage: *"We use traditional knowledge in protecting tree nurseries from livestock. We use livestock dung and mix with water and spread on trees in the nursery, and livestock do not come close to the nursery."*

Overall, these challenges lower farmers' motivation and restoration efforts at either individual or collective level, undermining the areal extent of restoration and the diversification of restoration practices.

> *"Our extension workers are also not motivated by government and they do not help us to meet our expectations. They do not give us enough training that we can pass on to other people. We are not satisfied with services offered by extension workers."* (FGD collective restoration, Kachindamoto, Dedza)

3.5 Discussion

We discuss the findings with focus on what is exceptionally relevant for advancing FLR in Malawi and other SSA countries with relatively similar restoration features, while considering existing literature, our own empirical observations, and insights from the restoration challenges.

3.5.1 Local patterns and extent of forest-agriscapes restoration

Diverse land-management practices are implemented in local efforts to restore degraded farmlands, but in terms of areal extent, there is relatively little restoration taking place in the study area. Farmers' small landholdings in Malawi's context, along with other challenges that they face in restoration, contribute to the low areal impact. Nonetheless, farmers' willingness to restore degraded landscapes is reflected in their implementation of diverse and multiple restoration practices – two to three different practices on their land plots and four different activities in collective restoration, on average.

District differences are worth noticing for the areal extent of land restored and for the diversity and configuration of restoration practices. Dedza seems to lead the efforts for restoring land plots and collective resources within the customary domain as opposed to resources in protected areas where Ntchisi farmers performed better. First, the higher population density in Dedza reduces farmland availability, with slightly lower mean farm size, and constrains expansion. Farmers therefore focus on enhancing the productivity of the limited and degraded land (plots) with agroforestry using fertilizer trees, notably *Faidherbia albida*. Several efforts in Malawi promote agroforestry practices to meet multiple related objectives that also contribute to FLR goals. Such goals include enhanced food security, reversing environmental degradation, and adapting to climate change (Musa et al., 2018; Amadu et al., 2020). Also, the extent of functional degradation in the agricultural landscape is more acute in Dedza than in Ntchisi (MNFLR, 2017b), thus justifying implementation of more SWC techniques for restoration than in Ntchisi. Furthermore, the Boserupian more-people-more-regreening argument attributing agricultural intensification to population change (e.g., Tiffen et al., 1994) can explain these district differences. Second, while both districts benefited from government programs under co-management and participatory forest management arrangements, the phase-out of these programs—without comparable replacement—in Dedza led to considerable free riding behavior particularly within co-managed protected areas and much less so on customary lands. Our study reiterates previous observations of a failure to sustain previous successes while addressing known weaknesses of these programs in Dedza MLFR (Senganimalunje et al., 2016). In Ntchisi, in contrast, a new program continued with efforts to address past governance failures, refocusing on collective resources restoration in protected areas.

3.5.2 Customization of restoration technological combinations for diversity

The configurations of restoration practices implemented illustrate the multi-purpose nature of agrarian land-restoration technologies and the underlying restoration goals prioritized by farmers given their limited resources endowments. Farmers harness the complementarities among tree-based and non-tree-based practices to achieve their livelihoods, food security, and ecological goals through restoration while minimizing costs, particularly on labor. For instance, the association of manure applications (as organic carbon and nitrogen-enhancing strategy) and CA points to the need to address soil degradation and fertility decline and to increase yield, while combining SWC techniques with vetiver grass planting helped to reduce soil erosion in steep terrain. Agroforestry and FMNR are complementary tree-based practices that were often combined. In contrast, farmers rarely combined high labor-demanding practices, such as SWC and CA or FMNR. SWC techniques, involving building small-scale infrastructure, demand substantial labor. Insights from these findings can inform restoration program planners in Malawi and elsewhere to enhance the matching of restoration practices and technologies to particular problems, objectives, and prevalent farmer resource endowments (particularly land and labor) and help restoration policy makers to reframe expectations from farmer-led restoration. Such need-based restoration and associated intensification or diversification justifies the importance of examining specific combinations of technologies and practices rather than looking at them individually, as studies have traditionally done.

3.5.3 Contextual drivers of forest-agriscapes restoration

While most sociocultural factors considered are significant determinants of individual-level restoration in spatial extent and diversity (Tables 3-4 and 3-6), gender, age, and social capital indicators were the most consistent across sites. First, male-headed households dominate land restoration and the underlying decisions on land-management practices despite the dominant matrilineal kinship system regulating land inheritance and control in the study area. Findings from both the survey and focus groups resonate with previous evidence in Malawi's matrilocal settings that gender-based norms that grant men de-facto authority and privileged access to productive inputs, restrict women (and women-headed household)'s land restoration efforts especially for high labor demanding activities (Djurfeldt et al., 2018). Findings further support earlier calls for gender-responsive FLR interventions (Sijapati Basnett et al., 2017). Second, findings suggest that older farmers more likely invest in farmlands restoration, suggesting that younger farmers may face potential barriers empeding their engagement with land restoration. Third, findings on the influence of farmers' social capital imply that social development and environment-oriented groups allow farmers to take up and enhance agroforestry, FMNR practices, and manure application, while membership in economic-oriented cooperatives (including VSL schemes) reinforces farmers' capacity to afford necessary restoration resources. Consistent with Etongo et al. (2018), these findings substantiate group membership as a channel through which farmers can access restoration resources and support.

Economic factors, particularly resource endowment, and some plot characteristics also emerged as statistically significant drivers of household-level restoration. First, findings on availability and use of external labor, and on raising poultry, underscore the importance of productive resources of labor and capital for restoration. External labor compensates for household-level shortages to meet the intensive labor requirements of some restoration activities. Livestock (poultry) are not only a source of income but also a source of animal manure commonly applied to farm plots. This evidence aligns with the influential effect of livestock holdings on implementation of land management practices in West-Africa (Etongo et al., 2018). Second, the influences of land endowment on restoration are more nuanced than in previous studies that associate larger landholdings with agroforestry adoption in Malawi (Musa et al., 2018). They also reflect the overall mixed effect of farm size on land-management decisions observed in other studies (Amsalu and de Graaff, 2007; Mango et al., 2017; Etongo et al., 2018; Holden et al., 2018). The core finding is that land fragmentation undermined restoration efforts. Thus, in contrast to the positive influence of bigger plot size, the negative influence of higher numbers of land plots on the areal extent restored with agroforestry suggests that consolidation, rather than fragmentation, of landholdings is conducive to boost agroforestry practice. Also, findings on larger landholdings appearing to disincentivize restoration of degraded lands, particularly with manure and SWC techniques, align with arguments that farmers with smaller landholdings in Shashui, Tanzania invest more in SLM (Nyanga et al., 2016). Adding such a seemingly counterintuitive finding to another that suggests more restoration occurs nearest to homesteads, consistent with patterns evidenced in Bolivia (Kessler, 2006), affirm high labor demands and costs (availability and transport of manure) as major limiting factors to cover land plots that are larger and farther from homesteads. Third, findings that more restoration occurs when plots are deemed highly degraded resonate with findings on the acuteness of observed land degradation and low soil fertility as major rationales for restoring farm households' lands (Djenontin et al., 2020b – next chapter).

Findings suggest that the actual or tangible benefits from and the shared perceived value of the resources being restored are key drivers for both individual and collective restoration. First, the actual gains in specific ecosystem products such as firewood, NTFPs, and timber, are critical determinants, especially for farmlands restored with agroforestry, FMNR practices, manure application, vetiver grass planting, and even with SWC techniques. Our findings confirm firewood as a critical resource sourced from collectively-managed forest resources, consistent with earlier research (Senganimalunje et al., 2016). Second, perceptual values that farmers have about the restoration of their plots in relation to attaining food security, supplying biomass energy, and helping to cope with or mitigate climate change impacts are influential. Similarly, provisioning energy needs and enhancing household capacity to adapt to climate change impacts are critical drivers of engagement with collective restoration. Altogether, these findings substantiate arguments that resources restoration within the FLR approach should be linked to local livelihoods, well-being, and climate change goals with tangible strategies to improve them (Erbaugh and Oldekop, 2018). However, the conflicting observation that the food-security value of the resources being restored would not favor collective restoration activities illustrates a long-held puzzle on how to strike a balance in the forced marriage of resources conservation and sustainable livelihoods in the context of poverty and struggles for food security (Sunderlin et al., 2005). The findings further suggest that both the institutional arrangements and benefits from collective restoration should reinforce household-level benefits and goals, or at least reconcile them to increase farmers' participation. While doing this might seem elusive in practice (Adams et al., 2004), accepting the presence of trade-offs and anticipating how to address them in a contextually-appropriate framing of landscape restoration goals and outcomes is recommended (Sunderlin et al., 2005).

Findings regarding institutional factors reinforce the importance of secure land tenure and resources-property rights to enhance restoration efforts both at individual and collective levels. Specifically, inherited land and customary land allocated by local authorities are perceived secure to promote restoration, and more so when guaranteed by a supporting documentation or agreement. Purchased land is perceived exceptionally secure to support restoration with agroforestry and FMNR practices at household-level. These findings confirm others on tenure insecurity as an impeding factor both in Malawi (Lovo, 2016; Silberg et al., 2017) and elsewhere (Ayamga et al., 2016; Etongo et al., 2018). They also align with arguments for enhancing tenure security to foster farmers' restoration efforts (Legesse et al., 2018). For collective restoration, conducive institutional factors include rights to collect firewood for household use and free access to pasture for livestock grazing within the managed landscape. This finding reinforces calls for a rights-based approach to restoration of degraded landscapes (McLain et al., 2018). However, the negative influence when farmers are granted tenure or use rights over some collectively-managed resources reflect residual suspicions among some farmers that granting such resource rights might be more of a problem than a solution. This suggests the need to articulate context-appropriate rights-based approach to restoration take-up.

Finally, good leadership is perceived to enhance restoration efforts (Kachindamoto in Dedza and Nthondo in Ntchisi) while uninspiring leadership undermined restoration (Kamenyagwaza, Dedza) at both individual and community level. While these findings confirm previous evidence on local leadership's role in restoration efforts (Zulu, 2013; Djenontin et al., 2020b – next chapter), leadership was not an absolute disincentivize for farmers to participate in collective restoration, as Kassakula (Ntchisi) case illustrates.

3.5.4 Study limitations

The study has some limitations. First, our measurement of the areal extent of restoration relies on farmers' self-reported land sizes. While these data have been triangulated with several visits to the farm plots that each interviewed farm household owned, spatial mapping to improve and confirm their accuracy would be recommended. Second, we have attempted to account for diverse tree and non-tree-based restoration techniques and activities, both at individual and collective level, which do not have a simple shared metric of restoration, and also sometimes take place in different but connected landscapes – the forest-agriscapes. While we are confident in our proxy variables capturing the areal extent of and diversification patterns in restoration, finding indicators that could capture better such diverse restoration efforts holistically and systematically is encouraged. Third, that none of the social capital variables are found influential for collective restoration activities, despite the centrality of social capital to the functioning and sustenance of the necessary restoration institutions, could be the effect of endogeneity with an implicit covariate denoting membership in collective restoration groups. Finally, we have used cross-sectional data, thereby missing the temporal dynamics of these local efforts. This limitation calls for further research that explores the spatiotemporal dynamics of farmers' restoration actions.

3.6 Conclusion

We investigated how forest-agriscapes restoration is implemented in rural Central Malawi. We examined the areal extent of land restored, the diversity and configuration of restoration practices at both farm-plot and community (collective) levels, and the factors that influence choices of restoration practices.

Our analyses reveal that while farmers diversify their restoration in terms of the number, types, and configurations of practices and activities implemented, the aggregate landscape impacts of farm level restoration efforts remain relatively low in terms of actual areal extent of restored lands. While this does not negate the widely agreed premise that local farmers remain critical to reaching restoration goals in forest-agriscapes, it reflects the need for reinvigorated, more effective, context-appropriate, and consistent interventions to mitigate the many constraints that farmers face. These challenges include limited land, labor and other resources, and ineffective extension services. Further, the findings support our argument that farmers select a combination of restoration practices or technologies that fit their priority restoration problems, objectives, and resource endowments. Also, various, context-appropriate measures of success should be used to monitor restoration attainments because local restoration objectives and priorities are context-specific and vary within and between household-level and collective-level restoration. Our findings of specific socio-cultural, economic, cognitive valuation, biophysical, geographical, and institutional factors that influence the areal extent and diversification patterns of restoration also reveal leverage points to enhance forest-agriscape restoration. Notably, increasing land-ownership security among farmers where possible, while minimizing fragmentation withing landholdings is critical. For collective restoration, reinforcing local leadership, enhancing tangible benefits from ecosystem goods and services, strengthening resources rights, and balancing perceived payoffs with socio-ecological goals are capital.

Methodologically, identifying factors that determine the choice of the number, variety, and configurations of restoration practices, and their spatial impact in terms of areal extent provides potentially valuable inputs into future computational modeling to examine the spatiotemporal dynamics and impacts of restoration in central Malawi based on particular policy scenarios. More generally, the study contributes to the literature on restoration patterns and drivers in Malawi and beyond. The findings can inform future policy options and management practices to implement FLR interventions addressing the severe problems of land degradation and deforestation, biodiversity loss and food and livelihood insecurity not only in Malawi but also in other SSA countries with similar realities.

APPENDIX

Table 3-A. Description, unit, and summary means of potential variables to include in the models for individual-level restoration

Variables	RP1: Application of Agroforestry on plots				RP2: Application of FMNG on plots				RP3: Application of Manure on plots				Full sample (n=1,015)
	NO (n=770)	YES (n=245)	t test	P-value	NO (n=593)	YES (n=422)	t test	P-value	NO (n=467)	YES (n=548)	t test	P-value	
SOCIOCULTURAL													
Age (Years)	45.65 (14.41)	47.93 (15.62)	-2.02	0.0437	46.09 (14.65)	46.35 (14.86)	-0.27	0.7873	45.48 (15.03)	46.81 (14.46)	-1.43	0.153	46.20 (14.73)
Gender (D)	0.83 (0.36)	0.87 (0.34)	-1.38	0.1689	0.83 (0.38)	0.85 (0.35)	-1.08	0.2798	0.83 (0.37)	0.84 (0.36)	-0.43	0.6644	0.84 (0.37)
Educated (D)	0.76 (0.43)	0.79 (0.41)	-0.92	0.3569	0.76 (0.43)	0.77 (0.42)	-0.38	0.7023	0.73 (0.45)	0.8 (0.4)	-2.66	0.008	0.77 (0.42)
Chewa Ethnicity (D)	0.82 (0.38)	0.68 (0.47)	4.34	0.0000	0.82 (0.38)	0.73 (0.44)	3.47	0.0006	0.8 (0.4)	0.78 (0.42)	0.74	0.4564	0.79 (0.41)
SOCIAL CAPITAL - ASSOCIATION/GROUP/COOPERATIVE													
Membership (D)	0.21 (0.41)	0.23 (0.42)	-0.72	0.47	0.21 (0.41)	0.22 (0.41)	-0.3	0.7638	0.16 (0.37)	0.26 (0.44)	-4.19	0.0000	0.22 (0.41)
Environment Type Activity other than resources restoration (D)	0.03 (0.18)	0.04 (0.21)	-0.84	0.3989	0.04 (0.19)	0.03 (0.17)	0.69	0.4906	0.03 (0.16)	0.04 (0.2)	-1.59	0.1131	0.04 (0.19)
Social Type Activity (D)	0.05 (0.22)	0.05 (0.22)	0.01	0.9910	0.06 (0.23)	0.05 (0.22)	0.42	0.6782	0.04 (0.19)	0.07 (0.25)	-1.96	0.0502	0.05 (0.22)
Economic Type Activity & VSL (D)	0.16 (0.36)	0.20 (0.40)	-1.62	0.1057	0.17 (0.37)	0.17 (0.38)	-0.32	0.7470	0.11 (0.31)	0.22 (0.41)	-4.63	0.0000	0.17 (0.37)
ECONOMIC													
Household (HH) Size (Count)	5.32 (2.05)	5.16 (1.98)	1.15	0.2522	5.31 (2.11)	5.24 (1.94)	0.52	0.6051	5.28 (2.19)	5.29 (1.9)	-0.06	0.9501	5.28 (2.04)
HH Active Member (Count)	3.3 (1.53)	3.17 (1.58)	1.15	0.2489	3.31 (1.58)	3.2 (1.48)	1.13	0.257	3.28 (1.59)	3.26 (1.49)	0.16	0.8755	3.27 (1.54)
External Labor (Count)	1.12 (3.08)	2.33 (4.76)	-3.75	0.0002	1.1 (2.97)	1.86 (4.27)	-3.17	0.0016	1.26 (3.15)	1.54 (3.93)	-1.26	0.2067	1.41 (3.59)
Total Farmlands (Acres)	2.52 (1.54)	2.37 (1.46)	1.4	0.1633	2.48 (1.49)	2.49 (1.6)	-0.14	0.887	2.6 (1.58)	2.38 (1.47)	2.29	0.0223	2.48 (1.52)
Number of Plots (Count)	2.58 (2.5)	2.31 (2.18)	3.74	0.0002	2.46 (0.99)	2.59 (1.1)	-1.83	0.0681	2.53 (0.92)	2.5 (1.14)	0.57	0.5684	2.51 (1.04)
Livestock: Ruminants & Pigs (Count)	2.48 (4.1)	2.43 (3.5)	0.17	0.8622	2.51 (4.4)	2.4 (3.25)	0.45	0.6547	2.38 (4.37)	2.54 (3.59)	-0.62	0.5363	2.47 (3.96)
Livestock: Poultry (Count)	3.83 (7.45)	5.17 (7.4)	-2.47	0.014	4.19 (8.21)	4.11 (6.25)	0.17	0.8663	3.59 (7.13)	4.63 (7.7)	-2.23	0.0261	4.15 (7.46)
Annual Income (Kwacha)	202227.7 (334071.4)	189699.1 (257220.3)	0.62	0.5388	212742.3 (355268.2)	180178.9 (253315.4)	1.7	0.0886	200497.3 (349675.3)	198101.1 (286871.3)	0.12	0.9061	199203.60 (317155.80)
Off Farm Income (D)	0.21 (0.4)1	0.2 (0.4)	0.31	0.7582	0.21 (0.41)	0.2 (0.4)	0.52	0.6017	0.22 (0.41)	0.2 (0.4)	0.83	0.4049	0.21 (0.41)
LOCATION													
Ntchisi DISTRICT (D)	0.69 (0.46)	0.54 (0.5)	4.11	0.0000	0.69 (0.46)	0.6 (0.49)	3.13	0.0018	0.67 (0.47)	0.64 (0.48)	1.07	0.2867	0.66 (0.48)
Kachindamoto TA (D)	0.16 (0.37)	0.33 (0.47)	-5.18	0.0000	0.15 (0.35)	0.29 (0.45)	-5.3	0.0000	0.17 (0.38)	0.23 (0.42)	-2.48	0.0134	0.20 (0.40)
Kamenyagwaza TA (D)	0.15 (0.35)	0.12 (0.33)	0.94	0.349	0.16 (0.37)	0.11 (0.32)	2.08	0.0381	0.16 (0.36)	0.13 (0.33)	1.38	0.1674	0.14 (0.35)
Kasakula TA (D)	0.28 (0.45)	0.21 (0.41)	2.49	0.0132	0.27 (0.44)	0.26 (0.44)	0.18	0.8564	0.32 (0.47)	0.22 (0.42)	3.52	0.0005	0.27 (0.44)
Nthondo TA (D)	0.28 (0.45)	0.24 (0.43)	1.09	0.2779	0.32 (0.47)	0.2 (0.4)	4.27	0.0000	0.22 (0.42)	0.3 (0.46)	-2.98	0.003	0.27 (0.44)
Vuso Jere TA (D)	0.13 (0.34)	0.09 (0.29)	1.67	0.095	0.11 (0.31)	0.14 (0.34)	-1.23	0.2175	0.13 (0.34)	0.11 (0.32)	0.76	0.4502	0.12 (0.33)
GENERAL & GEOGRAPHICAL (PLOT)													
HH Head Manager (D)	0.88 (0.32)	0.87 (0.34)	0.67	0.5053	0.89 (0.32)	0.87 (0.34)	0.85	0.3929	0.86 (0.35)	0.9 (0.3)	-1.89	0.0586	0.88 (0.33)
Spouse Manager (D)	0.09 (0.29)	0.12 (0.32)	-1.07	0.2844	0.09 (0.29)	0.11 (0.31)	-1.05	0.2945	0.12 (0.32)	0.09 (0.28)	1.57	0.1172	0.10 (0.30)
Plot Utilization Year (Year)	18.27 (12.94)	21.18 (12.9)	-3.07	0.0022	19 (13.42)	18.92 (12.36)	0.09	0.9266	18.66 (12.47)	19.24 (13.41)	-0.72	0.473	18.97 (12.99)
Distance (Km)	1.34 (1.78)	1.24 (1.31)	0.96	0.3389	1.29 (1.85)	1.36 (1.39)	-0.67	0.5015	1.48 (2.06)	1.18 (1.25)	2.76	0.006	1.31 (1.68)

Table 3-A. (cont'd)

BIOPHYSICAL (PLOT)													
Plot Size (Acres)	1 (0.67)	1.11 (0.69)	-2.15	0.0318	1.04 (0.69)	1.01 (0.66)	0.5	0.6175	1.02 (0.7)	1.02 (0.65)	-0.11	0.9097	1.03 (0.67)
High Slope (D)	0.32 (0.47)	0.31 (0.46)	0.16	0.8744	0.33 (0.47)	0.29 (0.45)	1.33	0.1844	0.31 (0.46)	0.31 (0.46)	0.03	0.9753	0.31 (0.46)
Medium Slope (D)	0.46 (0.5)	0.4 (0.49)	1.62	0.1067	0.46 (0.42)	0.5 (0.49)	1.48	0.1397	0.47 (0.5)	0.42 (0.49)	1.58	0.1138	0.44 (0.50)
Low Slope (D)	0.23 (0.42)	0.29 (0.45)	-1.95	0.0519	0.21 (0.4)	0.29 (0.45)	-3.1	0.002	0.21 (0.41)	0.26 (0.44)	-1.88	0.0597	0.24 (0.43)
High Degraded (D)	0.51 (0.5)	0.58 (0.5)	-1.82	0.0689	0.5 (0.5)	0.57 (0.5)	-2.23	0.0263	0.49 (0.5)	0.55 (0.5)	-2.05	0.0408	0.53 (0.50)
Moderately Degraded (D)	0.32 (0.47)	0.27 (0.44)	1.4	0.162	0.32 (0.46)	0.29 (0.45)	0.9	0.369	0.32 (0.47)	0.29 (0.45)	1.2	0.2285	0.30 (0.46)
Slightly Degraded (D)	0.18 (0.38)	0.16 (0.36)	0.75	0.4531	0.19 (0.39)	0.14 (0.35)	1.89	0.0597	0.19 (0.39)	0.16 (0.36)	1.23	0.2179	0.17 (0.38)
LANDUSE (PLOT)													
Rainfed Agric Field (D)	0.88 (0.32)	0.96 (0.21)	-4.02	0.0001	0.89 (0.31)	0.92 (0.27)	-1.66	0.0974	0.92 (0.28)	0.89 (0.31)	1.5	0.1348	0.90 (0.30)
Dambo Field (D)	0.11 (0.32)	0.04 (0.2)	4.3	0.0000	0.11 (0.31)	0.08 (0.27)	1.71	0.0869	0.08 (0.27)	0.11 (0.31)	-1.75	0.081	0.10 (0.30)
Grain & Legume Crops (D)	0.89 (0.32)	0.95 (0.22)	-3.51	0.0005	0.9 (0.31)	0.91 (0.28)	-1.04	0.2993	0.9 (0.3)	0.91 (0.29)	-0.19	0.8465	0.90 (0.30)
Vegetable Crops (D)	0.08 (0.28)	0.02 (0.15)	4.18	0.0000	0.08 (0.27)	0.06 (0.23)	1.31	0.1893	0.05 (0.09)	0.21 (0.28)	-2.6	0.0095	0.07 (0.25)
Potato Crops (D)	0.02 (0.14)	0.01 (0.09)	1.78	0.0759	0.02 (0.15)	0.01 (0.11)	1.44	0.1503	0.03 (0.18)	0.01 (0.07)	3.2	0.0015	0.02 (0.14)
INSTITUTIONAL FACTORS													
Customary Allocated with Documented Agreement (D)	0.46 (0.5)	0.62 (0.49)	-4.32	0.0000	0.39 (0.49)	0.65 (0.48)	-8.4	0.0000	0.52 (0.5)	0.48 (0.5)	1.16	0.2475	0.50 (0.50)
Customary Allocated without Documented Agreement (D)	0.48 (0.5)	0.35 (0.48)	3.81	0.0002	0.56 (0.5)	0.29 (0.45)	8.97	0.0000	0.43 (0.5)	0.47 (0.5)	-1.12	0.2651	0.45 (0.50)
Customary Allocated Land (D)	0.94 (0.23)	0.96 (0.19)	-1.39	0.1647	0.95 (0.21)	0.94 (0.24)	0.83	0.4051	0.95 (0.22)	0.95 (0.22)	0.11	0.9132	0.95 (0.22)
Customary Unallocated Land (D)	0.001 (0.04)	0.004 (0.06)	-0.65	0.5164	0.003 (0.06)	0 (0)	1.42	0.1575	0.002 (0.05)	0.001 (0.04)	0.11	0.9104	0.002 (0.04)
Leasehold with some form of legal document (D)	0.04 (0.2)	0.03 (0.17)	0.91	0.3619	0.03 (0.16)	0.05 (0.23)	-2.28	0.0229	0.04 (0.19)	0.04 (0.19)	0.17	0.8645	0.04 (0.19)
Public Land (D)	0.02 (0.12)	0.004 (0.06)	1.9	0.0576	0.02 (0.14)	0.01 (0.07)	2.13	0.0333	0.01 (0.1)	0.02 (0.12)	-0.56	0.5785	0.01 (0.11)
Inherited (D)	0.55 (0.5)	0.51 (0.5)	1.21	0.2274	0.59 (0.49)	0.48 (0.5)	3.27	0.0011	0.54 (0.5)	0.55 (0.5)	-0.5	0.6158	0.54 (0.50)
Allocated by Family Member (D)	0.22 (0.42)	0.26 (0.44)	-1.19	0.2359	0.17 (0.38)	0.32 (0.47)	-5.44	0.0000	0.24 (0.43)	0.22 (0.42)	0.8	0.4211	0.23 (0.42)
Allocated by Local Leader (D)	0.14 (0.35)	0.18 (0.38)	-1.29	0.1988	0.16 (0.36)	0.14 (0.34)	0.86	0.3885	0.14 (0.34)	0.16 (0.37)	-0.97	0.3307	0.15 (0.36)
Purchased (D)	0.001 (0.04)	0.02 (0.15)	-2.32	0.0209	0.003 (0.06)	0.01 (0.11)	-1.46	0.1435	0.004 (0.07)	0.01 (0.09)	-0.96	0.3396	0.01 (0.08)
Rented or Borrowed (D)	0.06 (0.23)	0.02 (0.13)	3.41	0.0007	0.06 (0.24)	0.03 (0.17)	2.42	0.0156	0.05 (0.22)	0.04 (0.20)	0.71	0.4804	0.05 (0.21)
ADDITIONAL HARVEST													
Additional Harvest (D)	0.46 (0.5)	0.75 (0.44)	-8.59	0.0000	0.37 (0.48)	0.76 (0.43)	-13.51	0.0000	0.43 (0.5)	0.61 (0.49)	-5.76	0.0000	0.53 (0.50)
NTFPs (D)	0.19 (0.39)	0.24 (0.43)	-1.71	0.0881	0.12 (0.33)	0.3 (0.46)	-6.96	0.0000	15 (0.36)	0.24 (0.42)	-3.39	0.0007	0.20 (0.40)
Timber (D)	0.04 (0.19)	0.04 (0.19)	0.16	0.873	0.04 (0.18)	0.04 (0.2)	-0.58	0.5606	0.03 (0.18)	0.04 (0.2)	-0.98	0.3296	0.04 (0.19)
Firewood (D)	0.38 (0.48)	0.67 (0.47)	-8.31	0.0000	0.3 (0.46)	0.65 (0.48)	-11.67	0.0000	0.36 (0.48)	0.52 (0.5)	-5.27	0.0000	0.45 (0.50)
RELATIVE IMPORTANCE (COGNITIVE FACTORS)													
High for Food Security (D)	0.52 (0.5)	0.64 (0.48)	-3.48	0.006	0.53 (0.5)	0.58 (0.5)	-1.57	0.1167	0.4 (0.49)	0.67 (0.47)	-8.66	0.0000	0.55 (0.50)
High for Energy needs (D)	0.15 (0.35)	0.22 (0.42)	-2.56	0.0113	0.12 (0.32)	0.23 (0.42)	-4.66	0.0000	0.14 (0.35)	0.18 (0.39)	-1.78	0.075	0.16 (0.37)
High for Climate Change A&M (D)	0.32 (0.47)	0.38 (0.49)	-1.63	0.1048	0.26 (0.44)	0.43 (0.5)	-5.77	0.0000	0.25 (0.43)	0.4 (0.49)	-5.2	0.0000	0.33 (0.47)
High for Income Source (D)	0.44 (0.5)	0.35 (0.48)	2.63	0.0089	0.47 (0.5)	0.35 (0.48)	3.92	0.0001	0.51 (0.5)	0.35 (0.48)	5.02	0.0000	0.42 (0.49)

RP= Restoration Practice; (D) = Dummy variable; SD in brackets; bolded p-values show significance at either 0.1%; 1%, 5%, and 10%

Table 3-A. (cont'd)

Variables	RP4: Planting of Vetiver grass (*Chrysopogon zizanioides*) on plots				RP5: Practice of Conservation Agriculture on plots				RP6: Application of SWC techniques on plots				Full sample (n=1,015)
	NO (n=686)	YES (n=323)	t test	P-value	NO (n=552)	YES (n=463)	t test	P-value	NO (n=556)	YES (n=459)	t test	P-value	
SOCIOCULTURAL													
Age (Years)	45.28 (15.21)	48.11 (13.51)	-2.99	0.0029	45.93 (14.63)	46.52 (14.87)	-0.63	0.532	45.45 (14.52)	47.11 (14.95)	-1.78	0.0749	46.20 (14.73)
Gender (D)	0.83 (0.37)	0.85 (0.36)	-0.58	0.5606	0.83 (0.38)	0.85 (0.36)	-0.99	0.3179	0.79 (0.41)	0.9 (0.31)	-4.64	0.0000	0.84 (0.37)
Educated (D)	0.76 (0.43)	0.78 (0.41)	-0.77	0.4402	0.76 (0.42)	0.77 (0.42)	-0.17	0.8688	0.76 (0.43)	0.77 (0.42)	-0.47	0.6358	0.77 (0.42)
Chewa Ethnicity (D)	0.8 (0.4)	0.75 (0.43)	1.69	0.0901	0.77 (0.42)	0.8 (0.4)	-1.23	0.2178	0.83 (0.38)	0.74 (0.44)	3.48	0.0005	0.79 (0.41)
SOCIAL CAPITAL - ASSOCIATION/GROUP/COOPERATIVE													
Membership (D)	0.22 (0.42)	0.2 (0.4)	0.99	0.3219	0.16 (0.36)	0.29 (0.45)	-4.88	0.0000	0.28 (0.45)	0.14 (0.35)	5.24	0.0000	0.22 (0.41)
Environment Type Activity other than resources restoration (D)	0.04 (0.2)	0.02 (0.14)	1.9	0.0582	0.03 (0.17)	0.04 (0.2)	-1.2	0.2309	0.06 (0.24)	0.004 (0.07)	5.34	0.0000	0.04 (0.19)
Social Type Activity (D)	0.05 (0.22)	0.06 (0.24)	-0.72	0.4715	0.04 (0.20)	0.07 (0.25)	-2.03	0.0431	0.05 (0.22)	0.06 (0.23)	-0.44	0.6591	0.05 (0.22)
Economic Type Activity & VSL (D)	0.18 (0.38)	0.15 (0.36)	0.99	0.3214	0.12 (0.32)	0.23 (0.42)	-4.82	0.0000	0.22 (0.42)	0.10 (0.30)	5.33	0.0000	0.17 (0.37)
ECONOMIC													
Household (HH) Size (Count)	5.18 (2.07)	5.49 (1.96)	-2.32	0.0208	5.24 (2.07)	5.33 (2.00)	-0.75	0.4554	5.42 (2.04)	5.11 (2.02)	2.38	0.0173	5.28 (2.04)
HH Active Member (Count)	3.14 (1.48)	3.54 (1.62)	-3.82	0.0001	3.31 (1.57)	3.21 (1.50)	1.11	0.2659	3.23 (1.57)	3.32 (1.51)	-0.95	0.3447	3.27 (1.54)
External Labor (Count)	1.26 (3.41)	1.73 (3.94)	-1.87	0.062	1.54 (4.07)	1.26 (2.92)	1.28	0.1994	1.35 (1.49)	3.29 (3.93)	-0.58	0.5629	1.41 (3.59)
Total Farmlands (Acres)	2.42 (1.5)	2.62 (1.58)	-2.01	0.0444	2.46 (1.47)	2.51 (1.59)	-0.456	0.648	2.52 (1.7)	2.44 (1.27)	0.84	0.4027	2.48 (1.52)
Number of Plots (Count)	2.45 (1.05)	2.65 (1.02)	-2.87	0.0042	2.57 (0.95)	2.44 (1.14)	1.95	0.0518	2.56 (1.19)	2.45 (0.83)	1.79	0.0736	2.51 (1.04)
Livestock: Ruminants & Pigs (Count)	2.22 (3.7)	2.98 (4.42)	-2.7	0.0072	2.41 (3.81)	2.54 (4.14)	-0.54	0.5881	2.34 (4.26)	2.63 (3.56)	-1.17	0.2427	2.47 (3.96)
Livestock: Poultry (Count)	3.67 (7.52)	5.17 (7.22)	-3.06	0.0023	4.06 (7.86)	4.27 (6.95)	-0.44	0.6581	3.65 (6.09)	4.77 (8.8)	-2.31	0.0213	4.15 (7.46)
Annual Income (Kwacha)	195650.9 (340920.7)	206611.3 (261059.7)	-0.56	0.5724	181640.4 (313043.5)	220142.8 (321073.8)	-1.92	0.0546	213505.6 (347307.3)	181879.1 (275646)	1.62	0.1062	199203.60 (317155.80)
Off Farm Income (D)	0.21 (0.41)	0.19 (0.39)	0.85	0.3951	0.18 (0.38)	0.24 (0.43)	-2.66	0.0081	0.22 (0.41)	0.19 (0.36)	0.93	0.3516	0.21 (0.41)
LOCATION													
Ntchisi DISTRICT (D)	0.67 (0.47)	0.62 (0.49)	1.75	0.0808	0.65 (0.48)	0.66 (0.48)	-0.09	0.9309	0.7 (0.46)	0.61 (0.49)	3.01	0.0027	0.66 (0.48)
Kachindamoto TA (D)	0.16 (0.37)	0.29 (0.46)	-4.61	0.0000	0.2 (0.4)	0.2 (0.41)	-0.17	0.8616	0.17 (0.38)	0.25 (0.43)	-2.93	0.0035	0.20 (0.40)
Kamenyagwaza TA (D)	0.16 (0.37	0.09 (0.28)	3.63	0.0003	0.14 (0.35)	0.14 (0.34)	0.32	0.747	0.13 (0.34)	0.15 (0.36)	-0.68	0.4937	0.14 (0.35)
Kasakula TA (D)	0.24 (0.43)	0.33 (0.47)	-3.01	0.0027	0.25 (0.43)	0.29 (0.45)	-1.54	0.1241	0.29 (0.46)	0.23 (0.42)	2.17	0.03	0.27 (0.44)
Nthondo TA (D)	0.3 (0.46)	0.21 (0.41)	3.15	0.0017	0.25 (0.44)	0.28 (0.45)	-1.05	0.295	0.31 (0.46)	0.21 (0.41)	3.71	0.0002	0.27 (0.44)
Vuso Jere TA (D)	0.14 (0.35)	0.08 (0.27)	2.94	0.0034	0.15 (0.36)	0.08 (0.28)	3.47	0.0005	0.09 (0.27)	0.16 (0.37)	-3.39	0.0007	0.12 (0.33)
GENERAL & GEOGRAPHICAL (PLOT)													
HH Head Manager (D)	0.88 (0.33)	0.88 (0.32)	-0.25	0.806	0.88 (0.33)	0.88 (0.32)	-0.3	0.7633	0.87 (0.34)	0.89 (0.31)	-1.18	0.2386	0.88 (0.33)
Spouse Manager (D)	0.1 (0.3)	0.09 (0.29)	0.63	0.5322	0.09 (0.3)	0.09 (0.3)	0.01	0.9879	0.1 (0.3)	0.1 (0.3)	-0.07	0.9453	0.10 (0.30)
Plot Utilization Year (Year)	18.55 (13.48)	19.86 (11.86)	-1.58	0.1152	18.51 (12.8)	19.52 (13.2)	-1.24	0.2143	18.59 (13.31)	19.43 (12.58)	-1.03	0.3018	18.97 (12.99)
Distance (Km)	1.29 (1.73)	1.38 (1.57)	-0.84	0.3997	1.51 (2.01)	1.08 (1.13)	4.35	0.0000	1.14 (1.37)	1.52 (1.97)	-3.47	0.0005	1.31 (1.68)

Table 3-A. (cont'd)

BIOPHYSICAL (PLOT)													
Plot Size (Acres)	1.02 (0.7)	1.03 (0.63)	-0.14	0.8863	0.97 (0.66)	1.09 (0.69)	-2.66	0.0079	1.01 (0.73)	1.04 (0.6)	-0.67	0.5029	1.03 (0.67)
High Slope (D)	0.35 (0.48)	0.23 (0.42)	4.16	0.0000	0.27 (0.45)	0.35 (0.48)	-2.09	0.0364	0.31 (0.46)	0.32 (0.47)	-0.1	0.9197	0.31 (0.46)
Medium Slope (D)	0.43 (0.49)	0.48 (0.5)	-1.59	0.1126	0.49 (0.5)	0.39 (0.49)	3.41	0.0007	0.4 (0.49)	0.49 (0.5)	-2.93	0.0035	0.44 (0.50)
Low Slope (D)	0.22 (0.41)	0.29 (0.45)	-2.37	0.0182	0.22 (0.42)	0.27 (0.44)	-1.65	0.0999	0.28 (0.45)	0.19 (0.39)	3.57	0.0004	0.24 (0.43)
High Degraded (D)	0.55 (0.5)	0.48 (0.5)	1.85	0.0652	0.5 (0.5)	0.55 (0.5)	-1.5	0.1343	0.56 (0.5)	0.49 (0.5)	2.28	0.0229	0.53 (0.50)
Moderately Degraded (D)	0.3 (0.46)	0.32 (0.47)	-0.56	0.5783	0.33 (0.47)	0.27 (0.45)	2.06	0.0397	0.27 (0.44)	0.35 (0.48)	-2.63	0.0087	0.30 (0.46)
Slightly Degraded (D)	0.16 (0.36)	0.2 (0.4)	-1.71	0.0878	0.16 (0.37)	0.18 (0.38)	-0.52	0.6065	0.17 (0.38)	0.17 (0.3)	0.21	0.8361	0.17 (0.38)
LANDUSE (PLOT)													
Rainfed Agric Field (D)	0.89 (0.31)	0.91 (0.28)	-1.03	0.3054	0.88 (0.32)	0.92 (0.26)	-2.29	0.0224	0.88 (0.32)	0.92 (0.27)	-2.21	0.0277	0.90 (0.30)
Dambo Field (D)	0.1 (0.3)	0.09 (0.28)	0.88	0.3797	0.11 (0.32)	0.08 (0.26)	2.11	0.0354	0.11 (0.09)	0.08 (0.27)	2.03	0.0431	0.10 (0.30)
Grain & Legume Crops (D)	0.87 (0.32)	0.94 (0.24)	-2.95	0.0032	0.88 (0.32)	0.93 (0.26)	-2.33	0.0201	0.9 (0.3)	0.9 (0.29)	-0.07	0.946	0.90 (0.30)
Vegetable Crops (D)	0.08 (0.27)	0.05 (0.21)	2.23	0.026	0.07 (0.26)	0.06 (0.24)	0.7335	0.4634	0.09 (0.28)	0.05 (0.21)	2.47	0.0137	0.07 (0.25)
Potato Crops (D)	0.02 (0.16)	0.01 (0.08)	2.55	0.0109	0.03 (0.16)	0.01 (0.09)	2.27	0.0233	0.01 (0.07)	0.03 (0.18)	-3.23	0.0013	0.02 (0.14)
INSTITUTIONAL FACTORS													
Customary Allocated with Documented Agreement (D)	0.48 (0.5)	0.53 (0.5)	-1.61	0.1082	0.48 (0.5)	0.52 (0.5)	-1.28	0.1997	0.52 (0.5)	0.48 (0.5)	1.36	0.1726	0.50 (0.50)
Customary Allocated without Documented Agreement (D)	0.45 (0.5)	0.44 (0.5)	0.51	0.6079	0.46 (0.5)	0.44 (0.5)	0.51	0.6119	0.42 (0.49)	0.48 (0.5)	-2	0.0456	0.45 (0.50)
Customary Allocated (D)	0.94 (0.25)	0.97 (0.16)	-2.83	0.0047	0.94 (0.24)	0.96 (0.19)	-1.79	0.0744	0.94 (0.24)	0.96 (0.2)	-1.43	0.1522	0.95 (0.22)
Customary Unallocated Land (D)	0.001 (0.04)	0.003 (0.06)	-0.47	0.6391	0 (0)	0.004 (0.07)	-1.42	0.1575	0.002 (0.04)	0.002 (0.05)	-0.13	0.893	0.002 (0.04)
Leasehold with some form of legal document (D)	0.05 (0.21)	0.02 (0.14)	2.13	0.0338	0.04 (0.2)	0.03 (0.17)	1.12	0.2616	0.05 (0.22)	0.02 (0.15)	2.48	0.0133	0.04 (0.19)
Public Land (D)	0.02 (0.13)	0.003 (0.06)	2.47	0.0138	0.02 (0.14)	0.004 (0.07)	2.33	0.0199	0.009 (0.09)	0.017 (0.13)	-1.15	0.2489	0.01 (0.11)
Inherited (D)	0.54 (0.5)	0.56 (0.5)	-0.69	0.4944	0.57 (0.5)	0.52 (0.5)	1.62	0.1058	0.52 (0.5)	0.57 (0.5)	-1.57	0.117	0.54 (0.50)
Allocated by Family Member (D)	0.23 (0.42)	0.24 (0.43)	-0.39	0.6932	0.21 (0.41)	0.26 (0.44)	-1.68	0.0926	0.23 (0.42)	0.23 (0.42)	0.11	0.9141	0.23 (0.42)
Allocated by Local Leader (D)	0.16 (0.36)	0.13 (0.34)	1.15	0.2503	0.14 (0.34)	0.16 (0.37)	-1.25	0.2109	0.14 (0.35)	0.15 (0.36)	-0.48	0.6318	0.15 (0.36)
Purchased (D)	0.01 (0.09)	0.01 (0.08)	0.22	0.8223	0.01 (0.07)	0.01 (0.09)	-0.6	0.5474	0.01 (0.11)	0 (0)	2.66	0.0080	0.01 (0.08)
Rented or Borrowed (D)	0.05 (0.21)	0.05 (0.21)	0.08	0.9402	0.05 (0.22)	0.04 (0.19)	1.04	0.2968	0.05 (0.22)	0.04 (0.19)	0.99	0.3230	0.05 (0.21)
ADDITIONAL HARVESTED PRODUCTS													
Additional Harvest (D)	0.49 (0.5)	0.61 (0.49)	-3.72	0.0002	0.54 (0.5)	0.52 (0.5)	0.36	0.7175	0.54 (0.5)	0.52 (0.5)	0.73	0.4685	0.53 (0.50)
NTFPs (D)	0.18 (0.38)	0.24 (0.43)	-2.3	0.0218	0.2 (0.4)	0.19 (0.39)	0.35	0.7236	0.21 (0.41)	0.18 (0.39)	1.19	0.2358	0.20 (0.40)
Timber (D)	0.03 (0.16)	0.06 (0.24)	-2.54	0.0115	0.05 (0.22)	0.03 (0.16)	1.95	0.0515	0.01 (0.1)	0.07 (0.26)	-4.76	0.0000	0.04 (0.19)
Firewood (D)	0.41 (0.49)	0.53 (0.5)	-3.57	0.0004	0.44 (0.5)	0.45 (0.5)	-0.36	0.7214	0.42 (0.49)	0.47 (0.5)	-1.6	0.1105	0.45 (0.50)
RELATIVE IMPORTANCE (COGNITIVE FACTORS)													
High for Food Security (D)	0.56 (0.5)	0.53 (0.5)	0.93	0.3545	0.48 (0.5)	0.63 (0.48)	-4.85	0.0000	0.54 (0.5)	0.55 (0.5)	-0.26	0.7983	0.55 (0.50)
High for Energy needs (D)	0.14 (0.35)	0.22 (0.41)	-2.94	0.0034	0.18 (0.38)	0.15 (0.37)	1.15	0.2497	0.09 (0.29)	0.25 (0.43)	-6.71	0.0000	0.16 (0.37)
High for Climate Change A&M	0.3 (0.46)	0.4 (0.49)	-3.18	0.0016	0.34 (0.48)	0.32 (0.47)	0.9	0.3678	0.33 (0.47)	0.34 (0.47)	-0.48	0.6302	0.33 (0.47)
High for Income Source (D)	0.42 (0.49)	0.43 (0.5)	-0.44	0.6281	0.47 (0.5)	0.36 (0.48)	3.5	0.0005	0.36 (0.48)	0.5 (0.5)	-4.68	0.0000	0.42 (0.49)

RP= Restoration Practice; (D) = Dummy variable; SD in brackets; bolded p-values show significance at either 0.1%; 1%, 5%, and 10%

Table 3-B. Description, unit, and summary means of potential variables to include in the model for collective-level restoration

Variables	RA1: Tree Planting activities				RA2: Natural Regeneration activities				RA3: Forest Protection activities				Full sample
	NO (n=85)	YES n=238)	t test	P-value	NO (n=85)	YES (n=238)	t test	P-value	NO (n=35)	YES n=288)	t test	P-value	Mean
SOCIOCULTURAL													
Age (Years)	44.05 (13.88)	45.4 (13.35)	-0.78	0.436	44.92 (14.47)	45.09 (13.15)	-0.1	0.9222	44.4 (14.02)	45.12 (13.44)	-0.29	0.7731	45.05 (13.48)
Gender (D)	0.93 (0.26)	0.84 (0.37)	2.43	0.0161	0.86 (0.35)	0.87 (0.34)	-0.15	0.8787	0.86 (0.36)	0.86 (0.34)	-0.12	0.907	0.86 (0.34)
Educated (D)	0.8 (0.4)	0.77 (0.42)	0.52	0.6018	0.82 (0.38)	0.76 (0.42)	1.18	0.2401	0.77 (0.43)	0.78 (0.41)	-0.13	0.8978	0.78 (0.41)
Chewa Ethnicity (D)	0.89 (0.31)	0.71 (0.45)	4.12	0.0001	0.59 (0.49)	0.82 (0.39)	-3.9	0.0002	0.83 (0.38)	0.75 (0.43)	1.13	0.2642	0.76 (0.43)
SOCIAL CAPITAL - ASSOCIATION/GROUP/COOPERATIVE													
Membership (D)	0.14 (0.35)	0.26 (0.44)	-2.43	0.0161	0.16 (0.37)	0.25 (0.43)	-1.69	0.0929	0.23 (0.43)	0.23 (0.42)	0.04	0.97	0.23 (0.42)
Environment Type Activity other than resources restoration (D)	0.02 (0.15)	0.03 (0.18)	-0.5	0.6193	0.01 (0.11)	0.04 (0.19)	-1.52	0.1285	0.03 (0.17)	0.03 (0.17)	-0.09	0.9301	0.03 (0.17)
Social Type Activity (D)	0.04 (0.19)	0.06 (0.24)	-1.08	0.2797	0.01 (0.11)	0.07 (0.26)	-2.92	0.0038	0.06 (0.24)	0.06 (0.23)	0.04	0.9701	0.06 (0.23)
Economic Type Activity & VSL (D)	0.11 (0.31)	0.19 (0.4)	-2.07	0.0399	0.14 (0.35)	0.18 (0.39)	-0.87	0.3864	0.17 (0.38)	0.17 (0.38)	0.02	0.985	0.17 (0.38)
LOCATION													
Ntchisi DISTRICT (D)	0.76 (0.43)	0.55 (0.5)	3.72	0.0003	0.44 (0.5)	0.67 (0.47)	-3.82	0.0002	0.69 (0.47)	0.6 (0.49)	1	0.321	0.61 (0.49)
Kachindamoto TA (D)	0.11 (0.31)	0.27 (0.44)	-3.69	0.0003	0.22 (0.42)	0.23 (0.42)	-0.06	0.9495	0.2 (0.41)	0.23 (0.42)	-0.4	0.6012	0.23 (0.42)
Kamenyagwaza TA (D)	0.13 (0.34)	0.18 (0.38)	-1.06	0.2886	0.34 (0.48)	0.1 (0.3)	4.35	0.0000	0.11 (0.32)	0.17 (0.38)	-0.95	0.3479	0.16 (0.37)
Kasakula TA (D)	0.29 (0.46)	0.25 (0.44)	0.74	0.4635	0.19 (0.39)	0.29 (0.45)	-1.96	0.0515	0.37 (0.49)	0.25 (0.43)	1.4	0.1689	0.26 (0.44)
Nthondo TA (D)	0.35 (0.48)	0.18 (0.38)	3.06	0.0027	0.21 (0.41)	0.23 (0.42)	-0.29	0.7725	0.23 (0.43)	0.22 (0.42)	0.08	0.9339	0.22 (0.42)
Vuso Jere TA (D)	0.12 (0.32)	0.13 (0.33)	-0.2	0.8388	0.04 (0.19)	0.16 (0.36)	-3.88	0.0001	0.09 (0.28)	0.13 (0.34)	-0.82	0.4143	0.12 (0.33)
RELATIVE IMPORTANCE (COGNITIVE FACTORS)													
High for Food Security (D)	0.02 (0.15)	0.004 (0.06)	1.13	0.2602	0.02 (0.15)	0.004 (0.06)	1.13	0.2602	0.06 (0.24)	0.003 (0.06)	1.34	0.188	0.01 (0.10)
High for Energy needs (D)	0.26 (0.44)	0.32 (0.47)	-1.07	0.2865	0.27 (0.45)	0.32 (0.47)	-0.78	0.4366	0.14 (0.36)	0.32 (0.47)	-2.73	0.0088	0.30 (0.46)
High for Climate Change A&M (D)	0.88 (0.32)	0.89 (0.31)	-0.31	0.7555	0.89 (0.31)	0.89 (0.31)	0.09	0.9318	0.74 (0.44)	0.91 (0.29)	-2.17	0.0362	0.89 (0.31)
High for Income Source (D)	0.06 (0.24)	0.06 (0.24)	0	1	0.08 (0.28)	0.05 (0.22)	0.96	0.3379	0.06 (0.24)	0.06 (0.24)	-0.04	0.9646	0.06 (0.24)
Good Leadership Authority (D)	0.81 (0.39)	0.82 (0.39)	-0.15	0.8786	0.75 (0.43)	0.84 (0.37)	-1.66	0.0999	0.86 (0.36)	0.81 (0.39)	0.69	0.4909	0.82 (0.39)
Bad Leadership Authority (D)	0.05 (0.21)	0.06 (0.24)	-0.42	0.6716	0.06 (0.24)	0.05 (0.23)	0.14	0.8874	0 (0)	0.06 (0.24)	-4.37	0.0000	0.06 (0.23)
ADDITIONAL BENEFITS													
NTFPs (D)	0.41 (0.5)	0.26 (0.44)	2.49	0.0141	0.26 (0.44)	0.32 (0.47)	-1.00	0.3207	0.23 (0.43)	0.31 (0.46)	-1.04	0.3017	0.30 (0.46)
Firewood (D)	0.59 (0.5)	0.58 (0.5)	0.2	0.8406	0.54 (0.5)	0.59 (0.49)	-0.81	0.4175	0.34 (0.48)	0.61 (0.49)	-3.07	0.0037	0.58 (0.49)
Timber (D)	0.12 (0.32)	0.14 (0.35)	-0.5	0.6152	0.18 (0.38)	0.12 (0.32)	1.26	0.2087	0.06 (0.24)	0.14 (0.35)	-1.9	0.0625	0.13 (0.34)
Free time/areas for Grazing (Pasture) (D)	0.01 (0.11)	0.01 (0.09)	0.26	0.799	0 (0)	0.01 (0.11)	-1.74	0.0833	0.03 (0.17)	0.01 (0.08)	0.75	0.4605	0.01 (0.10)
Some Resources use rights (D)	0.08 (0.28)	0.03 (0.17)	1.66	0.1003	0.01 (0.11)	0.05 (0.23)	-2.27	0.0239	0 (0)	0.04 (0.22)	-3.83	0.0002	0.04 (0.20)
Actions for Community Development (D)	0.02 (0.15)	0.01 (0.11)	0.61	0.5463	0.01 (0.11)	0.02 (0.13)	-0.35	0.7271	0 (0)	0.02 (0.13)	-2.25	0.0251	0.02 (0.12)
Cash Money	0.01 (0.11)	0.05 (0.21)	-1.91	0.0568	0.08 (0.28)	0.02 (0.14)	1.95	0.0536	0.06 (0.24)	0.03 (0.18)	0.54	0.5898	0.04 (0.19)
No gained benefits (D)	0.27 (0.45)	0.33 (0.47)	-1.07	0.2861	0.26 (0.44)	0.34 (0.47)	-1.36	0.1753	0.49 (0.51)	0.3 (0.46)	2.12	0.0399	0.32 (0.47)

RA= Restoration Activity; (D) = Dummy variable; SD in brackets; bolded p-values show significance at either 0.1%; 1%, 5%, and 10%

Table 3-B. (cont'd)

Variables	RA4: Activities of Awareness about tree cutting				RA5: Firebreak activities				RA6: Other restoration activities				Full sample
	NO (n=142)	YES	t test	P-value	NO (n=28)	YES (n=295)	t test	P-value	NO (n= 250)	YES (n=73)	t test	P-value	Mean
SOCIOCULTURAL													
Age (Years)	44.46 (14)	45.5 (13.08)	-0.68	0.4967	44.43 (12.71)	45.1 (13.57)	-0.27	0.7906	45.13 (13.56)	44.77 (13.32)	0.2	0.84	45.05 (13.48)
Gender (D)	0.89 (0.31)	0.84 (0.37)	1.45	0.1481	0.71 (0.46)	0.88 (0.33)	-1.84	0.0759	0.86 (0.35)	0.88 (0.33)	-0.38	0.7082	0.86 (0.34)
Educated (D)	0.84 (0.37)	0.73 (0.44)	2.28	0.0231	0.71 (0.46)	0.79 (0.41)	-0.8	0.4296	0.8 (0.4)	0.73 (0.45)	1.2	0.2337	0.78 (0.41)
Chewa Ethnicity (D)	0.78 (0.41)	0.74 (0.44)	0.87	0.3869	0.82 (0.39)	0.75 (0.43)	0.88	0.3826	0.8 (0.4)	0.62 (0.49)	2.93	0.0042	0.76 (0.43)
SOCIAL CAPITAL - ASSOCIATION/GROUP/COOPERATIVE													
Membership (D)	0.29 (0.45)	0.18 (0.38)	2.35	0.0194	0.43 (0.5)	0.21 (0.41)	2.26	0.0311	0.26 (0.44)	0.12 (0.33)	2.79	0.006	0.23 (0.42)
Environment Type Activity other than resources restoration (D)	0.07 (0.23)	0.01 (0.1)	2.16	0.0317	0 (0)	0.03 (0.18)	-3.21	0.0015	0.04 (0.19)	0.01 (0.12)	1.23	0.219	0.03 (0.17)
Social Type Activity (D)	0.08 (0.28)	0.03 (0.18)	1.91	0.0580	0.11 (0.31)	0.05 (0.22)	0.92	0.3626	0.06 (0.24)	0.04 (0.20)	0.68	0.4979	0.06 (0.23)
Economic Type Activity & VSL (D)	0.20 (0.40)	0.14 (0.35)	1.41	0.1585	0.36 (0.49)	0.15 (0.36)	2.16	0.0386	0.20 (0.40)	0.07 (0.25)	3.36	0.0009	0.17 (0.38)
LOCATION													
Ntchisi DISTRICT (D)	0.61 (0.49)	0.61 (0.49)	0.09	0.9283	0.79 (0.42)	0.59 (0.49)	2.29	0.0281	0.67 (0.47)	0.4 (0.49)	4.23	0.0000	0.61 (0.49)
Kachindamoto TA (D)	0.23 (0.42)	0.23 (0.42)	-0.02	0.9802	0.14 (0.36)	0.23 (0.42)	-1.27	0.2127	0.17 (0.38)	0.41 (0.5)	-3.81	0.0002	0.23 (0.42)
Kamenyagwaza TA (D)	0.16 (0.37)	0.17 (0.37)	-0.09	0.9278	0.07 (0.26)	0.17 (0.38)	-1.87	0.0689	0.16 (0.36)	0.19 (0.4)	-0.69	0.491	0.16 (0.37)
Kasakula TA (D)	0.26 (0.44)	0.27 (0.44)	-0.09	0.9255	0.5 (0.51)	0.25 (0.430	2.61	0.0139	0.3 (0.46)	0.15 (0.36)	2.84	0.0051	0.26 (0.44)
Nthondo TA (D)	0.22 (0.41)	0.23 (0.42)	-0.18	0.8607	0.21 (0.42)	0.22 (0.42)	-0.11	0.9097	0.22 (0.42)	0.22 (0.42)	0.09	0.9309	0.22 (0.42)
Vuso Jere TA (D)	0.13 (0.34)	0.12 (0.32)	0.48	0.634	0.07 (0.26)	0.13 (0.34)	-1.08	0.2885	0.15 (0.36)	0.03 (0.16)	4.18	0.000	0.12 (0.33)
RELATIVE IMPORTANCE (COGNITIVE FACTORS)													
High for Food Security (D)	0.01 (0.08)	0.01 (0.1)	-0.38	0.703	0.04 (0.19)	0.01 (0.08)	0.8	0.4287	0.01 (0.11)	0 (0)	1.74	0.0833	0.01 (0.10)
High for Energy needs (D)	0.23 (0.42)	0.36 (0.48)	-2.51	0.0125	0.18 (0.39)	0.32 (0.47)	-1.74	0.0905	0.28 (0.45)	0.4 (0.49)	-1.89	0.0618	0.30 (0.46)
High for Climate Change A&M (D)	0.87 (0.34)	0.91 (0.28)	-1.27	0.2036	0.61 (0.5)	0.92 (0.27)	-3.27	0.0028	0.89 (0.31)	0.89 (0.31)	0.04	0.9697	0.89 (0.31)
High for Income Source (D)	0.04 (0.18)	0.08 (0.27)	-1.67	0.0961	0.07 (0.26)	0.06 (0.23)	0.27	0.79	0.03 (0.18)	0.15 (0.36)	-2.72	0.0079	0.06 (0.24)
Good Leadership of local Authority (D)	0.76 (0.43)	0.86 (0.35)	-2.29	0.0226	0.75 (0.44)	0.82 (0.38)	-0.85	0.3991	0.79 (0.41)	0.9 (0.3)	-2.6	0.0103	0.82 (0.39)
Bad Leadership of local Authority (D)	0.08 (0.27)	0.04 (0.19)	1.45	0.1477	0 (0)	0.06 (0.24)	-4.37	0.0000	0.06 (0.23)	0.05 (0.23)	0.04	0.9686	0.06 (0.23)
ADDITIONAL BENEFITS													
NTFPs (D)	0.3 (0.46)	0.3 (0.46)	-0.16	0.8752	0.18 (0.39)	0.31 (0.46)	-1.7	0.0983	0.3 (0.46)	0.3 (0.46)	-0.02	0.9822	0.30 (0.46)
Firewood (D)	0.61 (0.49)	0.55 (0.5)	1.09	0.2771	0.32 (0.48)	0.6 (0.49)	-2.99	0.0052	0.59 (0.49)	0.53 (0.5)	0.87	0.3871	0.58 (0.49)
Timber (D)	0.18 (0.39)	0.09 (0.29)	2.28	0.0236	0.07 (0.26)	0.14 (0.35)	-1.26	0.2146	0.14 (0.35)	0.11 (0.31)	0.71	0.4795	0.13 (0.34)
Free time/areas for Grazing (Pasture) (D)	0 (0)	0.02 (0.13)	-1.74	0.0833	0.04 (0.19)	0.01 (0.08)	0.8	0.4287	0.004 (0.06)	0.03 (0.16)	-1.19	0.2373	0.01 (0.10)
Some Resources use rights (D)	0.06 (0.23)	0.03 (0.18)	0.98	0.3259	0 (0)	0.05 (0.21)	-3.83	0.0002	0.05 (0.22)	0.01 (0.12)	1.95	0.0523	0.04 (0.20)
Actions for Community Development (D)	0.03 (0.17)	0.01 (0.07)	1.51	0.1326	0 (0)	0.02 (0.13)	-2.25	0.0251	0.02 (0.14)	0 (0)	2.25	0.0251	0.02 (0.12)
Cash Money	0.01 (0.12)	0.06 (0.23)	-2.09	0.0376	0.04 (0.19)	0.04 (0.19)	-0.04	0.9667	0.02 (0.15)	0.08 (0.28)	-1.72	0.0887	0.04 (0.19)
No gained benefits (D)	0.31 (0.46)	0.32 (0.47)	-0.2	0.8395	0.43 (0.5)	0.31 (0.46)	1.25	0.2212	0.32 (0.47)	0.32 (0.48)	0.02	0.9881	0.32 (0.47)

RA= Restoration Activity; (D) = Dummy variable; SD in brackets; bolded p-values show significance at either 0.1%; 1%, 5%, and 10%

Table 3-C. Side-by-side Multivariate and Univariates tobit results of the extent of restoration in agrarian landscapes in Central Malawi

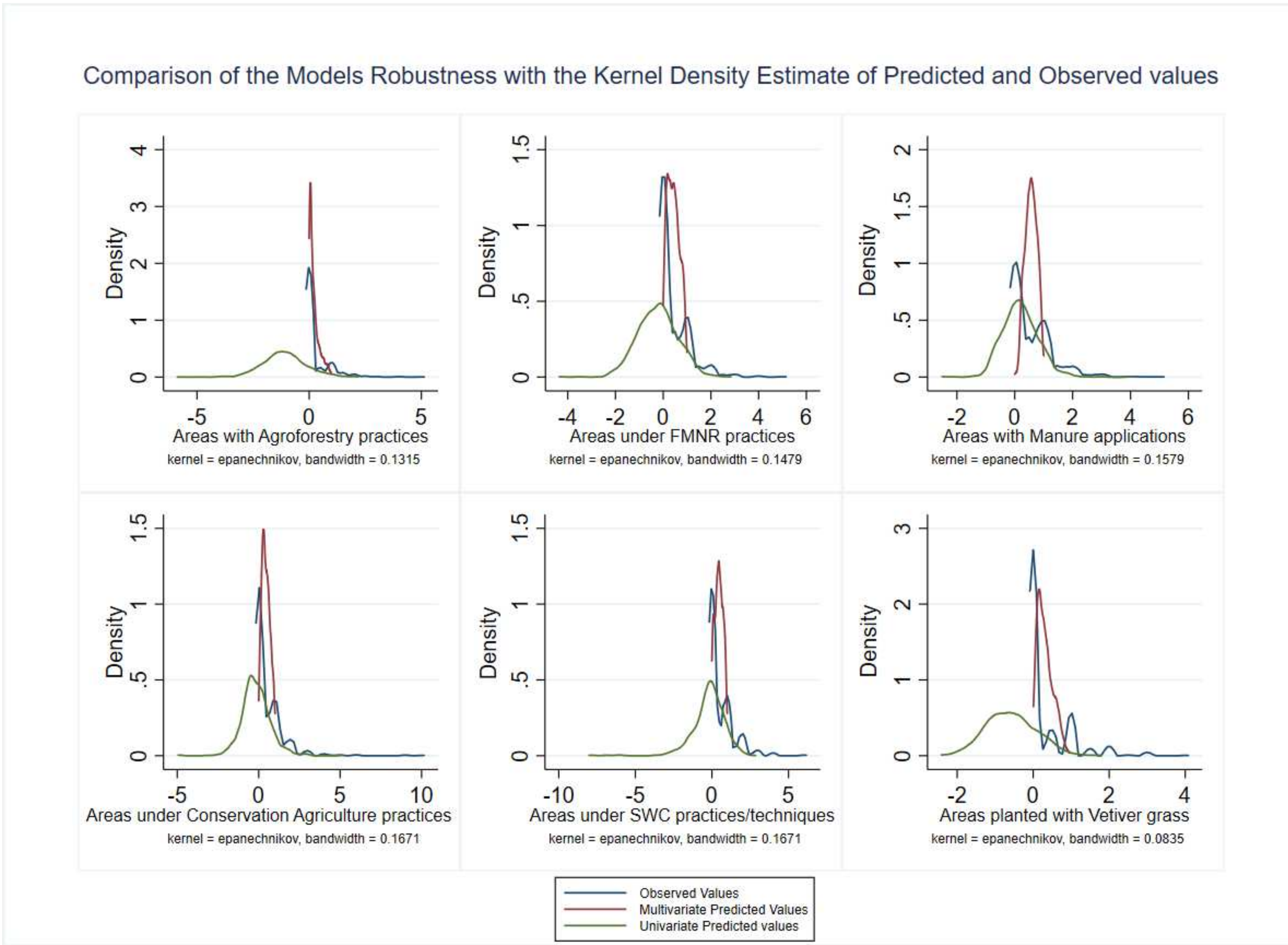
VARIABLES	MULTIVARIATE MODEL						UNIVARIATE MODELS					
	Agroforestry	FMNR	Manure	CA	SWC	Vetiver Grass	Agroforestry	FMNR	Manure	CA	SWC	Vetiver Grass
Gender of the Household Head (1=Male, 0=Female)	0.150	0.0896	-0.0193	0.183	0.783***	-0.146	0.198	0.0863	-0.0215	0.191	0.786***	-0.143
= 1, Male	(0.185)	(0.118)	(0.0920)	(0.147)	(0.157)	(0.153)	(0.188)	(0.121)	(0.0924)	(0.151)	(0.157)	(0.152)
Age (Years)	-0.00617	0.00275	0.00267	0.000375	0.00952*	0.00753	-0.00633	0.00276	0.00299	0.000210	0.0101*	0.00766
	(0.00591)	(0.00413)	(0.00348)	(0.00524)	(0.00522)	(0.00515)	(0.00590)	(0.00408)	(0.00349)	(0.00527)	(0.00524)	(0.00521)
Education (1= Educated, 0=Not Educated) = 1,	0.113	0.108	0.220**	0.0242	-0.0815	0.230*	0.0878	0.109	0.228***	0.0368	-0.0790	0.208
Educated	(0.158)	(0.0997)	(0.0871)	(0.126)	(0.128)	(0.131)	(0.159)	(0.101)	(0.0875)	(0.128)	(0.128)	(0.130)
Association with Environmental Activities other than	0.603*	0.176	0.0962	0.389	-1.633***	-0.520	0.582*	0.197	0.103	0.353	-1.672***	-0.477
resources restoration (1=yes, 0=no) = 1, Yes	(0.321)	(0.241)	(0.171)	(0.271)	(0.553)	(0.343)	(0.323)	(0.243)	(0.171)	(0.277)	(0.597)	(0.339)
Association with Social Activities (1=yes, 0=no) = 1,	-0.112	0.128	0.256**	0.222	0.313	0.269	-0.0769	0.158	0.257**	0.217	0.293	0.277
Yes	(0.267)	(0.187)	(0.129)	(0.214)	(0.211)	(0.213)	(0.265)	(0.187)	(0.129)	(0.214)	(0.212)	(0.214)
Association with Economic Activities & VSL (1=yes,	0.413**	0.203*	0.345***	0.528***	-0.710***	-0.0736	0.425***	0.212*	0.350***	0.533***	-0.693***	-0.0796
0=no) = 1, Yes	(0.163)	(0.114)	(0.0858)	(0.125)	(0.143)	(0.140)	(0.163)	(0.114)	(0.0859)	(0.127)	(0.143)	(0.141)
Number of Active Household Member (Count)	-0.0180	-0.0365	0.00237	-0.0528	0.00851	0.107***	-0.0212	-0.0331	0.00277	-0.0580*	0.00774	0.110***
	(0.0384)	(0.0265)	(0.0218)	(0.0332)	(0.0321)	(0.0317)	(0.0387)	(0.0266)	(0.0219)	(0.0335)	(0.0323)	(0.0315)
External Labor Use (Count)	0.0446***	0.00716	-0.00336	-0.0294**	0.00390	-0.000856	0.0437***	0.00672	-0.00413	-0.0340**	0.00309	-0.000596
	(0.0146)	(0.0103)	(0.00914)	(0.0143)	(0.0123)	(0.0137)	(0.0146)	(0.0104)	(0.00919)	(0.0152)	(0.0124)	(0.0137)
Total Farmlands (Acres)	0.0585	-0.00735	-0.0933**	0.0220	-0.132**	-0.0738	0.0612	-0.00424	-0.0969**	0.0271	-0.128**	-0.0705
	(0.0711)	(0.0466)	(0.0442)	(0.0605)	(0.0613)	(0.0597)	(0.0725)	(0.0466)	(0.0445)	(0.0617)	(0.0609)	(0.0589)
Number of Plots (Count)	-0.299***	0.0341	0.0274	-0.0678	0.132*	0.231***	-0.312***	0.0313	0.0294	-0.0780	0.132*	0.226***
	(0.0948)	(0.0568)	(0.0474)	(0.0700)	(0.0740)	(0.0765)	(0.0966)	(0.0574)	(0.0476)	(0.0708)	(0.0738)	(0.0763)
Livestock: Ruminants & Pigs (Count)	-0.00303	0.00124	0.0116	0.000243	0.0164	0.0286**	-0.00341	0.000565	0.0110	0.000560	0.0147	0.0266*
	(0.0166)	(0.0115)	(0.0110)	(0.0164)	(0.0143)	(0.0146)	(0.0166)	(0.0117)	(0.0111)	(0.0165)	(0.0142)	(0.0144)
Livestock: Poultry (Count)	0.00791	-0.00576	0.00131	-0.000273	0.00717	0.0122*	0.00864	-0.00565	0.00128	-0.000805	0.00688	0.0126*
	(0.00759)	(0.00544)	(0.00379)	(0.00633)	(0.00597)	(0.00699)	(0.00736)	(0.00542)	(0.00375)	(0.00634)	(0.00590)	(0.00689)
Off Farm Income (1=yes, 0=no) = 1, Yes	-0.0662	-0.0523	-0.118	0.200*	0.0253	-0.175	-0.0735	-0.0611	-0.122	0.206*	0.0515	-0.172
	(0.144)	(0.0985)	(0.0826)	(0.118)	(0.123)	(0.124)	(0.146)	(0.0997)	(0.0827)	(0.118)	(0.123)	(0.125)
Kachindamoto Traditional Authority Area (1=yes,	0.668***	0.136	0.0374	0.642***	0.136	0.601***	0.700***	0.152	0.0396	0.642***	0.155	0.631***
0=no) = 1, Yes	(0.233)	(0.134)	(0.118)	(0.218)	(0.166)	(0.199)	(0.235)	(0.137)	(0.119)	(0.221)	(0.167)	(0.200)
Kamenyagwaza Traditional Authority Area (1=yes,	0.105	-0.390**	-0.224*	0.637***	-0.0125	-0.0704	0.131	-0.366**	-0.223*	0.607***	0.00959	-0.0463
0=no) = 1, Yes	(0.256)	(0.158)	(0.133)	(0.224)	(0.176)	(0.229)	(0.258)	(0.160)	(0.133)	(0.226)	(0.177)	(0.230)
Kassakula Traditional Authority Area (1=yes, 0=no) =	-0.157	-0.264*	-0.177	0.605***	-0.395***	0.466**	-0.135	-0.243*	-0.170	0.616***	-0.374**	0.485**
1, Yes	(0.237)	(0.138)	(0.116)	(0.191)	(0.152)	(0.196)	(0.241)	(0.140)	(0.116)	(0.194)	(0.153)	(0.198)
Nthondo Traditional Authority Area (1=yes, 0=no) =	-0.0406	-0.727***	0.0465	0.451**	-0.621***	-0.165	-0.0406	-0.735***	0.0366	0.431**	-0.591***	-0.157
1, Yes	(0.233)	(0.148)	(0.117)	(0.196)	(0.160)	(0.210)	(0.239)	(0.151)	(0.117)	(0.200)	(0.160)	(0.214)
Household Head is the plot manager (1=yes,0=no) =	-0.0213	0.219*	0.195*	-0.0349	0.0470	0.210	-0.00874	0.205*	0.195*	-0.00290	0.0764	0.228
1, Yes	(0.181)	(0.120)	(0.110)	(0.168)	(0.159)	(0.155)	(0.181)	(0.119)	(0.109)	(0.170)	(0.161)	(0.157)
Number of Years of utilization of the plot	0.0104	-0.00802*	-0.00296	0.00548	-0.00341	-0.00210	0.0110	-0.00757*	-0.00292	0.00535	-0.00307	-0.00183
	(0.00671)	(0.00448)	(0.00370)	(0.00599)	(0.00589)	(0.00570)	(0.00668)	(0.00449)	(0.00370)	(0.00602)	(0.00586)	(0.00570)
Distance Plot to household (Km)	-0.141***	-0.105***	-0.0888***	-0.208***	0.111***	0.00781	-0.145***	-0.105***	-0.0893***	-0.205***	0.109***	0.00954
	(0.0528)	(0.0304)	(0.0249)	(0.0443)	(0.0235)	(0.0300)	(0.0544)	(0.0311)	(0.0253)	(0.0456)	(0.0235)	(0.0297)
Plot size (Acres)	0.403**	0.552***	0.671***	0.851***	0.662***	0.442***	0.405**	0.553***	0.679***	0.852***	0.674***	0.446***
	(0.160)	(0.129)	(0.140)	(0.197)	(0.152)	(0.144)	(0.162)	(0.129)	(0.140)	(0.199)	(0.151)	(0.141)
Plot is on high slope (1=yes,0=no), = 1, Yes	0.0734	-0.0438	0.00548	0.455***	-0.0639	-0.354***	0.0716	-0.0443	0.00293	0.446***	-0.0638	-0.358***
	(0.149)	(0.0998)	(0.0826)	(0.132)	(0.117)	(0.133)	(0.151)	(0.101)	(0.0827)	(0.134)	(0.117)	(0.134)
Plot is on low slope (1=yes,0=no), = 1, Yes	-0.0858	-0.131	0.0789	0.285**	-0.628***	-0.172	-0.0751	-0.120	0.0775	0.299**	-0.638***	-0.161
	(0.159)	(0.0947)	(0.0855)	(0.132)	(0.134)	(0.123)	(0.159)	(0.0941)	(0.0858)	(0.132)	(0.134)	(0.122)
Plot land is perceived as highly degraded (1=yes,	0.259*	0.194**	0.166**	-0.0539	-0.246**	-0.0877	0.260*	0.185**	0.171**	-0.0423	-0.245**	-0.0784
0=no), = 1, Yes	(0.140)	(0.0907)	(0.0767)	(0.124)	(0.112)	(0.117)	(0.142)	(0.0909)	(0.0773)	(0.125)	(0.113)	(0.118)
Plot land is perceived as slightly degraded (1=yes,	0.145	-0.0231	-0.150	-0.0517	-0.157	0.239	0.152	-0.0188	-0.140	-0.0530	-0.147	0.242
0=no), = 1, Yes	(0.190)	(0.129)	(0.107)	(0.164)	(0.144)	(0.148)	(0.191)	(0.130)	(0.107)	(0.166)	(0.143)	(0.148)
Land Type: Main rain-fed Agriculture field (1=yes,	0.260	0.115	0.108	0.595	0.357	0.0641	0.297	0.124	0.127	0.559	0.379	0.0850
0=no), = 1, Yes	(0.374)	(0.247)	(0.228)	(0.378)	(0.266)	(0.228)	(0.391)	(0.250)	(0.236)	(0.379)	(0.264)	(0.236)
Land use: Fresh vegetables Garden (1=yes, 0=no),	0.0979	0.205	0.604***	0.739**	-0.243	-0.313	0.110	0.199	0.621***	0.720*	-0.239	-0.303
= 1, Yes	(0.424)	(0.264)	(0.217)	(0.370)	(0.285)	(0.287)	(0.431)	(0.262)	(0.222)	(0.370)	(0.285)	(0.292)
Plot Tenure: Customary Allocated land with	0.765***	0.861***	-0.00470	0.259**	0.0124	0.282**	0.763***	0.881***	-0.00775	0.240**	-0.00392	0.273**
documented letter/agreement (1=yes,0=no) = 1, Yes	(0.139)	(0.0927)	(0.0743)	(0.115)	(0.109)	(0.117)	(0.140)	(0.0931)	(0.0744)	(0.115)	(0.110)	(0.117)
Plot Tenure: Leasehold land with some form of legal	0.198	0.702***	-0.230	-0.123	-0.193	-0.271	0.199	0.743***	-0.209	-0.174	-0.182	-0.281
document (1=yes,0=no) = 1, Yes	(0.343)	(0.178)	(0.175)	(0.258)	(0.264)	(0.294)	(0.350)	(0.178)	(0.173)	(0.262)	(0.261)	(0.301)
Plot Acquisition mode: Inherited land (1=yes,0=no) =	0.0862	0.353	-0.0685	0.492	1.605***	0.231	0.0602	0.333	-0.0663	0.434	1.334**	0.202
1, Yes	(0.496)	(0.256)	(0.248)	(0.342)	(0.512)	(0.331)	(0.491)	(0.247)	(0.248)	(0.337)	(0.541)	(0.325)

Table 3-C (cont'd)

VARIABLES	MULTIVARIATE MODEL						UNIVARIATE MODELS					
	Agroforestry	**FMNR**	**Manure**	**CA**	**SWC**	**Vetiver Grass**	**Agroforestry**	**FMNR**	**Manure**	**CA**	**SWC**	**Vetiver Grass**
Plot Acquisition mode: Land acquired from/allocated	0.261	0.175	-0.0671	0.410	1.927***	0.151	0.239	0.160	-0.0648	0.336	1.642***	0.117
by local leader (1=yes,0=no) = 1, Yes	(0.514)	(0.268)	(0.259)	(0.355)	(0.519)	(0.357)	(0.512)	(0.261)	(0.259)	(0.352)	(0.548)	(0.350)
Plot Acquisition mode: Purchased land	2.139***	1.032***	0.543	0.988*	-	0.132	2.141***	1.010***	0.572	0.966*	-5.516***	0.0256
(1=yes,0=no) = 1, Yes	(0.599)	(0.383)	(0.473)	(0.554)	-	(0.649)	(0.593)	(0.391)	(0.479)	(0.561)	(0.643)	(0.657)
Plot Acquisition mode: Rented or Borrowed Land	-0.328	0.129	-0.273	0.322	1.761***	0.153	-0.354	0.0981	-0.274	0.265	1.474**	0.0892
(1=yes,0=no) = 1, Yes	(0.650)	(0.348)	(0.289)	(0.405)	(0.552)	(0.397)	(0.646)	(0.341)	(0.287)	(0.401)	(0.576)	(0.395)
NTFPs as Additional Harvest (1=yes, 0=no), = 1,	0.105	0.407***	0.172**	-0.0135	-0.135	0.113	0.112	0.408***	0.166*	-0.00998	-0.125	0.127
Yes	(0.154)	(0.0953)	(0.0853)	(0.131)	(0.138)	(0.132)	(0.156)	(0.0959)	(0.0860)	(0.132)	(0.138)	(0.132)
Timber as Additional Harvest (1=yes, 0=no), = 1,	-0.226	0.226	0.0506	-0.647*	0.647***	0.719***	-0.227	0.244	0.0697	-0.636*	0.615***	0.697***
Yes	(0.370)	(0.236)	(0.188)	(0.345)	(0.211)	(0.260)	(0.370)	(0.237)	(0.187)	(0.347)	(0.206)	(0.259)
Firewood as Additional Harvest (1=yes, 0=no), = 1,	0.996***	0.862***	0.362***	0.0874	-0.0635	0.232**	1.008***	0.871***	0.358***	0.0935	-0.0594	0.227*
Yes	(0.136)	(0.0884)	(0.0735)	(0.120)	(0.119)	(0.117)	(0.137)	(0.0892)	(0.0743)	(0.122)	(0.119)	(0.117)
Plot land is perceived as highly important for Food	0.274*	0.0759	0.472***	0.490***	0.271**	-0.0392	0.274*	0.0735	0.474***	0.471***	0.259**	-0.0291
security (1=yes, 0=no), = 1, Yes	(0.140)	(0.0899)	(0.0803)	(0.120)	(0.114)	(0.116)	(0.142)	(0.0906)	(0.0815)	(0.121)	(0.114)	(0.116)
Plot land is perceived as highly important for Energy	0.0994	0.0323	-0.0592	0.0198	0.634***	0.00949	0.113	0.0326	-0.0582	0.0145	0.630***	0.00383
needs (1=yes, 0=no), = 1, Yes	(0.181)	(0.110)	(0.0992)	(0.164)	(0.144)	(0.146)	(0.183)	(0.111)	(0.100)	(0.166)	(0.144)	(0.146)
Plot land is perceived as highly important for Climate	0.0760	0.308***	0.178**	-0.135	-0.201	0.155	0.0491	0.308***	0.184**	-0.126	-0.185	0.177
Change A&M (1=yes, 0=no), = 1, Yes	(0.148)	(0.0922)	(0.0772)	(0.127)	(0.127)	(0.120)	(0.151)	(0.0934)	(0.0779)	(0.129)	(0.126)	(0.121)
Plot land is perceived as highly important for Income	0.0464	-0.0309	-0.0475	0.0139	0.563***	0.0212	0.0724	-0.0219	-0.0371	0.0234	0.573***	0.0341
(1=yes, 0=no), = 1, Yes	(0.139)	(0.0955)	(0.0799)	(0.123)	(0.121)	(0.119)	(0.142)	(0.0964)	(0.0807)	(0.124)	(0.122)	(0.118)
Constant	-2.575***	-2.206***	-1.249***	-2.931***	-3.686***	-3.003***	-2.630***	-2.238***	-1.304***	-2.833***	-3.529***	-3.056***
	(0.787)	(0.481)	(0.415)	(0.690)	(0.740)	(0.582)	(0.790)	(0.475)	(0.421)	(0.676)	(0.758)	(0.587)
/sigma (Univariates' estimated standard error terms)	-						1.836***	0.984***	0.816***	1.877***	1.530***	1.545***
							(0.147)	(0.0762)	(0.0672)	(0.228)	(0.132)	(0.112)
Likelihood-ratio test for all null correlations (atanhrho_12 = atanhrho_13 = atanhrho_14 = atanhrho_15 = atanhrho_16 = atanhrho_23 = atanhrho_24 = atanhrho_25 = atanhrho_26 = atanhrho_34 = atanhrho_35 = atanhrho_36 = atanhrho_45 = atanhrho_46 = atanhrho_56 = 0) : **LR chi2(15) = 139.42 (Prob > chi2 = 0.0000)**							-	-	-	-	-	-
Wald chi2 (281) Multivariate / F (40, 975) Univariates	1565.86						6.49	10.48	8.27	4.14	18.41	4.76
Prob > chi2 (Multivariate) / Prob>F (Univariates)	0.0000						0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Log pseudolikelihood	--5598.8352						-692.64644	-884.60756	-1039.1927	-1128.9417	-1050.6237	-862.19219
Pseudo R2 (Univariates)	-						0.1474	0.1801	0.1355	0.1051	0.1342	0.0904
Observations	1,015						1,015	1,015	1,015	1,015	1,015	1,015
Uncensored (Univariates)	-						245	422	548	463	459	329
Left-censored (Univariates)	-						770	593	467	552	556	686
Right-censored (Univariates)	-						0	0	0	0	0	0

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Figure 3-A. Comparison of the robustness of the multivariate and univariate Tobit models



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4 CHAPTER 4

Paper 3: Improving Representation of Decision Rules in LUCC-ABM: An Example with an Elicitation of Farmers' Decision Making for Landscape Restoration in Central Malawi

Abstract

Restoring interlocking forest-agricultural landscapes—*forest-agriscapes*—to sustainably supply ecosystem services for socio-ecological well-being is one of Malawi's priorities. Engaging local farmers is crucial in implementing restoration schemes. While farmers' land-use decisions shape land-use/cover and changes (LUCC) and ecological conditions, why and how farmers decide to embrace restoration activities is poorly understood and neglected in forest-agriscape restoration. Using mixed methods, we analyze the nature of farmers' restoration decisions in Central Malawi, both individually and collectively. We characterize, qualitatively and quantitatively, the underlying contextual rationales, motives, benefits, and incentives. Decision-making rules identified reflect diverse and nuanced goal frames of relative importance that are featured in various combinations. We categorize the decision-making rules as: problem-solving oriented, resource/material-constrained, benefit-oriented, incentive-based, peers/leaders-influenced, knowledge/skill-dependent, altruistic-oriented, rules/norms-constrained, economic capacity-dependent, awareness-dependent, and risk averse-oriented. We link them with the corresponding vegetation and non-vegetation-based restoration practices to depict the overall decision-making processes. Findings advance the representation of farmers' decision rules and behavioral responses in computational agent-based modeling (ABM) through the decomposition of empirical data. The approach used can inform other modeling works seeking to better capture social actors' decision rules. Such LUCC-ABMs are valuable for exploring spatially explicit outcomes of restoration investments by modeling such decision-making processes and policy scenarios.

Keywords: *Goal frames; Restoration, Decision-making rules; Decision-making processes; Mixed methods; Farmers; Central Malawi.*

4.1 Introduction

Restoring *forest-agriscapes* to address various environmental threats such as land degradation, deforestation, climate change, and to sustainably supply ecosystem services for socio-ecological well-being is increasingly embraced in Sub-Saharan Africa (SSA). *Forest-agriscapes* capture natural landscapes made of interspaced agricultural and forested lands—typical of rural areas in SSA—that should be managed holistically for landscape-scale restoration. Researchers stress that engaging local farmers and landowners is necessary for successful implementation of forest-agriscape restoration schemes (Mansourian, 2017). Local farmers' engagement with restoration occurs at both individual and collective levels and is often taken for granted or assumed to occur spontaneously. Yet, there is evidence of a low take-up of forest and land restoration by farmers (Galabuzi et al., 2014; Meijer et al., 2015; Cordingley et al., 2015). This suggests that common efforts in promoting restoration technologies and practices are inefficient. While farmers' land-use decisions contribute to shaping the associated environmental conditions (Villamor et al., 2014), the role of their decision making on forest-agriscapes restoration remain overlooked (Djenontin et al., 2018).

In Malawi, 39% of the total land area holds opportunities for household-level restoration on allocated or privately-owned customary lands. Another eight percent (8%) is suitable for collective restoration on unallocated communal lands and in woodlands to help meet food security, climate resilience, poverty alleviation, and energy needs (MNREM, 2017a&b). It is, therefore, essential to understand why (or why not) and how farmers decide to embrace restoration activities individually or collectively. Insights into these socio-environmental behaviors are key for farmer-centered restoration efforts. Incorporating socio-political and cultural considerations and choices that shape behaviors toward restoration (Wilson and Cagalanan, 2016) is necessary to understand farmers' needs in effective policy attempts to increase their engagement.

The goal of this study is to analyze the nature of the decisions to engage in restoration at individual (farm-household) level and in collective actions (community-level) in Central Malawi and depict the decision-making processes. We use a mixed-method approach with qualitative data from seven focus group discussions during which we introduced role-playing games, and quantitative data from a household survey of 480 participants in Dedza and Ntchisi districts. We examine the rationales, motives, benefits, and incentives that underlie farmers' restoration activities in selected forest-agriscapes. We characterize the restoration decision-making rules using combined insights from both qualitative and survey data. Emergent decision-making rules appear to be diverse, with nuanced goal frames reflecting environmental problems, livelihood needs and gains, constraints, socio-political influences, morals, values, and risk attitudes, all featured in various combinations.

Findings on the contextual reasons and the nature of the goal frames central to undertaking restoration practices and activities can offer insights for policy and programming, including identifying entry points to boost restoration efforts from a management perspective. Further, farmers' restoration decision-making rules constitute an important input for representing agents' decisions in computational agent-based models (ABMs) that explore outcomes of restoration investments by simulating such social processes and predicting the effects of different scenarios. The identified decision-making rules linked to the corresponding social actors' actions (specific restoration activities and practices) provide the overall decision-making processes to encode into a land-use/cover and change (LUCC)-ABM. These rules can substitute the often-ad hoc representation of human decisions in LUCC-ABMs. Crooks et al. (2008) have stressed such challenges and Groeneveld et al. (2017) discovered that out of 134 LUCC-ABMs reviewed worldwide, 83 did not ground the representation of the socio-behavioral processes in theory or in empirical observations. Earlier reviews of ABM applications have also pointed to such challenges (Matthews et al., 2007). In this paper, we offer a conceptual approach, with methodological application, to elicit restoration decisions using empirical data to improve such representation.

For the remainder of the paper, Section 4-2 elaborates on the theoretical perspectives to capturing human environmental behavior for computational modeling and our guiding framework to generate the restoration decision-making rules. It also describes the data collection and analysis methods. Section 4-3 presents the findings. Section 4-4 discusses the findings, including translation of the decision-making rules into a LUCC-ABM. Section 4-5 concludes the paper with implications and suggestions for future work.

4.2 Materials and Methods

4.2.1 Modeling Human–Environmental Behaviors and Decision Processes

Understanding environmental decision making has remained critical in the management of common resources (Vlek and Steg, 2007). Environmental behavior can be shaped by resource management approaches, although in practice, management interventions have often ignored the behaviors of local farmers and resource managers and users, including how these contribute to desired environmental conditions. Understanding these environmental behaviors is particularly important for contemporary landscape restoration efforts. We draw on the goal-framing theory (GFT) on environmental behavior rooted in social psychology literature and its utility for modeling.

The GFT is appropriate to understand environmental behavior and its impacts as it allows for consideration of several heterogeneous and concurrent goal frames (Lindenberg and Steg, 2007). “A goal frame is, … the way in which people process information and act upon it. … When it is activated or focal, a goal is a combination of a motive and an activated knowledge structure (especially causal knowledge related to means–end relationships concerning the goal … A goal frame is a focal goal together with its framing effects …” (Lindenberg and Steg, 2007 p.118). A goal-framing perspective suggests that environmental behavior is shaped by diverse goal frames (conflictual or not) categorized as hedonic (level of pleasure/pain), profit, or normative. These goals represent the determinants of environmental decisions and their encoded or expressed behaviors, and are usually a mixture of motives, logic (causal reasoning or rationales), and other potentially influential factors in relation to the goal. Groeneveld et al. (2017) listed six such other influential factors of environmental behaviors: economic, social influence, social impact, environmental-altruistic, non-economic benefits, and spatial accessibility. Etienne (2011) argued that the GFT also aligns with the advocated paradigm of bounded rationality, which postulates that human decision making is constrained by limited information mediated by social, cognitive, economic, and temporal factors (Groeneveld et al., 2017). Such considerations can inform the computational modeling of human decisions within a socio-ecological system as an approach to improve the management and governance of commonly held environmental resources (Jager and Mosler, 2007).

❖ Representation of Human–Environmental Decisions in Agent-Based Modeling

Computational modeling approaches that emphasize socio-ecological interactions, specifically those that contribute to enhanced understanding of LUCC dynamics, have been widely used in recent decades (Gilbert, 2008; Rounsevell et al., 2012). An example is agent-based models (ABMs), which help to account for the agency of individual social actors of the socio-ecological system and their interactions with and impacts on the shared biophysical environment. The focus is on capturing actors’ heterogeneity, resource constraints, interconnectedness, and interactions that conjointly constitute their decision making (Miller and

Page, 2007; Kelly et al., 2013; Huber et al., 2018). Recent large review studies of ABMs have focused on the representation and characterization of human (agent) decision making, including implementation frameworks for the decision architecture generically (Huber et al., 2018; DeAngelis and Diaz, 2019), at the narrow farm level as potential complements to traditional farm models in policy analysis (Kremmydas et al., 2018), and specifically to LUCC-ABMs (Groeneveld et al., 2017; Huber et al., 2018). We draw on these reviews which concur that understanding and representing human decision making in ABMs, including in collective action settings, remain underexplored. Huber et al. (2018) specifically decry the reduced efforts to model farmers' emotions, values, learning, risk and uncertainty, or social interactions as part of decision-making elements.

The main reasons advanced for such under-exploration include the lack of context-appropriate socio-economic data and variables, and the challenging use of frameworks to parameterize those social/human behaviors properly and accurately. First, to formulate an appropriate context for the decision-making component, researchers use data from social surveys, role-playing games, semi-structured interviews, surveys, and expert knowledge to characterize and parameterize the behavioral aspects (Groeneveld et al., 2017; Rounsevell et al., 2012; Smajgl et al., 2011; Smajgl and Barreteau, 2017; An, 2012). Smajgl and Barreteau (2017), in particular, offer a generic characterization and parameterization (CAP) framework "that allows for a structured and unambiguous description of the characterization and parameterization process" (p. 29), and demonstrate its use in several modeling situations. However, their framework does not illustrate explicitly how to decompose the various types of data into decisions rules and their types and how to integrate them into empirical ABMs. The provided guiding options (e.g., steps M3 and M4b) remain theoretical. Second, to incorporate a relevant framework, many human decision heuristics have been employed (Groeneveld et al., 2017; An, 2012; Balke and Gilbert, 2014; Kennedy, 2012). Nine types of decision models are mostly used in modeling human decisions in ABMs (An, 2012). These include microeconomic models, space-theory-based models, psychosocial and cognitive models, institution-based models, experience/preference-based models, participatory agent-based modeling, empirical/heuristic rules, evolutionary programming, and assumption- and/or calibration-based rules. Some of these frameworks have been used in combination (An, 2012). Balke and Gilbert (2014) categorized 14 agent decision-making models along five main dimensions that incorporate: cognitive processes, affective aspects, social dimensions, norms, and learning. Groeneveld et al. (2017) further investigated the use of theories to implement human decision making in LUCC-ABMs. They concluded that in cases where theories are used, preference is mostly given to the expected utility theory within a rational or a bounded rational paradigm. These authors suggested considering psychological theories and blending both cognitive and affective dimensions following the categories advanced by Balke and Gilbert (2014). While the challenge of behavioral theoretical grounding in LUCC-ABMs is an identified gap and barrier for the broader reusability and policy relevance of such ABMs, this study responds to the first specific need for enhancement of empirical ABMs—the elicitation of decision rules from empirical multi-type data. This can contribute to easing the representation of the behavioral components.

We use insights from the GFT and the literature reviewed above to build a conceptual approach that allows us to systematically and comprehensively process and analyze data gathered from multiple sources to capture the decision making of human agents in LUCC-ABMs. Specifically, we use the approach to develop locally informed representations of farmers' restoration decision making for a future simulation of associated socio-ecological outcomes at a higher (aggregate) forest-agriscape scale in Central Malawi using an ABM. While this study is part of a larger and growing body of research on participatory modeling ranging from the effective capture of human behavior in models on socio-ecological problems generically (Jordan et al., 2018; Voinov et al., 2018) to the capture of such behavior specifically among farmers and other environment-related land managers (Mehryar et al., 2019; Giabbanelli et al., 2017; Davis et al., 2019), a detailed examination of participatory modeling for ABM is beyond the scope of this paper. The focus of this paper is only on our empirical-based approach to depicting the behavioral rules.

4.2.2 Conceptual Approach to Develop Restoration Decision Rules

We elaborate below on the approach (Figure 4-1) that we followed to arrive at the restoration decision rules (RDRs, *rules* for short) to use later in an empirical LUCC-ABM (not part of this article) that simulates the restoration processes in the study area.

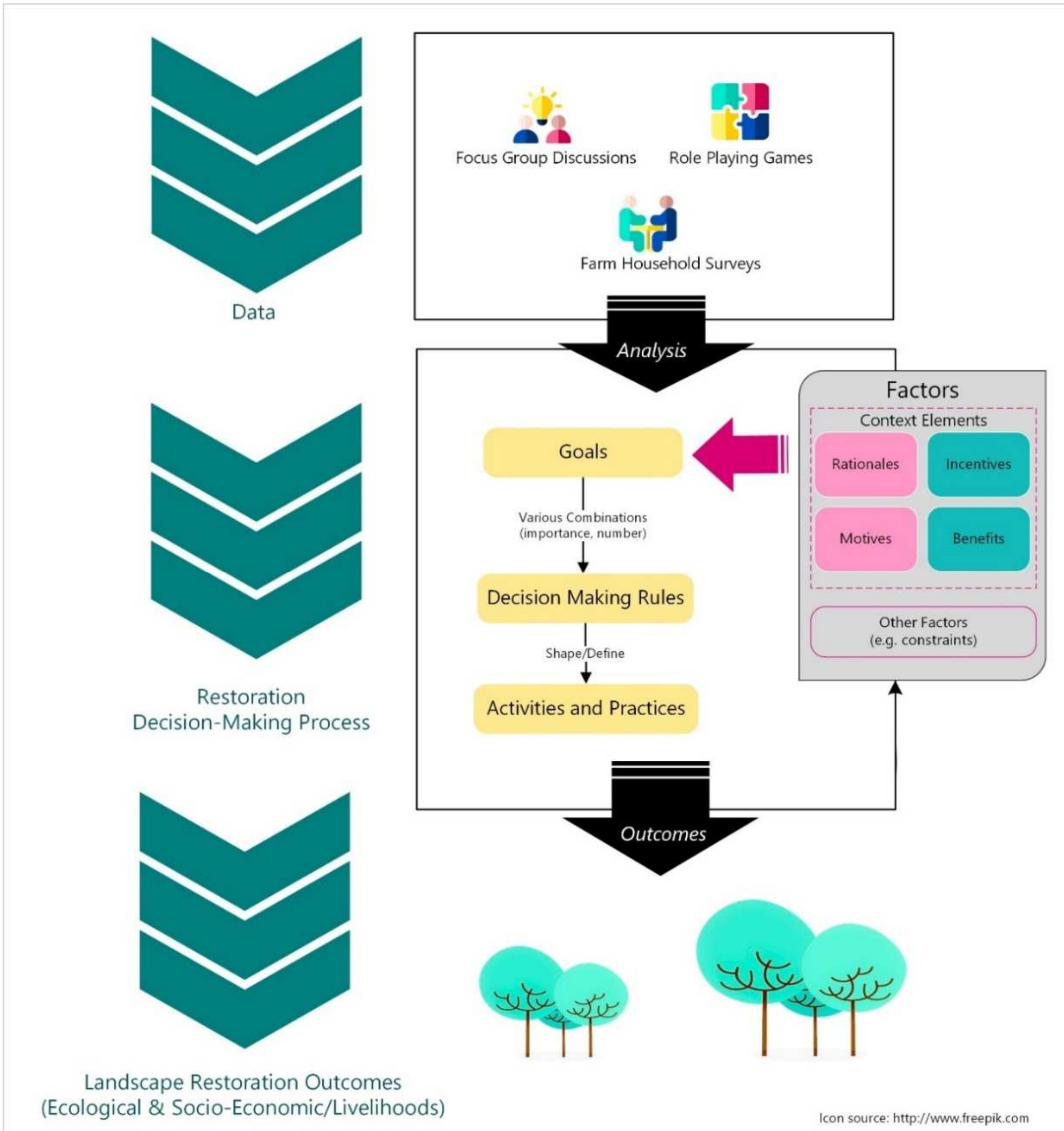
Data used in our study come from three different sources: focus group discussions (FGDs or *discussions*), participatory role-playing games (RPGs or *games*), and a farm-household survey (FHH, *survey* for short). Such a mixed-method approach, detailed further below, enables us to harness the analytical power of integrating data-gathering methods, data types, and data analyses to cross-validate the findings (Creswell, 2014). Data from *discussions* and *games* provide in-depth qualitative contextual information for the RDRs (*rules*); the *survey* furnishes numerical variables and parameters needed in the future LUCC-ABM.

To arrive at well-defined *rules*, we first depict the broader mechanisms in which the rules are embedded. We call these decision-making processes (DMPs, aka *processes*). We define them as explicit constructs that synthesize the overarching information on decision making for forest-agriscape restoration in the study area. These *processes* (DMPs) are executed through *rules* (RDRs), which we define as procedures that result in the implementation of specific restoration activities and practices. The *rules* are, therefore, the drivers of the observed restoration landscape.

To provide the context for the *processes*, we identified four groups of reasons that justify the undertaking of the various forest-agriscape restoration activities and practices: rationales, motives, benefits, and incentives. Restoration rationales are drivers of the *rules* that stem from logical reasoning (rational thinking). Restoration motives are more implicitly guided by worldviews, beliefs, and emotions. Benefits and incentives constitute rewards from a course of action. Benefits are endogenous (self-directed)—what individuals perceive as rewards that they generate if they undertake a specific restoration activity (e.g., economic, environmental). Incentives are exogenous—these are rewards obtained from outside sources—mainly gains (monetary and non-monetary) obtained from government programs or non-government organizations (NGO).

Separately from the context for the *processes*, we generated the *rules* from the data provided by farmers. The *rules* synthesize the articulated decision-making factors (*factors*), which we first grouped into categories representing the decision-making goal frames (*goal frames*). For example, Problem solving constitutes a *goal frame* that reflects rational thinking to address perceived environmental problems with actions (cognitively imagined) that are adequate to meet the specified goal.

Figure 4-1. Conceptual approach.



In this section, we have introduced our conceptual approach, unavoidably including many abbreviations for the constructs. In the consecutive sections, however, we use the alternative—simpler names provided in italics in the parentheses.

4.2.3 Study Area, Data Collection, and Analysis

4.2.3.1. Study Area

We selected one research site in Ntchisi and one in Dedza districts in Malawi's central region (Figure 1-3) as introduced in Chapter 1, section 1.3.2.

4.2.3.2. Data Collection

We conducted seven *discussions* of 15–20 participants to capture the *rules* underlying engagement in forest-agriscape restoration. We sought four discussions per district, two with representatives of collective resource-management groups and two with representatives of farmers engaged in restoration at farm-household level in separate venues. However, in Ntchisi district one of the discussions combined the two types of representatives (hence, seven discussions in total), with distinguished questions for individual and collective restoration. We selected the participants purposely with the help of local extension agent.

During the *discussions*, we used open-ended questions to gain insights into the general context for the development of the rules for both individual and collective restoration activities. Specifically, we sought farmers' perceptions of environmental restoration, the (frequency of the) restoration practices and activities they use, and the reasons underlying the restoration behaviors. Since these narratives are more reflective than actionable, we also introduced *games* (Anderies et al., 2011; Pak and Brieva, 2010) where the participants were actively engaged in realistic restoration action-situations to express their behaviors. Through *games*, we could observe and gain insights on the "whys" and the "hows" behind farmers' decisions to embark on individual and collective restoration activities under real-world circumstances. After listing their *factors* on colored cards, farmers ordered them by level of importance on flip charts. Sub-groups of 5–6 farmers then simulated their rules using colored cards for ten minutes, separate from the others. The simulated rules were then subjected to plenary discussions where all the participants commented and discussed similarities or differences (Figure 4-2). Finally, farmers were asked if they would change the rules in case of extreme weather events such as floods and droughts, or when government policies (affecting environmental degradation) change.

Finally, we conducted a *survey* of 480 participants using a questionnaire entered into the Qualtrics software and administered in offline mode through tablets (Leisher, 2014). Data collected included farmers' sociodemographic characteristics, engagement (or not) in restoration and associated practices, as well as underlying rationales, motives, benefits, and incentives. We also gathered farmers' self-identified mental rules for engaging in individual-level restoration practices and for considering participation in collective action restoration activities.

Figure 4-2. Illustrations of farmers simulating their restoration rules and participating in plenary discussion.

4.2.3.3. Data Analysis

Our holistic analytical approach consists of complementing and cross validating the qualitative information from the discussions and games with the survey data. First, using Nvivo 12 pro, we code the text data to reveal themes related to local understandings of restoration; practices and activities; the rationales, motives, benefits, and incentives for restoration; and the restoration rules.

Second, using Stata 15, we describe the respondents' socio-demographics as reported in Appendix Table 4-A. We also perform descriptive analyses of variables representing the diverse restoration rationales, motives, benefits, and incentives. We compare them by gender, education level, and geographic location (i.e., TAs covered in the study) to show any statistically significant patterns. For this, we use non-parametric statistical tests of group-mean comparison, including Student's t-tests and one-way ANOVAs, where relevant. For the one-way ANOVA, we check for not only independence and normality, but also for variance homogeneity to guide appropriate post hoc multiple comparison tests. Specifically, we refer to the Scheffe test when the assumption of variance homogeneity is met following Bartlett's test, and the Games and Howell test when the assumption is not met, to show differences among groups being compared.

Third, we combine the qualitative insights with the survey data to enhance our analyses of the restoration *factors* and *rules* at two levels. On one hand, we categorize the *factors* into *goal frames*. We start with the *goal frames* generated from the *discussions* and account for any new *goal frames* included in the *survey.* On the other hand, we link the *rules* drawn from the *games* (Figure 4-3 and Table 4-1) to the ones captured through the *survey* and estimate their occurrence. We note that most farmers in the survey emulated only one main mental rule for each restoration approach, although they were given three possibilities. We thus consider their main mental rules for eliciting the potential rules from the survey.

Figure 4-3. Illustration of the rules simulated during role-playing games—the one of the left is from Dedza and the one on the right is from Ntchisi.

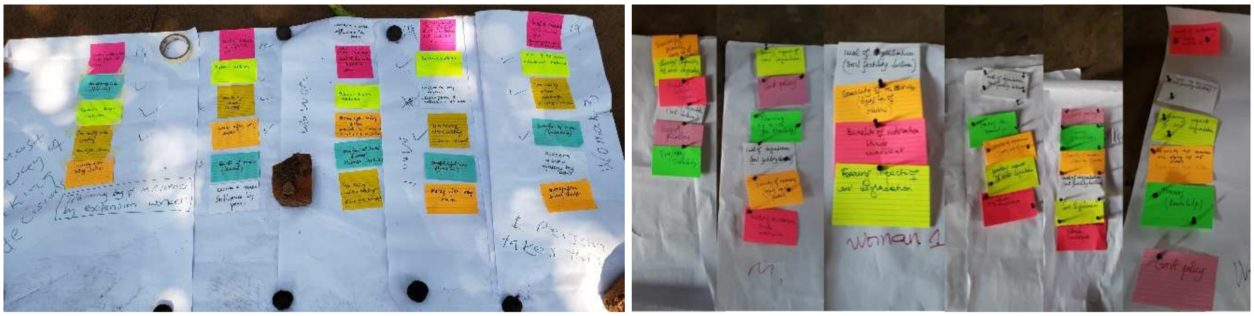


Table 4-1. Illustration of Two Rules Depicted During Role-Playing Games, Showing the Initial Decision-Making Factors.

Factor 1	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Factor 6**
Dedza					
Level of Deforestation in the Forest Reserve	Benefits of Trees (Firewood)	Lack of Firewood	Time Saving When Cooking	Money After Selling Timber	Training by Extension Workers
Ntchisi					
Scarcity of Water Resources (Drying of Rivers)	Fearing Impacts of Environmental Degradation	Benefits of Restoration (Wind Break and Shade)	Level of Degradation (Soil Fertility Loss)	Government Policy	Training, e.g., Knowledge in Tree Management

Factor = decision-making factors, the initial (raw) factors that respondents use in articulating their restoration decision-making rules. (Extracted from Figure 4 above).

The rules simulated during the games showcase various combinations of 3–4 goal frames on average. Similarly, the individual mental rules from the survey are based on 2–4 goal frames on average (Table 4-2).

Table 4-2. Number of Goal Frames Included in the Individual Mental Decision-Making Rules from the Survey.

Number of Goal Frames Considered		**0 [a]**	**1**	**2**	**3**	**4**	**5**
Rules for Individual-Level Restoration	Main Rule (n = 443)	1.58	10.38	36.79	39.05	9.03	3.16
	Secondary Rule (n = 23)	94.81	0.23	1.35	2.71	0.9	-
	Tertiary Rule (n = 3)	99.32	-	-	0.68	-	-
Rules for Collective-Level Restoration	Main Rule (n = 268)	0.75	8.21	17.54	45.52	23.88	4.1
	Secondary Rule (n = 14)	94.78	-	1.12	1.87	2.24	-
	Tertiary Rule (n = 1)	99.63	-	0.37	-	-	-

[a] 0 represents respondents who stated that they did not consider any element for restoration decision making.

Overall, insights from the discussions, games, and the survey suggest that the absence or presence of the goal frames creates distinctive rules. Therefore, in accounting for all possible rules from both the qualitative and quantitative data, we create variables consisting of 2–4 goal frames for which we fix, alternatively, the most recurrent goal frames.

4.3 Results

4.3.1 Forest-Agriscape Restoration and Restoration Activities and Practices

We uncovered five different ways local farmers understand restoration of degraded forest-agriscapes, including the activities and the practices they implement (Table 4-3). An important observation was the connections farmers made with afforestation/reforestation, soil, and water conservation, and addressing land degradation and soil fertility decline to illustrate complementarity of restoration activities for soil, water, and forest resources.

Table 4-3. Local Perspectives on Environmental Resource Restoration in Dedza and Ntchisi Communities.

Local References to Resources Restoration	Examples of Narratives [a]
Planting More Trees to Attract Reliable Rains	*"Planting more trees to attract reliable rains, and where we have cut trees, we are supposed to replace them by planting some more trees. Trees also help in preventing our buildings from heavy wind by acting as wind breaks."*
Using Agroforestry Systems, Including Intercropping to Restore Soil Fertility	*"For us agroforestry people, restoration is using fertilizer trees to conserve and improve soil fertility. Not using inorganic fertilizer that degrades soil fertility further."* *[…] In the past, our parents were cultivating with no fertilizer, but they were harvesting higher yields and we want to turn our soils back to that state."* *"Planting trees helps to ensure we are receiving reliable rains that help crops that we grow on improved soils to grow well. Some other trees act as both fertilizer trees and when they grow, they act as forests, for instance, Gliricidia."*
Biodiversity Recovery	*"Making sure that wildlife like birds, hares, and grasshoppers are back into the environment by planting trees. There were more wildlife animals in the past because there were more trees."*
Forest Management and Protection Through Beekeeping	*"Restoration is about protection of forests by keeping bees and doing all bee keeping activities; for instance, killing pests and applying oil. […] Beehives in both village forests and forest reserves help to protect trees because people are afraid of bees."*
Managing Natural Regeneration	*"…after cutting down trees by making fire breaks and pruning; where there are natural regenerants, we make sure we manage."*

[a] Excerpts from all focus group discussions (FGDs).

Restoration practices were both vegetation-based and non-vegetation-based. For the former, mostly implemented for afforestation/reforestation and soil-fertility improvement, farmers cited: planting vetiver grass; practicing agroforestry with fertilizer trees; planting indigenous trees in bare areas and along rivers/stream banks; managing natural regeneration (pruning); and developing woodlots. For non-vegetation-based activities, often implemented for soil and water resource conservation on farms and forest-resource management, farmers listed: making contour, marker, and box ridges; constructing swales and water-check dams; applying manure; practicing mulching and doing no or minimum tillage as part of conservation agriculture; using intercropping and crop rotation; making fire breaks; and keeping beehives.

Furthermore, the types of collective action groups that engage in restoration endeavors ranged from tree-nursery management groups, forest-reserves management groups, village forests management groups, land and water resources conservation groups, to irrigation groups, beekeeping groups, and cookstove-making groups. Forest-related collective actions were part of the formally recognized Village Natural Resources Management Committees (VNRMCs), and the other collective actions made up what is commonly referred to as Community-based Natural Resources Management Committees and resource users' groups. Activities implemented in collective actions are illustrated below.

> *"We do swales making, conservation agriculture with mulching and minimum tillage, tree planting and management, vetiver planting, construction of check dams, making and applying of manure. For example, in manure making, we conduct trainings to encourage people to make and use manure. In tree management, we make tree nurseries, prepare land for tree planting; we do actual planting of trees, making firebreaks to prevent trees from uncontrolled fire."* (FGD, Bwanali Community, Kachindamoto, Dedza).

> *"As VNRMC, we do a lot of things to protect and manage trees through encouraging community members to have individual forests and protect the trees as we were trained by PERFORM [a forest project]. We also make sure that people are collecting firewood sustainably as trained by PEFORM. We also do patrols to check whosoever is illegally harvesting trees. We also use firewood-saving cookstoves as a way of reducing firewood that we use to cook."* (FGD, Ntchisi).

These activities epitomize and exemplify the nexuses in the restoration and management of lands, water, trees, and forests.

4.3.2 Farmers' Restoration Rationales, Motives, Benefits, and Incentives

Farmers evoked several reasons justifying why they undertake restoration activities and practices. These provided a contextual understanding of the complex factors involved in their restoration decision making.

4.3.2.1. Farmers' Restoration Rationales and Motives

Farmers' rationales for restoration at the individual level included concerns for environmental degradation and its adverse impacts on people's lives, severe soil erosion, wind-induced destruction in treeless landscapes, changing climate, and declining soil fertility that reduces crop yields. Therefore, the aspirations and actions prescribed by logical reasoning to address those issues included keeping trees to reduce land erosion/degradation caused by runoff, improving soil fertility to harvest higher yields by using adequate fertility-enhancement farming methods, and growing trees that also served as windbreaks to protect houses and prevent other property destruction. Some farmers from both Ntchisi and Dedza (Kapenuka and Bwanali communities) illustrated these logics: *"before starting restoration activities, I was experiencing heavy soil erosion but after planting vetiver grass, soil from my field has stopped eroding"*; "*before I started conservation agriculture, I was harvesting little";* and *"with increased population growth and inadequate farmlands, this has made us to change to new farming methods that improve soil fertility, and we are restoring soil fertility to maximize yields […] I practice crop rotation to maximize yields."* Further illustrations of restoration rationales include: "*we have realized that climate has changed, for instance we are receiving unreliable rains […]".*

At the collective level, objective arguments boiled down to the need to protect the environment, maintain reliable rains, conserve trees for the next generation given growing tree scarcity, sustainably use forest resources by reducing demand on forest products along with using efficient cookstoves that demand less firewood, and conserving soil and water resources that are being degraded. In terms of forest resources, farmers referred to both state-owned and community forests. The following excerpts are illustrative.

> *"People have interest in tree planting both individually and collectively because of scarcity of firewood and to maintain reliable rains that come when the forest is intact. We also want to conserve trees for our generation. With the pace [at which] trees are being cut down, our children will not have the chance to know some tree species, for example 'Mbawa' [Pterocarpus angolensis]."* (FGD, Kapenuka Community, Kamenyagwaza, Dedza).

> *"We get involved in community work because we have similar objectives of protecting and restoring the environment that is being degraded. We have the same purpose of forest protection [because] trees provide fresh air and can host our beehives, and people do not cut trees where there is beehive as they are afraid of bees."* (FGD, Kabulika Community, Kachindamoto, Dedza).

Restoration motives included influences from peers, encouragement and incitation from local authorities, and sensitization from NGOs, projects, and project funders. In both districts and across the discussions, some individuals affirmed these restoration motives in language such as: *"I was also influenced by my friend who is in the scheme. I admired her harvesting more yields and she had food all the year"*; and *"forest officers in coordination with local leaders* [Traditional Authorities and Group Village Headmen] *urge us to plant trees and conserve soil."* Concerning sensitization, one farmer's views from Ntchisi were representative: *"People have been sensitized by NGOs on importance of restoring the environment. They tell us to conserve soil by making contour lines."* The narratives were similar for collective-level restoration motives among farmers from the Kabulika community, emphasizing awareness raising by external actors: *"we receive many motivations from NGOs; EU gave us beehives first before World Vision came also with beehives"*, observed one. Another farmer from Kapenuka voiced the widespread reliance on extension workers, along with NGOs: *"we are encouraged by extension workers to work in collective action, and we are also motivated by projects that require people to work in groups."*

We observed that the line setting apart restoration rationales and motives is not always crisp – these two underlying reasons are often interrelated. For instance, farmers from Bwanali community in Dedza explained during a discussion that *"we were experiencing floods but after being trained to dig water check dams, we are able to control runoff that causes erosion also. Water is also conserved and controlled through swales and contour ridges."*

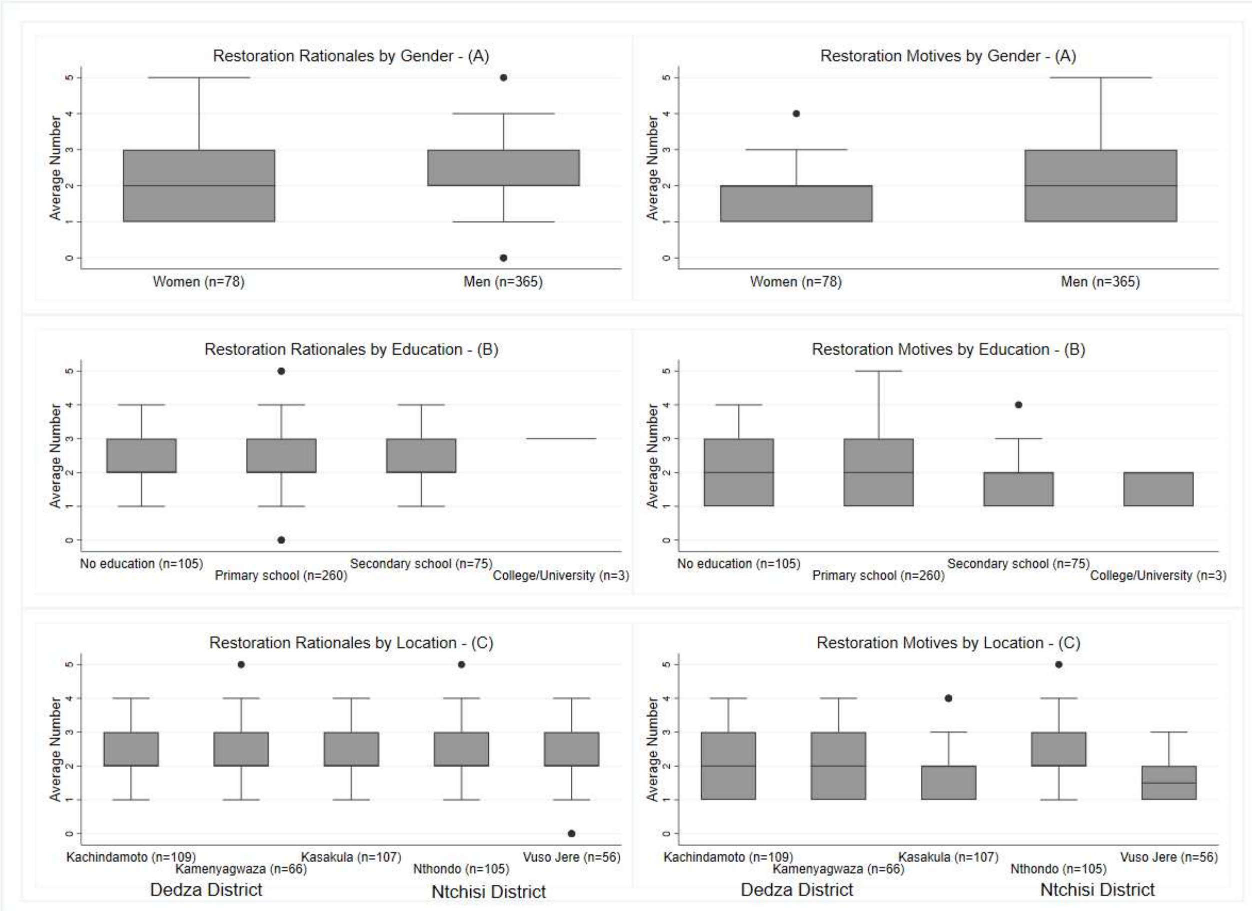
- <u>Importance and Variability of Restoration Rationales and Motives by Gender, Education, and Location</u>

The survey data reinforced the qualitative findings and revealed such interchangeability between restoration rationales and motives. On average, farmers considered 2 ± 0.9 rationales and ≈2 ± 0.9 motives. Specifically, the two most important restoration rationales were the acuteness of observed land degradation (soil erosion and formation of gullies) and low soil fertility (perceived as driving low crop yields), as mentioned by 91% and 73% of responding farmers, respectively. Other less important rationales were the difficult provision of biomass energy due to scarce firewood and scarce trees to produce charcoal (22%), and the awareness of and sensitivity to biodiversity loss (21%). The most critical restoration motives were project-based motivations, either through incentives from NGOs or government programs (52%), or through the demonstrated leadership, encouragement, and support of local authorities—the Traditional Authority—for their community (43%). Influences from either peers and friends or the media (37%), and altruistic behaviors or environmental civism in the context of scarce resources (35%) were next in importance. Specific rationales that were interchangeably considered as motives (mostly in Nthondo and Vuso Jere TAs) included severe soil erosion and land degradation, low yields, deforestation, and rainfall scarcity.

When compared by gender, education levels, and locations (Appendix Table 4-B), gender did not show any statistically significant difference in terms of average numbers of rationales or motives applied. On average, both men and women consistently considered two rationales and motives each (Figure 4-4, panel A). Their rationales and motives for engaging with restoration activities are like the ones described above, with similar relative importance levels (Figure 4-5, panel A). Likewise, there was no statistically significant difference in the average numbers of restoration rationales and motives among the education levels attained (Figure 4-4, panel B). The typical motives and rationales described above are also applicable across the different education levels (Figure 4-5, panel B).

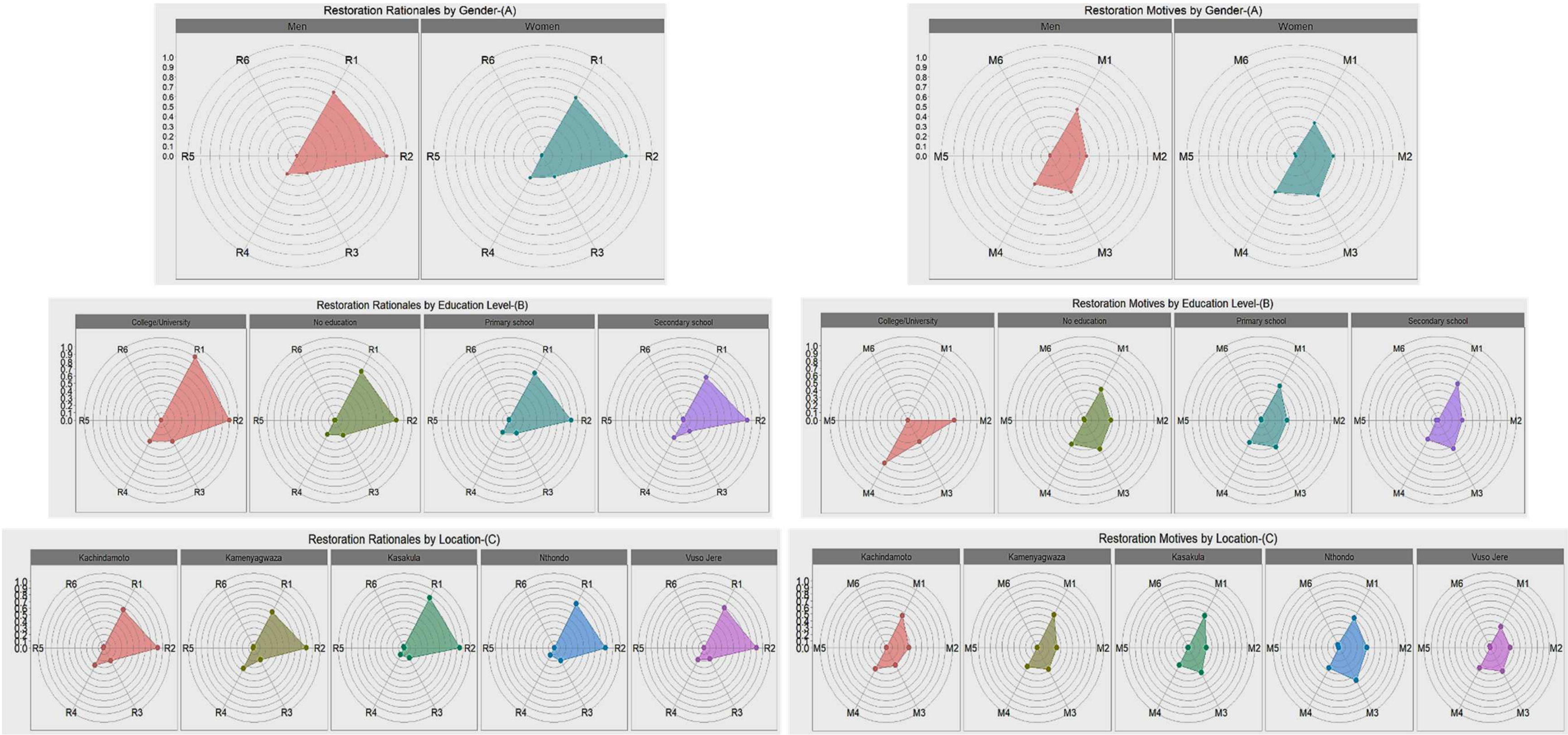
In contrast, for the locations there are some statistically significant differences ($p = 0.0106$) for the average number of restoration motives, but not for the average number of restoration rationales advanced (Figure 4-4, panel C). That the restoration motives are different across the locations is vital to underscore, and such differences lie at two levels as suggested by the post hoc comparison tests. First, across all the five TAs, farmers in Vuso Jere consider fewer motives (<2) than their peers from the other four TAs (≥2), and this is strongly apparent when compared with TA Nthondo. The second difference centers on how some motives varied in importance from one location to another (Appendix Table 4-B). One prominent example is the "leadership, encouragement, and support of local authority (M3)" when compared between TA Nthondo in Ntchisi District and TAs Kachindamoto and Kamenyagwaza in Dedza District (Figure 4-5, panel C). During the discussions in Ntchisi, farmers from Nthondo emphasized how their traditional authority encourages them and holds strong and respected leadership for addressing environmental degradation.

Figure 4-4. Differences in the average number of restoration rationales and motives by gender, education, and location among farmers engaged in restoration (N = 443).



Note: Each box-and-whisker diagram depicts the quartile-based distribution of the number of rationales/motives per group/factor of comparison. The boxes indicate the interquartile range; the lines (whiskers) show the minimum and maximum range outside the quartiles; and the dots are extreme values (outliers).

Figure 4-5. Types of restoration rationales and motives by gender, education, and location.



Notes: Radar charts comparing the mean value (on a scale of 0–1) of each type of rationale/motive among the different groups/factors. **Rationales:** R1 = Severe land erosion and gully formation; R2 = Low soil fertility/low crop yield; R3 = Awareness of biodiversity loss; R4 = Difficult provision of biomass energy (scarce firewood and tree scarcity limits charcoal making); R5 = Water resource scarcity (siltation of rivers and scarce water from catchment); R6 = Other restoration rationales. **Motives:** M1 = Project-based motivations (NGOs incentives and government-promoted programs); M2 = Influences from peers/friends and the media; M3 = Leadership, encouragement, and support of local authority; M4 = Altruistic behaviors and environmental civism (bequest/altruist behavior and civic morality/community loyalty); M5 = Other restoration motives; M6 = Rationales elements (soil erosion/land degradation, low yield, deforestation, and rainfall scarcity).

4.3.2.2. Farmers' Restoration Benefits and Incentives

Discussion participants underscored several restoration benefits and incentives. Benefits were mainly economic (honey produced and sold from beehives put in trees, timbers, selling of crops yield surplus), environmental (moisture and nutrient added to the soil, fresh air and temperature regulation, good and reliable rains), and altruistic (care for future generation and natural trees). Other benefits are food-related (fruits from trees, high crops yield), non-economic and utility-oriented (poles for constructions, coffins, firewood for cooking, and medicinal plants), and socio-cultural (sharing of tree seedlings, access to free firewood during funerals). Illustrative perspectives include:

> *"… trees are used as poles for construction and are used for domestic activities such as firewood for cooking, and this reduces pressure on state-owned forest reserves."* (FGD, Bwanali Community, Kachindamoto, Dedza).

> *"Through conservation-agriculture practices, higher yields are harvested since mulching conserves moisture and adds nutrients to the soil."* (FGD, Kapenuka Community, Kamenyagwaza, Dedza).

> *"Forest and trees regulate temperature; it feels cold in hot season and it feels fresh always. I have a water point that runs from my forest. We receive reliable rains because we have more trees. [Also,] trees improve soil fertility in our fields and conserve moisture. We get manure from the tree leaves. If we plant trees, vetiver, and make contour ridges we make our lands fertile. […] Trees act as wind break and our houses are protected from severe winds. In the end, the benefits of trees are what motivate us."* (FGD, Ntchisi).

Farmers participating in collective-level restoration in Kabulika community noted economic benefits, as one explained: *"we also sell poles from the forest and we do this in collaboration with the chief. This is about our village forest which has both exotic and natural trees; people also get timber from the forest at agreed fees, poles are also harvested at a fee."* In reference to social benefits, the following was a represenrtative perspective: *"we collect firewood from the forest when there is a funeral; for instance, there was a funeral in our village and women came to ask me as chairperson of the tree nursery management committee if they can go into the forest to collect firewood [and] I told the chief and we granted them permission to go and collect firewood."* Another farmer added that community members also *"share tree seedlings that [they] plant on [their] farms and house compounds, and people are motivated."* In Ntchisi, farmers bundled restoration benefits that motivate them, as one illustrates:

> *"We do receive good rains because our forest is intact and that is one reason that motivates us. [Also], we get firewood for cooking. Other people who do not have trees in their areas use clothes and sacks for heating and cooking. [Moreover], we are motivated by a lot of water that our mountain and forest conserve and we use the water for irrigation."* (FGD, Ntchisi)

Incentives and rewards in the areas varied. For individual-level restoration, many farmers indicated being recipients of both in-kind and money-based incentives from NGOs and government-led programs.

One explained: *“at first, people were receiving food and materials such as soybean flower, cooking oil and beans, tree seeds, hoes, and such, and after some time United Purpose started giving us money.”* Adding to that, another farmer noted: *“MASAF was also giving us money, MK7200 [≈$9.52] for two weeks; then payment rose from MK7200 [≈$9.52] to MK21600 [≈$28.57].*” Many considered the training they received from various government, NGOs, and development agencies and projects on restoration matters and the perception of restoration practices as non-labor intensive, as forms of incentives.

> *“We have been trained before in environment restoration [and] these restoration activities are cheap. For instance, manure making does not demand monetary costs as compared to inorganic fertilizers. […] Mulching also reduces labor; we do not make ridges and we do not go and weed because weeds do not grow in a field where ridges were not made. […]”* (FGDs, Bwanali and Kapenuka Communities, Dedza).

> *“We received training in beekeeping, and we are making money out of bee farming. Discovery project trained us in cookstoves making; we have also been trained in briquettes making and we are making money from those activities. We received training in bamboo planting although not enough. We received training from World Vision, EU, CADECOM in environment management and restoration. For example, CADECOM trained us in local tree seedlings production and we can produce own seedlings locally.”* (FGD, Kabulika Community, Kachindamoto, Dedza).

Beside these testimonials, farmers argued why training is a critical incentive, as one farmer wrapped it up:

> *“For us to do our work properly we need to be trained and when we are trained, we can easily pass knowledge to all the people in the community. Training is very important for a common approach and strategy to restoration activities. We can all have one common idea of the technology and there cannot be confusion. Local knowledge is not universal; some people know things differently from other people.”* (FGD, Bwanali Community, Kachindamoto, Dedza).

External restoration incentives are not always required by farmers, and some indicated that their ongoing restoration efforts precede the renewed momentum in forest-agriscape restoration.

> *“… some of us started doing restoration activities in 2015 and 2016 when there were no projects [while] others started a long time ago when there was a project by ICRAF. Now people are used to these restoration activities and we are doing these without being paid or expecting to be paid.”* (FGD, Bwanali Community, Kachindamoto, Dedza).

Still, many farmers complained about the lack of incentives. A farmer participating in collective action restoration in Ntchisi expressed long-standing resentment at such lack of incentives:

> *“We do lots of work to conserve the forest and people come to see it because we are managing it perfectly. Unfortunately, communities are not benefiting. For instance, we do not have potable water in our community yet our forest conserves water. People from Blantyre, Mzuzu, and all over the country and even abroad come here to see this place just because the forest is well-conserved and managed, but the communities are not benefiting anything apart from good rains we receive. […] We work in dangerous environments with no protective gear, yet we do not receive anything.”* (FGD, Ntchisi).

Hence, many farmers made a case for incentives. They also suggested operational resources and materials as well as training and exchange visits for restoration activities as incentives. For instance, during the discussion in Kapenuka in Dedza, one farmer elaborated that "*we don't receive incentives, but we would prefer being given operational resources*"; another that *"there has to be incentives such as fertilizer."* In Ntchisi, a farmer was also specific: *"incentives we need are soft loans with very low interest [and] energy-saving stoves that reduce pressure on forest resources."* Other forms of suggested incentives include money payments as allowance for collective action tasks, such as patrolling, or in the form of recurrent salary, an important element for restoration sustainability.

> *"With the amount of work that we do, we are supposed to receive something in the form of money. I want to remove some perception that organizations have … they think on our behalf and they think we cannot conserve or manage forests if they give us money. […] The money should be in the form of allowance and not salary. Whenever you go to patrol or do forest management activities, you should get an allowance, which is MK900 [≈$1.19] according to the government's rate."* (FGD, Ntchisi).

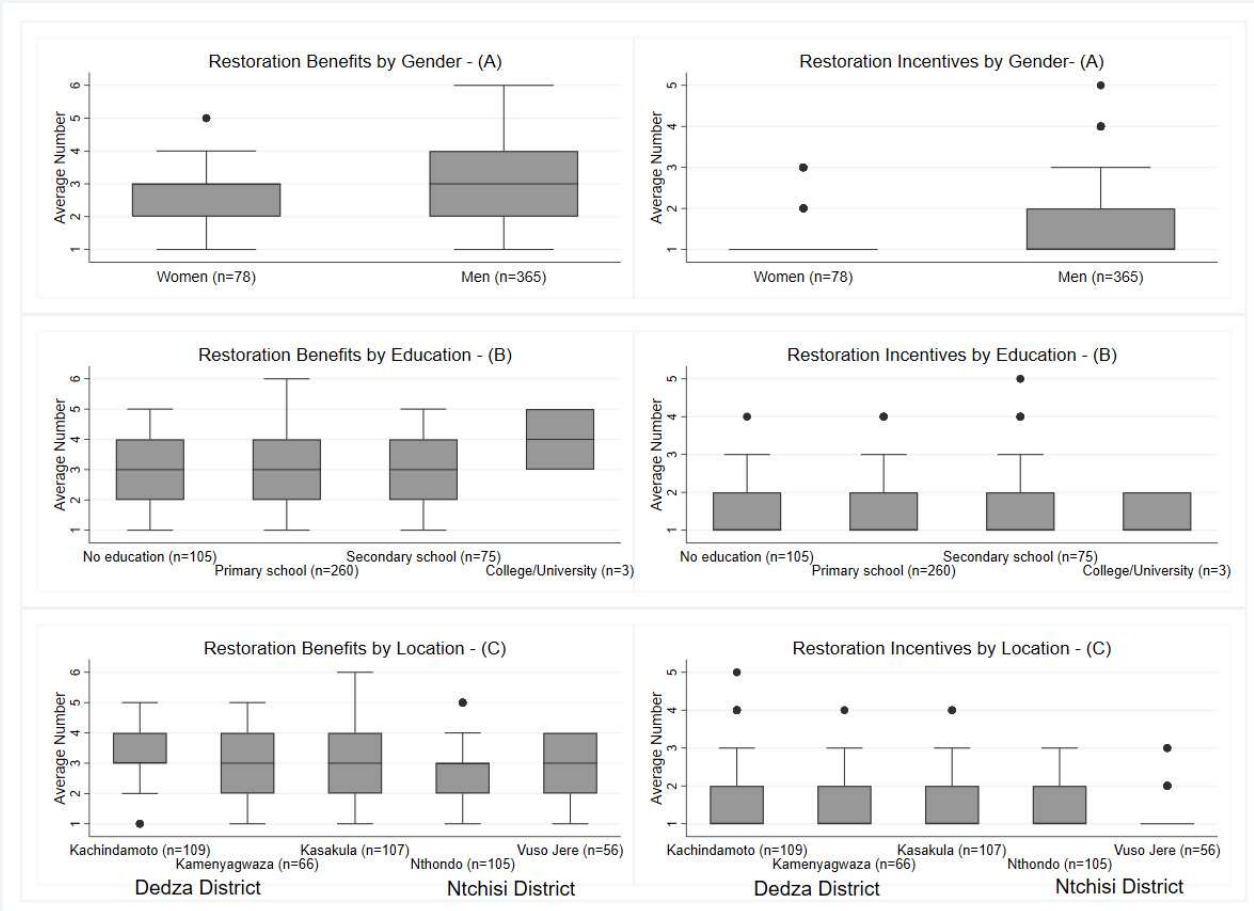
Here also, benefits and incentives for both individual farmer and collective action are intertwined and folded into the restoration motives. For instance, one farmer from the discussion in Kapenuka in Dedza advanced that *"we are also motivated by the high yields we are harvesting from fields where we are practicing soil-conservation technologies. For instance, where we apply manure and use fertilizer trees, we harvest more."* Some farmers from the discussions in Bwanali and Ntchisi also stressed that *"benefits we realize from restoration activities are already incentives on their own […] for example, food, firewood and water supply […] and also the activities such as money from sales of trees and from yield surplus."* An unusual perspective was underscored as follows, citing group learning and labor pooling: *"working in a group is incentive already because we learn from the group and implement on our farms; for instance, planting trees and making contour ridges. It is also less laborious when working in a group [because] it reduces time and labor demand as we share responsibilities and knowledge in a group. We can easily make manure and apply on our farms."*

❖ Importance and Differences in Restoration Benefits and Incentives by Gender, Education, and Location

While substantiating the qualitative findings, the survey data depict the relative importance that farmers attribute to restoration benefits and incentives. On average, farmers considered 3 ± 1 benefits and ≈1 ± 1 incentive. Specifically, crop yield improvement (96%), sustainable supply of biomass energy (firewood provision and charcoal production) (69%), positive environmental effects of reforestation (66%), and adaptation strategies to climate change impacts (59%) are the most critical benefits cited. Sustainable provision of non-timber forest products (NTFPs) was mentioned less (11%). When asked what incentives they received, *"no incentives"* was the most reported response (54%) by farmers, confirming the limited existence of restoration incentives in the area. The two most important incentives mentioned were knowledge and information support from extension services such as training on sustainable land management practices and supply of information on restoration matters (36%), and free or subsidized inputs such as tree seedlings and agricultural fertilizers (25%). Incentive schemes such as cash for work and credit/loan provision were less cited (6%).

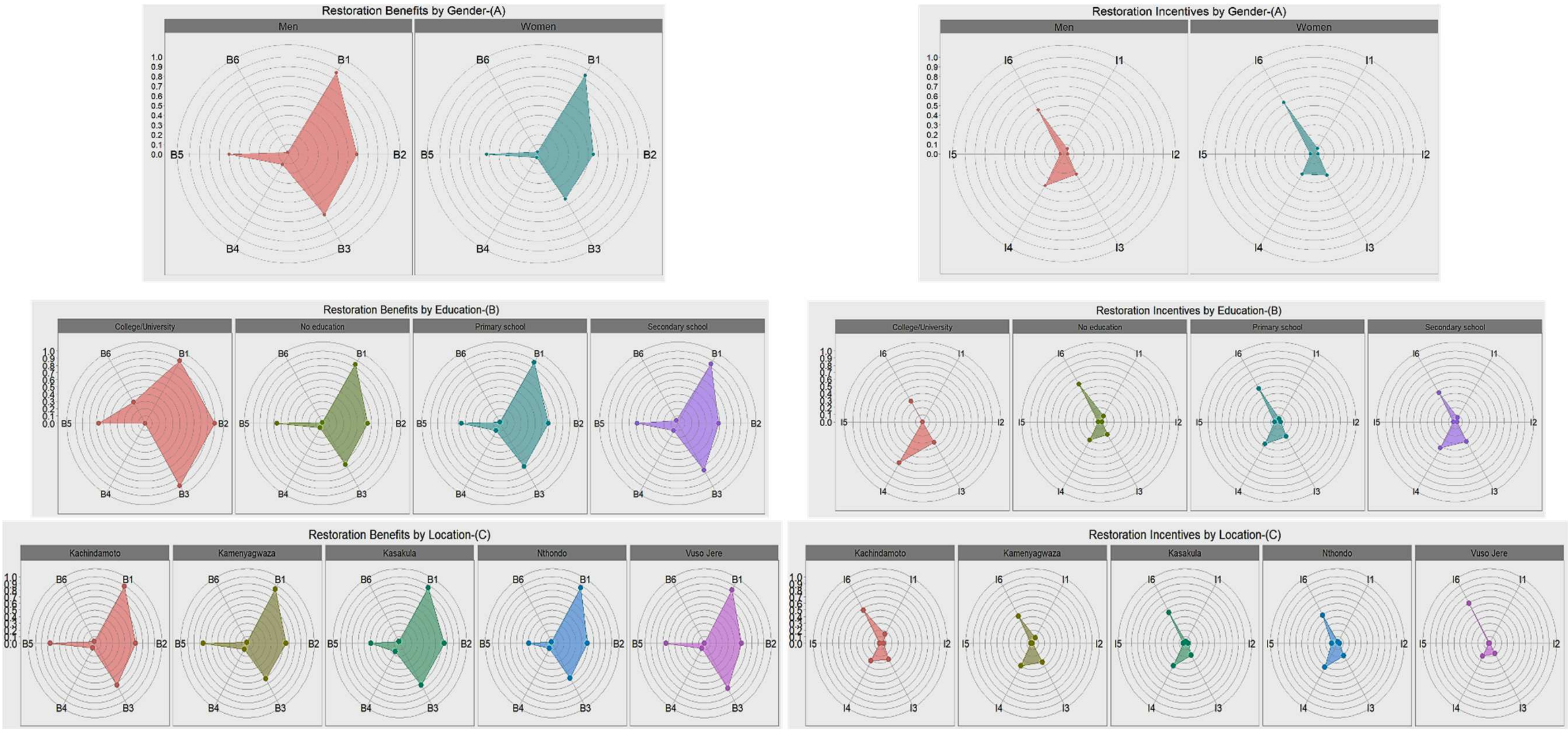
The mean number of restoration benefits was significantly different (p = 0.0001) between men and women, but restoration incentives were not (Appendix Table 4-C). On average, male farmers reported enjoying more benefits (>3) than female farmers (<3) (Figure 4-6, panel A). Among the typical benefits described above, men perceived very strongly the positive environmental effects of reforestation and were more likely to report sustainable firewood provision and charcoal production than women. Men also referred to the sustainable provision of NTFPs as part of restoration benefits, which women barely pointed to (Figure 4-7, panel A). Likewise, the average number of restoration benefits was statistically different (p = 0.0003) by location, but restoration incentives were not (Figure 4-6, panel C). Farmers from TA Nthondo reported fewer benefits from restoration (=2) than farmers from the other TAs, who reported more (≥3). Restoration as a coping strategy for climate change and as contributing to a sustainable supply of biomass energy was not emphasized in the TAs of Ntchisi as it was in the TAs of Dedza (Figure 4-7, panel C). In contrast, no statistically significant difference is observed for the number of restoration benefits and incentives across education levels (Figure 4-6, panel B). Both types of benefits and incentives are similar across the different education levels (Figure 4-7, panel B).

Figure 4-6. Differences in the average number of restoration benefits and incentives by gender, education, and location among farmers engaged in restoration (N = 443).



Note: Each box-and-whisker diagram depicts the quartile-based distribution of the number of benefits/incentives per group/factor of comparison. The boxes indicate the interquartile range; the lines (whiskers) show the minimum and maximum range outside the quartiles; and the dots are extreme values (outliers).

Figure 4-7. Types of restoration benefits and incentives by gender, education, and location.



Notes: Radar charts comparing the mean value (on a scale of 0–1) of each type of benefit/incentive among the different groups/factors. **Benefits:** B1 = Crops yield improvement; B2 = Reforestation and its environmental benefits; B3 = Sustainable provision of firewood and production of charcoal; B4 = Sustainable provision of NTFPs; B5 = Cope with climate change impacts; B6 = Increase tourism/income source/other benefits. **Incentives:** I1 = Cash for work incentives schemes and credit/loan provision schemes; I2 = Free improved cookstoves; I3 = Free/subsidized seedlings for nurseries and agricultural fertilizers; I4 = Training on SLM practices and supply of agricultural information; I5 = Granted land/tree use rights/training allowances/in-kind incentives/other incentives; I6 = No incentive.

4.3.3 Farmers' Restoration Decision-Making Processes

We followed two steps to develop the overarching restoration decision-making processes in a table/matrix format. These include the depiction and description of the goal frames, and the identification and characterization of the different rules.

4.3.3.1. Restoration Decision-Making Goal Frames

We identified a total of 17 goal frames representing different categories of the registered factors (Table 4-4). We first identified 10 goal frames from the discussions. Further, we drew 15 goal frames from the survey that included eight of the previous goal frames uncovered from the qualitative data, thus adding seven new goal frames to the list. Together, the 17 goal frames indicate a mixture of the restoration rationales, motives, benefits, and incentives described above, to which new elements, indicating factors reflecting concerns and constrains, are added. We report their respective incidences in individual and collective-level restoration.

4.3.3.2. Restoration Decision-Making Rules

We draw out 21 distinctive rules for individual-level restoration and 19 rules for collective-level restoration. All but two rules from the discussions match those from the survey. The rules reflect how the goal frames are ordered. The highly occurring rules are displayed in Table 4-5 (full list in Appendix Tables 4-D and 4-E).

Following their root goal frames, the rules that influence farmers' restoration behaviors are: problem-solving oriented, resource/material-constrained, benefit-driven, incentive-driven, peers/leaders-influenced, knowledge-dependent, altruistic-oriented, rules/norms-constrained, economic capacity-dependent, awareness-dependent, and risk averse-oriented. The main root goal frames for rules at the individual level were problem solving, resource/material constraints, incentives, knowledge, and benefits. When considering rules in collective actions, leadership of local authority, problem solving, benefits, and incentives stood out as highly critical root goal frames, followed by resource/material constraints.

Table 4-4. Restoration Decision-Making Goal Frames and Their Occurrence in the Focus Group Discussions and the Survey.

#	Types of Goal Frames	Description (From Initial Factors)	Occurrence in Discussions [a] (Count)	Occurrence in Survey (%) [b]	
				Individual Level (n = 443)	Collective Action (n = 268)
1	Problem Solving	Land Degradation Level; Scarcity of Water; Deforestation; Avoidance/Control of Soil Erosion; Low Fertility Rate/Improve Soil Fertility; Low yield/Increase Crop Yield; Insufficient food	26	89.39%	47.01%
2	Benefits	Access to/Free Firewood, Poles, Non-Timber Food Products, and other Materials Benefits from Trees Resources	30	20.54%	54.48%
3	Knowledge	Skills/Knowledge on Land Restoration	18	24.15%	9.70%
4	Risk Aversion	Avoiding Climate Change Effects	9	1.58%	19.40%
5	Influence of Peers	Influenced by Peers/Friends/Wives	13	9.26%	2.24%
6	Outcomes	Impacts and Outcomes	9	1.13%	0.37%
7	Time-Efficiency	Saving on Labor Time	9	N/A	N/A
8	Bequest/Altruist Value	Interest in Conserving the Environment	4	1.58%	1.87%
9	Rules of Collective/ Community Work	Rules and Laws Associated with Collective Action/Community-Village work	3	0	1.49%
10	Resource/Material Constraints	Access to Resources for Manure Making; Affording to Buy Fertilizer; Access to Water Source; Access to Tree Seedlings; Availability of/Access to Resources/Materials; Labor Demand	N/A	45.6%	25.37%
11	Incentives	Training/Knowledge Benefits from Extension Workers/NGOs; Incentives from projects; Cash/Food for Work	N/A	40.41%	36.57%
12	Government Promotion or Requirement	Government-Led/Required Programs with or without Schemes of Rewards	4	N/A	N/A
13	Leadership of Local Authority	Good and Strong Leadership of Local Authority	N/A	2.93%	77.24%
14	Morality/Community Loyalty	Community Involvement/Participation Civic Education/Community Responsibility	N/A	1.81%	15.30%
15	Media Awareness	Information/Awareness from Media	N/A	1.81%	0
16	Extension Service	Advice/Encouragement from Extension Services/NGOs	N/A	6.77%	2.99%
17	Economic Capacity	Economic Capacity	N/A	6.09%	1.87%

[a]: A simple count of the number of times the goal frame was registered from all the focus group discussions. [b]: The percentage value denoting the occurrence of the goal frames among the survey respondents; Bold: The most important goal frames. Italics: Common goal frames in the discussions and the survey.

Table 4-5. Most Commonly Occurring Decision-Making Rules Drawn from Both Focus Group Discussions and the Survey.

No	Rules [a]	Abbreviation [a]	Percentage [b]
	Individual-Level Restoration (n = 436) *		
Three Main Goal Frames as Base Plus One Alternative			
1	**Problem Solving—Resource/Material Constraints**—Incentives—*Knowledge—Benefits—Economic Capacity*	**PsMcInc**_*KBEc*	11.7%
2	**Problem Solving—Resource/Material Constraints—Knowledge**—Benefits—Economic Capacity—Extension Service—Influence of Peers	**PsMcK**_BEcExtIf	11.2%
Two Main Goal Frames as Base Plus One/Two Alternative(s)			
6	**Problem Solving—Resource/Material Constraints**—Media Awareness—Extension Service—Influence of Peers—Economic Capacity—Leadership of Local Authority—Bequest/Altruist Value	**PsMc**_MaExtIfEcLaAl	13.1%
7	**Problem Solving—Incentives**—Knowledge—Morality/Community Loyalty—Media Awareness—Risk Averse—Extension Service—Influence of Peers—Leadership of Local Authority—Economic Capacity—Bequest/Altruist Value	**PsInc**_KMoMaRExtIfLaEcAl	18.8%
One Main Goal Frame as Base Plus One or No Alternative			
15	**Problem Solving**—Resource/Material Constraints—Benefits	**Ps**_*McB*	10.6%
	Collective-level Restoration (n = 266) #		
Three Main Goal Frames as Base Plus One Alternative			
1	**Leadership of Local Authority—Problem Solving—Benefits**—Knowledge—Risk Averse—Rules of Collective/Community Work	**LaPsB**_*KRRu*	11.7%
2	**Leadership of Local Authority—Problem Solving—Incentives**—*Benefits—Risk Averse*	**LaPsInc**_*BR*	10.5%
5	**Leadership of Local Authority—Resource/Material Constraints—Incentives**—*Knowledge—Benefits—Risk Averse*	**LaMcInc**_*KBR*	10.2%
Two Main Goal Frames as Base Plus One/Two Alternative(s)			
7	**Leadership of Local Authority—Resource/Material Constraints**—*Benefits—Knowledge—Extension Service—Influence of Peers*	**LaMc**_ BKExtIf	9.0%
8	**Leadership of Local Authority—Benefits**—Knowledge –Risk Averse—Bequest/Altruist Value	**LaB**_*KRAl*	9.0%
12	**Problem Solving—Incentives**—Morality/Community Loyalty –Influence of Peers—Benefits—Risk Averse—Economic Capacity	**PsInc**_ MoIfBREc	7.1%
One Main Goal Frame as Base Plus One or No Alternative			
16	**Leadership of Local Authority** OR **Rules of Collective/Community Work**—*Resource/Material Constraints—Economic Capacity*	**La_Ru**_*McEc*	8.3%

[a] Bold denotes related goal frames as base/root for the rules; Italic denotes the related secondary goal frames, which are either absent or present in the rules, alternatively; [b] Number of times the rules emerged (whether with the goal frames in same order or not) expressed as % of the survey sample; * Seven respondents, among the 443 who claimed to restore land at the individual level, did not provide any factors and rules; # Two respondents, among the 268 who claimed to restore land at the collective level, did not provide any factors and rules.

4.3.3.3. Restoration Decision-Making Processes

We construct the processes as a matrix table linking each rule with the vegetation-based and non-vegetation-based restoration practices/activities (Tables 4-6 and 4-7; see details of their occurrences in Appendix Tables 4-F and 4-G). On average, the total number of restoration practices farmers applied is 3-4 (mean 3.59) and 4–5 (mean 4.53) for individual-level and collective-level restoration, respectively. Many restoration practices/activities are common across the rules.

At the individual farm-household level, common vegetation-based restoration activities include agroforestry, farmer-managed natural regeneration (FMNR), and vetiver grass (*Chrysopogon zizanioides)* planting. Farmers aligned with rules #8 implement vegetation-based restoration to a lower extent. Those applying rules #12 and #18 implemented only one practice, FMNR and vetiver grass planting, respectively. Farmers associated with rules #11, #13, #20, and #21 engage with only two of the vegetation-based practices. Most recurrent non-vegetation-based restoration activities are manure application, mulching, and construction of contours ridges. For farmers following rules #8, #18, and #20 mulching comes first ahead of manure application, in contrast to the common trend. Secondary implemented practices include intercropping, swales making, markers/box ridges construction, and minimum or no tillage. Farmers utilizing rules #12, #16, and #19 strongly engage with intercropping, and a fair number of farmers following rules #11 and #18 construct swales.

At the collective-action level, vegetation-based restoration activities center on tree planting and natural regeneration in forest areas. All types of rules greatly reflect those restoration activities, except rule #13 which leads to less engagement in such activities. Farmers following rule #19 plant trees also for riverbank protection. The non-vegetation-based restoration activities most encountered are activities involving firebreaks in communally held forest areas, awareness against tree cutting and deforestation in the community, and other forest protection activities such as patrolling and monitoring. Construction of swales is observed to a lower extent on communal lands. Additionally, farmers following rule #19 are involved in gully reclamation.

Table 4-6. Decision-Making Processes for Individual Restoration of Forest-Agriscapes in the Study Areas

Rules	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Vegetation-based restoration practices	a **b** d *c*	a b d *e*	a **b** d *c*	a **b** **d** *c*	a **b** **d** *e*	a b d *c*	a **b** **d** *c*	a b d	**a** **b** d *c* *e*	a **b** d	a d	**b**	**a** **d**	**a** **b** **d**	a b *d* *c*	*a* *b* d	**a** b d	**d**	**a** **b** d	**b** **d**	a b
Non-vegetation-based restoration practices	**g** **i** k *f* *h* *j* *l* *m*	g **i** **k** *f* *h* *j* *l*	**g** **i** j **k** *l*	**g** **i** **k** *f* *h* *j* *l*	**g** **i** *f* *j*	f g **i** **k** *h* *j* *l* *m*	**g** **i** **k** l *f* *h* *j*	f **g** **i** *k* *h* *j*	f g **i** k *h* *j* *l*	f **i** **k** *g* *h* *l*	g **i** **k** j l *f*	**f** g h **i** k	**g** **i** **k**	f **g** **h** **i** **k** *l*	**g** **i** k *f* *h* *j* *l*	f **g** **i** *h* *j* *k*	**g** **i** k l	**g** **i** **j** **k** **l**	**f** **g** **i** **k**	**g** **i** **k** **l**	g **k** l

Bolded letters refer to restoration practices applied by at least half of the respondents who display the specific rule; letters in italics represent related restoration practices with very low occurrence (<20%).

Table 4-7. Decision-Making Processes for Collective Restoration of Forest-Agriscapes in the Study Areas

Rules	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Vegetation-Based Restoration Activities	**a** **b** *c* *d* *q*	**a** **b** *c* *d* *q*	**a** **b** *c* *d*	**a** **b** *c* *d*	**a** b		**a** b *d*	**a** b	**a** **b** *c*	**a** **b** *c* *d* *q*	**a** **b**	**a** **b** *c*	a b	a **b**	**a** b	**a** **b** *d*	**a** **b** *d*	**a** b *q*	**a** q
Non-Vegetation-Based Restoration Activities	**n** o **p**	**n** **o** **p** *r*	**n** o **p**	**n** **o** **p** *r*	**n** **o** **p** *r*		**n** o **p** *r*	**n** o **p**	**n** o **p**	**n** o **p** *r*	**n** **p**	**n** o **p**	**n** *o* **p**	**n** **o** **p**	**n** **o** **p**	**n** *o* **p**	**n** o **p**	**n** o **p**	n o p r

Bolded letters refer to restoration activities applied by at least 75% of the respondents who display the specific rule; letters in italics represent related restoration activities with a relatively low occurrence (<40%). The specific restoration activities and their magnitude could not be elicited for Rule#6 as this rule was identified only from the games and not from the survey.

Key: Vegetation-based restoration practices*:* *a* = Agroforestry on farms or active tree planting in forest areas; *b* = Farmer-managed natural regeneration on farms or Natural Regeneration in forest areas; *c* = Pits planting *(Zai)* on farms or on communal lands; *d* = Vetiver grass/other grasses on farms or on communal lands; *e* = Improved fallow on farms; *q* = Riverbank planting for protection of rivers/streams.

Non-vegetation-based restoration practices: *f* = Crop association/intercropping on farms; *g* = Mulching + crop residue incorporation on farms; *h* = No or minimum tillage on farms*, i* = Manure making and application on farms or on communal lands; *j* = Swales on farms or on communal lands; *k* = Contour ridges on farms; *l* = Marker/box ridges on farms or on communal lands; *m* = Rotation on farms; *n* = Fire-breaks in forest areas; *o* = Awareness against tree cutting and deforestation in the community; *p* = Other forest protection activities in forest areas; *r* = Gully reclamation on community lands.

4.4 Discussion

4.4.1 Local Perspectives on Landscape Restoration

Our findings on the local farmers' perspectives on landscape restoration reflect concerns over both adverse ecological and socioeconomic/livelihood conditions that need concurrent improvement. This dual consideration shapes the practices and activities used for restoration. These findings align with the perspective of the contemporary restoration movement, especially as codified in the forest landscape restoration (FLR) paradigm being promoted widely in SSA, including Malawi. Indeed, the new wave of restoration has departed from pure eco-centric perspectives, as is often promoted under ecological restoration, to accommodate more social dimensions, especially with regard to socio-economic well-being to which ecosystem services are a major contributor (Djenontin et al., *2020a*). As reflected in the commonly used definition of FLR (a planned process aimed at regaining ecological integrity and functions to enhance human well-being in deforested or degraded forest landscapes (IISD, 2002)), emphasis is put on social, economic, and ecological goals and outcomes.

Moreover, in a previous review, Djenontin et al. (2018) pointed to considerations of local contextual factors and aspirations in defining the objectives and goals of such landscape-scale restoration as well as in choosing and promoting technological packages. In that regard, our findings can inform efforts to operationalize FLR goals and practices in mosaic forest-agriscapes, without obscuring the embedded socio-cultural context, to achieve more meaningful and sustainable outcomes. Puspitaloka et al. (2020) recently attempted such contextual operationalization by rearticulating restoration in peatland ecosystems in Indonesia, following empirical assessment of the definitions, goals, and practices of peatland restoration across four restoration interventions in Central Kalimantan.

4.4.2 Landscape Restoration Rationales, Motives, Benefits, and Incentives

Our study reveals that while the boundary between restoration rationales and motives remains fuzzy, their nature differs. The former follows the line of logical/causal reasoning while the latter follows affective/emotional action. The distinction is worth making as it has implications on the proper specification of behavioral paradigms and subsequent parameterizations of decision rules in modeling restoration behaviors, as we discuss below. Moreover, our findings provide justification for treating benefits and incentives as extensions of restoration motives. Benefits and incentives were regarded as personal advantages and gains, and they considerably shape restoration behaviors at individual farm-household and collective-action levels. This study confirms, empirically, the need to consider them in restoration programs and policies as observed with benefits/incentives-based interventions in enhancing restoration behaviors.

Furthermore, the motives and benefits vary significantly by location and gender. Notably, having strong leadership from local authorities who support and encourage their community members through self-engagement and exemplary actions has emerged as an integral motivational element. Ntchisi district, exemplified by TA Nthondo, holds that advantage over Dedza district. This finding confirms previous evidence of the importance of strong, engaged, and inspiring leadership in collectively addressing environmental degradation (Zulu, 2008; 2013). Further, while there were many types of perceived or actual benefits from restoring forest-agriscapes, the gender and locational differences regarding environmental and energy supply-related benefits are important to note in planning restoration interventions. Specifically, this finding can inform the design of restoration programs as to what place-specific and gender-inclusive motives to leverage, and benefits to enhance or promote.

4.4.3 Landscape Restoration Decision Making and Behavior

Our findings indicate that restoration rules show various combinations of goal frames, the most important ones making up the roots for the rules. This nature of rules confirms that environmental behaviors are the result of multiple goal frames with some dominating ones. This means that one or more goal frames shift to become focal goal(s) over the others in the process of cognitively constructing the decision-making rules. This corroborates the postulate of the GFT (Lindenberg and Steg, 2007; Etienne, 2011).

Furthermore, insights on the defining constituents of the goal frames themselves indicate that incentives, benefits, and knowledge could be assimilated with the gain and hedonic goal framings, following (Lindenberg and Steg, 2007). These factors also compare with some of the factors influencing land-use and environmental-management decision making, notably the consideration of economic and non-economic benefits (Groeneveld et al., 2017). In our study areas, incentives and benefits were primarily not expressed in monetary terms, but more as in-kind (both soft, like training incentives, and concrete, like crop yields, poles, and other tree-resource benefits), a departure from the widespread over-reliance on cash incentives in collective conservation or restoration policies and strategies (see Zulu, 2013).

However, problem solving, resource constraints, and leadership of local authorities stand out as contextual types of goal frames associated with restoration behaviors. From the perspective of the GFT (Lindenberg and Steg, 2007), these elements do not reflect nor qualify as normative, gain, or hedonic goal framings. Rather, they refer to environmental concerns, capability, and political impulsion. The latter is of interest as the leadership of local authorities greatly influences collective action restoration decisions. These findings underscore the need to ground understanding of restoration behaviors within their local contexts.

4.4.4 Representation of Restoration Decision Rules in a LUCC-ABM

We have developed a conceptual approach to depict restoration decision-making processes based on our effort to empirically depict farmers' decision-making rules and the corresponding vegetation-based and non-vegetation-based restoration practices and activities in Central Malawi. This effort is similar to Keshavarz and Karami's (2014) effort to identify farmers' decision making and actions for drought management in Iran. It can serve as an input into future ABM-based restoration modeling aimed at simulating farmers' restoration behaviors, underlying decisions, and the spatially explicit socio-ecological outcomes at a higher (aggregate) forest-agriscape scale in Central Malawi. This approach can also be replicated elsewhere for similar studies attempting to ground social actors' decision rules in empirical data.

Significantly, we have uncovered that farmers incorporate both rationally grounded and motive-based goal frames in their critical decision making on using different restoration practices or getting involved in collective action restoration activities. This implies that when exploring landscape restoration using an ABM with a focus on farmers' restoration decision rules, one cannot solely espouse a rational behavior paradigm. Rather, one should also consider the role of motivational factors, including benefits and incentives. Groeneveld et al. (2017) argued that the importance of such non-rational factors influencing land-use and environmental management decisions had significantly been overlooked in LUCC-ABMs, whereas they are appropriately emphasized in behavioral economics. In this regard, our findings support the adoption of a bounded rational behavior paradigm in such future modeling of restoration behaviors.

In addition, we encourage adopting a process-based decision-making model to represent human decision making and circumvent the difficulties of applying theories following previous studies (An, 2012; Villamor et al., 2012). Insights suggest that blending ideas of experience/preference-based decision models with empirical/heuristic decision rules (An, 2012) would be an appropriate decision framework for exploring the future impact of landscape restoration in Central Malawi. Thus, our empirically grounded restoration-decision rules and processes are relevant to inform the parameterization of decision rules and representation of restoration actions for such an ABM. The occurrence of the rules could inform their respective probability distribution in the ABM and the restoration practices and activities would inform the actual actions taken by the farmer-agents.

Finally, methodologically, this study contributes to testing or putting into practice relevant recommendations on data gathering methods and processes to improve the representation of human decision making in empirical ABMs and enhance their analytical and policy value (Groeneveld et al., 2017; Rounsevell et al., 2012; Kremmydas et al., 2018; Smajgl et al., 2011; Smajgl and Barreteau, 2017; Elsawah et al., 2015). Adopting mixed social science data-collection methods, including semi-structured interviews through discussions and games, and a structured interview via surveys, appears useful. They can enhance understanding of the decision making underlying farmers' behaviors to characterize decision rules for further modeling processes.

4.5 Conclusion

This study sought to analyze the nature of the decisions to engage in forest-agriscape restoration through individual and collective actions in Central Malawi using a mixed-method approach to data collection and analysis. The study uncovers local farmers' perceptions of forest-agriscape restoration, and the nature of the influential factors considered when deciding to engage in restoration efforts. Furthermore, it reveals how these factors generate diverse goal frames determining restoration decision making, and ultimately the observed restoration practices and activities. Specifically, the study finds that the decision-making rules leading to restoration behaviors appear to be very diverse. They are made of goal frames that reflect nuanced considerations of environmental problems, livelihood needs and gains, constraints, socio-political influences, morals, values, and attitude to risks; all featured in diverse combinations. These restoration goal frames are categorized as problem-solving oriented, resource/material-constrained, benefit-oriented, incentive-based, peers/leaders-influenced, knowledge-dependent, altruistic-oriented, rules/norms-constrained, economic capacity-dependent, awareness-dependent, and risk averse-oriented. Improved understanding of the goal frames underscoring restoration decision-making rules is critical to inform potential management and policy mechanisms to boost restoration delivery. Finally, the study contributes a conceptual approach, with methodological application, to elicit restoration decision-making processes that associate various decision rules with the vegetation-based and non-vegetation-based restoration practices and activities undertaken by farmers. This will contribute to empirically ground the design and parameterization of farmers' restoration behaviors in an ABM that will explore effective governance modalities and spatially explicit policy options to boost landscape restoration in Malawi. Beyond that, this approach can be replicated elsewhere for similar studies attempting to ground social actors' decision rules in empirical data.

APPENDIX

Table 4-A. Sample Characteristics Across the Study Area.

Locations (TAs)	Kachindamoto (n = 120)	Kamenyagwaza (n = 72)	Kasakula (n = 120)	Nthondo (n = 108)	Vuso Jere (n = 60)	Total (n = 480)
Variables	Percentages					
AGE (Min = 19; Max = 92)	50.62	46.42	45.22	44.67	43.2	46.37
AGE GROUP						
Young Farmers	30.80	37.50	41.70	44.40	45.00	39.40
Adult Farmers	69.20	62.50	58.30	55.60	55.00	60.60
Pearson's $chi^2(4) = 5.9957$ Pr = 0.199						
GENDER						
Women	20.00	20.80	16.70	17.60	11.70	17.70
Men	80.00	79.20	83.30	82.40	88.30	82.30
Pearson's $chi^2(4) = 2.5082$ Pr = 0.643						
ETHNICITY						
Chewa	48.30	25.00	100.00	98.10	100.00	75.40
Ngoni	42.50	75.00	0.00	0.90	0.00	22.10
Other Ethnicities	9.20	0.00	0.00	0.90	0.00	2.50
Pearson's $chi^2(8) = 262.0546$ Pr = 0.000						
RELIGION						
Christian	89.20	98.60	93.30	93.50	100.00	94.00
Muslim	6.70	0.00	0.00	0.00	0.00	1.70
Animist	0.80	0.00	2.50	2.80	0.00	1.50
No religion	3.30	1.40	4.20	3.70	0.00	2.90
Pearson's $chi^2(12) = 32.3978$ Pr = 0.001						
MARITAL STATUS						
Bachelor	0.00	1.40	1.70	2.80	3.30	1.70
Married	76.70	80.60	85.00	83.30	85.00	81.90
Widow	12.50	8.30	6.70	7.40	10.00	9.00
Divorced	8.30	6.90	2.50	4.60	1.70	5.00
Separated	2.50	2.80	4.20	1.90	0.00	2.50
Pearson's $chi^2(16) = 16.3779$ Pr = 0.427						
EDUCATION LEVEL						
No Education	30.80	15.30	23.30	21.30	25.00	23.80
Primary School	57.50	66.70	55.80	56.50	65.00	59.20
Secondary School	10.80	18.10	20.00	21.30	10.00	16.50
College/University	0.80	0.00	0.80	0.90	0.00	0.60
Pearson's $chi^2(12) = 14.0138$ Pr = 0.300						
LITERACY						
No	37.50	25.00	30.80	26.90	28.30	30.40
Yes	62.50	75.00	69.20	73.10	71.70	69.60
Pearson's $chi^2(4) = 4.6242$ Pr = 0.328						
PRACTICING ENVIRONMENTAL RESOURCES RESTORATION						
No	9.20	8.30	10.80	2.80	6.70	7.70
Yes	90.80	91.70	89.20	97.20	93.30	92.30
Pearson's $chi^2(4) = 5.8276$ Pr = 0.212						

Table 4-B. Differences in the Number of Restoration Rationales and Motives by Gender, Education, and Location.

Dependent Variable	T or F [a]	Prob.[a]
Gender as Factor 1		
Restoration Rationales (Continuous [0–5])	-1.2403	0.2155
Restoration Motives (Continuous [1–5])	-1.3813	0.1679
Education as Factor 2		
Restoration Rationales (Continuous [0–5])	0.62	0.5992
Restoration Motives (Continuous [1–5])	0.20	0.8961
Location (Traditional Authority Area) as Factor 3		
Restoration Rationales [b] (Continuous [0–5])	0.72	0.5801
Restoration Motives (Continuous [1–5])	3.33	0.0106
M1: Project-Based Motivations: Government Requirement/Promotion (Dummy [0-1])	2.21	0.0669
M3: Leadership of Local Authority/Encouragement/Support (Dummy [0-1])	4.00	0.0034
M4: Altruistic Behaviors and Environmental Civism: Altruist Behavior (Dummy [0-1])	2.15	0.0738

[a] Student's t-test or one-way ANOVA test of variables ''Restoration Rationales'' and ''Restoration Motives" with either equal or unequal variances; [b] Variable violates the Bartlett's test (homogeneity of variances): assumption of homogeneity of variance is not met. Only the Games and Howell post comparison test is robust then, compared to the Scheffe Test. We consider the multiple comparison tests only for variables with significant t or F test.

Table 4-C. Differences in the Number of Restoration Benefits and Incentives by Gender, Education, and Location.

Dependent Variable	T or F[a]	Prob.[a]
Gender as Factor 1		
Restoration Benefits (Continuous [1–6])	-4.0866	0.0001
B2: Reforestation and Environmental Benefits (Dummy [0–1])	-2.3231	0.0206
B3: Sustainable Provision of Fuelwood and production of Charcoal (Dummy [0–1])	-3.2923	0.0011
B4: Sustainable Provision of NTFPs (Dummy [0–1])	-2.1431	0.0327
Restoration Incentives (Continuous [0–5])	-1.2804	0.2011
Education as Factor 2		
Restoration Benefits (Continuous [1–6])	0.93	0.4264
Restoration Incentives (Continuous [0–5])	1.16	0.3230
Location (Traditional Authority Area) as Factor 3		
Restoration Benefits [b] (Continuous [1–6])	5.35	0.0003
B3: Sustainable Provision of Fuelwood and Production of Charcoal (Dummy [0–1])	2.22	0.0658
B5: Cope with Climate Change Impacts (Dummy [0–1])	11.11	0.0000
Restoration Incentives [b] (Continuous [0–5])	1.62	0.1672

[a] Student's t-test or one-way ANOVA test of variables ''Restoration Benefits'' and ''Restoration Incentives" with either equal or unequal variances; [b] Variable violates the Bartlett's test (homogeneity of variances): assumption of homogeneity of variance is not met. Only the Games and Howell post comparison test is robust then, compared to the Scheffe Test. We consider the multiple comparison tests only for variables with significant t or F test.

Table 4-D. All Types of Decision-Making Rules for Individual-Level Restoration Elicited from FDGs and the Survey.

#	Rules [a]	Abbreviation [a]	Percentage [b] (n = 436) *
Three Main Goal Frames as Base Plus One Alternative			
1	**Problem Solving—Resource/Material Constraints—Incentives**—*Knowledge—Benefits—Economic Capacity*	**PsMcInc**_*KBEc*	11.7%
2	**Problem Solving—Resource/Material Constraints—Knowledge**—*Benefits—Economic Capacity—Extension Service—Influence of Peers*	**PsMcK**_*BEcExtIf*	11.2%
3	**Problem Solving—Resource/Material Constraints—Benefits**—*Outcomes—Economic Capacity—Leadership of Local Authority—Morality/Community Loyalty*	**PsMcB**_*OEcLaMo*	3.7%
4	**Problem Solving—Incentives—Benefits**—*Knowledge—Outcomes—Economic Capacity—Leadership of Local Authority*	**PsIncB**_*KOEcLa*	6.4%
5	**Problem Solving—Knowledge—Benefits**—*Economic Capacity—Risk Averse—Government promotion*	**PsKB**_*EcRGo* (10 similar cases from the FGDs)	2.1%
Two Main Goal Frames as Base Plus One/Two Alternatives			
6	**Problem Solving—Resource/Material Constraints**—*Media Awareness—Extension Service—Influence of Peers—Economic Capacity—Leadership of Local Authority—Bequest/Altruist Value*	**PsMc**_*MaExtIfEcLaAl*	13.1%
7	**Problem Solving—Incentives**—*Knowledge—Morality/Community Loyalty—Media Awareness—Risk Averse—Extension Service—Influence of Peers—Leadership of Local Authority—Economic Capacity—Bequest/Altruist Value*	**PsInc**_*KMoMaRExtIfLaEcAl*	18.8%
8	**Problem Solving—Knowledge**—*Extension Service—Economic Capacity*	**PsK**_*ExtEc*	5.0%
9	**Problem Solving—Benefits**—*Risk Averse—Influence of Peers*	**PsB**_*RIf* (1 similar case from the FGDs)	4.4%
10	**Resource/Material Constraints—Incentives**—*Benefits—Extension Service—Economic Capacity*	**McInc**_*BExtEc*	2.3%
11	**Resource/Material Constraints—Knowledge** – *Extension Service—Media Awareness—Influence of Peers—Risk Averse*	**McK**_*ExtMaIfR*	1.4%
12	**Resource/Material Constraints—Influence of Peers**—*Risk Averse—Leadership of Local Authority*	**McIf**_*RLa*	1.1%
13	Incentives—Benefits—*Risk Averse*	**IncB**_*R*	0.5%
14	**Incentives—Knowledge**—*Bequest/Altruist Value—Extension Service*	**IncK**_*AlExt*	0.9%
One Main Goal Frame as Base Plus One Alternative			
15	**Problem Solving**—*Resource/Material Constraints—Benefits*	**Ps**_*McB*	10.8%
16	**Influence of Peers**—*Problem Solving—Incentives—Knowledge—Benefits—Time efficiency—Outcomes*	**If**_*PsIncK_BTO* (6 similar cases from the FGDs)	2.3%
17	**Extension Service**—*Problem Solving—Resource/Material Constraints*	**Ext**_*PsMc*	1.4%
18	**Morality/Community Loyalty**—*Problem Solving—Incentives*	**Mo**_*PsInc*	0.5%
19	**Bequest/Altruist Value**—*Problem Solving—Resource/Material Constraints—Knowledge*	**Al**_*PsMcK*	0.9%
20	**Risk Averse**—*Problem Solving—Resource/Material Constraints—Media Awareness*	**R**_*PsMcMa*	0.5%
21	**Leadership of Local Authority**—*Problem Solving—Resource/Material Constraints*	**La**_*PsMc*	1.1%

[a] Bold denotes related goal frames as base/root for the rules; Italics denotes the related secondary goal frames, which are either absent or present in the rules, alternatively; [b] Number of times the rule emerged (whether with the goal frames in same order or not): expressed as % of survey sample; *Seven respondents, among the 443 who claimed to restore land at individual level, did not provide any factors and rules.

Table 4-E. All Types of Decision-Making Rules for Collective Action Restoration Elicited from FDGs and the Survey.

#	Rules [a]	Abbreviation [a]	Percentage [b] (n=266) *
Three Main Goal Frames as Base Plus One Alternative			
1	**Leadership of Local Authority—Problem Solving—Benefits**—*Knowledge—Risk Averse—Rules of Collective/Community Work*	**LaPsB**_*KRRu*	11.7%
2	**Leadership of Local Authority—Problem Solving—Incentives**—*Benefits—Risk Averse*	**LaPsInc**_*BR*	10.5%
3	**Leadership of Local Authority—Problem Solving—Morality/Community Loyalty**—*Benefits—Risk Averse*	**LaPsMo**_*BR*	3.8%
4	**Leadership of Local Authority—Problem Solving—Resource/Material Constraints**—*Incentives—Knowledge—Benefits*	**LaPsMc**_*IncKB*	3.4%
5	**Leadership of Local Authority—Resource/Material Constraints—Incentives**—*Knowledge—Benefits—Risk Averse*	**LaMcInc**_*KBR*	10.2%
6	**Problem Solving—Benefits—Knowledge**—*Influence of Peers—Time Efficiency—Outcomes*	**PsBK**_*IfTO* (11 cases from FGDs only)	–
Two Main Goal Frames as Base Plus One/Two Alternatives			
7	**Leadership of Local Authority—Resource/Material Constraints**—*Benefits—Knowledge—Extension Service—Influence of Peers*	**LaMc**_ *BKExtIf*	9.0%
8	**Leadership of Local Authority—Benefits**—*Knowledge – Risk Averse—Bequest/Altruist Value*	**LaB**_*KRAl*	9.0%
9	**Leadership of Local Authority—Morality/Community Loyalty**—*Benefits—Extension Service*	**LaMo**_*BExt*	4.9%
10	**Leadership of Local Authority—Incentives**—*Benefits—Risk Averse—Morality/Community Loyalty*	**LaInc**_*BRMo*	4.5%
11	**Leadership of Local Authority—Problem Solving**—*Risk Averse—Influence of Peers—Extension Service*	**LaPs**_*RIfExt*	3.0%
12	**Problem Solving—Incentives**—*Morality/Community Loyalty –Influence of Peers—Benefits—Risk Averse—Economic Capacity*	**PsInc**_ *MoIfBREc*	7.1%
13	**Problem Solving—Benefits**—*Morality/Community Loyalty—Risk Averse—Influence of Peers—Time efficiency—Bequest/Altruist Value—Rules of Collective/Community Work*	**PsB**_ *MoRIfT_AlRu* (9 similar cases from FGDs)	5.3%
14	**Problem Solving—Resource/Material Constraints**—*Knowledge—Incentives—Benefits*	**PsMc**_*KIncB*	1.9%
15	**Benefits—Incentives**—*Risk Averse—Resource/Material Constraints—Morality/Community Loyalty*	**BInc**_*RMcMo*	2.3%
One Main Goal Frame as Base Plus One Alternative or Not			
16	**Leadership of Local Authority OR Rules of Collective/Community Work**—*Resource/Material Constraints—Economic Capacity*	**La_Ru**_*McEc*	8.3%
17	**Benefits**—*Bequest/Altruist Value—Influence of Peers—Extension Service—Economic Capacity*	**B**_*AlIfExtEc*	3.4%
18	Risk Averse—*Incentives—Leadership of Local Authority*	**R**_*IncLa*	1.1%
19	**Morality/Community Loyalty**—*Problem Solving—Benefits—Risk Averse*	**Mo**_*PsBR*	0.8%

[a] Bold denotes related goal frames as base/root for the rule; Italics denotes the related secondary goal frames, which are either absent or not in the rules, alternatively; [b] Number of times the rule emerged (whether with the goal frames in same order or not): expressed as % of survey sample ";" * Two respondents, among the 268 who claimed to restore land at collective level, did not provide any factors and rules.

Table 4-F. Occurrence (%) of Restoration Practices for Different Decision-Making Rules for Individual-Level Restoration in the Study Areas.

Rules Restoration Practices	1 (n=51)	2 (n=49)	3 (n=16)	4 (n=28)	5 (n=9)	6 (n=57)	7 (n=82)	8 (n=22)	9 (n=19)	10 (n=10)	11 (n=6)	12 (n=5)	13 (n=2)	14 (n=4)	15 (n=47)	16 (n=10)	17 (n=6)	18 (n=2)	19 (n=4)	20 (n=2)	21 (n=5)
Agroforestry (a)	***45***	33	38	***43***	***44***	25	***49***	23	**53**	***40***	33	0	**50**	**75**	28	10	**50**	0	**50**	0	***40***
FMNR (b)	**61**	39	**75**	**89**	**89**	***49***	**56**	27	**84**	**50**	0	**60**	0	**50**	34	20	33	0	**75**	**50**	20
Pits Plant on Farms (c)	2	0	6	7	0	2	5	0	11	0	0	0	0	0	2	0	0	0	0	0	0
Vetiver (d)	***45***	***45***	***44***	**57**	**67**	***42***	**54**	27	37	***40***	33	0	**50**	**50**	17	30	33	**50**	25	**50**	0
Improved Fallow (e)	0	2	0	0	11	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0
Intercropping (f)	18	16	0	18	11	23	13	23	21	20	17	**60**	0	25	19	***40***	0	0	**50**	0	0
Mulching (g)	**53**	***49***	**56**	**79**	**100**	***42***	**65**	**73**	***42***	10	33	***40***	**100**	**50**	**55**	**60**	**50**	**100**	**50**	**100**	20
No Tillage (h)	4	12	0	4	0	5	2	9	5	10	0	20	0	**50**	2	10	0	0	0	0	0
Manure Application (i)	**86**	**84**	**81**	**86**	**100**	**86**	**82**	**68**	**84**	**90**	**67**	**60**	**50**	**100**	**64**	**70**	**83**	**50**	**75**	**50**	0
Swales (j)	16	20	25	7	11	11	10	5	16	0	33	0	0	0	6	10	0	**50**	0	0	0
Contour Ridges (k)	***47***	**57**	**56**	**57**	0	**53**	***50***	18	37	**80**	**50**	***40***	**50**	**50**	32	10	33	**50**	**50**	**50**	**80**
Marker/Box Ridges (l)	10	18	6	14	0	9	20	0	16	10	33	0	0	**50**	9	0	33	**50**	0	**50**	***40***
Rotation (m)	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Average Number of practices [Min-Max]	3.9 [1–8]	3.8 [1–7]	3.9 [1–7]	4.6 [1–8]	4.3 [3–6]	3.5 [1–7]	4.0 [1–9]	2.7 [1–5]	4.2 [2–5]	3.5 [2–5]	3 [2–4]	2.8 [1–5]	3 [2–4]	5 [3–7]	2.7 [1–4]	2.6 [1–4]	3.2 [1–6]	3.5 [3–4]	3.8 [2–5]	3.5 [3–4]	2 [1–3]

Bold and Underline = restoration practices applied by at least half of the respondents; Bold and Italics = restoration practices applied by at least 40% of the respondents.

Table 4-G. Occurrence (%) of Restoration Activities for Different Decision-Making Rules for Collective-Level Restoration in the Study Areas

Rules Restoration Activities	1 (n=31)	2 (n=28)	3 (n=10)	4 (n=9)	5 (n=27)	6 (n=11)	7 (n=24)	8 (n=24)	9 (n=13)	10 (n=12)	11 (n=8)	12 (n=19)	13 (n=14)	14 (n=5)	15 (n=6)	16 (n=22)	17 (n=9)	18 (n=3)	19 (n=2)
Active Tree Planting in Forest (a)	**77**	**93**	**80**	**89**	**78**		**88**	**79**	**92**	**83**	**75**	**84**	***57***	40	**100**	**82**	**100**	**100**	**100**
Natural Regeneration in Forest (b)	**97**	**79**	**80**	**100**	***67***		***63***	***71***	**92**	**83**	**75**	**84**	***71***	**80**	***67***	**82**	**89**	***67***	0
Pits Planting on Communal Lands (c)	23	39	30	11	0		0	0	8	8	0	5	0	0	0	0	0	0	0
Vetiver grass Planting (d)	6	25	10	22	0		8	0	0	8	0	0	0	0	0	5	11	0	0
Riverbank Planting (q)	6	14	0	0	0		0	0	0	8	0	0	0	0	0	0	0	33	**50**
Firebreak in Forest Areas (n)	**94**	**93**	**100**	**100**	**100**		**100**	**92**	**92**	**100**	**100**	**100**	**93**	**100**	**100**	**91**	**100**	**100**	***50***
Awareness Against (0) Tree Cutting/Deforestation	***58***	**86**	***60***	**89**	**78**		***71***	33	***69***	***67***	0	***68***	21	**80**	**83**	32	44	***67***	***50***
Forest Protection (p)	**97**	**93**	**100**	**100**	**93**		**88**	**100**	**92**	**92**	**100**	**95**	**79**	**100**	**100**	**100**	**100**	**100**	***50***
Manure Application (i)	6	32	0	33	11		8	0	0	8	0	5	0	0	17	0	0	0	0
Swales (i)	0	36	20	11	7		4	0	8	33	0	21	0	0	17	0	0	33	0
Marker/Box Ridges (l)	0	4	0	0	0		0	0	0	8	0	0	0	20	17	0	0	0	0
Gully Reclamation (r)	0	14	0	22	4		4	0	0	8	0	0	0	0	0	0	0	0	**50**
Average Number of Activities [Min-Max]	4.6 [3–7]	6.1 [2–11]	4.8 [3–7]	5.8 [3–8]	4.4 [2–6]		4.3 [3–7]	3.8 [2–5]	4.5 [2–6]	5.1 [3–12]	3.5 [3–4]	4.6 [3–6]	3.2 [0–4]	4.2 [3–5]	5 [3–7]	3.9 [2–6]	4.4 [3–6]	5 [4–7]	3.5 [3–4]

Bold and Underline = restoration practices applied by at least 75% of the respondents; Bold and Italics = restoration practices applied by at least 50% of the respondents. The specific restoration activities and their occurrence could not be elicited for Rule#6 as this rule was depicted from the games only and not from the survey.

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5 CHAPTER 5

Paper 4: Landscape-Scale Effects of Farmers' Restoration Decision Making and Investments in Central Malawi: An Agent-Based Modeling Approach.

Abstract

Understanding the contributions of local smallholder farmers and resource users to landscape-scale resources restoration is important to inform restoration policy implementation. However, empirical context-situated knowledge on the spatial-temporal patterns and environmental impacts of such restoration efforts, shaped by farmers' land-management decisions and actions, remain understudied. This study contributes to addressing this gap. Using Agent-based Modeling (ABM), we explore the potential space-time dynamics of aggregate outcomes from individual farmland and collective restoration efforts in Central Malawi and strategies to strengthen such efforts. The ABM integrates data from focus group discussions, role-playing games, a household survey, remote sensing products, and secondary sources. We conduct six model simulations and statistical post-processing analyses. Findings uncover a 10-year trend and spatially explicit potential restoration extent and intensity, greenness, and land productivity, all varying by participation level. Landscape regreening is modestly optimistic with fluctuating greenness in collective restoration and low, slightly incremental, and steady land productivity in individually restored farmlands. Findings also show that devising appropriate incentive schemes would enhance both collective and individual farmland restoration efforts. Offering necessary restoration knowledge—including through training and improved extension systems—and empowering local leadership would boost individual farmland and collective restoration, respectively. Importantly, operationalizing a management and policy package that bundles several enabling options would maximize restoration in forest-agriscapes. These findings suggest empowering local, bottom-up restoration efforts for enhanced landscape-level environmental outcomes. The study offers insights for spatially targeted, evidence-based landscape-restoration implementation in Central Malawi and demonstrates the potential of ABM as a tool to inform restoration policy.

Keywords: *Restoration extent, Restoration intensification; Participation; Greenness; Land productivity; Space-time patterns; Agent-based Model, Forest landscape restoration, Central Malawi*.

5.1 Introduction

The undeniable severe environmental degradation occurring globally has sparked calls for restoring degraded and deforested landscapes. It has generated much political will and momentum, including the recently launched United Nation Decade of Ecosystem Restoration that anchors existing restoration narratives and related regional initiatives. In sub-Saharan Africa (SSA), 31 out of 54 countries have committed to restore specific amounts of their degraded lands by 2030, adopting the Forest Landscape Restoration (FLR) paradigm as an approach of ecosystem restoration (Djenontin et al., 2018; 2020a). Malawi has pledged to restore 4.5 million hectares of degraded lands and became a leading country in terms of framing a clear FLR strategy that includes 7.7 million hectares, representing 80% of the country's land area, as potential degraded areas to be restored (MNREM, 2017; 2018). The narratives promoting and reshaping landscape-scale resources restoration acknowledge the crucial role of local communities, including smallholder farmers and resource users, hereafter 'farmers', as local agents of change to drive much restoration processes (Erbaugh et al., 2020; Mansourian, 2021; Singh et al., 2021; Sigman and Elias, 2021). Farmers have been shown to make complex decisions, shaped by their socio-cultural contexts to adopt pro-environmental technologies and practices to manage and restore both their degraded private lands and collective resources in forest-agriscapes (Schlecht et al., 2006; Meyfroidt, 2013; Andersson and D'Souza, 2014; Djenontin et al., 2020b). Such complex land-use/management decisions and resulting restoration actions produce aggregate, landscape-level environmental impacts, including improved land health and sustained provision of ecosystem services and functions.

However, empirical assessment of the environmental impacts of local farmers' restoration decisions and associated activities on forest-agriscapes is lacking. Relatively few studies have documented regreening trends in forest-agriscapes to increase understanding of the potential of existing local restoration efforts and different ways to reinforce them. This gap in scholarship also undermines evidence-based governance and policy implementation of FLR and broader restoration interventions. Many endeavors monitor deforestation and resources degradation worldwide, regionally, and at country and local scales. They include the global forest resources assessment by the FAO, the Global Forest Watch, the Global Land Analysis and Discovery lab at the University of Maryland, and individual scholarly studies (FAO 2020; Hansen et al., 2013; Curtis et al., 2018; Gondwe et al., 2019). Such studies mostly rely on remote sensing and latest artificial intelligence analytical power to assess the drivers, scale and magnitude of forest loss, degradation, permanent deforestation, and their detrimental social, ecological, and economic impacts. Yet, only few studies have begun to offer some glimpses of locally-driven regrowth, including regrowth evidenced in West African Sahara, the Sahel, the sub-humid zone, and in parts of Malawi, which is enhanced by trees outside forests and on-farm (Brandt et al., 2020 for the; USGS-USAID, 2018).

Challenges in integrating social-cultural dimensions and ecological aspects (le Polain de Waroux; 2021), with only just emerging attempts regarding restoration issues (see Hughes et al., 2020), make assessing local land-management action-driven aggregate environmental impacts on forest-agriscapes particularly difficult. In the case of forest and tree regrowth in particular, there is limited knowledge on the spatial and temporal patterns and outcomes of resources restoration and their links to the social agents involved in managing and restoring the resources. Also missing is a proper context-situated understanding of management strategies that can enable and positively influence local restoration efforts. Addressing such lack of evidence is now pressing to inform context-specific, propitious management and policy choices to accelerate restoration.

This study contributes to addressing these knowledge gaps by using a modeling approach of complex socio-ecological system (SES). We develop a bottom-up agent-based model (ABM) to explore the potential aggregate patterns and environmental outcomes of farmers' restoration decisions and activities in Central Malawi. ABMs offer a unique method to explore complex SES by simulating the impacts over space and time of local farmers' decision to engage and invest in restoration activities, while also identifying the likely effects of locally-deployed management/policy options to enhance farmers' restoration endeavors. The purpose of the model is to shed light on how the dynamics of landscape-scale patterns of restoration are shaped by the decisions of social agents (local farmers), including subsequent use of land-management practices, and to prospect for policy options to hasten resources restoration in Malawian forest-agriscapes.

Our objective is to evaluate the potential environmental impacts of farmers' restoration decisions and investments on forest-agriscapes and identify enabling policy options to foster restoration. The space-time dynamics examined include local participation levels, intensification patterns, and biophysical outcomes such as land productivity and vegetation cover. Our findings demonstrate spatially targeted and evidence-based restoration policy making and implementation.

In Section 2, we elaborate on spatial ABM as a social science simulation method of human-environment interactions to explore macro-scale patterns, emphasizing individual micro decisions and behaviors. In Section 3, we describe the materials and methods including the study area and the multi-source and multi-type data used to inform the model. We then present the conceptual ABM, along with the experiments, and describe the analysis processes. In Section 4, we report the simulation results including both spatial and non-spatial outputs. We discuss the findings in Section 5 and conclude in Section 6. The paper is supplemented with Overview, Design concepts, and Details (ODD) description of the model (Grimm et al., 2010; 2017; 2020), with an additional description of the social agents' decisions as emphasized by the ODD + Decision protocol (Müller et al., 2013).

5.2 Agent-Based Modeling: A Complex System Approach to Human-Environment Modeling

Modeling complex land-use/land-cover (LULC) change enhances our understanding of the spatial and temporal dynamics of land systems and supports implementation decisions and policies for resources management (Gilbert, 2008). Modeling of land use requires complex systems thinking that integrates socio-economic factors and processes with environmental and biophysical ones. This allows the capturing of feedbacks and emergent features at the system's level (An, 2012; Sayama, 2015).

ABMs are increasingly used because of their power to enhance the systematic understanding of problems involving complex SES for several reasons (Parker et al., 2003; Miller and Page, 2007; An, 2012). Advantages include enabling the integration of different disciplinary perspectives (Gilbert, 2008) and the ability to present outcomes of socio-ecological processes in a spatially explicit manner (Matthews et al., 2007; Kelly et al., 2013). ABMs are particularly effective for exploring aggregate macroscale (e.g., landscape level) impacts of micro scale land-use decisions and actions of farmers, land managers, and other social agents. Using a behavioral modeling approach helps to account for the agency of individual social actors that share a common environment, and to focus on heterogeneity, resource constraints, interconnectedness, interactions, and behavioral patterns (Miller and Page, 2007; Kelly et al., 2013). Another ABM advantage is the ability to explore and test outcomes of specific policy options for devising natural resource management decisions and policy making without having to wait for long term field-based impact analysis (Matthews et al., 2007). Also, using uncertainty and sensitivity analysis of ABMs provides stronger methods to determine the most influential factors driving certain observed emergent behaviors

(Ligmann-Zielinska and Sun 2010; Ligmann-Zielinska and Jankowski, 2014, Ligmann-Zielinska, 2018). These ABM advantages can help to capture the dynamics of the complex system of land-use conversion through restoration practices, which remains a gap to address to support and advance the new FLR paradigm.

This study employs ABM as a comprehensive method to explore the spatial and temporal impacts of the decisions to invest in tree and non-tree-based restoration practices both at the individual farm/household and collective levels in Central Malawi. It simulates the environmental conditions of a forest-agriscape with different policy options over a 10-year period, which is a common timeframe for restoration assessment (Wortley et al., 2013). We build on several studies that have employed ABMs to explore different facets of land-use conversion and change (see Berger, 2001; Parker et al., 2003; Bakker and van Doorn, 2009; Valbuena et al., 2010; Bert et al., 2011; Schreinemachers and Berger, 2011).

5.3 Materials and Methods

5.3.1 Study Area and Data

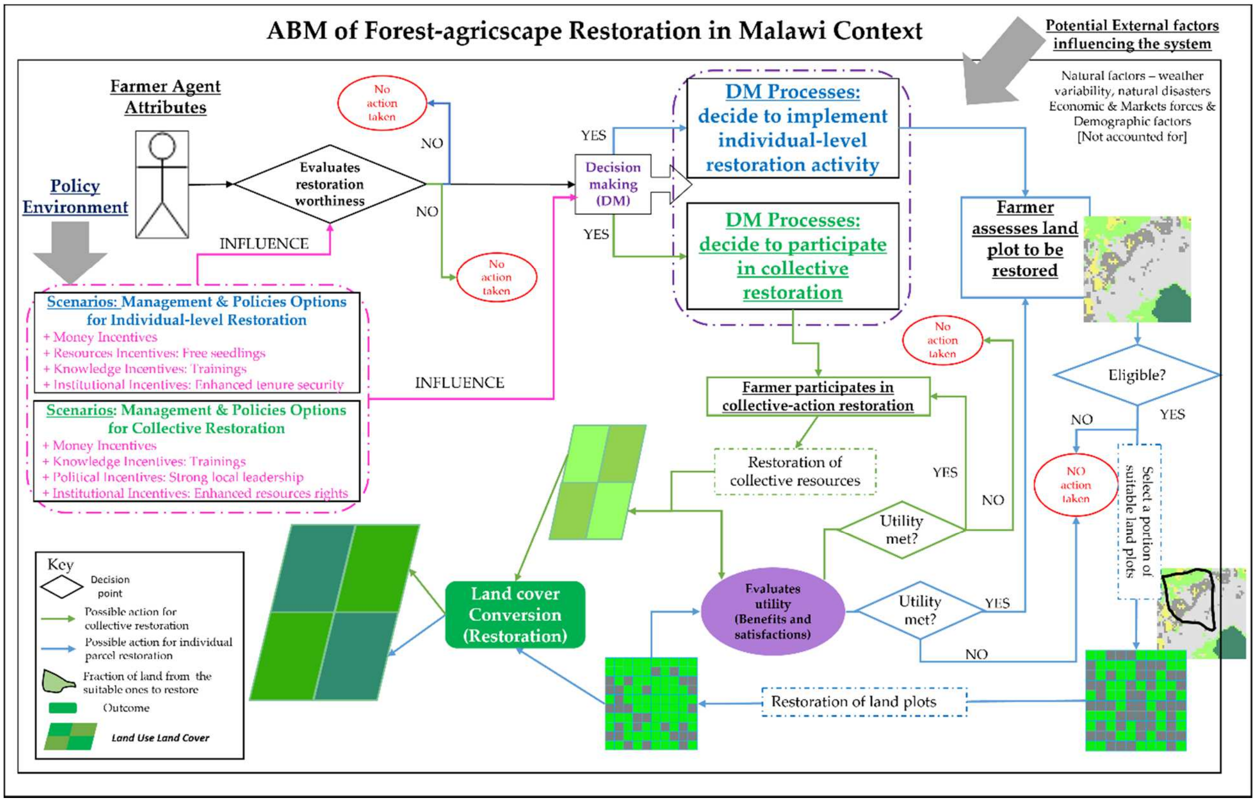
We focus on ongoing restoration efforts in Ntchisi and Dedza Districts in the central region of Malawi (Figure 1-3) as described in Section 1.3.2 in Chapter 1. However, this chapter/paper focuses on the modeling processes for Ntchisi district only to maintain consistency in reporting the results.

The ABM integrates several types of data and variables that we gathered from multiple sources. These include focus group discussions (FGDs) along with role-playing games (RPGs), a household survey (HHS), remote sensing products, and secondary data. First, in summer 2019, we conducted seven FGDs during which we used RPGs as a participatory approach to elicit farmers' decision-making processes on forest-agriscape restoration. Second, we conducted a HHS of 480 respondents, which provided quantitative data on the restoration decisions and on socio-demographic characteristics, socio-economic activities, farmer assets, and social, financial, and natural capitals. Other information collected was group-level variables that affect restoration activities (see Chatper 3 and Chapter 4 (Djenontin et al., 2020b) for more details on the primary data). Third, we gathered four types of remote sensing data products – one land-use/cover map, two vegetation and productivity indices, and one land marginality parameter (LMP) spatial dataset. The map product is a 1km-resolution land-use/cover map of Malawi for 2017 (based on images from April to September) derived from combined Sentinel-2 and Landsat 8 satellite data (USGS-USAID, 2018). The two indices are the Normalized Difference Vegetation Index (NDVI) that measures greenness, denoting tree and other vegetation cover, and Net Primary Productivity (NPP) that measures land productivity. NPP represents the energy stored as biomass by all plants and other primary producers, but excluding energy lost in respiration (essentially, biomass production measured in kg C m-2). We have retrieved 19-year (2000-2018) 16-day NDVI time series data (MOD13Q1.006 - 250meter resolution) and 19-year (2000-2018) NPP time series (MOD17A3HGF.006 - 500m resolution from the Terra satellite) from the NASA MODIS Reverb Web portal (NASA LP DAAC, accessed in August 2020 and February 2021). NPP has a direct relationship with agricultural production and is a reliable indicator of total land productivity (Messina et al., 2017; Qi et al., 2020). The land marginality parameter (LMP) represents land productivity estimates from a range of geospatial multi-scalar data sources including soil suitability, climate and interannual variability and other factors. LMP determines the level of land marginality in terms of productivity of the dominant grain cropping system developed for Malawi (Peter et al., 2018). Fourth, we draw on secondary data from peer-reviewed literature and existing public national surveys for additional information necessary in the model building, such as farm-household population. These data sources include Malawi's 2015/16 fourth integrated household survey (IHS4), the 2018 Population and Housing Census (NSO, 2019), and the National Census of Agriculture and Livestock (NACAL 2006/2007).

5.3.2 Conceptual ABM

The ABM developed for this research draws insights from previous models in studies informing natural resource governance and policy making for land-use conversion (Castella et al., 2005; Ligmann-Zielinska et al., 2014; Mwangi, 2017; Wimolsakcharoen et al., 2021). Our ABM conceptual diagram is presented in Figure 5-1. The ABM is composed of farmer agents whose local land-use decisions and subsequent implementation of restoration practices are considered as the major driving force of land-use conversion (restoration). Agent's environment is represented by the interlocked agrarian and forested landscapes within which restoration occurs. The agrarian area is made up of individual croplands divided into plots on which farmer agents can decide to implement restoration practices. It also includes some collectively-managed areas where farmer agents implement land and water resources conservation (LWRC) practices and infrastructures in organized groups on customary lands. The forested area comprises documented collectively-managed community trees and forests (Chapter 3). These include designated village forest areas (VFAs), community woodlots (CW), and natural forest patches (NF) located on customary lands, and the state-owned forest reserve (FR) sited in the protected areas.

Figure 5-1. ABM Diagram Flow



5.3.2.1. Agent's decision process and its implications

The model starts from setting up farmer agents who are assigned to land plots and collective resources. Agents follow different empirically informed decision rules (see Djenontin et al., 2020a) that lead to (some level of) restoration of their environment, upon evaluating whether they engage in restoration. Guided by their decision rules, agents implement a certain number of land-management practices and activities: (i) on a defined fraction of candidate plots deemed eligible and tagged for restoration and (ii) in selected collectively-managed resources also evaluated as suitable for restoration. A combination of farmer-level attributes and resource-level factors determine land-plot eligibility and selection of collective resources. In the modeling process, farmer agents evaluate land utility – the benefits and satisfactions from changes in land condition induced by the applied restoration practices. Land utility further informs farmer agents' willingness to continue with restoration in the following year. Specifically, farmer agents assess whether their selected plots and collective resources for restoration (i) show an increase in NPP and NDVI values, and (ii) are associated with additional harvest and resource access/use-rights. The assumption is that an increase in NPP, when comparing initial and final values associated with individual land plots, denotes a positive change in land productivity leading to denser vegetation (Qi et al., 2020). Similarly, an increase in NDVI, when comparing initial and final values associated with collective resources, denotes a positive change in landscape greenness from collective restoration. Upon updating their willingness to continue with restoration, farmer agents repeat the decision process for the following year. The model is simulated over ten years. Different management and policy scenarios are later explored as separate simulations.

5.3.2.2. Agent-environment feedback

The restoration decisions and actions of farmer agents induce changes in the environment. We simulate the likelihood of restoration of land plots and collective resources, offering an overview of the extent of restoration. For each time step (year), we record the number of times a land plot or collective resource is selected for restoration. We also simulate restoration intensity as the number of restoration practices applied on each restored land plot or collective resource. Further, we consider the overall landscape productivity and greenness. Among land plots and collective resource areas selected for restoration, we denote those with increased NPP and NDVI values as more productive or regreened (successfully restored) and we record their number as well as the value of the annual benefits.

5.3.2.3. Experiments

The experiments, also called scenarios, explore which resource-management options and policy provisions would sustain farmer engagement with restoration and enhance restoration outcomes. Drawing on earlier research insights (Chapter 3 and Chapter 4 (Djenontin et al., 2020b)), our experiments target previously identified underlying decision-making goal frames and critical determinants of restoration investments. The experiment elements are mainly external to farmer agents (often provided by government and NGOs) and are socioeconomic and institutional in nature (Table 5-1). Specifically, we introduce incentives and options addressing some resource constraints. We also include factors denoting increased restoration knowledge and enhanced local leadership. In addition to targeting restoration decisions, the experiments affect the number of farmers engaged in restoration, thereby potentially altering the number of land plots and collective resources to restore.

Table 5-1. Dimensions and categories of attributes in the experiments

Dimensions	Categories	Attributes
Socio-economic	Incentives	Money-based or in-kind incentives to farmers
	Leveraged Constraints	Free tree seedling Free or subsidized agricultural fertilizer use
Institutional	Knowledge	Restoration training Increased extension services
	Local leadership	Training on leadership for traditional authorities

The following operational questions are used for the experiments:

- Experiment 1: What is the effect of providing different forms of incentives (monetary and in-kind) on restoration patterns and outcomes?
- Experiment 2: What are the implications of enhancing local leadership on the patterns and outcomes of restoration?
- Experiment 3: How does farmer agents' access to restoration inputs (free tree seedlings and agricultural fertilizers) shape the patterns and outcomes of restoration?
- Experiment 4: How does farmer agents' access to knowledge (via training on restoration practices and reinforcement of extension services) shape the patterns and outcomes of restoration?
- Experiment 5: How does enabling all of the above management options and provisions shape the patterns and outcomes of restoration?

It is important to note that some external elements may influence the environment and the larger socio-economic and political system of farmer agents, but, for simplicity, we did not include them in our ABM. We elaborate further detailed specifications of the ABM components, including agents, their environment, decision rules and actions, and the experiments in the ODD+D documentation (Supplemental file).

5.3.3 Analyses

Our evaluations include six model simulations (base model and five experiments) and analysis of their respective outputs. First, for each model simulation, the number of farmer agents initialized (NF =

18820) reflects an estimated population of farm households for the region of interest (the extent of the forest-agriscapes). That number is inferred from both the potential number of land plots in the extent of the forest-agriscape (NP =52,701 plots) and the distribution of average land-plot ownership (number of plots) by household in the study site as informed by the HHS. Further, we maintain the number of land plots (NP) and collective resources (NC =30 collectives) constant in the models throughout the simulations because the spatial area does not expand, even though land plot fragmentation may occur. More details on these assumptions and other model specifications are described in the ODD+D documentation. Each scenario comprises 10 years (ticks) and is executed 420 times. We estimated this number based on 21 covariates included in the model, each needing 20 observations (see Harrell, 2015). We save and store the spatial and scalar output data for each year of simulation. We developed the model in Python programming language (https://www.python.org/). The elapse time per model simulation was 39 hours on average.

Second, outputs processing involves evaluating the aggregate spatial and temporal trends of the extent of restoration; biophysical changes, including the level of productivity and greenness and their value (restoration benefits); restoration intensity; level of participation; and the differential impacts of the experiments. For each year we compute: (i) the ratio of restored land plots and collective resources to the total available land plots and collective resources, respectively; (ii) the ratio of productive land plots and regreened collective resources over the total available land plots and collective resources; (iii) the sums of productivity and greenness values for all productive plots and regreened collectives; (iv) the number of farmer agents who engage in restoration individually and collectively; and (v) the number of restoration practices applied on land plots and in collective resources. For each year, these statistics are averaged over all 420 simulation runs. We repeat the analyses for each experiment and use one-way ANOVA and selected post hoc tests to compare the respective outputs and detect any statistically significant differences across experiments. This process can guide identification of propitious management and policy choices for restoration. For these analyses, we use Stata 15 and R, in combination with ArcGIS.

5.4 Results

We present the non-spatial and spatial results of the model simulations, which offer complementary insights.

5.4.1 Collective Resources Restoration

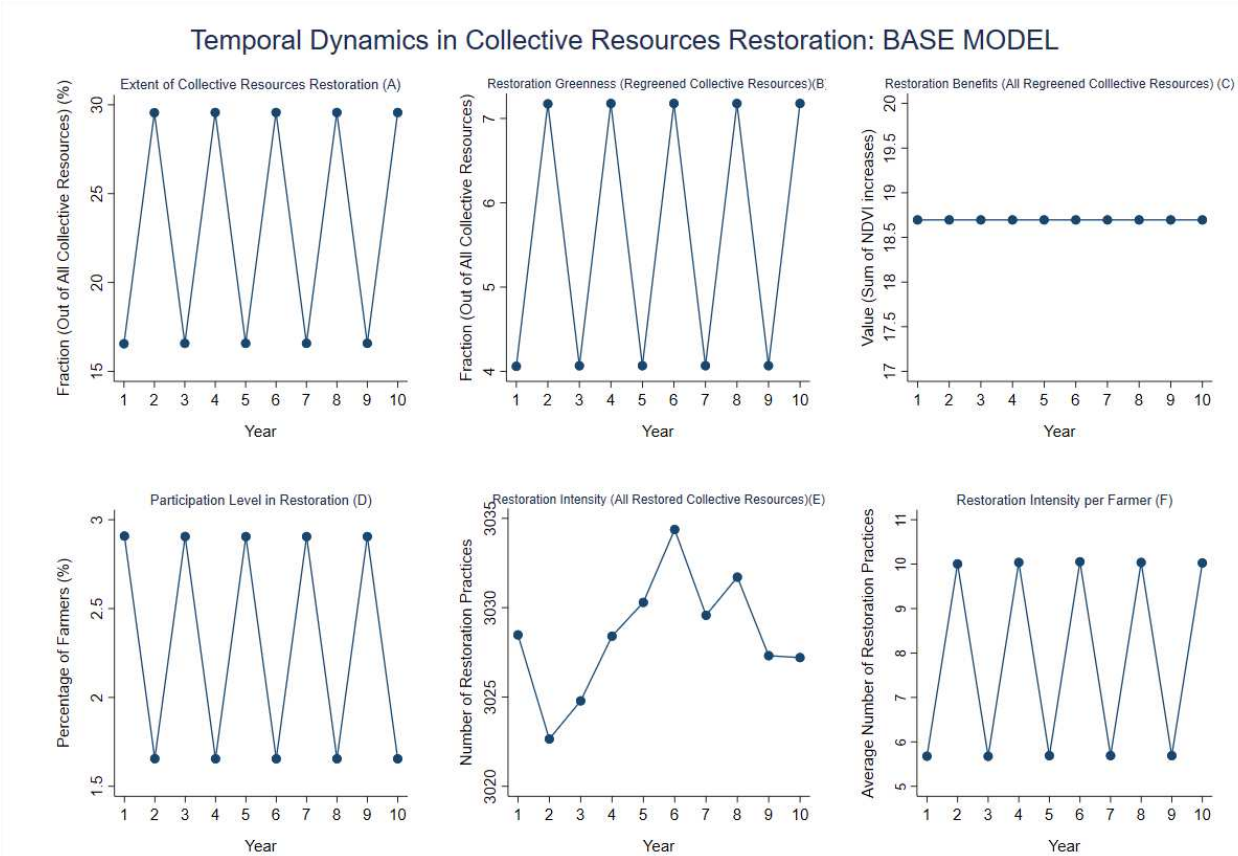
5.4.1.1. Emerging aggregate patterns and outcomes of collective restoration (the base model)

Extent of restoration: In this experiment, less than half of the collective resource areas in the forest-agriscape are selected for restoration. Figure 5-2, graph A shows an up and down pattern of approximately 16.6% of collective resources restored in year 1. This increases to 29.6% in year 2, falls to 16.6% in year 3, goes up again to 29.6% for year 4, and so forth. Spatially, findings show which specific collective resources are likely to be restored yearly, indicating their frequency of selection for restoration (Figure 5-3, panel A). While there is no clear temporal difference, the spatial patterns illustrate that each year, the NFR in the protected area has a high frequency of selection; thus, is likely restored. However, only a small share of collective resources on customary areas has a high likelihood of being restored given their relatively low selection frequencies (orange and yellow polygons in Figure 5-3, panel A). The collective resources on customary areas include village forest areas (VFAs), community woodlots (CW), natural forest patches (NF), and areas devoted to LWRC activities.

Landscape-greenness levels and values: Upon restoration, a few number of collective resources are regreened, denoted by an increase in their NDVI values (difference between final and initial values). Similar to the pattern of the extent of restoration, Figure 5-2, graph B illustrates an up and down trend of approximately 4.1% of regreened collectives for year 1, changing to about 7.2% for year 2, then coming down to 4.1% for year 3, and up again to 7.2% for year 4, and so forth. Despite such a temporal up and down trend of regreening, the aggregate yearly landscape-level greenness value (sum of all NDVI increases) remains the same and is equal to 18.7 (Figure 5-2, graph C). Therefore, years with low numbers of regreened collective resources would still show a denser vegetation cover in those collective resources. When distributed equally on the landscape (and considering all resources), the average NDVI value would correspond to approximately 0.62.

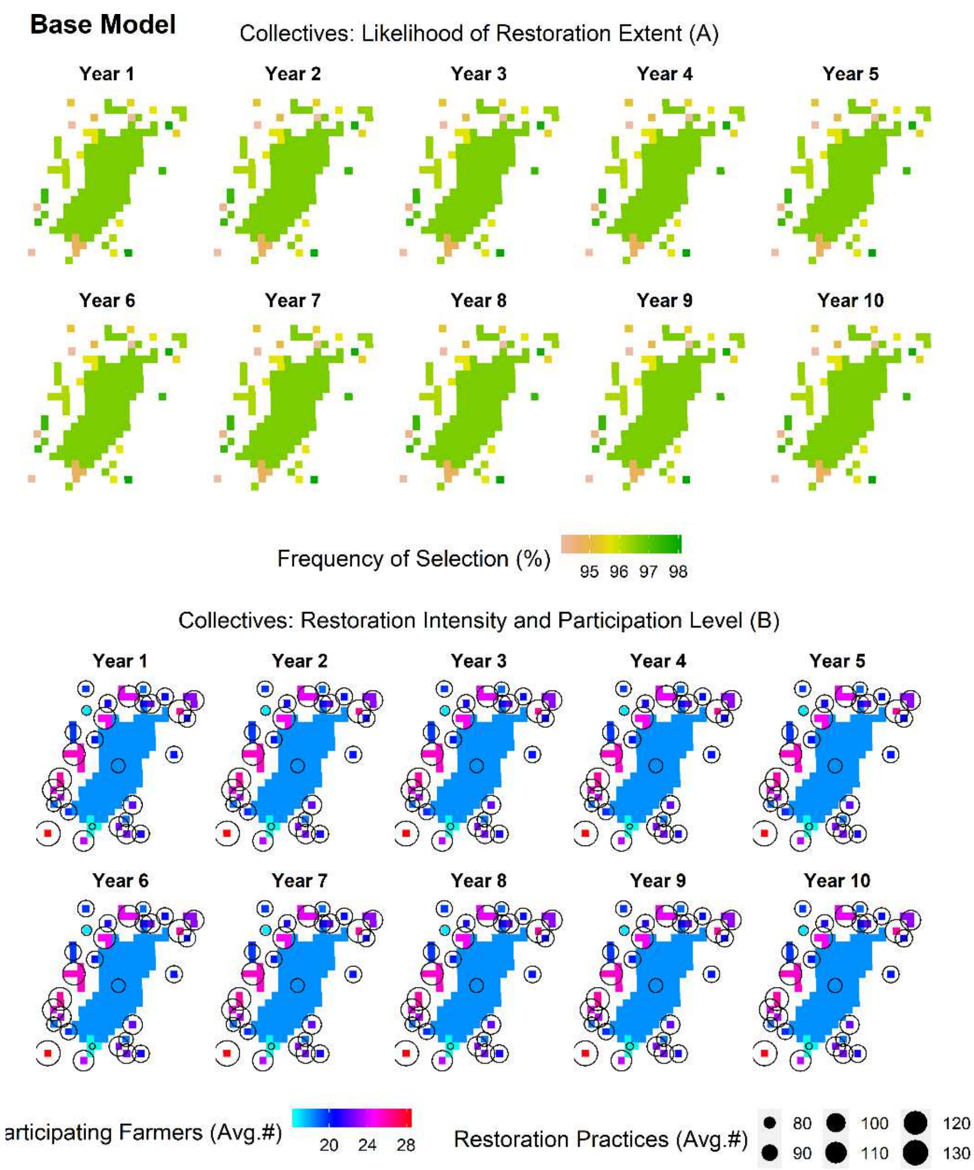
Levels of participation: Farmer agents' engagement in collective restoration exhibits an inverse relationship with the extent of restoration. Figure 5-2, graph D shows a relatively higher number of farmer agents (2.9%) involved in restoring the collective resources in years with low restoration extent, while a smaller number of farmer agents (1.7%) are involved in restoring collective resources in years with high restoration extent. Spatially, findings indicate that farmer agents participate more in collective restoration on customary areas (collective resources in purple to red colors in figure 5-3, panel B), while they engage less in collective restoration in the protected areas as indicated by the dominant blue color of the NFR polygon. We infer that the tenure system drives this pattern of participation level, indicating higher ease of access to and management of community-owned resources on customary areas than state-owned resources in protected areas.

Figure 5-2. Aggregate temporal patterns and outcomes of collective restoration (Base model, graphs A-F)



Restoration intensity: Farmer agents apply a high number of restoration practices in restoring the collective resources, demonstrating restoration intensification. Figure 5-2, graph E indicates that for all collective resources under restoration, the ten-year average aggregate number of restoration practices applied is 3028, with a narrow variation ranging from 3022 (year 2) to 3034 (year 6). Individually, each farmer agent applies on average 5-6 restoration practices in years with high participation level, which increased to around 10 restoration practices in years with low participation level (Figure 5-2, graph F), signaling a hidden maximization rationale to achieve the same aggregate level of greenness. Spatially, findings illustrating the average number of restoration practices applied on each collective resource unit indicate a relatively higher number (big circle sizes) on collective resources on customary areas than the ones in protected areas (Figure 5-3, panel B).

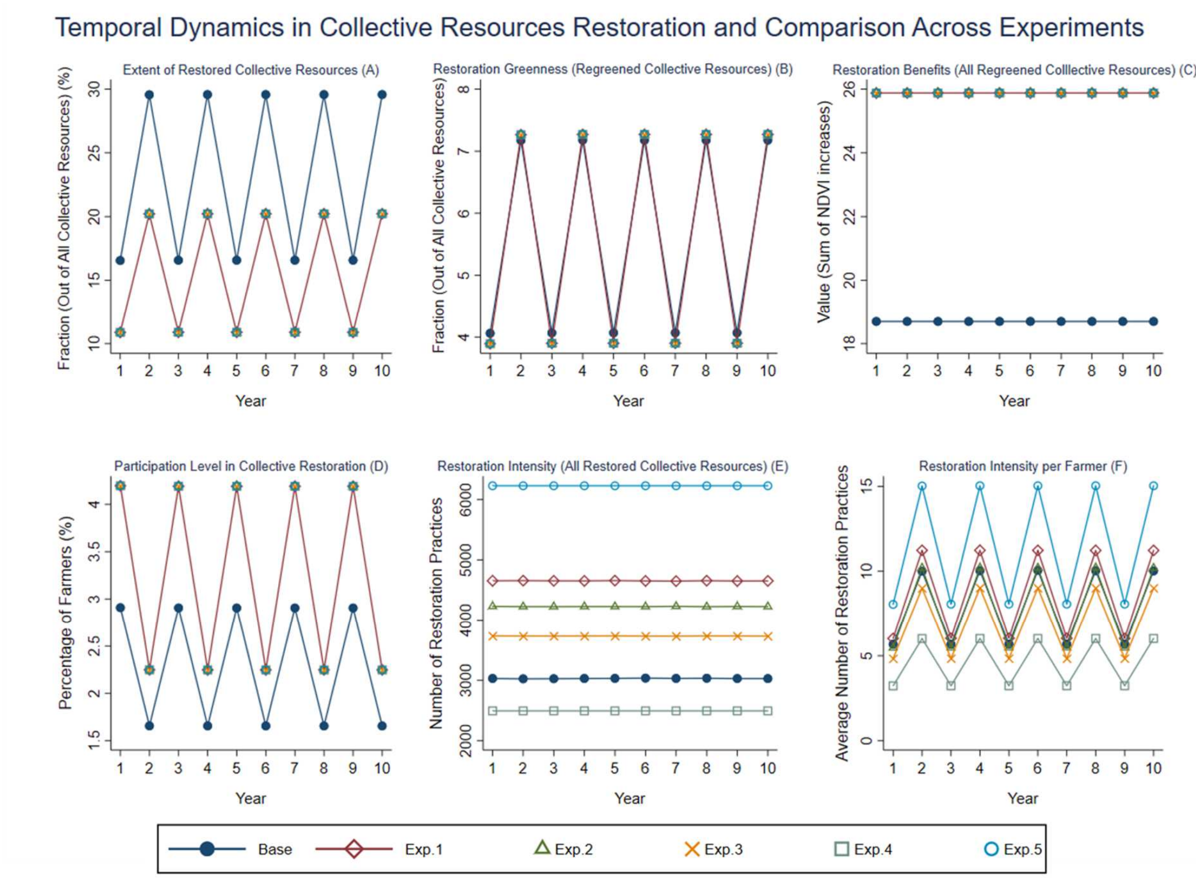
Figure 5-3. Spatially-explicit and temporal trends of collective restoration outcomes (Base model, panels A-B)



5.4.1.2. Differential effects of the experiments on emerging patterns and outcomes of collective restoration

The experiments indicate few differential effects from the comparative analysis (Figure 5-4, graphs A-F), with some showing a statistical significance (Table 5-2). First, for the **extent of restoration,** all five experiments indicate a reduction of the yearly number of collective resources restored compared to the base model (Figure 5-4, graph A), with statistically significant differences. However, despite such a relatively low extents of restoration, all five experiments display similar temporal trends as the base model. Spatially, all five experiments show a shift in the frequency of selection of some collective resources. They all indicate an increase in the likelihood of restoring the NFR (protected area) while showing a decrease in the likelihood of restoring some collective resources on customary areas (Figure 5-5). Second, regarding **biophysical changes,** all five experiments share similar fluctuating temporal trends and have the same aggregate levels of greenness, with no obvious difference compared to the base model (Figure 5-4, graph B). However, all five experiments indicate increased aggregate greenness value of approximately 25.9 (sum of all NDVI increases) that is consistent for all years (Figure 5-4, graph C) but shows no statistically significant difference compared to the base model. This suggests a slightly greener landscape than the base model value indicates. Third, for **participation level,** all experiments increase the level of participation in a similar fashion compared to the base model (Figure 5-4, graph D), but with a marginal statistically significant difference. Spatially, such increases are also observed without changing the featured dynamic supported by the tenure system – more participation for community-owned collective resources compared to state-owned collective resources (Figure 5-6). Finally, regarding **restoration intensity,** while there is no temporal difference within each experiment, they all show differentiated restoration intensification (Figure 5-4, graphs E-F) that is statistically very significant. Experiments 1 and 5 increase substantially the number of restoration practices applied both at system (landscape) level and at farmer level, compared to the base model. Experiment 4 shows a lower intensification both at landscape and at farmer levels, compared to the base model and the other experiments. Experiments 2 and 3 also increase the number of restoration practices applied, but only at the aggregate landscape level when compared to the base model. At the farmer level, experiments 2 and 3 show similar and lower restoration intensification, respectively, compared to the base model. Spatially, these landscape-level trends are confirmed, indicating increased ranges of the number of restoration practices applied on the collective resources for all experiments except for experiment 4 compared to the base model (Figure 5-6).

Figure 5-4. Comparison of the aggregate temporal patterns and outcomes of collective restoration among the base and experimental models (Graphs A-F)



Note: For panels A-D, experiments 1-5 show very undistinguished difference and, in panel B, are even very similar to the base model

Table 5-2. Statistical comparison of the aggregate patterns and outcomes of collective restoration among experiments

Variables	**F[a]**	**Prob.[a]**
Extent of Restoration	*3.37*	*0.0102*
All five experiments are significantly different from the base model (Scheffe Test and Games and Howell Test's p-values=0.090)		
Level of Greenness	*0.00*	*1.0000*
Restoration Benefits (Re-greenness value)	--	--
Level of participation	*1.55*	*0.1898*
Restoration Intensification (aggregate landscape level) [b]	4.5e+06	0.0000
All five experiments and base model are significantly different from one another (Scheffe Test and Games and Howell Test's p-values=0.000)		
Restoration Intensification (farmer level)	7.7	0.0000
Experiment 1 is significantly different from experiment 4 (p-value = 0.046) and experiment 5 is significantly different from the base model (p-value = 0.084) and from experiments 2, 3, and 4 (p-values = 0.081, 0.012, and 0.000 respectively)		

[a] One-way ANOVA test of the variables with either equal or unequal variances; [b] Variable violates the Bartlett's test (homogeneity of variances), hence assumption of homogeneity of variance is not met. Only the Games and Howell post comparison test is robust compared to the Scheffe Test. We consider the multiple comparison tests only for variables with a significant F test.

Figure 5-5. Comparison of the spatially-explicit trends of the extent of restoration among the base and experimental models for collective restoration

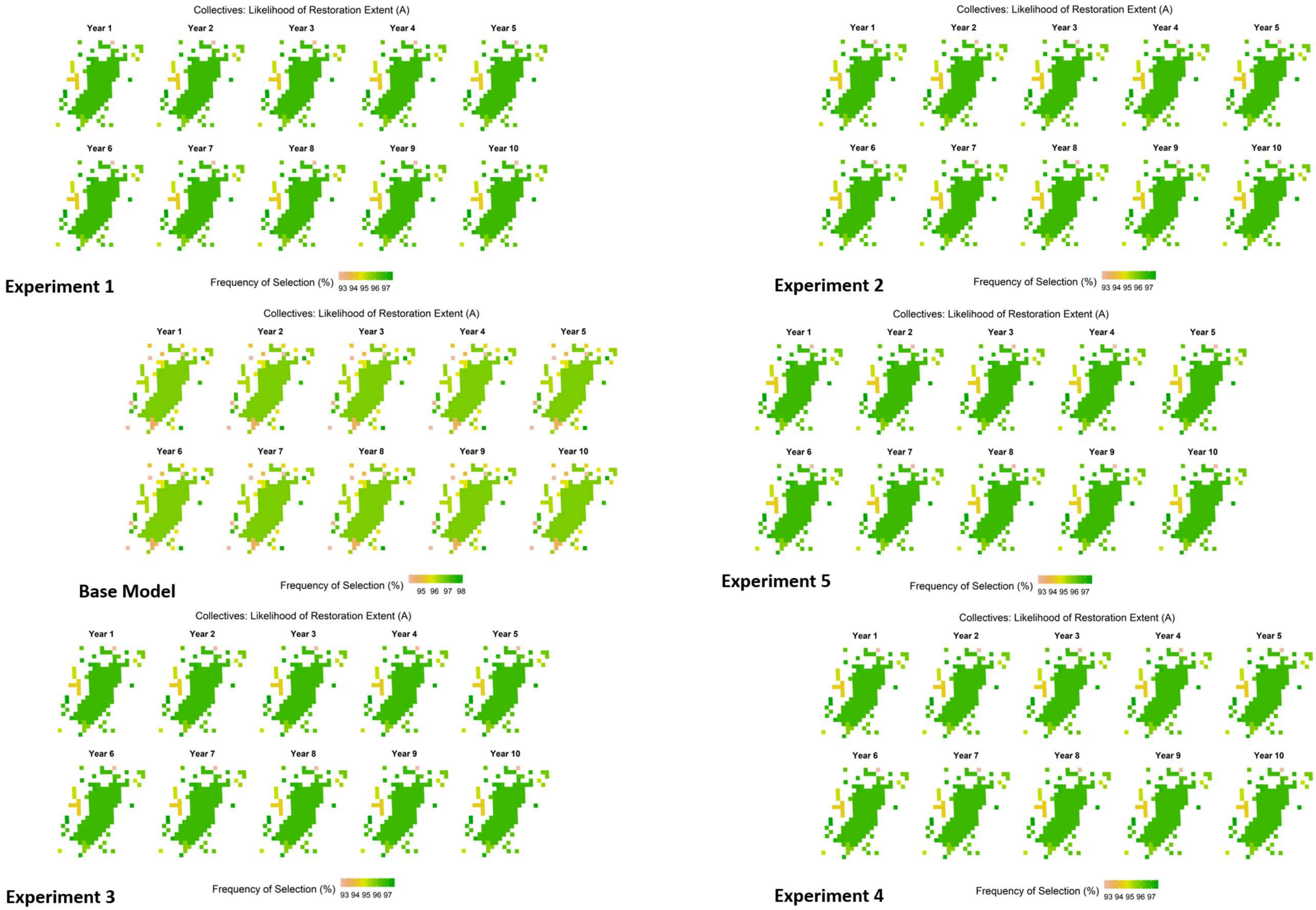
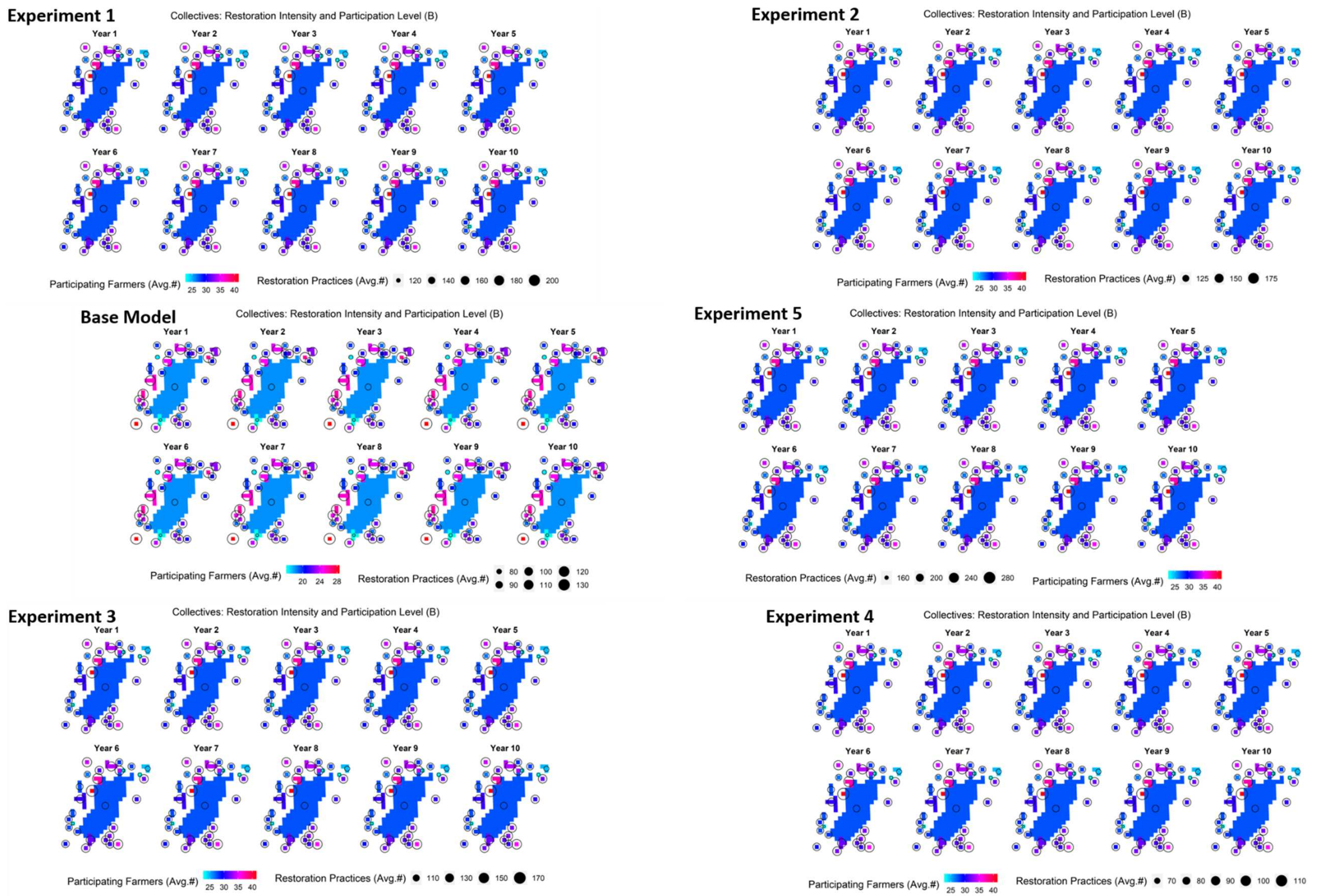


Figure 5-6. Comparison of the spatially-explicit trends of restoration intensity and participation level among the base and experimental models for collective restoration



5.4.2 Individual Land-Plot Restoration

5.4.2.1. Emerging aggregate patterns and outcomes of individual restoration (the base model)

Extent of restoration: Less than half of the land plots in the forest-agriscape are part of the restoration processes all the way from their eligibility to consideration and selection for restoration. Figure 5-7, graph A indicates that while 37.5% are deemed eligible for restoration, 29.7% are actually considered, and finally only 15.3% are restored. Temporally, this trend is linear and remains almost the same, with a slight decline (nearly indistinguishable) from year 2 and onward. Spatially, findings show the yearly frequency of selection of land plots for restoration (over the 420 runs of simulation), which ranges from 60% to 78% in year 1 and declines to about 55-74% in year 2 and onward (see the subset land-plots image). The spatial patterns illustrate a random selection of land plots within the forest-agriscape, with no noticeable clustering as shown in the mapped plots subset (Figure 5-8, panel A).

Land-productivity levels and values: Upon restoration, a few number of land plots are productive, represented by an increase in their NPP values (difference between final and initial values). Figure 5-7, graph B illustrates a cumulative rising trend, with a steep increase in the first 2 years (16. 29%[1] and 16.89%), a slight decrease in year 3 (16.88%), and rebound in year 4 (16.89%) that then plateaued for the remaining years. The aggregate yearly landscape-level productivity value (sum of all NPP increases) follows a similar modest rising pattern, starting from 4173.9 and plateauing around 4326.4 (Figure 5-7, graph C). When distributed equally across all land plots in the landscape, the average NPP value would be approximately 0.083-0.086 kg C m-2, indicating a positive but low productivity based on the potential 19-year mean values used (ranges of 'NPP final' – see ODD documentation).

Levels of participation: Farmer agents' engagement with individual land-plot restoration features an inverse relationship with the levels and values of land productivity. Figure 5-7, graph D shows a reverse j-shape denoted by a very small but noticeable decline in the number of farmer agents restoring land plots (22.52% down to 22.49%) between year 1 and 4, and by a steady trend from year 4 and onward.

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[1] The productivity level for year 0 is 14.25%, but this is not displayed in the figure because we actually run the model for 11 years and subset ten timesteps (from year 1-10). Year 0 is mostly a legacy of the model set up and a training year that masks the remaining variations in the simulations (see ODD+D documentation for more detailed explanation).

Restoration intensity: Farmer agents apply a high number of land-management practices in restoring their land plots, demonstrating a restoration intensification. Figure 5-7, graph E indicates that, for all land plots being restored, the aggregate number of restoration practices applied is very high but decreasing notably in the first five years, with a narrow range of variation overall. Also, each time the number of restoration practices reaches its low-end values (year 5 and 7), there is more rebounding effort to a seemingly acceptable aggregate number to maintain land-productivity levels and values (restoration benefits). Individually, each farmer agent applies on average approximately 4 restoration practices on their respective farmlands (total of land plots owned), with narrow temporal variation (Figure 5-7, graph F). Spatially, findings illustrate that the average number of restoration practices applied on each land plot ranges 2-3, with few plots receiving more than 3 practices as shown in the mapped plots subset (Figure 5-8, panel B). This range corroborates the above farmer-level trends because most farmers own just 2 land plots with few owning more or less, making the total number of restoration practices applied to likely sum up to the average number found over their entire farmlands.

Figure 5-7. Aggregate temporal patterns and outcomes of individual land-plot restoration (Base model, graphs A-F)

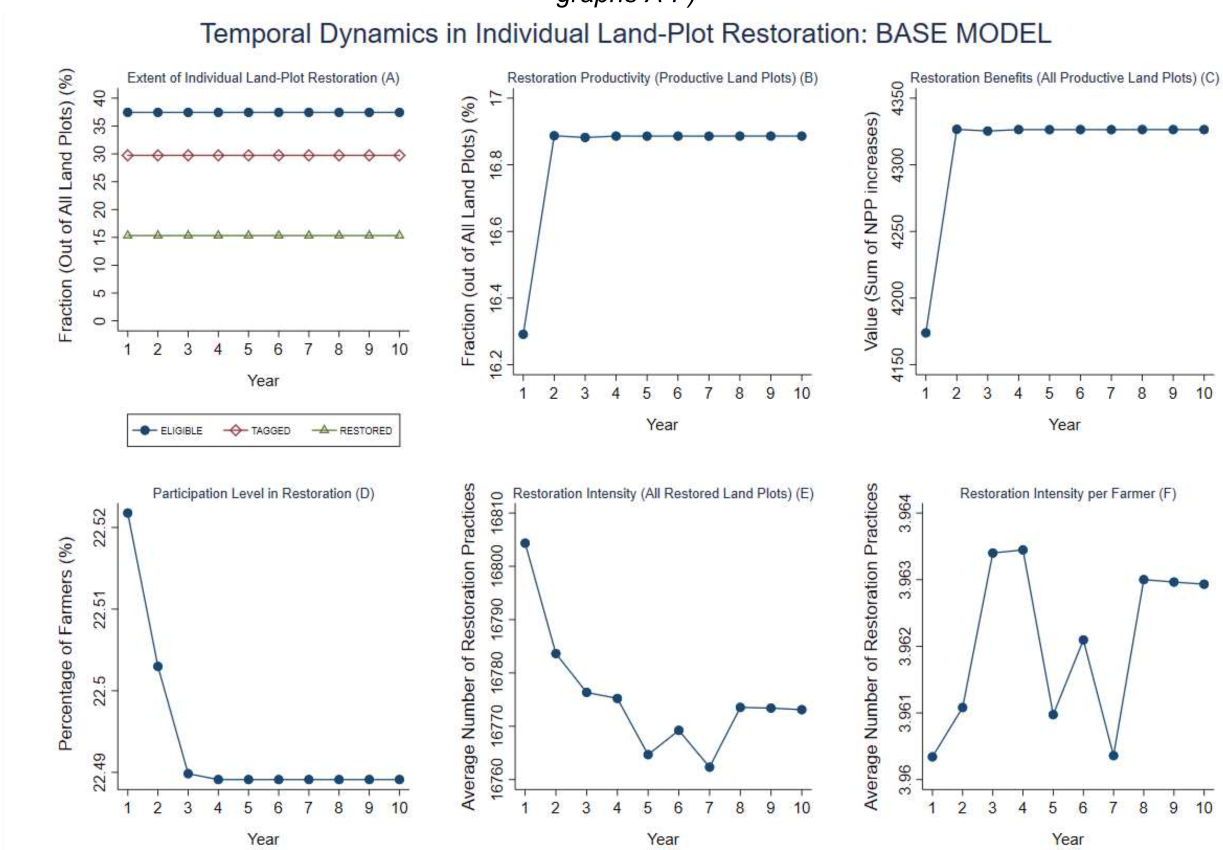
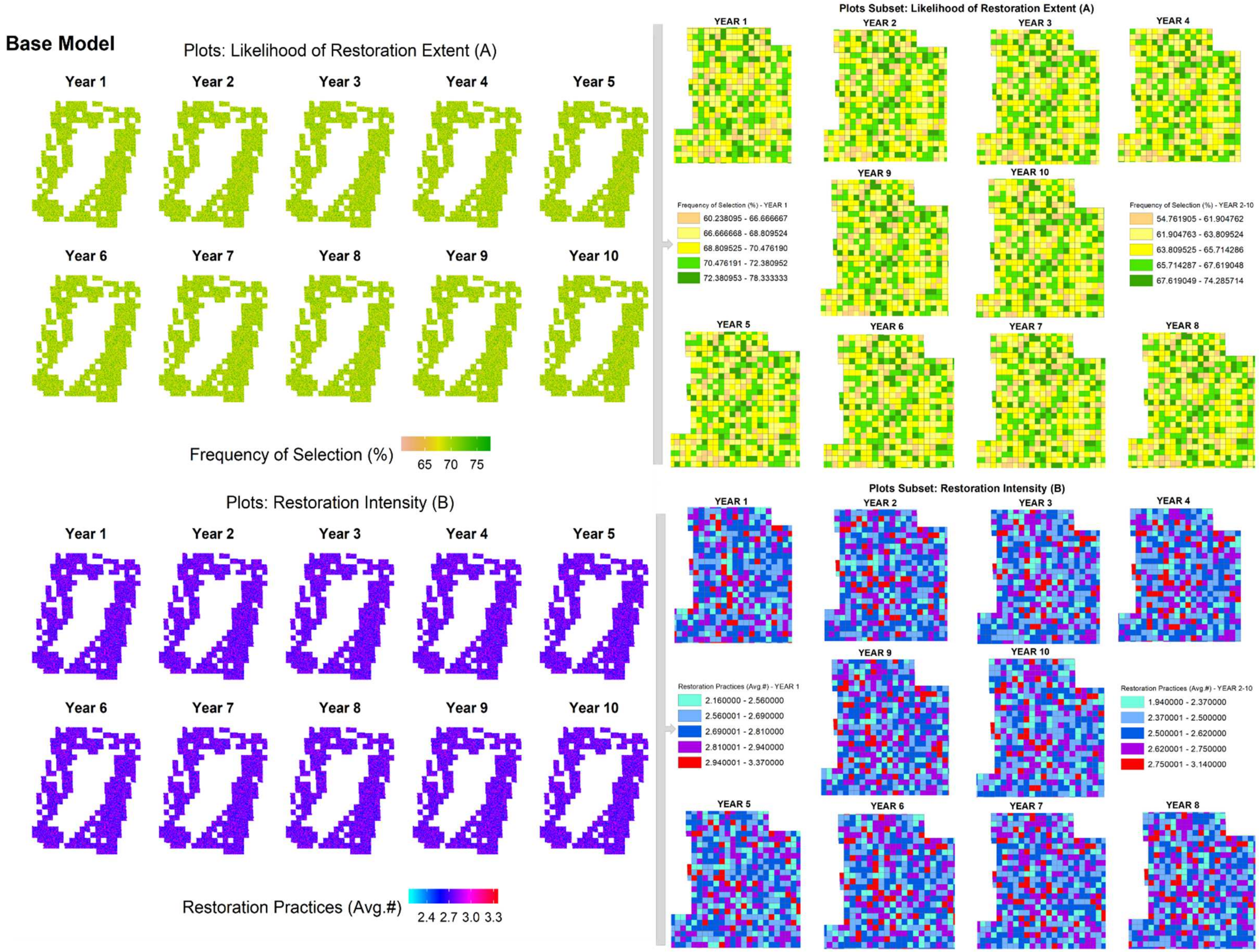


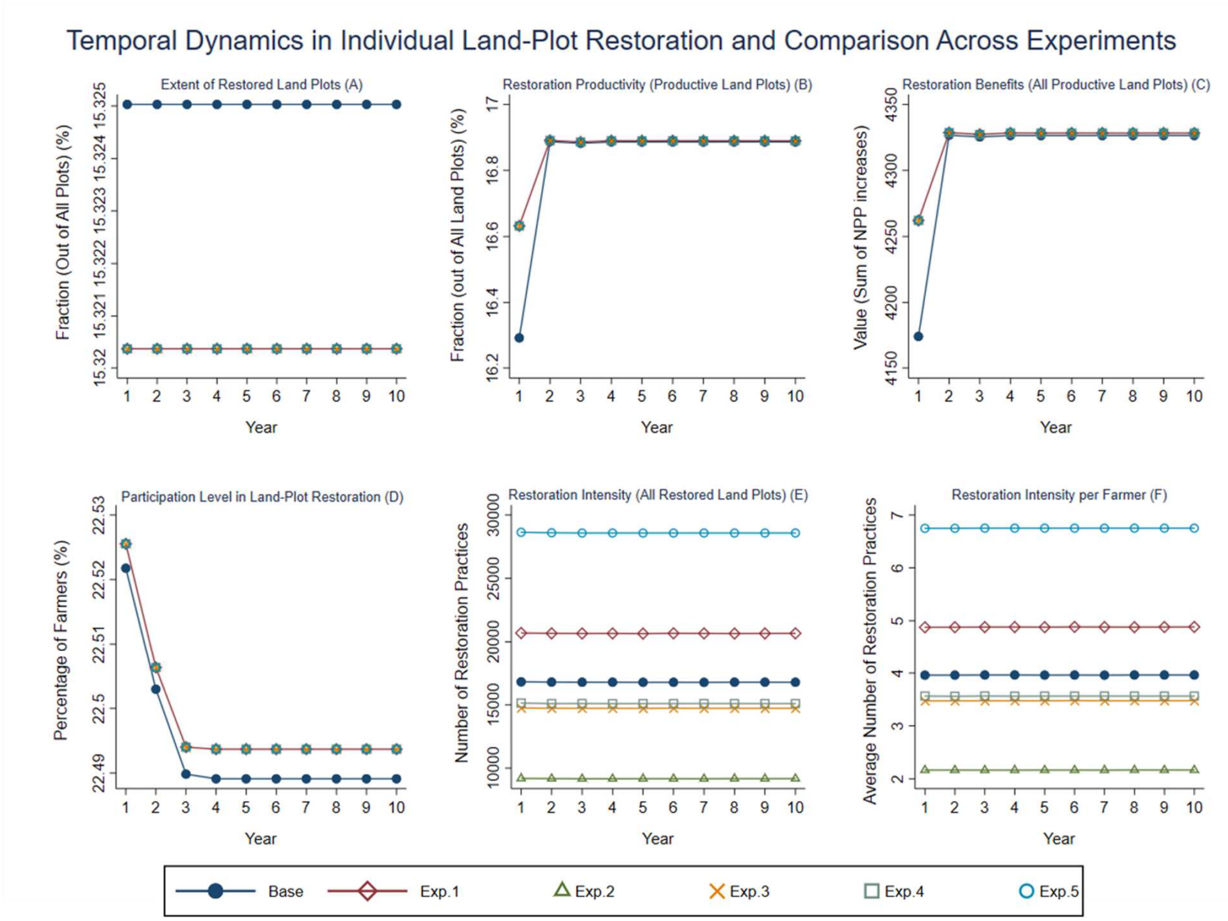
Figure 5-8. Spatially-explicit trends of patterns and outcomes of individual land restoration (Base model, panels A-B)



5.4.2.2. Differential effects of the experiments on emerging patterns and outcomes of individual restoration

For land plots, the experiments also reveal few differential effects from the comparative analysis (Figure 5-9, graphs A-F), with some showing a statistical significance (Table 5-3).

Figure 5-9. Comparison of the aggregate temporal patterns and outcomes of individual land-plot restoration among the base and experimental models (Graphs A-F)



Note: For panels A-D, experiments 1-5 show very undistinguished difference and, in panels B-C, are even very similar to the base model

First, for the **extent of restoration,** all the experiments show a slight decrease for the yearly number of land plots restored compared to the base model (Figure 5-9, graph A) but with no statistically significant difference. Notwithstanding such a low extent of restoration, all of them display similar temporal trends as the base model. Spatially, all five experiments narrow slightly the range of the likelihood of selection of land plots for restoration while shifting the frequency of selection of some land plots (see Appendix Figure 5-A). Second, regarding **biophysical changes,** all five experiments have the same aggregate levels and values of land productivity. Compared to the base model, the experiments offer some increase that is only prominent for year 1 (Figure 5-9, graphs B-C) but shows no statistically significant difference overall. The aggregate yearly landscape-level productivity value (sum of all NPP increases) starts from 4262.1, increases, and becomes steady around 4328.4, slightly above the base model's values (Figure 5-9, graph C). When distributed evenly across all land plots in the landscape, the average NPP value would approximate 0.085-0.086 kg C m-2, indicating a positive but low overall productivity. Third, for **participation level,** all experiments increase the level of participation in a similar fashion compared to the base model (Figure 5-9, graph D), but with no statistically significant differences. Finally, regarding **restoration intensity,** while there is no temporal difference within each experiment, they all show differentiated restoration intensification (Figure 5-9, graphs E-F), which is highly statistically significant. Similar to collective restoration, experiments 1 and 5 increase considerably the number of restoration practices both at landscape and farmer levels compared to the base model. The other experiments show a lower intensification compared to the base model, with experiments 2 and 4 offering the lowest and highest intensification, respectively. The spatial patterns confirm these landscape-level trends, showing that the number of restoration practices applied on land plots for all experiments, except for experiments 1 and 5, are lower than the base model (see Appendix Figure 5-B).

Table 5-3. Statistical comparison of the aggregate patterns and outcomes of individual land-plot restoration among experiments

Variables	**F[a]**	**Prob.[a]**
Extent of Restoration	--	--
Level of Greenness [b]	*0.20*	*0.9598*
Restoration Benefits (Re-greenness value) [b]	*0.24*	*0.9406*
Level of participation	*0.29*	*0.9183*
Restoration Intensification (aggregate landscape level)	2.6e+06	0.0000
All five experiments and base model are significantly different from one another (Scheffe Test and Games and Howell Test's p-values=0.000)		
Restoration Intensification (farmer level)	1.2e+07	0.0000
All five experiments and base model are significantly different from one another (Scheffe Test and Games and Howell Test's p-values=0.000)		

[a] One-way ANOVA test of the variables with either equal or unequal variances; [b] Variable violates the Bartlett's test (homogeneity of variances), thus the assumption of homogeneity of variance is not met. Only the Games and Howell post comparison test is robust compared to the Scheffe Test. We consider the multiple comparison tests only for variables with a significant F test.

5.5 Discussion

We discuss the findings in light of the two research questions, elaborate the contribution of the modeling approach, and articulate some limitations.

Our findings uncover both emerging aggregate spatial and temporal patterns and outcomes of local farmers' restoration decisions and activities on the studied forest-agriscape. These include the potential extent and intensification patterns of restoration, participation level, and potential environmental outcomes in terms of greenness and land productivity levels and values. First, the finding across the base model and the five experiments suggest that the extents of individual farmland and collective restoration remain a small fraction of all resources (land plots and collective resources) in the forest-agriscape. The opposite is true for restoration intensity, with an intensification of the number of land-management practices and activities to maximize restoration benefits (greenness and land productivity). Both findings align with and confirm previous findings of low areal impact of restoration efforts in the area although restoration intensity is high (Chapter 3). The additional new information is that within the current context, the landscape is likely to display some high and low restoration extents across the years for collective resources restoration. Therefore, farmers involved in such collective actions are likely to incrementally intensify the adoption and use of restoration practices, with some highs and lows. On one hand, individual farmland restoration is unlikely to generate significant change over the next ten years in terms of increasing the areal extent of farmland restoration. On the other hand, findings suggest that landscape-level restoration intensity for farmlands is driven by the participation level, suggesting an avenue for encouraging farmers to embrace restoration of their land plots. These findings might also reflect the fragmented nature and small size of land plots as a potential limiting factor to significant spatial gains in farmland restoration even as farmers respond to restoration needs by increasing (intensifying) restoration practices. This unearths existing conundrums over land fragmentation in agrarian landscapes in sub-Saharan Africa in general, and the spatial dimensions of tenure-related and other forms of fragmentation in particular (King and Burton, 1982; Asiama et al., 2017; 2019; Ntihinyurwa and de Vries, 2021).

Second, findings suggest that farmers engage less in restoring collective resources in the protected area than in community-owned collective resources. Such insight into the pattern of affiliation to community forestry collective actions reflects relatively easier access to collective resources on customary lands. It also confirms the role of a stronger sense of ownership through resource-tenure rights and security for enhancing local participation in restoration as confirmed in previous studies (Nagendra 2007; Lovo, 2016; Lawry et al., 2017; Sikor et al., 2017). Consequently, findings substantiate appeals for a rights-based approach to landscape restoration, particularly secure tenure as a critical incentive to participation in restoration and NRM generically (McLain et al., 2018), and the need to conduct tenure assessments to understand context-situated resource tenure dynamics (Kandel et al., 2021). For individual farmland restoration, farmers will likely engage more with restoration in the early years, but the engagement level might drop once they reach a certain steady land-productivity outcome. The emerging mechanism to highlight here is that individual farmer behavior tends to seek to balance and adjust restoration intensification in order to meet the same aggregate productivity level as participation stagnates. Improved understanding of current and potential future patterns of engagement level in restoration is important to foresee and envisage how to enhance farmer participation and contributions to forest-agriscape restoration and the balance between individual and collective restoration in protected and community areas. An important principle of FLR and other broader nature-based solutions involving restoration is to engage local stakeholders and increase local participation (Besseau et al., 2018; Cohen-Shacham et al., 2019).

Third, findings suggest overall positive restoration outcomes measured as changes in landscape environmental condition using NDVI and NPP indicators, although only a reduced fraction of collective resources and land plots would be successfully restored. For collective resources, the extent of greenness is likely to fluctuate following the highs and lows of the extent of restoration, but the same potential positive aggregate greenness value is likely attainable every year across the landscape overall. With the current situation, it is likely that local farmers' restoration efforts will positively affect landscape condition with an incremental number of more productive land plots, at least for the first two years. Such patterns drive a positive, but low aggregate landscape productivity that would increment to a certain level before becoming steady over time, illustrating the value of considering local farmer contributions to land restoration. Those regreening indicators represent indirect measures of both ecological and social benefits of restoration. Greenness levels and values indicate vegetation cover potential, and productivity levels and values reflect agricultural productivity potential, both providing ecosystem services and functions that support livelihoods and food security.

Our findings also offer insights into some propitious enabling management and policy options for enhanced restoration. Overall, two to three experimental management and policy options appear conducive to improving restoration patterns and outcomes. First, experiment 1 targeting incentives stands out for both individual and collective restoration, indicating that granting different types of incentives to local farmers is likely to amplify restoration efforts and outcomes. Different incentive mechanisms may involve either direct cash incentives (including meeting allowances for collective actions), in-kind incentives such as food or other items, or loan-based incentives. Loan schemes can be linked to specified unit-restoration outcomes – e.g., acres of land restored, number of trees planted/survived after 1 year, etc. However, as underscored in previous findings (Djenontin et al., 2020b), the nature of incentives should be made appealing to local farmers, with attention to gender and location differences. Also, harmonizing incentive approaches and mechanisms within a targeted landscape or location is critical for congruent and consistent restoration processes as part of necessary cohesive restoration governance (Djenontin et al., 2021).

Second, experiment 4 on knowledge and experiment 2 on local leadership are the next that stand out as enabling strategies to enhance individual and collective restoration, respectively. Experiment 4 indicates that investing in training farmers and strengthening extension services to provide some complementary or missing restoration-related knowledge would enhance restoration efforts and outcomes. Our findings align with studies that show a positive effect of training on adoption of environmental technologies in the regreening efforts in Sahel West Africa (Aker and Jack, 2021). Similarly, knowledge training is taken as a soft incentive that is much valued by local farmers in the studied area (Djenontin et al., 2020b). Experiment 2 suggests that reinforcing local leadership would increase collective restoration efforts, reasserting the significant role of exemplary local leadership in driving farmers' engagement with collective restoration (Zulu, 2008; 2013; Djenontin et al., 2020b).

Third, experiment 5, which is a combination of all the potential enabling options considered, remains the most outstanding in potential positive impact. This implies that operationalizing a management and policy package that incorporates several elements—incentives, ease of technological constraints, knowledge via training, and reinforced local leadership—would maximize restoration efforts in the forest-agriscape. This can inform both government agents and private actors promoting restoration interventions, with potential management options to integrate in implementation and governance processes.

In terms of modeling, this study exemplifies a way to address some recognized challenges of ABMs that limit their application for natural resource governance, including the ability to build a cognitive and behavioral model that effectively captures decision making underlying socio-ecological processes, and assesses their potential system-level outcomes (Ligmann-Zielinska, 2010). Our model operationalizes previously elicited local farmer restoration decision-making processes for both individual and collective restoration (Djenontin et al., 2020b) and translates them into decision rules for model simulations. Our model also integrates diverse empirically-sourced social data (qualitative and quantitative) from multiple sources to inform the model building and its validation, addressing the issue of poor parameterization linked to scarcity of necessary data to meet the known extensive parameterization requirements of ABMs.

Our modeling presents some limitations. The built models have reduced some complexities related to external forces that may influence the environment and the larger socio-economic and political system of farmer agents. Specifically, the model has not accounted for or included climate conditions and disaster risks (droughts, floods, fires, etc.), dynamics in resource uses (trees cutting, wood collections, and charcoal production), and economic and market forces. Moreover, we have not (yet) quantified explicitly the uncertainty of the model outcomes, an important modeling step (Kelly et al., 2013). There are emerging new advances in handling uncertainty in ABMs, with comprehensive tests between alternatives to prospect for plausible ranges and influential drivers. We intend to conduct a coupled uncertainty and sensitivity analysis to quantify the uncertainty of the model outcomes and identify the most influential factors driving each model's outputs following previous studies (Ligmann-Zielinska and Sun 2010; Ligmann-Zielinska and Jankowski, 2014, Ten Broeke et al., 2016; Ligmann-Zielinska, 2018). This is underway and will be part of another forthcoming paper. Further, running the model simulations for different sites and contexts will help in model refinement and broader applications for more context-informed restoration.

5.6 Conclusion

This study sets out to prospect for restoration implementation in Central Malawi and to offer evidence-based management and policy options to maximize existing local efforts for enhanced outcomes, using an ABM approach. The purpose was to shed light on how the spatial and temporal patterns and outcomes of landscape-scale restoration could be shaped by micro scale social agents' (local farmers') decisions and consequent use of land-management practices. We further examined potential adequate intervention options to accelerate resources restoration in Malawian forest-agriscapes.

The 10-year trends and spatially explicit potential features of restoration extent and intensification, patterns of participation level, and possible landscape regreening (greenness and productivity levels) that we uncover with both collective resources and individual farmland restoration point to the value and need for empowering local, bottom-up restoration efforts. Overall, in terms of potential aggregate environmental impacts from local farmers' restoration decisions and actions, our findings indicate that landscape greenness from collective restoration increases modestly but is fluctuating. Land productivity in individually restored farmland also increases (positive) but is much lower, with a slight increment in the early year that flattens out to remain steady for most of the remaining years.

While the spatial extent of individual farmland and collective restoration remains a small fraction of all available land plots and collective resources in the forest-agriscape studied, there is a tendency to intensify restoration to maximize greenness and productivity. Landscape-level restoration intensity for farmlands is driven mostly by participation level, showing this as a farmer strategy and potential intervention avenue to enhance farmer-driven restoration of agrarian landscapes. The prevailing resource-tenure system shapes participation level in restoring collective resources, with more involvement of farmers in community-owned collective resources than in state-owned collective resources. This validates appeals for enhanced resource tenure rights (access and use) and security as a key incentive to enhance local community participation in landscape restoration. It also supports the need for local tenure assessments to better understand context-explicit tenure-related obstacles to and opportunities for restoration.

In terms of enabling management and policy options, establishing appropriate incentive schemes would enhance both local collective and individual farmland restoration efforts. Harmonizing incentive mechanisms within a targeted landscape is important for cohesive restoration governance. In addition, providing necessary restoration-related knowledge, for instance through training and improved extension systems, and promoting inspiring local leadership would augment individual farmland and collective restoration, respectively. More importantly, putting in place a management and policy package that incorporates several important elements—incentives, ease of technological constraints, knowledge, and strengthened local leadership—would have the most impact to maximize restoration of forest-agriscapes. The study shows both the potential and limitations of local farmer contributions to FLR and the need for context-specific balancing of the nature and mix of individual and collective restoration efforts across different land tenure types (government, essential private, and communal), and combination of several restoration strategies to maximize ecological and socio-economic restoration outcomes.

Overall, the study offers insights for spatially targeted and evidence-based restoration implementation in Central Malawi and demonstrates the potential of using ABM as a comprehensive approach to inform restoration management and policy with forward looking explorative options.

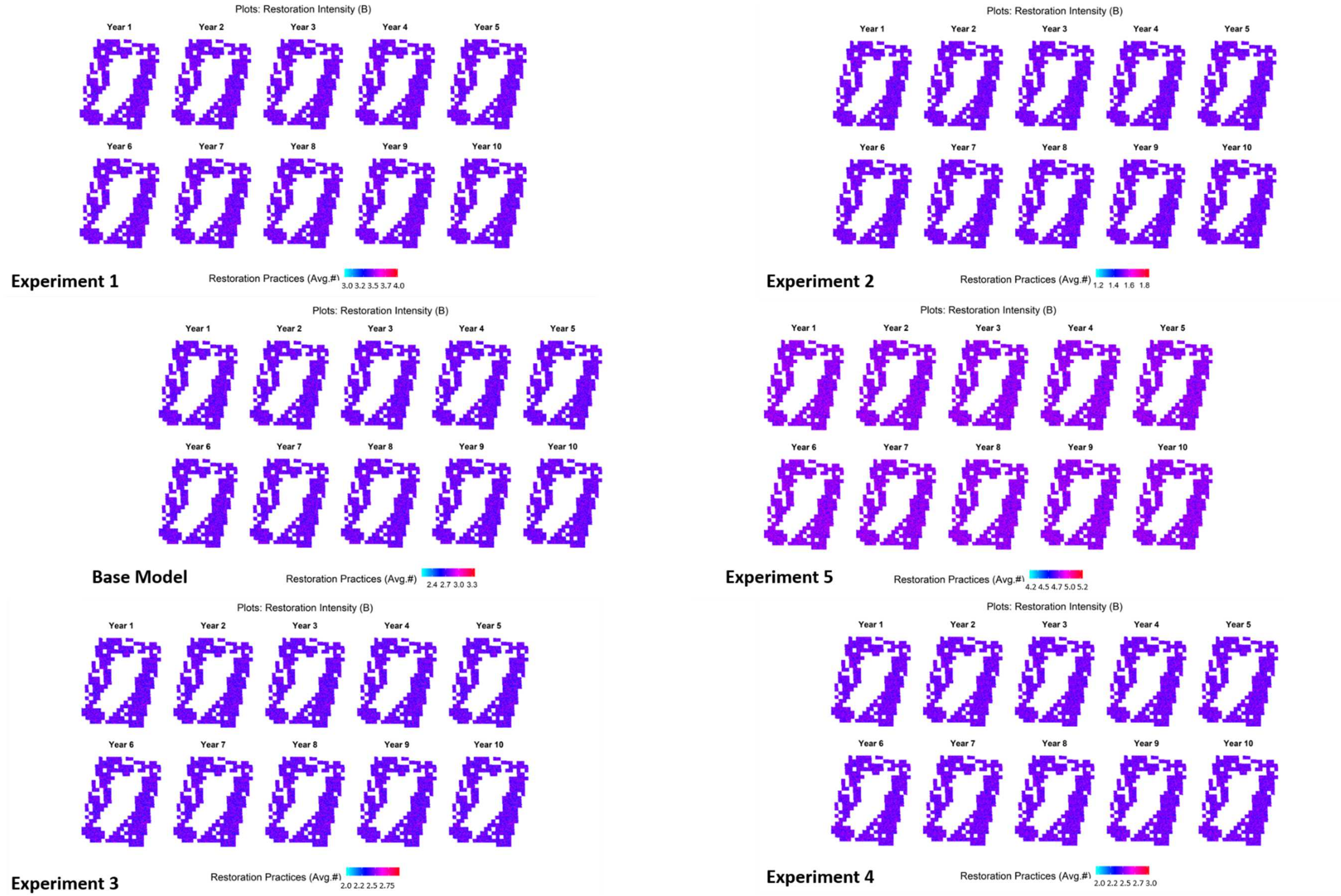
APPENDICES

APPENDIX A

Comparison Among the Base and Experimental Models for Individual Land-plot Restoration

Figure 5-A. Comparison of the spatially-explicit trends in the extent of restoration among the base and experimental models for individual land-plot restoration

Figure 5-B. Comparison of the spatially-explicit trends in restoration intensity and participation level among the base and experimental models for individual land-plot restoration



APPENDIX B

Supplemental File – Overview, Design Concepts, and Details (ODD) Documentation

Outline:

A- Purpose and Pattern

B- Entities, State variables and Scales

C- Process Overview and Scheduling

D- Design Concepts

E- Initialization

F- Input Data

G- Sub-models

A- Purpose and Pattern

The purpose of this ABM is to simulate the aggregate land-use patterns and outcomes of farmers' restoration decision and investments over space and time, while also identifying potential differential effects of selected management and policy options to boost local resources restoration efforts. Specifically, our experiments investigate the potential landscape-level features of restoration extent and intensity, patterns of participation level, and landscape regreening (greenness and land productivity) driven by farmer agents' restoration decision and subsequent actions, with different policy scenarios. First, we use a base model to shed light into how the dynamics of landscape-scale patterns and outcomes of restoration could be shaped by micro scale decisions of social agents' (local farmers') and consequent use of land-management practices. Second, we use five experiments to explore what adequate management and policy options might accelerate resources restoration in Malawian forest-agriscapes.

Each model is run for 11 years (ticks) and is simulated 420 times (batch runs) given that we have 21 covariates, which need each 20 observations, resulting in 21*20 = 420 model executions (see Harrell, 2015). We subset the last ten years for the analyses, ignoring the first initial year (tick=0) that is used to train the model. Put differently, the processes in year 0 are a legacy of the sampled inputs, masking out the follow up variations in the simulations. Therefore, we focus on the 10-year spatial and scalar output variables. We map spatially the key emerging restoration patterns and outcomes from the simulations, including the differential effects from the experiments.

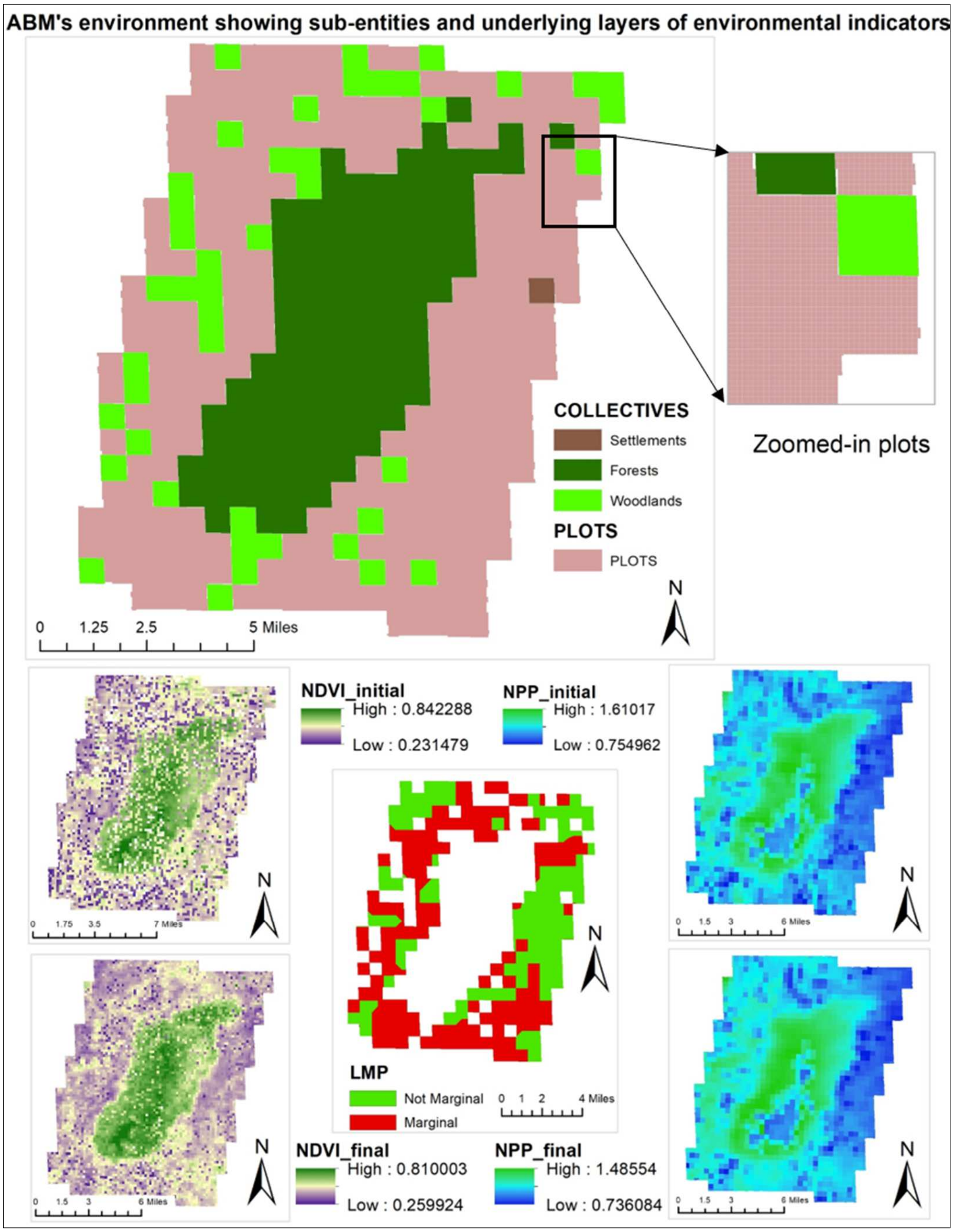
B- Entities, State variables and Scales

❖ *Model's entities*

The ABM simulates farmer agents implementing individual farmland (land-plot level) restoration within the agrarian domain and/or participating in collective resources restoration across the forest-agriscape. The first model entity is thus the agents [FARMERS] as decision makers of restoration. The other model's entity is the environment represented by the forest-agriscape within which restoration occurs. The forest-agriscape is composed of land plots [PLOTS] and collectively-managed resources [COLLECTIVES] as the basic spatial unit and physical boundaries within which restoration occurs.

To construct the ABM's environment (Figure 5-C), we start with the 1km-resolution LULC raster map of Malawi for 2017 (images from April to September) derived from combined Sentinel-2 and Landsat 8 satellite data (USGS-USAID, 2018). We extract the research area (Ntchisi district) using existing polygon shapefile and delineate our forest-agriscape defined by the Ntchisi Forest Reserve (NFR) by overlaying a Google Earth Pro-based layer of the region of interest (ROI). We resampled the delineated LULC product into 20x20 resolution and reclassified it to consider the only relevant classes, including croplands, woodlands, forests, and other land uses (areas for land and water resource conservation (LWRC) activities). We converted the obtained land-use classes into two separate polygon shapefiles, representing the two main sub-entities of the environment. Therefore, we created a CROPLAND polygon shapefile made of the croplands and a COLLECTIVE polygon shapefile made of the forest, woodlands, and LWRC areas. We divided the CROPLAND polygon shapefile into plots of $63.6*63.6m^2$, yielding 52,701 plots (N_P=52,701 plots), and thereby creating the PLOTS sub-entity of the environment. This is because data from the household survey (HHS) that we conducted indicated that, on average, plot size is 1.03 (±0.67) acres across the research site (Chapter 3). The COLLECTIVE shapefile contained 30 collective resources (N_C=30 collectives) based on the boundaries of the classes from the delineated and reclassified LULC product for the NFR region. In this physical environment, we overlaid a land marginality parameter (LMP) as raster data representing the biophysical status of the land plots in terms of their marginality level. We further overlaid the NDVIs and NPPs raster data as indices to monitor changes in the NFR's environmental state. It is important to note that, for the modeling purposes, we deleted plot polygons that were completely outside of the extent of all rasters, reducing their number to 50,355 (i.e., actual N_P=50,355 in the ABM model). The plots left out violate GIS topological rules and lacked underlying data for LMP, NPP, and NDVI. See appendix C for details on the geoprocessing tasks performed using ArcGIS 10.7 software. Further, we loaded and read these spatial data (polygon shapefiles and rasters) using appropriate packages in the Python programming software used to develop the ABM.

Figure 5-C. NFR forest-agriscape showing delineated croplands (divided into plots), forests (community and state-owned), woodlands, and settlement areas, as well as layers of land marginality, NDVIs, and NPPs



❖ *Agent and environment attributes*

The number of farmer agents allocated within the environment is N_F = 18820, reflecting an estimated population of farm-households for the region of interest. The number of farmer agents may potentially increase to a certain threshold, which we consider to be $N_{F\text{-}future}$ = 38911. However, we maintain farmer-agent population constant at N_F throughout the modeling. N_F is calculated based on both the potential number of land plots in the extent of the forest-agriscape (N_P) and the distribution of plot ownership (number of plots) by household in the studied site as informed by the HHS that we previously conducted. $N_{F\text{-}future}$ is the estimated total number of farm-households in the three jurisdictional areas—Traditional Authorities areas—covered during data collection in 2019.

We draw farmer agents' attributes and parameters from the HHS and focus group discussions (FGDs) to inform the model specifications. The first group of attributes are the restoration engagement status and level/scale (individual and/or collective). The second set of attributes are land endowments (number of plots) and related characteristics such as institutional status (tenure security and mode of acquisition) and some geographical and cognitive attributes. A farmer may own more than one plot because of uneven holdings as informed by the distribution of the number of plots per farmer. The third group of attributes include the collective restoration parameters such as the number and type of collective actions farmers participate in and related cognitive characteristics. Here, as well, farmers who engage in collective restoration may be assigned to more than one collective resource. We finally include a few relevant socio-demographic characteristics, including variables indicating labor availability/capability, quantity of external labor force available, and membership in associations other than restoration related (Table 5-A).

We further specify a number of attributes to farmer agents in relation to their environment (Table 5-A). For individual-level restoration, we equip farmer agents and their assigned land plots with six sets of attributes. *First*, the ELIGIBLE factor determines a plot's qualification for restoration in cases where its biophysical status is not provided by the land marginality spatial data. Thus, the ELIGIBLE factor helps to randomly select plots that miss a marginality indicator. *Second*, we hypothesize that farmer agents reassess their eligible plots based on their self-perceived degradation level and also integrate the plots' socioeconomic and institutional characteristics before considering them for restoration and further selecting only a certain FRACTION_PLOT_RESTOR (that may increase over time) as the final share of plots for restoration. *Third*, we also consider a plot PRODUCTIVITY factor retrieved from the spatial inputs, which is the initial utility level for the plots at individual level. We are dealing with an environment where maize cropping systems dominate relatively homogeneously across the farmland. Therefore, each plot is randomly assigned with an initial land productivity that is denoted by the NPP values for the baseline year 2018, such that the value of the plot PRODUCTIVITY variable falls within the range of low to high NPP (Figure 5-C). *Fourth*, it is expected that implementing restoration practices would improve socio-ecological benefits (the plot productivity and other ecosystem services). We have thus assigned the plot's FINAL PRODUCTIVITY that corresponds to the final registered annual NPP at the plot level. The potential values of the factor FINAL PRODUCTIVITY are assigned randomly such that they fall in the low to high range of mean NPP values from the 19-year NPP time series (2000-2018). The difference between FINAL PRODUCTIVITY and PRODUCTIVITY represents the ANNUAL PLOT BENEFIT, as a non-tree-based measure of the environmental improvement from restoration. *Fifth*, we have also integrated PLOT ADDITIONAL HARVEST that indicates whether or not farmers harvest any additional products such as firewood, NTFPs, and timber from their field, which is based on the survey data. *Finally*, at the end of each year, farmer agents evaluate their willingness to continue with the process of land-plots restoration by examining their annual productivity benefits and the chance of additional harvest. Harvesting additional products is also considered an indirect measure of the security of land-plot tenure, indicating that farmers hold more control over their land plots including any of its additional products.

For collective-level restoration, we also equip farmers with another set of five attributes that relate to their collectively-managed resources (Table 5-A). *First*, we hypothesize that farmer agents determine the number and type of collective action(s) they could contribute to restore by selecting the polygons representing the collectively-managed resources that they can be affiliated with. They also integrate their own socioeconomic characteristics and capabilities before a final consideration to join the collective restoration. *Second*, we consider a GREENNESS factor retrieved from the spatial inputs, which denotes the greenness status of the collective resources based on NDVI values. We set the environment with initial vegetation cover represented by the mean NDVI values of the year 2018, such that the values of GREENNESS fall within the range of low to high mean NDVI. *Third*, we assume that improving vegetation cover to sustainably supply more ecosystem services is the goal for participating in community forest restoration. Thus, we have computed a FINAL GREENNESS that represents the final recorded annual NDVI in the environment. The potential values of the FINAL GREENNESS are allocated randomly such that they fall in the low to high range of mean NDVI values from the 19-year NDVI time series (2000-2018). The difference between FINAL GREENNESS and GREENNESS represents the ANNUAL COLLECTIVE BENEFIT, indicating a vegetation-based measure of the environmental improvement from restoration. *Fourth*, we have also considered a COLLECTIVE ADDITIONAL HARVEST that indicates whether farmers have any extra access or use-rights to some of the collective resources such as firewood, NTFPs, timber, grazing area, or whether they get any other benefits from their collective restoration. *Finally*, at the end of each year, farmer agents evaluate their willingness to renew their participation in the collective restoration process by evaluating their annual greenness status and the chance of additional access or use-rights to collective resources. Having such extra access or use-rights also indicates an indirect measure of enhanced resources rights for the agents.

❖ *Agent decision rules*

We use previously elicited farmers' restoration decision making based on a mixed-method approach that combined data from the FGDs, role-playing games (RPGs), and the HHS (Djenontin et al., 2020b). The decision-making processes include decision-making rules and associated number of restoration practices at individual and collective levels. Technically at the agent level, we use the average number of restoration practices applied per plot as follows (see full range of decision-making processes provided in Table 5-B):

IF Decision rule for Individual Restoration *labeled* ***PsMcInc****_KBEc* ***THEN*** *Number of practices per eligible and selected plot =3.9 [1-8]*

IF Decision rule for Collective Restoration *labeled* ***LaPsB****_KRRu* ***THEN*** *Number of practices per eligible and selected =4.6 [3-7]*

❖ *Model-level experiments' specification*

Our experiments target selected decision-making goal frames and critical determinants of restoration investments, as illustrated in detail in Table 5-C. Four key input parameters are considered. First is the influence of a factor defined as incentives. Second is the influence of factors that measure options to leverage restoration-input constraints. Third is the effect of factors denoting supply of knowledge for restoration. Fourth is the effect of a factor representing the quality of local leadership. Through the experiments, we examine which enabling management and policy options would be effective for fostering restoration delivery from the bottom-up.

While we explore each scenario (made of a package of policies, reflecting insights from the data collected in the research area) by running the simulation for all 10 ticks (years), we opted for the approach of switching policies during the overall model execution following the scheme below:

1. Scenario one: t=0 to t=10: **a = 1,** b = 0, c=0, d=0, e=0, f=0
2. Scenario two: t=0 to t=10: a = 0, **b = 1,** c=0, d=0, e=0, f=0
3. Scenario three: t=0 to t=10: a = 0, b = 0, **c=1, d=1,** e=0, f=0
4. Scenario four: t=0 to t=10: a = 0, b = 0 c=0, d=0**, e=1, f=1**
5. Scenario five (enacting all policies together): t=0: **a = 1, b = 1, c=1, d=1, e=1, f=1**

where a = INCENTIVES; b = LOCAL LEADERSHIP; c and d = TREE_SEEDLINGS and AGRIC_FERTILIZ; and e and f = TRAININGS and EXTENSION_SERV.

C- <u>Process Overview and Scheduling</u>

For each time step, we initialize farmers and assign to each of them land plots and collective resources. Then, a set of user-defined functions and methods carry the remaining model processes. These include methods that define eligible plots, tagged plots, and plots to finally restore. Another method defines agent's decision rule to restore plots, including the number of restoration practices to apply (Table 5-B). Next, a main defined function informs the restoration mechanism. Here, agents pick a plot and restore, decide on the number of practices for that plot through its decision rule, restore the plot, keep inventory of restored plots, and then calculate total practices used, which can be retrieved per plot, per agent (considering all of their assigned plots), and for the entire landscape (aggregate number for all agents and plots). As such, this main function returns the overall system-level number of restoration practices, number of agents participating in restoration, and declares plots that have been selected for restoration to inform the extent of restoration. Two additional methods are further defined. One calculates the annual productivity benefits and the productivity level (the total number of restored plots that are productive) and the second updates agent's willingness to continue with the restoration based on their calculated annual utility/benefits. Finally, a defined method updates the environment for the next time step of simulation, informing farmer agents on land plots available for further restoration. For collective restoration, we defined these methods analogously to individual farmland restoration, with the difference that agents only tag and select their collective resources and proceed directly with their decision rules, restoration mechanism, and subsequent evaluation and update of willingness to proceed further.

D- <u>Design Concepts</u>

- *<u>Basic Concept</u>*

The basic concept is to shed light into how micro scale social agents' decisions and actions can produce aggregate system-level emergent patterns that can be explored in a forward-looking manner to inform resources management decisions and policy making from an ex-ante perspective.

- *<u>Stochasticity</u>*

Our ABM is a discrete time stochastic model, with individualized decision making as explained in section on agent decision rules.

- *<u>Emergence and Observation</u>*

We record emerging restoration patterns and outcomes at individual and collective levels. Here, we record annual landscape productivity represented by increases in NPP values (difference between final and initial values) and annual landscape greenness denoted by increases in NDVI values (difference between final and initial values). We also record the trend in the number of productive land plots (level of productivity) and the number of regreened collective resources (level of greenness). Other emerging trends of interest include the number of restoration practices at system (landscape) level, per plot/collective resource, and per agent (on all their plots/collective resources); the number of time a plot/collective resource has been selected for restoration, indicating the extent of restoration; and the number of farmers participating overall in individual farmland and collective restoration, respectively. For collective restoration, we were also interested in the number of farmers involved in restoring each collective resource. We then map spatially the extent of restoration, restoration intensity, and participation level for visualization.

- *<u>Learning</u>*

The modeling integrates separate user-defined methods that update agent's willingness to continue with individual farmland and collective restoration, respectively, as explained in the process overview and scheduling section. Specifically, agents evaluate yearly the "utility" from their undertaken restoration and then decide whether to proceed further.

E- Initialization

We initialize the model with 18820 agents to whom plots are assigned as explained in section on agent and environment attributes. Agents are bounded to the area of study and there is no increase in the total number of plots given land scarcity trend in the area. We also initialize for each agent a number of restoration practices/activities to consider after they make a restoration decision.

Other initialization steps involve calibration, verification, and validation. First, we developed scripts to sample and load the scalar covariates of the model using user-defined methods. The sampling script takes an excel file that contains five columns of information about the scalar covariates: *Group* (model's entity, i.e., agent, environment, main model), *Name*, *Number* (size of entity), *Distribution* (type of distribution), and the *Parameters* for each type of distribution (Table 5-A). The loading script takes the output sampled covariates to load and read them.

Second, we developed other scripts that read and load the spatial data (polygon shapefiles and rasters). The purpose was to extract the raster data (LULC, LMP, NDVIs, and NPPs) underlying the PLOTS and COLLECTIVES layers and associate them with their corresponding plots and collective resources. We used the plots' centroids to retrieve the corresponding environmental data from the LMP and NPPs rasters. For the collectives, using their centroids to retrieve the related environmental data from the NDVI rasters would be incorrect because of their relatively large size. Instead, we calculate the average value of NDVI data for each individual collective. This second step involved some iterative calibration and algorithm verification processes that also included adjustments of some issues in the spatial data, which influence the input data in the excel covariates distribution file. Concretely here, we defined an algorithm method to address the NODATA in the LMP, NDVIs, and NPPs rasters (see geoprocessing details in appendix C). Also, some plots, notably those at the edges, violate GIS topological rules and lack underlying data from the LMP and NPPs. We deleted those and the adjustments reduced the number of plots from 52,701 to 50,355 plots as previously elaborated. We then updated the sampling file containing the scalar covariates, accordingly.

Third, other user-defined functions and methods helped to set up farmer agents and assign the land plots and collective resources to each of them following appropriate covariates that inform on the number of land plots and the number and type of collective resources an agent can be associated with. *For plots* *assignment*: following the distribution of the number of land plots per agent, we assigned a first plot to all agents, then a second plot to agents who own 2 plots, third plot to agents who own 3 plots, etc. To avoid any coding artifact, we shuffle the agents and plots at the beginning of each simulation. We also considered information on the distance separating agents from their plots and used the queen contiguity method for plots neighborhood, denoting the area from which their plots can be selected from. *For collectives assignment:* considering information on the number and the type of collective resources assigned to each agent from sampling, we assign the nearest collective resource to agent's first plot (centroid to centroid distance), and if an agent needs more than one collective resource (here maximum number of collective resources = 3), then we look for the next nearest collective resource to that plot. It is important to recall that a collective resource can be assigned to multiple agents and, in such cases of several agents per collective resource, we opted to apply agents' decision consecutively with all agents having equal decision-making capacity.

Some attributes were used for model validation. One example is the number of restoration practices farmer agents apply on their plots and in collective resources, which is a measure of restoration intensification in the environment. We compute the average of these two returned outputs, separately. Each represents the total number of restoration practices farmers applied in restoring their farmlands (all owned plots combined) and the total number of restoration activities they implemented in restoring the collective resources they are affiliated with (all their selected collective resources), respectively. Our validation consisted of comparing the distribution of the simulated variables to that of the empirically-computed variables:

TOT_NUMBER_RESTORPRACT_INDIV *from model vs.* ***TOT_NUMBER_RESTORPRACT_INDIV*** *from empirical data*

TOT_NUMBER_RESTORPRACT_COLL *from model vs.* ***TOT_NUMBER_RESTORPRACT_COLL*** *from empirical data*

Ideally, the average sum of restoration practices used for all restored plots would approximate the total number of restoration practices that a farmer potentially implements on his entire farmland. Based on the results, each farmer applies on average approximately 4 restoration practices on their respective farmlands (total of land plots owned). For collective restoration, each farmer applies on average between

5-6 restoration practices in years with high participation level, which may increase to around 10 restoration practices in years with low participation level. These modeling results are close to findings that “on average, the total number of restoration practices farmers applied is 3-4 (mean 3.59) and 4–5 (mean 4.53) for individual-level and collective-level restoration, respectively” (Djenontin et al., 2020b - p22).

Similarly, another validation method was to compute the sum of plots’ area for each farmer agent and to check whether they are within the range of the empirically-computed total landholdings of farmers in the area of study. Concretely, we compared the distribution of:

Farmer’ TOT_PLOTS_AREA *from model vs.* ***farmer' TOT_LANDHOLDINGS*** *from empirical data.*

F- Input Data

Table 5-A. List of ABM input factors and constants and their probability distribution

Entities	Attributes		Range of Values		Distribution Function
	Description	**Label**	**Values**	**Probabilities**	
Farmers (Agents) – 11 variables	Engagement with individual restoration on farmlands	RESTOR_INDIVID	(0, 1)	(0.07, 0.93)	DISCRETE BINARY
	Participation in collective restoration in collectively-managed resources	RESTOR_COLLECTIVE	(0,1)	(0.41, 0.59)	DISCRETE BINARY
	Number of plots a farmer agent owns	NUMBER_PLOTS	(1, 2, 3, 4, 5, 6, 7)	(0.08, 0.40, 0.32, 0.12, 0.06, 0.01, 0.01)	DISCRETE
	Number of collective actions a farmer agent participates in	NUMBER_COLLECTIVE	(1, 2, 3)	(0.79, 0.19, 0.02)	DISCRETE
	Number of active family member - indicating labor availability/capability	HH_ACTIVMEMB	0	7	DISCRETE UNIFORM [FROMTO]
	Quantity of external labor force available and used (afforded)	EXTERNAL_LABOR	0	23	DISCRETE UNIFORM [FROMTO]
	Membership to associations other than restoration related	ASSOCIATION	(0,1)	(0.76, 0.24)	DISCRETE BINARY
	Decision-making rules for individual restoration	DMR_INDIV	(1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21)	(0.12, 0.11, 0.04, 0.06, 0.02, 0.13, 0.19, 0.05, 0.04, 0.02, 0.015, 0.01, 0.005, 0.01, 0.11, 0.02, 0.02, 0.005, 0.01, 0.005, 0.01)	DISCRETE
	Decision-making rules for collective restoration	DMR_COLLECTIVE	(1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18)	(0.12, 0.11, 0.04, 0.03, 0.10, 0.09, 0.09, 0.05, 0.05, 0.03, 0.07, 0.05, 0.02, 0.02, 0.08, 0.03, 0.01, 0.01)	DISCRETE
	Fraction of plots to restore	FRACTION_PLOT_RESTOR	0	1	UNIFORM
	Increase in the fraction of plots to restore	FRACTION_PLOT_RESTOR_INCREASE	1.05	1.4	UNIFORM
Plots (environment) – 6 variables	Tenure-security status	PLOT_TENURE	(1, 2, 3, 4)	(0.49, 0.44, 0.05, 0.02)	DISCRETE
	Acquisition mode	PLOT_ACQUISIT	(1, 2, 3, 4)	(0.51, 0.41, 0.01, 0.07)	DISCRETE
	Perceived degradation level	PLOT_PERCEIVED_DEGRADE	(1, 2, 3)	(0.51, 0.31, 0.18)	DISCRETE
	Perceived importance	PLOT_PERCEIVED_IMPORTANCES	(1, 2, 3, 4)	(0.3333333333333333, 0.10416666666666667, 0.24305555555555555, 0.3194444444444445)	DISCRETE
	How agent select their qualified plots for restoration (based on the land marginality input)	ELIGIBLE	(0,1)	(0.5, 0.5)	DISCRETE BINARY
	Harvest of additional products from plots	PLOT_ADDITIONAL_HARVEST	(0, 1)	(0.45, 0.55)	DISCRETE BINARY

Table 5-A (cont'd)

Entities	Attributes		Range of Values		Distribution Function
	Description	Label	Values	Probabilities	
Collectively-managed resources (Environment) – 2 variables	Farmer agent's perceived importance for its affiliated collective resources	COLL_PERCEIVED_IMPORTANCES	(1, 2, 3, 4)	(0.007751937984496124, 0.2558139534883721, 0.7054263565891473, 0.031007751937984496)	DISCRETE
	Extra access or use-rights to collective resources (firewood, NTFPs, timber, grazing area, etc.) from collective restoration.	COLLECT_ADDITIONAL_HARVEST	(0, 1)	(0.29, 0.71)	DISCRETE BINARY
Model – 2 variables	Initializing number of plots assigned to agents	SEED_ASSIGN_PLOTS	18820	38911	DISCRETE UNIFORM [FROMTO]
	Initializing number of restoration practices/methods	SEED_RESTORPRACT	18820	38911	DISCRETE UNIFORM [FROMTO]
Model – 9 Constants	All four land-use classes	LULC.tif	(Grid Code [0; 1; 2; 3] =>[for Settlements areas (for LWRC activities); Forest areas (FR+VFA+NF); Woodlands (CW); Croplands]		Raster TIFF file
	Plot polygon shapefile with 63.6x63.6m2 land plots	PLOTS.shp,dbf,shx	Croplands Layer at land plots scale		Polygon Shapefile
	Collective resources polygon shapefile (with forests, woodlands, and settlements)	COLLECTIVES.shp,.dbf,.shx	Collectively-Managed Resources Layer		Polygon Shapefile
	Land marginality spatial data indicating Plot biophysical status (productivity level)	LMP.tif	LMP (Indices)		Raster TIFF file
	Initial NPP values (using year 2018)	NPP_Initial.tif	NPP Initial (Indices)		Raster TIFF file
	Initial NDVI values (using year 2018)	NDVI_Initial.tif	NDVI Initial (Indices)		Raster TIFF file
	Final NPP based on Mean values of NPP 19-year long time series (2000-2018)	NPP_final.tif	NPP Final (Indices)		Raster TIFF file
	Final NDVI based on Mean values of NDVI 19-year long time series (2000-2018)	NDVI_final.tif	NDVI Final (Indices)		Raster TIFF file
	Plot neighborhoods	PLOTS_queen_order2.gal	Neighborhood radius for plots		Gal file

Table 5-B. Specification of the decision-making processes used in the ABM simulation

Level	Decision-making Rule		Actions: Average number of restoration practices [min-max]
	Description	**Label**	
Individual	1. **Problem Solving—Resource/Material Constraints—Incentives**—*Knowledge—Benefits—Economic Capacity*	**PsMcInc**_*KBEc*	3.9 [1-8]
	2. **Problem Solving—Resource/Material Constraints—Knowledge**—*Benefits—Economic Capacity—Extension Service—Influence of Peers*	**PsMcK**_*BEcExtIf*	3.8 [1-7]
	3. **Problem Solving—Resource/Material Constraints—Benefits**—*Outcomes—Economic Capacity—Leadership of Local Authority—Morality/Community Loyalty*	**PsMcB**_*OEcLaMo*	3.9 [1-7]
	4. **Problem Solving—Incentives—Benefits**—*Knowledge—Outcomes—Economic Capacity—Leadership of Local Authority*	**PsIncB**_*KOEcLa*	4.6 [1-8]
	5. **Problem Solving—Knowledge—Benefits**—*Economic Capacity—Risk Averse—Government promotion*	**PsKB**_*EcRGo*	4.3 [3-6]
	6. **Problem Solving—Resource/Material Constraints**—*Media Awareness—Extension Service—Influence of Peers—Economic Capacity—Leadership of Local Authority—Bequest/Altruist Value*	**PsMc**_*MaExtIfEcLaAl*	3.5 [1-7]
	7. **Problem Solving—Incentives**—*Knowledge—Morality/Community Loyalty—Media Awareness—Risk Averse—Extension Service—Influence of Peers—Leadership of Local Authority—Economic Capacity—Bequest/Altruist Value*	**PsInc**_*KMoMaRExtIfLaEcAl*	4.0 [1-9]
	8. **Problem Solving—Knowledge**—*Extension Service—Economic Capacity*	**PsK**_*ExtEc*	2.7 [1-5]
	9. **Problem Solving—Benefits**—*Risk Averse—Influence of Peers*	**PsB**_*Rif*	4.2 [2-5]
	10. **Resource/Material Constraints—Incentives**—*Benefits—Extension Service—Economic Capacity*	**McInc**_*BExtEc*	3.5 [2-5]
	11. **Resource/Material Constraints—Knowledge** –*Extension Service—Media Awareness—Influence of Peers—Risk Averse*	**McK**_*ExtMaIfR*	3.0 [2-4]
	12. **Resource/Material Constraints—Influence of Peers**—*Risk Averse—Leadership of Local Authority*	**McIf**_*RLa*	2.8 [1-5]
	13. **Incentives—Benefits**—*Risk Averse*	**IncB**_*R*	3.0 [2-4]
	14. **Incentives—Knowledge**—*Bequest/Altruist Value—Extension Service*	**IncK**_*AlExt*	5.0 [3-7]
	15. **Problem Solving**—*Resource/Material Constraints—Benefits*	**Ps**_*McB*	2.7 [1-4]
	16. **Influence of Peers**—*Problem Solving—Incentives—Knowledge—Benefits—Time efficiency—Outcomes*	**If**_*PsIncK_BTO*	2.6 [1-4]
	17. **Extension Service**—*Problem Solving—Resource/Material Constraints*	**Ext**_*PsMc*	3.2 [1-6]
	18. **Morality/Community Loyalty**—*Problem Solving—Incentives*	**Mo**_*PsInc*	3.5 [3-4]
	19. **Bequest/Altruist Value**—*Problem Solving—Resource/Material Constraints—Knowledge*	**Al**_*PsMcK*	3.8 [2-5]
	20. **Risk Averse**—*Problem Solving—Resource/Material Constraints—Media Awareness*	**R**_*PsMcMa*	3.5 [3-4]

Table 5-B (cont'd)

Level	Decision-making Rule		Actions: Average number of restoration practices [min-max]
	Description	Label	
Collective	21. **Leadership of Local Authority**—*Problem Solving—Resource/Material Constraints*	**La**_*PsMc*	2 [1-3]
	1. **Leadership of Local Authority—Problem Solving—Benefits**—*Knowledge—Risk Averse—Rules of Collective/Community Work*	**LaPsB**_*KRRu*	4.6 [3-7]
	2. **Leadership of Local Authority—Problem Solving—Incentives**—*Benefits—Risk Averse*	**LaPsInc**_*BR*	6.1 [2-11]
	3. **Leadership of Local Authority—Problem Solving—Morality/Community Loyalty**—*Benefits—Risk Averse*	**LaPsMo**_*BR*	4.8 [3-7]
	4. **Leadership of Local Authority—Problem Solving—Resource/Material Constraints**—*Incentives—Knowledge—Benefits*	**LaPsMc**_*IncKB*	5.8 [3-8]
	5. **Leadership of Local Authority—Resource/Material Constraints—Incentives**—*Knowledge—Benefits—Risk Averse*	**LaMcInc**_*KBR*	4.4 [2-6]
	6. **Leadership of Local Authority—Resource/Material Constraints**—*Benefits—Knowledge—Extension Service—Influence of Peers*	**LaMc**_ *BKExtIf*	4.3 [3-7]
	7. **Leadership of Local Authority—Benefits**—*Knowledge –Risk Averse—Bequest/Altruist Value*	**LaB**_*KRAI*	3.8 [2-5]
	8. **Leadership of Local Authority—Morality/Community Loyalty**—*Benefits—Extension Service*	**LaMo**_*BExt*	4.5 [2-6]
	9. **Leadership of Local Authority—Incentives**—*Benefits—Risk Averse—Morality/Community Loyalty*	**LaInc**_*BRMo*	5.1 [3-12]
	10. **Leadership of Local Authority—Problem Solving**—*Risk Averse—Influence of Peers—Extension Service*	**LaPs**_*RIfExt*	3.5 [3-4]
	11. **Problem Solving—Incentives**—*Morality/Community Loyalty –Influence of Peers—Benefits—Risk Averse—Economic Capacity*	**PsInc**_ *MoIfBREc*	4.6 [3-6]
	12. **Problem Solving—Benefits**—*Morality/Community Loyalty—Risk Averse—Influence of Peers—Time efficiency—Bequest/Altruist Value—Rules of Collective/Community Work*	**PsB**_*MoRIfT_AIRu*	3.2 [0-4]
	13. **Problem Solving—Resource/Material Constraints**—*Knowledge—Incentives—Benefits*	**PsMc**_*KIncB*	4.2 [3-5]
	14. **Benefits—Incentives**—*Risk Averse—Resource/Material Constraints—Morality/Community Loyalty*	**BInc**_*RMcMo*	5.0 [3-7]
	15. **Leadership of Local Authority OR Rules of Collective/Community Work**—*Resource/Material Constraints—Economic Capacity*	**La_Ru**_*McEc*	3.9 [2-6]
	16. **Benefits**—*Bequest/Altruist Value—Influence of Peers—Extension Service—Economic Capacity*	**B**_*AIIfExtEc*	4.4 [3-6]
	17. Risk Averse—*Incentives—Leadership of Local Authority*	**R**_*IncLa*	5.0 [4-7]
	18. **Morality/Community Loyalty**—*Problem Solving—Benefits—Risk Averse*	**Mo**_*PsBR*	3.5 [3-4]

Source: Based on Djenontin et al., 2020b

Table 5-C. Specification of the ABM experiments - Enabling restoration management and policy options (supplied by government and/or projects)

Id	**DIMENSION**	**SOCIO-ECONOMIC**			**INSTITUTIONAL**			**EFFECTS**
	CATEGORY	**Incentives**	**Input Constraints**		**Knowledge**		**Local leadership**	
	Variables **Experiments**	INCENTIVE	TREE SEEDLINGS	AGRICULTURE FERTILIZERS	TRAINING	EXTENSION SERVICE	LEADERSHIP TRAINING	
0	Base	DB (0)	DB (0)	DB (0)	DB (0)	DB (0)	DB (0)	Affect the decision rules (targeting those with goal frames that align with the enabling option(s)) Increase in the same way the Number of farmers engaging in individual restoration: RESTOR_INDIVID = 0.03 (probability of NO, which was 0.07 in the base model) Number of farmers engaging with collective restoration: RESTOR_COLLECTIVE = 0.20 (probability of NO, which was 0.41 in the base model)
1	Cash, food, or loans-based incentives	**DB (1)**	DB (0)	DB (0)	DB (0)	DB (0)	DB (0)	
2	Stronger/inspiring local leadership	DB (0)	DB (0)	DB (0)	DB (0)	DB (0)	**DB (1)**	
3	Access to free tree seedlings and to agriculture fertilizers	DB (0)	**DB (1)**	**DB (1)**	DB (0)	DB (0)	DB (0)	
4	Increased restoration training and access to extension services	DB (0)	DB (0)	DB (0)	**DB (1)**	**DB (1)**	DB (0)	
5	All options are enabled	**DB (1)**	**DB (1)**	**DB (1)**	**DB (1)**	**DB (1)**	**DB (1)**	

DB = Discrete Binary distribution of probability density function (probability of YES (all variables) or STRONG (LEADERSHIP_TRAIN)). Such setup implies that we have not introduced these policy provisions in the base model.

G- <u>Sub-models</u>

None.

APPENDIX C

Supplemental File – Geoprocessing Tasks for Setting up the ABM Environment

1. Start with the Land Use Land Cover (LULC) map product for 2017 (1km-spatial resolution)
2. Convert KMZ Files (study sites) from GEP to Shapefiles: For NFR ROI, MLFR ROI, and the Point data of surveyed farms and HHs
3. Add shapefiles: Districts, MLFR and NFR ROIs, MLFR and NFR (polygons), and MLFR and NFR (points)
4. Geoprocessing of the LULC data: This has originally 30 classes. Our interest is in specific land-use types, including croplands, forest reserves, village forest areas, and woodlands. We proceeded as follows:
    - Clipping the LULC raster data with each district boundary shapefile and then to each ROI shapefile
        - This results into fewer classes. In Dedza District, we have 19 classes and in Ntchisi District we have 14 classes. Further, in Dedza ROI, we have 9 classes and in Ntchisi ROI, we have 9 classes as well.
    - Resampling the clipped LULC rasters to 20x20 resolution
    - Reclassification of the clipped LULC rasters into only 4 new classes:
        - Forests (FR+VFA/NF)=1; Woodlands=2; Croplands=3; Settlements/Rivers/Streams=0
            - Old classes serving as FR = 2, 5, 31
            - Old classes serving as other forest areas = 3, 7
            - Old classes serving as Woodlands = 12, 13, 15
            - Old classes serving as Croplands = 8, 10, 11, 23
            - Old classes serving as Settlements/Rivers/Streams = 19, 20, 21
    - Converting the reclassified LULC rasters into a polygon shapefile
    - Extracting only polygons which represent the new classes of land:
        - Collectives entity = Forests + Woodlands+ Settlements/Rivers/Streams classes (26 woodlands, three forestlands, and one settlement area for LWRC practices)
        - Croplands entity = Croplands class
    - Using fishnet to divide the croplands polygon into farm plots of size 63.6*63.6m^2 (square blocks)

5. Clipping NDVI and NPP raster data (serving as indicator to monitor) with each district and ROI shapefile
    - ❖ Resampling the clipped NDVI and NPP rasters to 20x20 resolution
6. Using the land marginality raster data to represent data for land degradation level: resampling it to 20x20 resolution
7. Throughout the data processing all data sets were projected to UTM zone 36S.
8. Addressing NODATA in the LMP, NPP, and NDVI rasters:
    - ❖ For LMP layer: Use the Nibble tool to fill the gaps and reclip to Plots for
    - ❖ For NPP layers: Use raster calculator to update the null data
9. Deleting plot polygons that are completely outside of the extent of all rasters (violate GIS topological rules and lack underlying data information for LMP, NPP, and NDVI).
    - ❖ Recalling that plots were the outcome of the fishnet process, which can be adjusted for modelling purpose. Total number of plots after these adjustments is 50,355.
10. Generating Neighboring plots (GAL file) using GeoDa:
    - ❖ Using "queen contiguity" to build neighborhood with and order of contiguity = 2. This is because the distance between plot centroids is ≈ 63m. Maximizing the neighborhood to twice that distance, I used 130m neighborhood radius.

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6 CHAPTER 6: Conclusion

Conclusion: Overview, Summary of Findings, Limitations, Future Research

6.1 Overview

This chapter offers a summary of the main dissertation findings from investigating some socio-institutional dimensions of the Forest Landscape Restoration (FLR) paradigm as one approach to ecosystem restoration. The dissertation research examines holistically how to achieve integrated and sustainable governance in restoring lands, trees, and forests by deepening understanding of the institutional, socio-economic, cultural, and behavioral dimensions. The analyses account for processes occurring at different social, institutional, geographical (or jurisdictional), and ecological scales. The results and implications are laid out according to the three research questions. **RQ1:** What structural and functional governance arrangements can enhance the contextual processes and positive outcomes of collective restoration of forest-agriscape? **RQ2:** What are farmers' decision-making processes and drivers of observed restoration of individual farmlands and collective resources in forest-agriscapes? **RQ3:** What are potential aggregate environmental effects of farmers' restoration decisions and investments and propitious management and policy options to accelerate restoration delivery

This dissertation research addressed the lack of knowledge about what could be the nature of an appropriate governance system to support implementation of the FLR paradigm in Malawi, including understanding the challenges that the prevailing resource-governance system faces in realizing the tenets and demands of the landscape approach that is the integral management ethic of FLR. Indeed, to address the severe environmental degradation in sub-Saharan Africa (SSA) and manage the difficult trade-offs arising from largely ineffective sector-based approaches, scientists increasingly call for holistic and integrated management and governance of natural resources at the landscape level (Sayer et al., 2013; Ros-Tonen et al., 2018). The ascendant landscape approach to environmental management requires substantial sectoral policy integration and fosters consideration of interconnections among different land covers and interactions among the related resource-management institutions and actors. The FLR paradigm has emerged as one novel, people-centered ecosystem restoration approach that embodies a landscape approach to resources restoration. FLR advances sectoral interactions and policy integration to address holistically, the interlinked challenges of land degradation, deforestation, biodiversity loss, and climate change, and to sustain ecosystem services and functions necessary for enhancing socio-ecological well-being (Djenontin et al., 2018). Thus, FLR is cross-sectoral, subject to multiple environmental policies and goals, and embroils a constellation of actors straddling different land-tenure and land-use systems, and socio-political and ecological boundaries. This dissertation research also addressed why and how local farmers across forest-agriscapes decide to adopt restoration, what type of restoration activities they implement individually and/or collectively, and what could be the aggregate landscape-level environmental effects of their local restoration efforts. Indeed, FLR advocates for strong involvement of local communities, including farmers and resource users, in implementing restoration interventions across forest-agriscapes.

The multi-dimensionality of FLR interventions makes the research enquiry inherently cross-disciplinary, requiring integrative analytical frameworks and methods to articulate ingredients and features of a suitable restoration governance system and policy options to achieve it in Malawi. For that, this dissertation research employs a polycentric governance theoretical perspective and a systems-thinking approach to holistically enhance understanding of the complexities and dynamics of the attendant landscape-scale socio-ecological system. In Malawi, the country case study, the research draws on ongoing, restoration interventions within two forest-agriscapes in Dedza and Ntchisi Districts in the Central region and uses a mixed-methods approach to data collection and analyses. Specifically, the research uses several guide questions and a survey questionnaire (see appendices) to collect primary mixed qualitative and quantitative data. We conducted 42 focus group discussions (FGDs), including 7 conducted in combination with role-playing games (RPGs); 37 key informant interviews (KIIs); and a household survey (HHS) of 480 farm-households sampled using a multi-stage approach based on a statistical power of 80%. Farm households were later selected randomly following their close adjacency to the forest resources considered in the forest-agriscapes. The research also uses secondary data. These data include spatial data layers, remote sensing products of land-use/cover maps, and policy and project documents and reports. The research integrates both primary and secondary data for qualitative, econometric, and spatial agent-based modeling (ABM) analyses.

In addressing research question 1, we used the Ecology of Games Theory, (EGT – Lubell, 2013) as a theory guiding analysis of polycentric governance systems (PGS). The EGT offers theoretical grounding for context-appropriate assessment of the quality of a PGS, particularly allowing investigation of institutional externalities. We used qualitative analysis (structured content and thematic analysis) based on the 35 FGDs with local-level resource-governance bodies leading restoration efforts and the 37 KIIs – 21 with district-level officers and local traditional authorities, and 16 KIIs with national-level stakeholders. Analyses focused on four specific governance parameters: collaboration, competition, social learning, conflict-resolution mechanisms, and mechanisms for mitigating institutional externalities through coordination (Chapter 2). **For research question 2**, we used different methods to address the two sub-questions. First, we adopted an econometric perspective and used a multivariate Tobit regression model and a Poisson model to analyze the HHS data for the first sub-question. We reinforced the analyses with qualitative insights from a subset data from the 7 FGDs (Chapter 3). Second, we drew on an environmental behavior theoretical perspective rooted in social psychology and used mixed qualitative and statistical analyses (descriptive, T-test, and one-way ANOVA) of data from the 7 FGDs along with the RPGs, and from the HHS for the second sub-question (Chapter 4). **In addressing research question 3**, we used spatial ABM as a bottom-up computational modeling approach to human-environment interactions. Our ABM integrates insights and data from the FGDs, RPGs, HHS, plus some remote sensing products and other secondary data. We conducted six model simulations and statistical post-processing analyses of output data (Chapter 5). We recap below the main findings and implications for research and policy, organized by research question.

6.2 Summary of findings and implications

Research question 1: ***Which governance system can enhance the processes and positive outcomes of collective restoration in forest-agriscapes?*** This question investigates which governance system—including governance model, institutional arrangements, and regulatory framework—would adequately support an effective landscape-scale restoration process of forest, tree, and land resources to achieve multiple socio-ecological goals. Findings indicate that the current governance architecture shares some attributes of a PGS but does not foster adequate cooperation to address challenges of limited internal resource capacity, inequitable resource distribution, and negative institutional externalities. Social learning and coordination mechanisms helped to catalyze critical processes to realize some benefits of PGS but need strengthening. These findings show promise for a PGS that can achieve inter-sectoral and cross-scale coordination, building on the effective operationalization of existing decentralization institutions, which currently offer multi-stakeholder platforms and coordination venues. Dynamizing relevant policy spaces, processes, and institutions that foster necessary deliberation, learning, and coordination is important to mitigate negative institutional externalities. Overall, findings uncover challenges of governance integration and can inform the design of effective institutional arrangements for implementing landscape-scale restoration cohesively in Malawi and provide insights for similar contexts in sub-Saharan Africa. This study contributes to furthering knowledge on the framing of a PGS to support a landscape approach to resources restoration and management. Also, the study contributes to testing the EGT as an emerging theory of polycentric governance by assessing two of its hypotheses relating to: (i) the core processes of polycentric governance of multiple and interlinked policy issues, and (ii) the potential ways of handling challenges of institutional externalities.

Research question 2: ***What are farmers' decision-making processes and drivers of observed restoration of individual farmlands and collective resources in forest-agriscapes?*** This question examines how and why smallholder farmers and resource users engage with restoration of lands, trees, and forests, both individually and collectively. It answers the two sub-questions: The first sub-question is 2a): *What are the local patterns (nature, level, and areal extent) of farmers' restoration efforts in Malawian forest-agriscapes and the associated determinants?* Here, findings indicate some restoration diversification patterns whereby farmers generally combine two or more land-management practices based on their complementarities in achieving specific livelihood, food security, and ecological goals of restoration. Farmer considerations also include the compatibility of practices in terms of demand and timing of labor and other inputs. The estimated mean total area of restored farmlands is 1.10 (±0.76) and 1.07 (±0.72) acres in Dedza and Ntchisi, respectively. The restored area extent is less than half the average total landholdings in the area. Further, land configuration matters. Land plots that are spatially consolidated and tenure-secured are associated with higher restoration efforts. Notably, land purchased, inherited, or customary-allocated with supporting documentation are perceived secure enough to promote restoration. Findings therefore suggest that restoration policies should center on strategies that improve land-ownership security while minimizing spatial fragmentation within landholdings. Drivers of collective resources restoration include sound local leadership, perceived tangible benefits in ecosystem goods and services, secure resources rights, and perceived balance between payoffs and socio-ecological goals. These findings can inform restoration programs involving collective actions and their governance. The findings also offer insights and inputs for the computational ABM simulations and analyses.

The second sub-question is 2b): *What is the nature of farmers' decision-making processes for individual farmland and collective resources restoration in Malawian forest-agriscapes?* Findings here uncover the underlying contextual rationales, motives, benefits, and incentives of local restoration efforts. The decision-making rules identified reflect diverse and nuanced goal frames. Their configurations are distinct by the order and the weight of the goal frames, which are featured in various combinations. Restoration decision-making rules are categorized as: problem-solving oriented, resource/material-constrained, benefit-oriented, incentive-based, peer- or leader-influenced, knowledge-dependent, altruistic-oriented, rule- or norm-constrained, economic capacity-dependent, awareness-dependent, and risk averse-oriented. Linked to the corresponding vegetation- and non-vegetation-based restoration practices, these restoration decision-making rules help to elicit the underlying decision-making processes. These findings can advance the representation of farmers' decision rules and behavioral responses in computational ABM through the decomposition of empirical social data. This is true for the ABM that we develop for this study based on local farmers' observed restoration behavior and activities (Chapter 5). We seek to better capture these social actors' restoration decision-making processes in exploring the resulting potential aggregate environmental impacts. The approach that we use can also inform other similar modeling undertakings.

Research question 3: ***What are the potential environmental effects of farmers' restoration decisions and investments on forest-agriscapes and propitious management and policy options to accelerate restoration delivery?*** This question explores the temporal and spatially explicit potential aggregate (at the landscape level) patterns and environmental outcomes of local restoration decisions and subsequent investments. It also assesses prospects for promising policy scenarios to enhance local restoration efforts. Findings show a 10-year trend of the potential aggregate restoration outcomes in terms of spatial extent, intensity, and resulting greenness and land productivity. These outcomes vary by participation level. Findings indicate modest promise in landscape regreening from the bottom-up local restoration efforts. Specifically, greenness levels in collective restoration areas increase modestly but remain fluctuating. Land-productivity levels in individually restored farmlands are also relatively low, with a slight increase and an overall steady trend over the 10 years. Spatially, a small fraction of all resources (land plots and collective resources) in the forest-agriscape will be consistently restored, indicating a low magnitude and areal impact of restoration efforts. Insights from spatial patterns also indicate that farmers engage less in restoring collective resources in protected areas than on customary lands, reasserting the role of stronger resource ownership and tenure rights and security in enhancing local participation in restoration. Regarding the scenario testing, findings indicate that devising appropriate incentive schemes would enhance both collective and individual farmland restoration efforts. Offering necessary restoration knowledge—including through training and improved extension systems—and empowering local leadership would boost individual farmland and collective restoration, respectively. Importantly, operationalizing a management and policy package that bundles several enabling factors would maximize restoration in forest-agriscapes. These findings suggest the need for empowering local, bottom-up restoration efforts for enhanced landscape-level environmental outcomes. The study offers insights for spatially targeted, evidence-based landscape-restoration implementation in Central Malawi and demonstrates the potential of ABM as a tool to inform restoration policy.

Overall, the dissertation research contributes knowledge to the search for integrated governance of land, tree, and forest resources by deepening understanding of the institutional, socio-economic, and behavioral dimensions for their sustainable management and restoration. *First*, the research offers both theoretical and practical insights on the landscape approach to resource management in Malawi and other similar contexts. Findings advance knowledge on some relevant ingredients for a context-appropriate integrated governance system to implementing a landscape approach to resource restoration. This is lacking in Malawi. Our knowledge contribution is also relevant for other SSA countries engaged in FLR processes. Findings also advance scientific and policy discourse on the added value of the FLR paradigm compared to sector-based restoration approaches. *Second*, the research contributes insights on some socio-cultural drivers, challenges, and decisions underlying resources restoration, and advances knowledge on understanding and representing resource-restoration behavioral components in computational modeling. Findings offer relevant evidence to inform how to enhance local participation to maximize restoration outcomes. *Third*, the research further extends the use of mixed integrative approaches, including qualitative, econometric, and computational ABM approaches, to provide better evidence and forward-looking explorative options for improved governance and policies for resources restoration and the broader sustainable management of natural resources. *Finally*, on broader societal impacts, this dissertation research can contribute to informing restoration stakeholders (practitioners, policy makers, and investors) on effective restoration of degraded natural resources, with concrete actions to sharpen associated policies and management strategies in Malawi and other countries in similar African contexts.

6.3 Limitations and Future Research Outlook

This dissertation research has some limitations that we articulate in the specific studies, notably in chapter 3 (paper 2) and chapter 5 (paper 4). The assessment of restoration areal extent to understand the magnitude of local restoration efforts was based on farmers' self reported land sizes for land plots where restoration practices were applied. Despite triangulation of the data and direct observation of farm plots of interviewed farmers, using farm-measurement techniques and spatial mapping would improve and confirm accuracy and reduce uncertainties. Also, our attempt to account for tree and non-tree-based restoration practices and activities that occured with both individual and collective restoration efforts was challenged by the lack of simple shared metrics of restoration. Generating robust metrics, superior to the proxy variables that we used—land sizes under restoration and number of restoration practices implemented—is encouraged to better capture the diverse restoration efforts. Further, our econometric analysis poorly demarcated the influence of social capital on collective resource restoration efforts although social capital remained important to some functional processes of restoration institutions, notably informal social learning among members of resources governance bodies (see Chapter 2). Social capital was also built out of benefits that accrue from collective restoration and which represent a restoration decision-making factor (see Chapter 4). Therefore, we encourage the use of better indicators of social capital and/or model specification in assessing its influence on collective resources restoration efforts from an econometric perspective. Finally, our ABM analyses corrected somehow for the missed temporal dynamics of restoration efforts and even added a spatially explicit dimension, albeit on exploration of potential future patterns and trends. However, quantifying the uncertainty of the ABM outcomes and identifying the most influential factors driving the emergent trends and patterns remain a limitation that is yet to be addressed.

Therefore, we encourage future research to take on these unresolved limitations, starting with conducting a coupled uncertainty and sensitivity analysis of our ABM simulations, as has been done in previous studies (Ligmann-Zielinska and Jankowski, 2014, Ten Broeke et al., 2016). In doing so, we encourage running the model simulations for different sites and/or contexts to help with model refinement and re-articulation of broader potential impacts of local, bottom-up restoration efforts. Besides, future research may also explore and contribute to new areas of inquiry that this research suggests. Specifically, the research highlights the need to further deepen understanding of coordination processes and arrangements in the quest of processes to achieve well-integrated governance at the landscape scale. It also points to the need to disentangle the contribution of governance in observed or potential resources-restoration outcomes in order to reassert the importance of governance in shaping restoration success and sustainability. Moreover, the research calls for examining how to better integrate and monitor social outcomes in the design and monitoring processes of restoration interventions to enhance sustainability. Finally, the research suggests extending the questions addressed to other countries that are also engaged in resources restoration as a productive area of research to advance cross-country comparison and scaling up of landscape-restoration governance. This will allow some comparative analyses to contribute more nuanced and context-situated evidence to restoration policy making and implementation, thus reinforcing theoretical knowledge to tease out for climate change responses, biodiversity conservation, and provision of ecosystem services supporting livelihoods, food security and other socio-economic development.

APPENDICES

APPENDIX A

Guide Questions for FGDs on Restoration Decision-Making Processes with Resources Users Engaged in Collective Resources Restoration

This group discussion will be based on some questions but will remain flexible and open-ended. There are core themes that the researchers will seek to discuss with you. The themes and types of questions to guide the discussions are below.

Introduction

After the facilitators introduce themselves to the audience following the customs of the place, please **read associated consent form.**

Ask the participants to also introduce themselves.

Briefly reintroduce purpose of the FGD.

The purpose of this focus group is to learn from your experiences with collective actions associated to natural resources restoration. In particular, we will ask questions to understand what drives you (as an individual) to take part in collective resources restoration and sustainable management efforts. We would like to hear from you the elements that you consider and the process that you follow when making the decision to participate in collective-action restoration activities and the associated rationales.

Part 1: Identification of the rationale for collective-action resources restoration [15min]

- What types of collective-action restoration of the environment and natural resources do you implement in this community or area?
- What are the different restoration practices that you use to conduct such collective restoration efforts? Please specify by each type of restoration activity.
- How common would you say participation in collective-action restoration of the environment and natural resources is in your community?
- Why do you or people in your community restore trees and forest resources collectively:
    - on customary lands?
    - on protected areas?
- What motivates you or people to consider participating in collective restoration of trees and forest resources:
    - on customary lands?
    - on protected areas?

- What are the benefits you or people expect from participating in collective restoration of trees and forest resources in your community?
  - on customary lands?
  - on protected areas?
- Why do some people in your community not participate, or participate rarely, in collective restoration of trees and forest resources?

Part 2: Identification of the challenges and incentives mechanism associated to collective-action resources restoration [10mn]

- What difficulties/challenges do you or people encounter in collective-action efforts of restoring trees and forest resources:
  - on customary lands? Which challenges are the most critical, on a scale from 0 to 5?
  - on protected areas? Which challenges are the most critical, on a scale from 0 to 5?
- Do you or people receive any incentives or rewards that encourage or motivate to commit to collective-action restoration and sustainable management of trees and forest resources:
  - If you do, please list and explain the type and source (project, government, NGO) of the incentive for collective restoration on customary lands
  - If you do, please list and explain the type and source (project, government, NGO) of the incentive for collective restoration in protected areas
  - Are there incentives that you or people do not receive, but you think they would be effective in inducing you to participate in collective forest restoration or management? List and explain why you think each would be effective

Part 3: Identification of the factors determining engagement with collective-action resources restoration [15mn]

- What are the important factors you consider when deciding to engage in collective restoration actions for trees and forest resources:
  - on customary lands? Please specify
  - on protected areas? Please specify

- Now, let's rank each of these factors. What is the first important factor that you consider for your engagement in such group action?

Ranking/	Factors/	Justification: Why is that factor important for your engagement to the collective action?
Customary lands		
First important factor		
Second important factor		
Third important factor		
Fourth important factor		
Fifth important factor		
Protected areas		
First important factor		
Second important factor		
Third important factor		
Fourth important factor		
Fifth important factor		

Part 4: Identification and discussion of the processes of decision making to restore tree and forest resources land on customary lands and in protected areas: Role Playing [45min]

- Now, we will play a short game in which I want to understand the **process of your decision making**.
    - Let's imagine that you are in your household and you need to make the decision to participate to a collective-action effort for restoring tree and forest resources (on customary lands and /or protected areas). The factors that we talked about earlier are written on these colored cards. Those are the factors that you will weigh in your decisions. How do you consider them?
    - **Five volunteers will pick these cards.** Use the white board and stick the cards on it in an order, such that it will reflect the way you proceed to decide participating in collective action for tree and forest resources restoration. [This exercise may take 10-15min].
- Now, let us discuss the different decision-making features that some of you have sketched on the boards.
    - What do you think of them? Do you agree with any of them? You can also add new processes if you feel the need to.

    - Now, let us rank them from the most common to the least plausible. The objective is to retain the three most common processes of decision making that apply to this community. [The discussion may take 10- 15mn]
- How often do you change your decision-making processes? How will these decision-making processes change if:
    - There is a policy by the government to give more incentives to support collective efforts of trees and forests restoration (on customary lands and /or protected areas)?
    - There are severe droughts and other factors that continually prevent the trees to grow to the point where they are usable?

APPENDIX B

Guide Questions for FGDs on Restoration Decision-Making Processes with Smallholder Farmers and Land Managers Restoring their Individual Farmlands

This group discussion will be based on some questions but will remain flexible and open-ended. There are core themes that the researchers will seek to discuss with you. The themes and types of questions to guide the discussions are below.

Introduction

After the facilitators introduce themselves to the audience following the customs of the place, please **read associated consent form.**

Ask the participants to also introduce themselves.

Briefly reintroduce purpose of the FGD.

The purpose of this focus group is to learn from your experiences with restoration of agricultural lands. In particular, we will ask questions to understand what drives you (as individual farmers) to invest in the restoration of your agricultural. We would like to hear from you the elements that you consider and the process that you follow when making the decision to undertake restoration of your degraded land parcels and the associated rationales.

Part 1: Identification of the rationale for the restoration of agriculture lands [~15 min]

- How do you define agriculture land restoration in this community or area?
- What are the different practices or techniques you use for agriculture land restoration? Please specify
    - Why do you use those practices and technologies?
- How common is agriculture land restoration in this community? Are many farmers interested in the idea and doing it?
- Why do you or other farmers in your community restore agricultural lands?
- What motivate you or other farmers to consider restoring agricultural lands?
- What are the benefits you or other farmers expect from restoring agricultural lands?
- Why are some farmers in your community not interested and not investing, or less interested and rarely investing, in restoration of agricultural lands?

Part 2: Identification of the challenges and incentive mechanisms associated to restoration of agriculture lands [~10 min]

- What difficulties do you or other farmers encounter in restoring agriculture lands? Please list

- Which challenges are the most critical, on a scale from 0 to 5?

- Do you or other farmers receive any incentives or rewards that encourage or motivate to restore agriculture lands and manage them in a sustainable way?
  - If you do, please list and explain the type and source (project, government, NGO) of the incentives/rewards.
  - Are there incentives that you or other farmers do not receive, but you think they would be effective in inducing more restoration efforts/investments of agriculture lands and sustainable management? List and explain why you think each would be effective

Part 3: Identification of the factors determining engagement with land restoration [~15 min]

- What are the important factors you consider when deciding to restore your land parcels/plots?
  - Please specify.
  - Now, let's rank each of these factors. What is the first important factor that you consider before investing in the restoration of agriculture lands?

Ranking	Factors	Justification: Why is that element important?
First important factor		
Second important factor		
Third important factor		
Fourth important factor		
Fifth important factor		

Part 4: Identification and discussion of the processes of decision making to restore agriculture lands: Role Playing

- Now, we will play a short game in which I want to understand the **process of your decision making**.
  - Let's imagine that you are in your household and you need to make the decision to restore or not your land parcels/plots. The factors that we talked about earlier are written on these colored cards. Those are the factors that you will weigh in your decisions. How do you consider them?
  - **Five volunteers will pick these cards**. Use the white board and stick the cards on it in an order, such that it will reflect the way you proceed to decide

investing/implementing restoration of agriculture lands. [This exercise may take 10-15mn].

- Now, let us discuss the different decision-making features that they have sketched on the boards.
  - What do you think of them? Do you agree with any of them? You can also add new processes if you feel the need to.
  - Now, let us rank them from the most common to the least plausible. The objective is to retain the three most common processes of decision making that apply to this community. [The discussion may take 15- 20mn]
- How often do you change your decision-making processes? How will these decision-making processes change if?
  - There is a policy by the government to give more incentives for restoration of agriculture lands?
  - There are severe droughts or floods or pest ravages that continually undermine your crop yields?

APPENDIX C

Guide Questions for FGDs on Restoration Governance with Resources Governance Committees

In this focus group, we will gather data and information related the structural and functional configurations of the governance institutions (BMCs and VNMRCs, and other CBNRM institutions and resources-user groups/clubs) in place for collective resources restoration occurring both on customary lands and in protected areas. We will also collect information on manifestations of institutional externalities. While the focus group will be flexible and open-ended, there are core themes that the researcher will seek to discuss with you. The themes and types of questions to guide the discussions are included below.

Identification

(INTERV_DATE |__|__|/|__|__|/|__|__|__|__|	**Start time** (TIME START) [__ __] h [__ __] min
District Name (DISTR_ID) [__________________]	Traditional Authority (TA_ID): [________________]
Extension Planning Area (EPA_ID): [________]	Area Development Committee (ADC_ID): [_______]
Governance institution (GOV INSTIT_ID): [__________________________________]	
Village to which the governance structure is affiliated (VILG_ID): [______________________]	Group Village Head to which the governance structure is affiliated (GVH_ID): [_______________]
Phone number of the governance institution (if available): [________________________________]	**End Time** (TIMEEND): [___ ___] h [___ ___] mn

Introduction – Preliminary

- When was this governance committee/institution established to manage and govern the resources?
- What type of natural resources is your committee charged to manage and govern [e.g., forests; village forest areas; woodlots; plantations; agriculture resources; water resources, other natural resources in the landscape]?
- What is the **tenure system** associated with the natural resources that you manage? [e.g. protected area; customary unallocated lands; customary estate; other tenure types]?
- What is the size of (area covered by) the resource(s) you govern (acre, hectares)?
- For the resources that you manage, what are the rights for different users of your area? Do all users have equitable access and use to the resources?
    - Do the current resources rights threaten the security (livelihood activity, food security, peace, etc.) of any resource's users?

Part 1: Understanding structural features of the governance institutions in the forest-agriscape

a. Scale of governance, structure, and legal status

- At what jurisdictional scale does your committee operate?
  - How is your committee structured? Do you have an institutional diagram on paper or in digital format that you can share with me? What are the number and types of committee positions?
  - Is your committee officially registered? If yes, where or by what authority? Does it have a constitution?
  - Does the committee report to another institution/authority? If so, to whom?
  - How are members selected? Do you pay any consideration to the gender of incumbents?

b. Organizational roles, activities, and management features

- What are your mandated roles as committee with regard to restoration and sustainable management of the resources in this community?
- What are the specific activities you implement as a committee?
- What are the objectives for managing these resources?
- What restoration approach(es)/technique(s) do you use and what informed the choice of such approach(es)/technique(s)?
  - Do you or have you ever used any technological infrastructures (e.g., direct planting with seedlings, revegetation with natural regeneration, erosion-control techniques, fencing to control livestock, etc.) for the restoration of the resources?
- Does your committee have a functional management plan for the resources being managed? If yes, who developed the plan and when?
- Are there any rules set up for the management of the resources? If there are any:
  - What are the rules?
  - How were those rules formulated? Who participated in their formulation?
  - To what extent are they followed? What is the level compliance with the rules [e.g., most of the time, often, sometimes, rarely or never]
  - How are the rules enforced? Is the level of enforcement sufficient to protect the resource?

    - Are there any penalties for breaking these rules, and if yes, what are these penalties and how are they enforced and by whom?
- Are there any rules set up for the internal management of the committee? If yes, what are they? Are there any penalties for breaking these rules, and if yes, what are they?
- What is the frequency of meetings?
- What types of operational resources does your committee have to implement its resources management and restoration activities?
    - What are the sources of these resources?
    - Are they sufficient?

Part 2: Identification of cooperation features among stakeholders within and across forest-specific governance structures and other resources governance institutions in the forest-agriscape

c. Participation/Cooperation features within resources governance committees (social capital)

- How active or committed are members in performing their roles to achieve a common goal?
- Are you satisfied with the current level of participation of the members?
- What motivate such participation or commitment (or lack thereof)?
- How are decisions made within the committee? Do all members have an equal voice in the decision-making process?
- Are members transparent in their actions?
- Are members accountable for their actions? If so, to whom and how (e.g., to the entire committee, the wider community)?
- What measures are taken to ensure that committee members are transparent and accountable?
- Characterize the nature of the relationships among members:
    - On a scale of 1 to 5, what score would you assign to how well committee members cooperate to meet the shared resources-management goals [1=no cooperation; 5=full cooperation]. Explain your rating.
    - On a scale of 1 to 5, how would you rate the level of trust among the committee members [1=no trust; 5=full trust]? Explain you rating.

    - On a scale of 1 to 5, how would you rate the level of conflicts among the committee members [1=no conflict; 5=conflict all the time]? Explain you rating.
- If/when conflicts occur, what is commonly the nature of these conflicts?
- How are conflicts anticipated, managed, and avoided?

d. Horizontal relationship features across resources governance structures for cooperation and collaboration – extent of polycentricity

- Do you know other committees (local organization) managing/restoring other natural resources in this community or area? Please provide some examples.
    - Name them, the roles they play in resources restoration and sustainable management, the kinds of activities they implement, and the scales at which they operate (e.g., village, Group Village Head, Traditional Authority, district).
        - ***Probe with these if necessary*** *[Block Management Committees, Village Forest Committees, and other relevant local organizations/NRM committees such as agriculture land conservation committees, water conservation committees]*
- What kind of relationships do you develop with <u>these other committees</u>? Do you meet with them?
    - Do you share operational resources and costs (finances, logistical support, knowledge) for collaboration purposes to address your limited capacities and scarce resources? Explain.
    - Do you co-organize any collective actions together? If yes, with whom and at what frequency? If no, why?

e. Vertical relationship features with other governance structures (extent of polycentricity)

- What are your roles vis-à-vis the community of resources users under your jurisdiction? Explain
    - How will you characterize compliance with the rules governing the resources by members of the community at large?
- What are your roles vis-à-vis the <u>Village Development Committee and the GVH</u>? Explain
- What are your roles vis-à-vis the <u>Area Development Committee and the Traditional Authority</u>?
- What are your roles vis-à-vis <u>the Local Forest Management Board (LFMB)</u>? Explain
- What are your roles vis-à-vis <u>local authorities</u> such as the forestry, agriculture, livestock, water officers and district officers? Specify and explain

- Characterize the nature of the relationships between your committee and these other entities/ institutions.
    - On a scale of 0 to 5, how would you rate [ITEM]? Explain you rating

ITEM		Between your committee and the other local governance committees.	Between your committee and the LFMB	Between your committee and the traditional leader.	Between your committee and the group village headmen.	Between your committee and the community
The level of cooperation?						
The level of trust?						
Conflicts	Level					
	Nature					
Other relationship(s)						

- What are the biggest strengths and successes of your committee since it was set up?
    - What is/are the success(es) in relation to cross-scale (horizontal and vertical) collaboration(s) for resource restoration and sustainable management in the landscape?
- What are the biggest challenges that your committee faces in implementing its activities and fulfilling its mandate?
    - What is/are the challenge(s) in relation to cross-scale (horizontal and vertical) collaboration(s) for resource restoration and sustainable management in the landscape?

Part 3: Identification of cross-scale features of resources distribution among governance institutions present in the forest-agriscape

f. Distribution of operational resources within governance committees

- How are operational resources/costs associated with collective actions shared among members?
    - Are the physical burdens shared equitably among members? Or are only few members contributing the great bulk of the collective work?

g. Incentive mechanisms

- Are there any reward mechanisms to enhance participation in the collective action? If so, what type (financial/cash-based, resource rights-based, or ecosystem service- based, in-kind benefits)?
- Which of these incentives are the most effective, why? Which ones are the least effective, why?
- What other motivational options promote local participation in the collective action endeavors?
    - Do committee members have special benefits for their leadership roles? If so, what are the benefits and how were they determined?

- What do you think are the best incentives to promote local participation in collective resources management **[*Interviewer: focus on the resources they lean management on]?***

h. Sharing of benefits from resources management

- What types and amounts of benefits (monetary and non-monetary) do you obtain from the resources that you are managing and governing?
- How are these benefits distributed in the community, including users' groups?
- Are you satisfied with the modes and levels of benefit sharing in the community? Why?

<u>Part 4: Learning features for resources restoration and management in the forest-agriscape</u>

i. Monitoring and learning

- How are the collective-action endeavors monitored to ensure progress is being made toward meeting agreed upon restoration and sustainable management targets?
- How and to what extent has the committee mobilized knowledge about the extent of the degradation of the resources it has authority over in order to better inform its management and governance goals?
- What main challenges you encounter when monitoring work over the resources you manage?
- How do you learn about existing policies/laws and institutional provisions affecting the management of the resources?
- What is your best source of knowledge and skills on the technical aspects of resources management? On the leadership aspects?
- Have members of your institution attended training in order to perform their duties effectively? If so, what kind of training have they undergone?
- On a scale of 0-5, how much of the knowledge and skills that you use to lead the management of the resources have you learnt by yourself or by doing and from own experience *[not from formal or informal training from government or other development agencies]?*

<u>Part 5: Identification of institutional externalities in resources restoration and management at the forest-agriscape scale</u>

j. Institutional externalities: existence, types, extent, and frequency (of occurrence)

- Do the management and governance policies (including operating rules and bylaws), decisions and actions/practices implemented by other resources-governance committees in the landscape interfere with your collective-action work on resources restoration?
    - If yes, how, and how frequent and serious are the influences?
- Which [ITEMS] have **positive impact(s)** on your work and its outcomes? How (e.g., enabling, reinforcing, indivisible or essential), and at what level? Specify, explain and give examples
    - Specific policies/sectors of environmental management
    - Specific environmental management decisions
    - Specific environmental management practices/actions
- Which [ITEMS] have **negative impact(s)** on your work and its outcomes? How (e.g., constraining, counteracting, canceling), and at what level? Specify, explain and give examples
    - Specific policies/sectors of environmental management
    - Specific environmental management decisions
    - Specific environmental management practices/actions

k. Institutional externalities on resources governance performance and institutional effectiveness

- Does any member of this committee hold another leadership/membership position in another/other resource governance institution(s)? What institutions are these and what roles do you play?
- How does your double affiliation affect/influence the level of your participation in both/all institutions? How does it shape your ability to objectively make decisions in both/all institutions?
    - Positive – enabling, reinforcing, indivisible
    - Neutral – consistent
    - Negative – constraining, counteracting, canceling
- How do each of these transaction costs affect the functional effectiveness of your institution?

Transaction cost elements	Effects on functional effectiveness
Quality and intensity of participation	
Level and frequency of conflicts	
Availability of organizational and functional resources	
Accessibility of technical knowledge	
Political ability to understand actors' interests / bargaining power	

- What other factors (transaction costs), if any, influence your functional effectiveness? And how?

APPENDIX D

Guide Questions for KIIs on Restoration Governance with Restoration Practitioners at Sub-National and Local Levels

In this interview targeting representatives from District Council, Traditional Authority, and Group-Village Head, we will gather data and information related the structural and functional configurations of the governance institutions in place for collective forest resources restoration occurring both on customary lands and in protected areas. We will also collect information on manifestations of institutional externalities. While the interview will be flexible and open-ended, there are core themes that the researcher will seek to discuss with you. The themes and types of questions to guide the discussions are included below.

Identification

District Name (DISTR_ID): [________]	Traditional Authority (TA_ID): [__________________]
Extension Planning Area (EPA_ID): [_____]	Area Development Committee/ (ADC_ID): [_________]
Governance institution [____]	
Key Informant Code (KII_CODE): |___|___|	(INTERV_DATE)|___|___|/|___|___|/|___|___|___|___|
Phone number of the Informant (if any): [________________________________]	**Start time** (TIMESTART) [__ ___] h [___ ___] mn **End Time** (TIMEEND): [___ ___] h [___ ___] mn

Introduction – Preliminary

- Since when has this management board been established and started to operate?
- What types of natural resources is your institution linked to through its governance mandate [e.g., forests; village forest areas; woodlots; plantations; agriculture resources; water resources, other natural resources in the landscape]?
- What is the **tenure system** associated with those natural resources [e.g. protected area; customary unallocated lands; customary estate; other tenure types]?
- For the resources that you manage, what are the rights for different users of your area? Do all users have equitable access and use to the resources?

Part 1: Understanding structural features of governance institutions in the forest-agriscape

a. Scale of governance, structure, and legal status

- At what jurisdictional scale(s) does your governance institution operate?
- How is your governance institution structured? Do you have an institutional diagram on paper or in digital format that you can share with me? What are the number and types of positions?
- Is your governance board officially registered? Does it have a constitution?
- Who does your governance institution report to? How and how often?

- How are members selected? Do you pay any consideration to the gender of incumbents?

b. Organizational roles, activities, and internal management features

- What are the mandated roles of your institution with regard to restoration and sustainable management of the resources at the landscape scale?
- What are the specific activities you implement as an institution with regard to your mandated roles?
- Are there any rules to regulate the governance of forest and related resources? If yes:
    - What are the rules?
    - How were they developed? Who participated in their development? Were any population-wide consultations made when crafting the rules?
    - To what extent are they followed? [Specify: most of the time, often, sometimes, rarely, or never]
    - How are the rules enforced?
    - Are there any penalties for breaking these rules, and if yes, what are these penalties and how are they enforced and by whom?
- Are there any rules set up for the internal management of the board? If yes, what are they? Are there any penalties for breaking these rules, and if yes, what are they?
- How frequently do you meet as a board (how many times per month? Year)?
- What operational resources does your LFMB have to implement its governing activities (e.g., money, and others)?
    - What are the sources of any such resources?
    - Are they sufficient?

Part 2: Identification of cooperation features among stakeholders within and across forest-specific governance institutions and other resources governance institutions of the forest-agriscape

c. Participation and Cooperation features within the LFMB (social capital)

- What is the participation and commitment level of members to the activities defined to meet the LFMB's goals?
- Are you satisfied with such level of participation? Why?
- What do you think motivates your observed levels of participation or commitment?

- How are decisions made in your organization?
    - Do all members have an equal say in decision making in your organization?
    - Do some members dominate the decision-making processes?
- Are members accountable and transparent when undertaking the institution's actions?
- What mechanisms are used to ensure transparency and accountability among members?
- What is the nature of the relationships among members?
    - Is there mutual trust and respect for each other? On a scale of 0 to 5, how would you rate the level of trust?
    - How well do members cooperate to meet the shared resources-governance goals? On a scale of 0 to 5, how would you rate the level of cooperation?
    - What is the frequency of conflicts among members? On a scale of 0 (no conflicts) to 5 (very frequently), how would you rate the level of conflicts?
    - If/when conflicts occur, what is commonly the nature of these conflicts?
    - How are conflicts anticipated, managed, and avoided?

d. Cross-scale horizontal and vertical relationship features across resources governance institutions -- cooperation, collaboration, and coordination (extent of polycentricity)

- What committees and other local organizations for managing or restoring natural resources (forests, water, and soils) are you aware of in this community or area?
    - Name them, the roles they play in resources restoration and sustainable management, and the scales at which they operate (e.g., village, Group Village Head, Traditional Authority, district).
        - *Probe with these if necessary [Block Management Committees, Village Forest Committees, and other relevant local organizations/NRM committees such as agriculture land conservation committees, water conservation committees]*
- What authority does your LFMB have over these local resources' management committees involved in land restoration in the agriculture/forest landscape?
- What is your role in any of these local governance committees? How do you interact with them? Which ones specifically? Explain.

- Do you deal directly with <u>resources users' organizations</u> under the jurisdiction of your community? Explain, if any interactions.
- What are your roles with the Village Development Committees and the GVHs? Explain
- What are your roles with the Area Development Committee and the Traditional Authority?
- What are your roles with other <u>local authorities</u>, such as the forestry, agriculture, livestock, water officers and district officers?

- Characterize the nature of the relationships between the LFMB and these other governance institutions.
  - On a scale of 0 to 5, how would you rate [ITEM]? Explain you rating

ITEM		Between the LFMB and the local governance committees.	Between the LFMB and the traditional leaders.	Between the LFMB and the group village headmen.	Between the LFMB and the community (users' groups).
The level of cooperation?					
The level of trust?					
Conflicts	Level				
	Nature				

- Do you contribute resources, knowledge, or logistical support to the governance committees operating on resources restoration and sustainable management? If so, how?
- What mechanisms do you use to hold these governance committees accountable to the LFMB? What do you hold them accountable for, if at all?
- Do you coordinate any collective action together in relation to the forest reserve? If yes, with whom and at what frequency? If no, why?
- Are there rules and institutional arrangements for **<u>coordinating</u>** the activities of local resources-governance committees in managing the forest reserve and surrounding trees/forests resources?
  - If yes, what are these rules and arrangements, and how are the rules enforced or the arrangements implemented?
  - In your view, how effective are these rules and arrangements on a scale of 0-5? Explain.
  - How do these rules and arrangements enable you to perform the bridging/steering role to achieve the integrated management sought with environmental resources management?
- What are the biggest strengths and successes of the LFMB since it was set up?

- What is/are the success(es) in relation to cross-scale (horizontal and vertical) coordination for resource restoration and sustainable management in the landscape?

- What are the biggest challenges that the LFMB faces in implementing its activities and fulfilling its mandate?
  - What is/are the challenge(s) in relation to cross-scale (horizontal and vertical) coordination for resource restoration and sustainable management in the landscape?
- Do you perceive your institution as an important and appropriate institution with the necessary skills and resources to guide the integrated management sought with environmental resources management to avoid perverse trade-offs? Explain

Part 3: Identification of cross-scale features of resources distribution among governance institutions present in the forest-agriscape

e. Sharing of operational resources by the local governance institutions

For the types of operational resources and costs associated with managing and governing the resources (forest reserve and surrounding trees/forests resources):

- Do you promote sharing of operational resources and costs (finances, capacity, and knowledge) by the different governance committees for collaborative management? If yes, why? If no, why not?
- What and how are these operational resources and costs shared by the governance committees and the resources-users groups of the community/area? How do they contribute to them?

f. Sharing of benefits from resources management within and among governance institutions

- What types and amounts of benefits (monetary and non-monetary) are obtained from managing and governing the natural resources?
- How are these benefits distributed among the governance committees and the users' groups?
- Are you satisfied with the modes and levels of benefit sharing among these entities? Why?

g. Incentive mechanisms

- What are the types/mechanisms of reward to enhance participation in the collective restoration action? (e.g. cash-based, resource rights-based, ecosystem service-based, in-kind benefits)?
- Which of these incentives are the most effective, why? Which ones are the least effective, why?
- What other motivational options promote participation in the collective-action endeavors?

- What do you think are the best incentives to promote local participation in collective resources management of forest reserve and trees/forest resources outside reserves?

Part 4: Learning operational dynamics for resources restoration in the forest-agriscape

h. ***Monitoring and learning***

- How are the collective-action endeavors monitored to assure progress is being made toward meeting agreed upon restoration and sustainable management goals for the forest reserve? For trees and restoration outside the reserve?
- Is there a reporting system to the LFMB? If yes, by whom and what does it involve?
- What are/were the main challenges to the LFMB monitoring work over the co-management of the forest reserve along with community management activities outside the reserve?
- How do you learn about policies/institutional provisions affecting the resources management?
- What is your best source of knowledge and skills on the technical aspects of resources management? On the leadership aspects?
- Have members of your institution attended any training in order to perform their duties effectively? If yes, what type of training have they undergone?
- Has your institution trained other local resources-governance committees to build/reinforce their capacity to better perform their duties? What was the training about and how frequent is the training? What was the goal of the training? Who were trained?

Part 5: Identification of institutional externalities in resources restoration and management at the forest-agriscape scale

i. ***Institutional externalities: existence, types, extent, and frequency (of occurrence)***

- Do the management and governance policies (including operating rules and bylaws), decisions, and actions implemented by other resources-governance committees in the landscape interfere with your forest protection and restoration decisions, actions or outcomes? Explain.
    - If yes, how, and how frequent and serious are the influences?
- Which **[ITEMS]** have **positive impact(s)** on your work and its outcomes? How (e.g., enabling, reinforcing, indivisible or essential), and at what spatial level (e.g., village, TA, district, regional national level)? Specify, explain and give examples

- Specific policies/sectors of environmental management
- Specific environmental management decisions
- Specific environmental management practices/actions

- Which **[ITEMS]** have **negative impact(s)** on your work and its outcomes? How (e.g., constraining, counteracting, canceling), and at what spatial level (e.g., village, TA, district, regional national level)?? Specify, explain and give examples
    - Specific policies/sectors of environmental management
    - Specific environmental management decisions
    - Specific environmental management practices/actions

j. Institutional externalities on resources governance performance and institutional effectiveness

- Is there any member who belongs to or holds a leadership or membership position in a) another/other development/governance committee(s), and b) another/other resource-governance institution(s) in the area?
- How does your double affiliation affect/influence your ability to make decisions and perform effectively in both institutions? Explain by picking what you thinkis the best response below:
    - Positive – enabling, reinforcing, indivisible
    - Neutral – consistent
    - Negative – constraining, counteracting, canceling
- How do each of these transaction costs affect the functional effectiveness of your institution?

Transaction costs elements	**Effects on functional effectiveness**
Quality and intensity of participation	
Level and frequency of conflicts	
Availability or not of organizational and functional resources	
Accessibility of technical knowledge	
Political ability to understand actors' interests / bargaining power	

- What other factors (transaction costs), if any, influence your functional effectiveness? And how?

APPENDIX E

Guide Questions for KIIs on Restoration Governance with Restoration Practitioners and Policy makers at National Level

While the interview will be flexible and open-ended, there are core themes that the researcher will seek to discuss. The themes and types of questions asked to guide the discussions are included below.

Identification

Government Agency [____]	
Key Informant Code (KII_CODE) |__|__|	(INTERV_DATE|___|___|/|___|___|/|___|___|___|___|
Contacts of the Informant (if any)/ [__________]	**Start time** (TIMESTART) [__ ___] h [___ ___] mn **End Time** (TIMEEND): [__ __] h [__ __] mn

Introduction – Preliminary

- What do you do as an institution/agency/department? What are your roles with regard to natural resources management in the country?
- What are the legal mandate of your institution/agency/department with regard to restoration and sustainable management of natural resources at the landscape scale?
- Which natural resources does your institution have a governance mandate over?
- Which natural resources does your institution deal with but does not have a direct governance mandate over? In what role?

For the remaining of the interview, I will use the term "resources restoration" to mean conservation, sustainable management, and actual rehabilitation/reclamation of natural resources to address the problem of environmental degradation holistically.

Part 1: Understanding policy and regulatory instruments underlying national governance of forest-agriculture landscapes

a. Institutional policies and coordination

- What are the policies and laws (governance instruments) regulating those natural resources that your institution has a direct mandate over?
- What are the policies and laws (governance instruments) regulating other natural resources that you think are interlinked with the ones you have a mandate over?
- What are the main gaps in the legal and policy framework of your mandated sector to meet successful resources restoration in at the landscape level?

Part 2: Identification of institutional externalities in the regulatory and policy framework for ecological landscape restoration and their impacts on resources management and restoration in forest and agrarian landscapes

b. Resource-tenure provisions in laws and policies and their influence on landscape restoration

- How are resources rights and tenure articulated in the policies and laws that are associated with the natural resources that your agency has a legal mandate over? Please include the following:

Rights/Tenure	Types of resources rights conferred	Administration of access to these rights	Actors who have access to the rights

- How do these provisions on resources-tenure rights align with related provisions in other policies and laws? Specify the policies/laws and their impacts:

Type of influence Other Policies/Laws	Positive – enabling, reinforcing, indivisible / essential ingredient	Neutral – consistent	Negative – constraining, counteracting, canceling

c. Provisions on incentives in laws/policies and their influence on landscape restoration

- What incentive schemes are provided in policy and legal documents to promote ecological landscape restoration?
    - How effective do you think these incentive mechanisms have been to promote ecological landscape restoration?
- Do your sector's policies and laws include provisions on reward mechanisms for participation in collective resource-restoration action? If yes, what are they and their type?
    - In your view, how satisfied are the different stakeholders with these incentives on a scale of 0-5? (not satisfied at all, 5 fully satisfied). Specify for each reward mechanism and stakeholder, if possible.
    - How effective do you think these incentives are in promoting collective and individual restoration activities? How could the incentives schemes be improved?

Types	Incentives	Stakeholders' satisfaction	Effectiveness
Cash-based			
Other financial rewards			
Resource rights-based			
Ecosystem service-based			
Other in-kind rewards			
Other arrangements promoting participation in collective-action endeavors			

- How do these incentives provisions that promote ecological landscape restoration align with related provisions in other policies and laws?

Type of influence Other Policies/Laws	Positive – enabling, reinforcing, indivisible / essential ingredient	Neutral – consistent	Negative – constraining, counteracting, canceling

d. Provisions of cost sharing in restoring and managing resources

- What types of operational resources and functional costs are associated with managing and governing the resources you are mandated to manage/regulate?
- How do your regulation instruments articulate the bearing of such costs for restoring and managing the resources among governing committees as well as users' groups across scale?
- Do your sector's policy and legal system promote public-private partnerships as a financing mechanism for restoration activities? Payment for ecosystem services? Other?
- How do these financing provisions align with related provisions in other policies and laws?

Type of influence Other Policies/Laws	Positive – enabling, reinforcing, indivisible/ essential ingredient	Neutral – consistent	Negative – constraining, counteracting, canceling

- At the operational level, are there any practices, activities or arrangements that your agency uses to share restoration costs with agencies managing other resources? If yes, what are they and how effective have they been?

e. Provision of benefit sharing from resources management within and among governance structures

- What types of benefits (monetary and non-monetary) are obtained from managing and governing the resources that you have a mandate over, and by whom?

- What, if any, are the benefit-sharing mechanisms that your sector's regulatory instruments provide for the diverse stakeholders managing and governing the resources under your mandate *[among stakeholders, include resource user groups, governing committees, and the state facilitating agency*]
- In your view, how satisfied are the different stakeholders with these benefit-sharing arrangements on a scale of 0-5? Specify by each mechanism and stakeholder, if possible.
- How effective do you think these benefit-sharing arrangements are in promoting collective and individual restoration activities? How could the benefit sharing mechanisms be improved?
- How do these provisions for benefit sharing align with related provisions in other policies and laws?

Type of influence Other Policies/Laws	Positive – enabling, reinforcing, indivisible / essential ingredient	Neutral – consistent	Negative – constraining, counteracting, canceling

f. Provisions for law enforcement and challenges and strengths for landscape restoration

- What monitoring arrangements do your regulatory instruments articulate for collective-action endeavors to meet restoration and sustainable management goals?
- What monitoring activities does your sector perform with regards to: a) the condition of the resource(s), and b) enforcement of rules/laws?
- How do these provisions align with related provisions in other policies and laws?

Type of influence Other Policies/Laws	Positive – enabling, reinforcing, indivisible / essential ingredient	Neutral – consistent	Negative – constraining, counteracting, canceling

- How are these monitoring requirements enforced? What are the main challenges that your agencies face in enforcing those requirements?
- What are the best solutions to solve these challenges (explain for each challenge)

g. Other institutional externalities and effects on institutional performance and effectiveness

- What do you think are/would be the transaction costs [ITEMS] of building the cross-sector arrangements needed for an integrated approach to effective natural resources restoration at the landscape scale, such as under FLR?

Transaction cost elements	**Occurrence and Manifestations**	**Effects on functional effectiveness for integrated restoration at the landscape level**
Importance and frequency of conflicting policies		
Availability of organizational and functional resources		
Accessibility to technical knowledge		
Accessibility to scientific knowledge		
Ability to understand divers actors' interests and bargaining power		

Part 3: Sectoral integration for governance of landscape restoration and prospects for FLR

h. Sectoral integration and cohesiveness/supportiveness (or lack thereof) among different sectoral policies and

- To what extent do the main sectoral policies, such as in forestry, agriculture, environmental management, land administration, water resources and other relevant sectoral policies support: a) ecological landscape restoration, and b) FLR (if there is any difference)? Explain for each case.
- What are the specific activities you implement as an institution to coordinate policymaking and ensure alignment with other governance institutions and their laws and policies? Specify. What specific institutional mechanisms do you use for the co-ordination?
- Are there **cross-scale (e.g., cross village, TA, district, region)** institutional arrangements that help to manage ecological landscape restoration in a holistic manner within your sector?

Cross-scale institutional arrangements	How effective have each of them been?	What are the major challenges?	What do you think is/are the most effective cross-sectoral institutional arrangements?

- Are there **cross-sectoral** institutional arrangements (e.g., multi-stakeholder platforms, legal mandates, task forces, coordination units, etc.) that help to manage ecological landscape restoration activities in a holistic manner?

Cross-sectoral institutional arrangements	At what scales do they operate?	How effective have each of them been?	What are the major challenges?	What do you think is/are the most effective cross-sectoral institutional arrangements?

- Do you think that ecological landscape restoration can be governed effectively across sectors?
    - What would have to take place or be considered for this to happen?
    - What type of governance arrangements would make this work: a) given the current sectoral approach to natural resources management? b) Outside the current sectoral approach to natural resources management?
- What are your thoughts about FLR that includes ecological restoration on agricultural lands?
    - When you hear the term ecological restoration, what comes to your mind? What is being restored?
- Do you have any other thoughts or ideas that you would like to share on this issue of landscape restoration and its prospects for success?

APPENDIX F

Questionnaire for Household Survey

Link to Qualtrics Online

Edit Survey | Qualtrics Survey Software

https://msu.co1.qualtrics.com/surveys/SV_ctBla1W4LRkV5Bj/edit

APPENDIX G

Approved IRB

MICHIGAN STATE
UNIVERSITY

EXEMPT DETERMINATION
Revised Common Rule

March 29, 2019

To: Leo C Zulu

Re: **MSU Study ID:** STUDY00001409
Principal Investigator: Leo C Zulu
Category: Exempt 2ii
Exempt Determination Date: 3/29/2019
Limited IRB Review: Not Required.

Funding Title - Doctoral Dissertation Research: Environmental Governance of Forest-Agricscapes in Sub-Saharan Africa: Socio-Institutional Dimensions of People-centered Ecological Restoration.
Funding Agency - National Science Foundation 00401874
Funding Status - Pending

This study has been determined to be exempt under 45 CFR 46.104(d) 2ii.

Office of Regulatory Affairs
Human Research Protection Program

4000 Collins Road
Suite 136
Lansing, MI 48910

517-355-2180
Fax: 517-432-4503
Email: irb@msu.edu
www.hrpp.msu.edu

Principal Investigator (PI) Responsibilities: The PI assumes the responsibilities for the protection of human subjects in this study as outlined in Human Research Protection Program (HRPP) Manual Section 8-1, Exemptions.

Continuing Review: Exempt studies do not need to be renewed.

Modifications: In general, investigators are not required to submit changes to the Michigan State University (MSU) Institutional Review Board (IRB) once a research study is designated as exempt as long as those changes do not affect the exempt category or criteria for exempt determination (changing from exempt status to expedited or full review, changing exempt category) or that may substantially change the focus of the research study such as a change in hypothesis or study design. See HRPP Manual Section 8-1, Exemptions, for examples. If the study is modified to add additional sites for the research, please note that you may not begin the research at those sites until you receive the appropriate approvals/permissions from the sites.

Please contact the HRPP office if you have any questions about whether a change must be submitted for IRB review and approval.

New Funding: If new external funding is obtained for an active study that had been determined exempt, a new initial IRB submission will be required, with limited exceptions. If you are unsure if a new initial IRB submission is required, contact the HRPP office. IRB review of the new submission must be completed before new funds can be spent on human research activities, as the new funding source may have additional or different requirements.

Reportable Events: If issues should arise during the conduct of the research, such as unanticipated problems that may involve risks to subjects or others, or any problem that may increase the risk to the human subjects and change the category of review, notify the IRB office promptly. Any complaints from participants that may change the level of review from exempt to expedited or full review must be reported to the IRB. Please report new information through the study's workspace and contact the IRB office with any urgent events. Please visit the Human Research Protection Program (HRPP) website to obtain more information, including reporting timelines.

Personnel Changes: After determination of the exempt status, the PI is responsible for maintaining records of personnel changes and appropriate training. The PI is not required to notify the IRB of personnel changes on exempt research. However, he or she may wish to submit personnel changes to the IRB for recordkeeping purposes (e.g. communication with the Graduate School) and may submit such requests by submitting a Modification request. If there is a change in PI, the new PI must confirm acceptance of the PI Assurance form and the previous PI must submit the Supplemental Form to Change the Principal Investigator with the Modification request (available at hrpp.msu.edu).

Closure: Investigators are not required to notify the IRB when the research study can be closed. However, the PI can choose to notify the IRB when the study can be closed and is especially recommended when the PI leaves the university. Closure indicates that research activities with human subjects are no longer ongoing, have stopped, and are complete. Human research activities are complete when investigators are no longer obtaining information or biospecimens about a living person through interaction or intervention with the individual, obtaining identifiable private information or identifiable biospecimens about a living person, and/or using, studying, analyzing, or generating identifiable private information or identifiable biospecimens about a living person.

For More Information: See HRPP Manual, including Section 8-1, Exemptions (available at hrpp.msu.edu).

Contact Information: If we can be of further assistance or if you have questions, please contact us at 517-355-2180 or via email at IRB@msu.edu. Please visit hrpp.msu.edu to access the HRPP Manual, templates, etc.

Exemption Category. The full regulatory text from 45 CFR 46.104(d) for the exempt research categories is included below. [1234]

Exempt 1. Research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special education instructional strategies, and research on the

effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

Exempt 2. Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met:

(i) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects;

(ii) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or

(iii) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by 45 CFR 46.111(a)(7).

Exempt 3. (i) Research involving benign behavioral interventions in conjunction with the collection of information from an adult subject through verbal or written responses (including data entry) or audiovisual recording if the subject prospectively agrees to the intervention and information collection and at least one of the following criteria is met:

(A) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects;

(B) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or

(C) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by 45 CFR 46.111(a)(7).

(ii) For the purpose of this provision, benign behavioral interventions are brief in duration, harmless, painless, not physically invasive, not likely to have a significant adverse lasting impact on the subjects, and the investigator has no reason to think the subjects will find the interventions offensive or embarrassing. Provided all such criteria are met, examples of such benign behavioral interventions would include having the subjects play an online game, having them solve puzzles under various noise conditions, or having them decide how to allocate a nominal amount of received cash between themselves and someone else.

(iii) If the research involves deceiving the subjects regarding the nature or purposes of the research, this exemption is not applicable unless the subject authorizes the deception through a prospective agreement to participate in research in circumstances in which the subject is informed that he or she will be unaware of or misled regarding the nature or purposes of the research.

Exempt 4. Secondary research for which consent is not required: Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met:

(i) The identifiable private information or identifiable biospecimens are publicly available;

(ii) Information, which may include information about biospecimens, is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained directly or through identifiers linked to the subjects, the investigator does not contact the subjects, and the investigator will not re-identify subjects;

(iii) The research involves only information collection and analysis involving the investigator's use of identifiable health information when that use is regulated under 45 CFR parts 160 and 164, subparts A and E, for the purposes of ``health care operations'' or ``research'' as those terms are defined at 45 CFR 164.501 or for ``public health activities and purposes'' as described under 45 CFR 164.512(b); or

(iv) The research is conducted by, or on behalf of, a Federal department or agency using government-generated or government-collected information obtained for nonresearch activities, if the research generates identifiable private information that is or will be maintained on information technology that is subject to and in compliance with section 208(b) of the E-Government Act of 2002, 44 U.S.C. 3501 note, if all of the identifiable private information collected, used, or generated as part of the activity will be maintained in systems of records subject to the Privacy Act of 1974, 5 U.S.C. 552a, and, if applicable, the information used in the research was collected subject to the Paperwork Reduction Act of 1995, 44 U.S.C. 3501 et seq.

Exempt 5. Research and demonstration projects that are conducted or supported by a Federal department or agency, or otherwise subject to the approval of department or agency heads (or the approval of the heads of bureaus or other subordinate agencies that have been delegated authority to conduct the research and demonstration projects), and that are designed to study, evaluate, improve, or otherwise examine public benefit or service programs, including procedures for obtaining benefits or services under those programs, possible changes in or

alternatives to those programs or procedures, or possible changes in methods or levels of payment for benefits or services under those programs. Such projects include, but are not limited to, internal studies by Federal employees, and studies under contracts or consulting arrangements, cooperative agreements, or grants. Exempt projects also include waivers of otherwise mandatory requirements using authorities such as sections 1115 and 1115A of the Social Security Act, as amended. (i) Each Federal department or agency conducting or supporting the research and demonstration projects must establish, on a publicly accessible Federal Web site or in such other manner as the department or agency head may determine, a list of the research and demonstration projects that the Federal department or agency conducts or supports under this provision. The research or demonstration project must be published on this list prior to commencing the research involving human subjects.

Exempt 6. Taste and food quality evaluation and consumer acceptance studies: (i) If wholesome foods without additives are consumed, or (ii) If a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration or approved by the Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of Agriculture.

Exempt 7. Storage or maintenance for secondary research for which broad consent is required: Storage or maintenance of identifiable private information or identifiable biospecimens for potential secondary research use if an IRB conducts a limited IRB review and makes the determinations required by 45 CFR 46.111(a)(8).

Exempt 8. Secondary research for which broad consent is required: Research involving the use of identifiable private information or identifiable biospecimens for secondary research use, if the following criteria are met:

(i) Broad consent for the storage, maintenance, and secondary research use of the identifiable private information or identifiable biospecimens was obtained in accordance with 45 CFR 46.116(a)(1) through (4), (a)(6), and (d);

(ii) Documentation of informed consent or waiver of documentation of consent was obtained in accordance with 45 CFR 46.117;

(iii) An IRB conducts a limited IRB review and makes the determination required by 45 CFR 46.111(a)(7) and makes the determination that the research to be conducted is within the scope of the broad consent referenced in paragraph (d)(8)(i) of this section; and

(iv) The investigator does not include returning individual research results to subjects as part of the study plan. This provision does not prevent an investigator from abiding by any legal requirements to return individual research results.

[1]Exempt categories (1), (2), (3), (4), (5), (7), and (8) cannot be applied to activities that are FDA-regulated.

[2] Each of the exemptions at this section may be applied to research subject to subpart B (Additional Protections for Pregnant Women, Human Fetuses and Neonates Involved in Research) if the conditions of the exemption are met.

[3] The exemptions at this section do not apply to research subject to subpart C (Additional Protections for Research Involving Prisoners), except for research aimed at involving a broader subject population that only incidentally includes prisoners.

[4] Exemptions (1), (4), (5), (6), (7), and (8) of this section may be applied to research subject to subpart D (Additional Protections for Children Involved as Subjects in Research) if the conditions of the exemption are met. Exempt (2)(i) and (ii) only may apply to research subject to subpart D involving educational tests or the observation of public behavior when the investigator(s) do not participate in the activities being observed. Exempt (2)(iii) may not be applied to research subject to subpart D.

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